

**Improvement of Infrastructure:
Spatial Effects and How to Finance**

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1 Introduction

Improvement of infrastructure is an important tool of transport policy. The question arises how and in which extent an improvement of the infrastructure influences transport and the economy in space and time. For an adequate answer, two relationships must be taken into account:

- (1) the interaction between the economy and transport: the economy influences transport and transport influences the economy;
- (2) the way of financing the improvement of the infrastructure and its influence on the economy and transport; this relationship is important in case of large projects of infrastructure.

The paper describes these relationships, as they have been specified in the (extended) model MOBILEC (MOBILity/EConomy). This is a dynamic, interregional model about economy, mobility, infrastructure and other regional features. A specific way of financing improvements of infrastructure can be put into the model. We consider the following ways of financing:

- (1) reduction of other government spending;
- (2) increase of direct taxes;
- (3) increase of indirect taxes, including a levy on mobility;
- (4) increase of the government deficit;
- (5) private financing.

These ways of financing and the spatial distribution and allocation of the resources are specified in the paper. Attention is paid to passing on additional burdens to other economic subjects.

On the basis of these theoretical considerations, we make an empirical study in the form of a *scenario analysis* for Belgium and its three composing regions, namely the Flemish Region, the Walloon Region and the Brussels-Capital Region. It is performed with the help of the model MOBILEC-Belgium, which gives a spatial differentiation to 43 regions (*arrondissements*).

A *reference scenario* is presented, where the capacity of the road infrastructure is constant in the course of time. The travel time of the road traffic depends on the utilization of the road capacity: more vehicles on a certain stretch of infrastructure imply lower velocity and therefore longer travel time. Substitution for other transport modes is possible.

Then several *extension scenarios* are formulated where the capacity of the road infrastructure is extended in all regions in such a way that travel time of the road traffic does not rise in spite of the increasing road traffic. The only difference between these extension scenarios is the way of financing.

The extension scenarios are compared with the reference scenario. It shows the spatial effects that the extension scenarios generate, in terms of value-added and employment by region. In addition, the effects on transport of goods and passengers by transport mode are presented. Finally, a cost-benefit analysis for Belgium is accomplished. On the basis of these analyses, preferences can be formulated for certain ways of financing.

2 Transport and economy

We want to estimate the effects of an improvement of infrastructure on transport and the economy in space and time. For this purpose, we need a model. Initially, we can think of a *traffic model*. A traffic model is often used to examine to what extent the infrastructure has to adapt for conducting future mobility. In this approach, the economy is one of the factors that influences the size and the type of transport. It is represented by economic variables that are exogenous (see for instance the New Regional Model of the Dutch Ministry of Transport, Public Works and Management, 1997). The same is found in equations for transport of passengers and goods in the *activity-based approach* (see for instance Meersman & Van de Voorde, 1991 and 1997; see also Blauwens, De Baere & Van de Voorde, 2002).

The disadvantage of these approaches is that there is no feedback from transport to the economy. Consequently, it does not allow one to estimate the extent to which the construction of new infrastructure or the improvement of existing infrastructure promotes economic development.

There are also models where traffic infrastructure and so transport influences the economy. The following types can be mentioned:

- (1) *location models* (see for instance Rietveld & Bruinsma, 1998);
- (2) *approach of regional economic potentials* (see Biehl et al., 1975 and 1991);
- (3) *production function models* (see for instance Aschauer, 1989; Munnell, 1992; Gramlich, 1994; Gillen & Waters II, 1996; Gomez-Ibanez & Madrick, 1996; Rietveld & Bruinsma, 1998; Banister & Berechman, 2000);
- (4) *spatial general equilibrium models* (see Venables & Gasiorek, 1996 and Knaap & Oosterhaven, 2001, and for the underlying theory Fujita, Krugman & Venables, 1999).

In these models, the causal relation from national/regional product to transport and expenditures for improving infrastructure is neglected.

These disadvantages are eliminated if one combines the causal relationship from the economy to transport of traffic models and the activity-based models with the causal relationship from transport to the economy of the last mentioned models. A bicausal relationship between the economy and transport is defined in the model MOBILEC.

3 The model MOBILEC

MOBILEC (MOBILity/EConomy) is a dynamic, interregional model that describes the interaction between transport and economy in connection with infrastructure and other regional features. It belongs to the category of *land-use transportation interaction models* (see for instance Wilson, 1998 and Van der Hoorn & Van der Vlugt, 1998), but it does not have the restriction that the economy on a higher spatial scale is exogenous.

The model has region specific production functions. However, different from production function models, its production functions do not contain the total infrastructure as a production factor, but the part of it that is utilized by transport for the production. The infrastructure utilized is identified with the mobility for productive ends, expressed in terms of the number of passengers and the number of tons of goods that have been moved through this infrastructure.

Transport of goods and business traffic relates to productive mobility (expressed in the number of tons or passengers between two points in space). If the moving motive refers to shopping, attending of education courses, paying of visits/staying, recreation/sport and driving/walking, it is a matter of consumptive mobility (expressed in the number of passengers between two points in space). The nature of commuter traffic is more complicated to establish. Commuter traffic is the consequence of a productive performance outside the residence; for that reason it is a matter of productive mobility. On the other hand, it can be assumed that commuter traffic is the consequence of the consumptive wish of living in a more attractive environment than the one is working; in this view commuter traffic should be counted as consumptive mobility. This difficulty results in separate mathematical equations for commuter traffic in the model.

The production function contains productive mobility and no consumptive mobility. In accordance with the production function, the direction of the causal connection goes from mobility to economy. In the case of consumptive mobility, the consumption function, which describes the relation between income and consumption, plays a part. In accordance with the consumption function, the direction of the causal connection goes from economy to mobility.

Infrastructure is a limiting condition – to change by policy – for the total of productive and consumptive mobility and therefore for the economic development. Before the maximum mobility is reached, the limiting effect of infrastructure is revealed in the form of increased travel time and mobility price. The mobility price is defined as generalized transport costs per passenger or per ton (freight transport). It consists of two parts: travel-distance costs and travel-time costs; travel-time costs are the result of monetary evaluation of travel time (see for instance the Dutch Ministry of Transport, Public Works and Water Management, 1996). The smaller the difference between the actual mobility and the maximum possible mobility (capacity of infrastructure), the lower is the velocity of transport and the greater the travel-time costs. The type of infrastructure imposes restrictions on the means of transport and its velocity. These restrictions, too, are expressed in the mobility price.

The model makes use of matrices of origin-destination where the quality of accessibility within and between regions is expressed in terms of travel distance, travel time, travel-distance costs and travel-time costs, on the basis of a network of infrastructure. It generates the flows of transport within a region and between pairs of regions. It takes into account that the infrastructure of a region is utilized by transit traffic between other regions.

Infrastructure is one of the factors that characterize regions. Other regional features in the model are technological development, regional production structure, urbanisation (agglomeration economies and diseconomies), level of wage rate, existence of recreation areas, size of the population related to the area and the employment, investment premiums and geographic position. Their influence on the economy and mobility is also taken into consideration.

The model (see Van de Vooren, 1999, for a more extensive and mathematical treatment) works as follows.

The regional income in period t determines regional (private) saving in period t , which – dependent on the balance of government spending in the region and taxes levied in the region, and on the balance of payments of the region – is used as (private) investment (see also section 4.1). Regional (private) investment is just an extension of the (private) stock of capital

goods; so the region disposes of a larger *stock of capital goods* at the beginning of the next period t+1 than at the beginning of period t.

Neoclassical theory teaches that the marginal labour productivity determines the real wage rate. This relation is reversed in MOBILEC. The real wage rate, agreed by employers and employees, is considered as an exogenous variable. It determines the *marginal labour productivity*.¹ The real price of productive mobility determines the *marginal mobility productivity*.

The stock of capital goods, the marginal labour productivity and the marginal mobility productivity in period t+1 determine – given the production function – simultaneously the regional product, the employment and the productive mobility in period t+1. The state of technology, the regional structure of production and the degree of urbanisation in period t+1 are exogenous. The regional product accrues to the population in the form of regional income, which influences the consumptive mobility and the commuter traffic in period t+1. The consumptive mobility also depends on the price of consumptive mobility as well as the metropolitan character and the existence of recreation areas in the own region in relation to other regions. The commuter traffic also depends on the mobility price of commuter traffic as well as the per capita employment in the own region in relation to other regions.

From this point, the process starts again: the regional income determines regional saving in period t+1, which is used as investment in the own region or elsewhere, etc. The mobility prices rise as a result of an increasing utilization of the available infrastructure, what has a negative influence on the growth of economy and mobility. Substitution between transport modes is possible in the model.

This system of relations produces, as most important output, time paths of the following variables:

- regional/national product, employment and investment by region;
- transport of goods by lorry, train and ship (productive mobility) within a region and between regions;
- transport of passengers by car, train and bus/tram/metro within a region and between regions, split up into business traffic (productive mobility), commuter traffic and other traffic (consumptive mobility).

The model can be used for forecasting these time paths and for calculating effects of transport policy and spatial planning.

4 Financing an improvement of infrastructure

4.1 Extensions of the model

As we noted in section 3, regional (private) saving is used as (private) investment, dependent on the balance of government spending in the region and taxes levied in the region, and on the balance of payments of the region.²

$$I_r = S_r - (G_r - T_r) - (X_r - M_r) \quad (1)$$

where:

I_r - private investment in region r;

- S_r - private saving of region r;
 G_r - government spending in region r;
 T_r - taxes levied in region r;
 X_r - export of goods and services and transfer of incomes from region r to other regions;
 M_r - import of goods and services and transfer of incomes from other regions to region r.

All variables in the model are *real* quantities (fixed general price level).

The government spending G_r is supposed to be fully autonomous. The analysis does not change fundamentally if a part of G_r is dependent on the geographic product of region r, Y_r . For the sake of simplicity, regional income is assumed to be proportional to the geographic product.

Taxes consist of direct and indirect taxes (omitting index r):

$$T = T_d + T_i \quad (2)$$

The direct taxes T_d are supposed to be partly dependent on income and partly autonomous:

$$T_d = \tau_d Y + T_{da} \quad (3)$$

where :

- τ_d - marginal rate of direct taxes;
 T_{da} - direct autonomous taxes.

The indirect taxes T_i are supposed to be partly dependent on value-added, partly dependent on the number of kilometres driven (for instance excises on fuels) and partly autonomous (for instance taxes on the ownership of vehicles):

$$T_i = \tau_i Y + t d + T_{ia} \quad (4)$$

where :

- τ_i - marginal rate of indirect taxes;
 t - real levy by kilometre driven;
 d - number of kilometres driven;
 T_{ia} - indirect autonomous taxes.

Regional (private) saving S is a function of disposable income:

$$S = \sigma (Y - T_d) \quad (5)$$

where σ presents the propensity to save.

Substitution of (3) and (5) into (1) gives:

$$I = \sigma Y - G + (1 - \sigma) T_d + T_i - (X - M) \quad (6)$$

This result is transformed, because of the mathematical structure of MOBILEC, into:

$$I = \sigma Y \Gamma \quad (7)$$

where Γ is a parameter ($\Gamma \geq 0$).

It follows from (7) by substitution of (3), (4) and (6):

$$\Gamma = 1 + \left(\frac{1}{\sigma} - 1 \right) \tau_d + \frac{1}{\sigma} \tau_i + \frac{\frac{1}{\sigma} t d + \left(\frac{1}{\sigma} - 1 \right) T_{da} + \frac{1}{\sigma} T_{ia} - \frac{1}{\sigma} G - \frac{1}{\sigma} (X - M)}{Y} \quad (8)$$

With the help of (8), we can calculate the effects of government spending because of an improvement of infrastructure and its financing by increasing taxes or otherwise.

As we noted in section 3, the real wage rate determines the marginal labour productivity and the real price of productive mobility determines the marginal mobility productivity. When the indirect tax rate increases, the entrepreneurs try to pass on it into their sales prices. Therefore the equilibrium conditions for the marginal productivities must be adapted (omitting index r in τ_i and δ):³

$$\frac{\partial Y_r}{\partial N_r} = w_r \frac{1 + \tau_i + \Delta \tau_i}{1 + \tau_i + \delta \Delta \tau_i} \quad (9)$$

$$\frac{\partial Y_r}{\partial T p i_{sr}} = p p i_{sr} \frac{1 + \tau_i + \Delta \tau_i}{1 + \tau_i + \delta \Delta \tau_i} \quad (10)$$

$$\frac{\partial Y_r}{\partial T p l_{rs}} = p p l_{rs} \frac{1 + \tau_i + \Delta \tau_i}{1 + \tau_i + \delta \Delta \tau_i} \quad (11)$$

where:

N_r - labour volume in region r ;

$T p i_{sr}$ - productive mobility of goods (number of tons) by lorry from region s to region r ;

$T p l_{rs}$ - productive mobility of business traffic (number of passengers) by car from region r to

region s and back to the region of origin r ;

w - wage rate in region r ;

$p p i_{sr}$ - price of productive mobility of goods by lorry from region s to region r ;

$p p l_{rs}$ - price of productive mobility of passengers (business traffic) from region r to region s and back to the region of origin r ;

δ - factor concerning an increase of the indirect tax rate passing on into sales prices.

The same type of equations applies to the marginal productivity of freight transport by train ($T p i i_{sr}$) and by ship ($T p i i i_{sr}$) and to the marginal productivity of business traffic by train ($T p 2_{rs}$) and by bus/tram/metro ($T p 3_{rs}$). The factor δ depends on the elasticity of the demand curve and the supply curve. Full passing on into sales prices implies $\delta = 1$; the marginal factor productivities do not change. If the tax increase cannot be passed on, $\delta = 0$ and the marginal factor productivities are rising. The entrepreneurs implement the rising marginal factor productivities by reducing the use of labour and productive mobility, *ceteris paribus*.

4.2 Ways of public financing

If infrastructure is not improved, we assume that Γ_r is constant. This assumption requires a constant direct and indirect tax rate (τ_d and τ_i) and a constant fourth term in the right hand side of (8). A sufficient condition for a constant value of this fourth term is that the growth rates of the benefits t.d, the autonomous taxes T_{da} and T_{ia} , the (autonomous) government spending G and the balance of payments $X - M$ are equal to the growth rate of the regional product Y . In reality, the fourth term will be more or less constant in a balanced growing economy.

Suppose an improvement of the infrastructure in region r . The financing of its cost, F^r , goes via the national (federal) government. The contribution of region r to this cost in the form of taxes or otherwise is F_r . The other regions are represented by region s ; its contribution to the cost is F_s . So $F^r = F_r + \Sigma F_s$. We will analyse the effects of eight ways of financing on the parameter Γ_r .

Option 1. Financing the improvement of infrastructure by means of a reduction of other government spending, especially government consumption.

Analysis. Total government spending is maintained by this option, but its composition is modified. The cost F^r is financed by a reduction of government spending in region r amounting to F_r and by a reduction in region s amounting to F_s . So:

$$\Delta G_r = F^r - F_r; \Delta G_s = -F_s; \Delta X_s = F_s \text{ and } \Delta M_r = \Sigma F_s.$$

It follows from (8):

$$\begin{aligned} \Delta \Gamma_r &= [-(1/\sigma_r) (F^r - F_r) + (1/\sigma_r) \Sigma F_s]/Y_r = 0 \\ \Delta \Gamma_s &= [-(1/\sigma_s) (-F_s) - (1/\sigma_s) F_s]/Y_s = 0. \end{aligned}$$

Option 2. Financing of the improvement of infrastructure by means of an increase of direct autonomous taxes.

Analysis. The cost F^r is financed by an increase of the direct autonomous taxes in region r amounting to F_r and by an increase in region s amounting to F_s . So:

$$\Delta G_r = F^r; \Delta T_{da(r)} = F_r; \Delta T_{da(s)} = F_s; \Delta X_s = F_s \text{ and } \Delta M_r = \Sigma F_s.$$

It follows from (8):

$$\begin{aligned} \Delta \Gamma_r &= [(1/\sigma_r) F_r - F_r - (1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r = -F_r/Y_r \\ \Delta \Gamma_s &= [(1/\sigma_s) F_s - F_s - (1/\sigma_s) F_s]/Y_s = -F_s/Y_s. \end{aligned}$$

Option 3. Financing of the improvement of infrastructure by means of an increase of indirect autonomous taxes.

Analysis.

$$\Delta\Gamma_r = [(1/\sigma_r) F_r - (1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r = 0$$

$$\Delta\Gamma_s = [(1/\sigma_s) F_s - (1/\sigma_s) F_s]/Y_s = 0.$$

Option 4. Financing of the improvement of infrastructure by means of an increase of the direct tax rate.

Analysis. Assuming region specific direct tax rates, $\Delta\tau_{d(r)} = F_r/Y_r$ and $\Delta\tau_{d(s)} = F_s/Y_s$. In that case:

$$\Delta\Gamma_r = [(1/\sigma_r) F_r/Y_r - F_r/Y_r + [-(1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r = -F_r/Y_r$$

$$\Delta\Gamma_s = [(1/\sigma_s) F_s/Y_s - F_s/Y_s - (1/\sigma_s) F_s]/Y_s = -F_s/Y_s.$$

The results are the same as in option 2. If the direct tax rate is a national matter, then $\Delta\tau_d = F^r/Y_N$. So:

$$\Delta\Gamma_r = [(1/\sigma_r) F^r - F^r]/Y_N + [-(1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r$$

$$\Delta\Gamma_s = [(1/\sigma_s) F^r - F^r]/Y_N - (1/\sigma_s) F_s/Y_r.$$

The contribution of region r to the improvement of the infrastructure is:

$$[(1/\sigma_r) F^r - F^r]/Y_N.$$

Given Y_r , this contribution can be transformed into:

$$[(1/\sigma_r) F_r - F_r]/Y_r. \text{ So } [(1/\sigma_r) F^r - F^r]/Y_N = [(1/\sigma_r) F_r - F_r]/Y_r.$$

The contribution of region s can be transformed on the same way. The consequence of these transformations is that $\Delta\Gamma_r$ and $\Delta\Gamma_s$ are the same as in option 2.

Option 5. Financing of the improvement of infrastructure by means of an increase of indirect tax rates.

Analysis. The same method can be followed as in the analysis of option 4. $\Delta\Gamma_r$ and $\Delta\Gamma_s$ are the same as in option 3.

Option 6. Financing of the improvement of infrastructure by means of an increase of the government deficit, financed by domestic resources.

Analysis.

$$\Delta\Gamma_r = [-(1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r = -(1/\sigma_r) F_r/Y_r$$

$$\Delta\Gamma_s = -(1/\sigma_s) F_s/Y_s.$$

Option 7. Financing of the improvement of infrastructure by means of an increase of the government deficit, financed by foreign resources.

Analysis.

$$\Delta\Gamma_r = [-(1/\sigma_r) F^r + (1/\sigma_r) F^r]/Y_r = 0$$

$$\Delta\Gamma_s = 0.$$

Option 8. Financing of the improvement of infrastructure by means of an increase of the levy on mobility.

Analysis. The cost F^r is financed by an increase of the levy on mobility in region r amounting to $F_r (= \Delta t_r \cdot d_r)$ and by an increase in region s amounting to $F_s (= \Delta t_s \cdot d_s)$. So:

$$\Delta\Gamma_r = [(1/\sigma_r) F_r - (1/\sigma_r) F^r + (1/\sigma_r) \Sigma F_s]/Y_r = 0$$

$$\Delta\Gamma_s = [(1/\sigma_s) F_s - (1/\sigma_s) F_s]/Y_s = 0.$$

After the improvement of the infrastructure has been realized, Γ_r and Γ_s resume their old values. The new infrastructure implies lower mobility prices and consequently a higher national product, *ceteris paribus*.

4.3 Ways of private financing

Instead of the government, a private enterprise can improve the infrastructure. The enterprise reserves a part of its investments for this aim. Therefore (7) must be adapted:

$$I = \sigma Y \Gamma - V = \sigma Y [\Gamma - (1/\sigma) V/Y] \quad (7)'$$

where:

- I - private investment not concerning infrastructure;
- V - private investment in infrastructure.

I in (7)' has the same meaning as in (7), for in the framework of (7) the improvement of infrastructure is only done by the government and therefore it does not belong to the private investment I in (7). The parameter Γ contains the term $(1/\sigma) G/Y$; see (8). So (7)' shows that there is no difference of effect on I between $\Delta G = F$ in public financing and $V = F$ in private financing.

Suppose an improvement of the infrastructure in region r. Its cost is paid by a private enterprise. We discuss two cases.

The first case is private financing without paying back by the government. In the options 6 (financing by domestic resources), 7 (financing by foreign resources) and 8 (financing by a levy on mobility, utilizing the improved infrastructure), $\Delta G_r = F^r$ in public financing must be replaced by $V_r = F^r$. The effect on I_r (and I_s) is the same as in section 4.2. In the framework of private financing, it applies to option 8:

$$\Delta\Gamma_r = [(1/\sigma_r) F_r - (1/\sigma_r) F^r]/Y_r = 0$$

$$\Delta\Gamma_s = 0.$$

Further, options 2–5 do not apply. Finally, option 1 may be interpreted as a reduction of private investment not concerning infrastructure such that total private investment remains

constant. The difference with option 1 in public financing is that now a reduction of private *investment* not concerning infrastructure is under discussion instead of a reduction of government *consumption*; only investment influences the stock of capital goods and so economic growth.

The second case is private financing with paying back by the government. In the options 2–5 and option 8 (a levy on mobility by the government), $\Delta G_r = F^r$ in public financing must be replaced by $V_r = F^r$. In the options 1, 6 and 7, the paying back by the government implies on balance $V_r = 0$, $\Delta G_r = F^r - F_r$ (option 1) and $\Delta G_r = F^r$ (options 6 and 7). So there is no difference of effect on I_r (and I_s) compared with public financing. Usually, if the government pays back, it does after the private realization of the infrastructure. This time lag causes a difference of effect between public and private financing, which manifests in successive periods, but the total effect over all periods is approximately the same.

4.4 Evaluating ways of financing

The second column of table 1 summarizes the results with regard to the ways of financing that have been deduced in section 4.2.

Table 1 Effects of ways of public financing an improvement of infrastructure, with a contribution of region r amounting to F (omitting index r)

<i>Way of financing</i>	<i>Value of Γ</i>	<i>Other variables</i>
(1) decrease G, consumptive	$\Delta\Gamma = 0$	
(2) increase T_{da}	$\Delta\Gamma = -F/Y$	decrease of travel time
(3) increase T_{ia}	$\Delta\Gamma = 0$	
(4) increase τ_d	$\Delta\Gamma = -F/Y$	decrease of travel time
(5) increase τ_i	$\Delta\Gamma = 0$	increase of sales prices
(6) increase G - T, domestic resources	$\Delta\Gamma = [-(1/\sigma) F]/Y$	
(7) increase G - T, foreign resources	$\Delta\Gamma = 0$	
(8) increase t	$\Delta\Gamma = 0$	increase mobility prices

A higher Γ leads to more investment, *ceteris paribus*, and consequently to a higher economic growth. Therefore we conclude *on the basis of $\Delta\Gamma$* :

- 1st preference: options 1, 3, 5, 7 and 8;
- 2nd preference: options 2 and 4;
- 3rd preference: option 6.

However, some ways of financing have not only effects on Γ but also additional effects (third column of table 1). Firstly, higher direct taxes lead to lower disposable income, *ceteris paribus*, to a lower consumptive mobility and commuter traffic (which do not contribute to national product via the production function), so to a lower utilization of the road capacity, to a shorter travel time and consequently to a higher national product (options 2 and 4). Secondly, a higher indirect tax rate leads, in general, to higher sales prices, to a lower use of production factors and consequently a to lower national product (option 5). Thirdly, an increase of the levy on mobility leads to higher mobility prices and consequently to a lower domestic product (option 8). The consequences of these additional effects are that options 2 and 4 rise and options 5 and 8 fall in the scale of preference. A more detailed ranking is

possible by a quantitative analysis of concrete cases with the help of the model (see section 5.3).

Other additional effects are conceivable, for instance an increase of the interest rate, but we leave them aside in our analysis. In reality, the final ranking of the ways of financing is also based on non-economic judgments.

If the head “Value of Γ ” in table 1 is replaced by the head “Value of $\Gamma - (1/\sigma) V/Y$ ”, this table also applies to private financing. So the ranking of the options in private financing is the same as in public financing. However, if there is no paying back by the government, option 1 falls in the scale of preference compared with public financing because of its negative effect on economic growth.

These conclusions have been based on the assumption that no time lag exists between private financing and paying back by government. A time lag may be an argument for a government to prefer private financing, for it relieves its financial situation. This may also be an argument to prefer private financing without paying back. Finally, our analysis neglects possible microeconomic advantages and disadvantages of improvement of infrastructure with private financing compared with public financing.

5 Empirical analysis

5.1 Scenario analysis

We make a scenario analysis for estimating spatial effects of an improvement of the infrastructure on the economy and mobility in the 43 Belgian regions (*arrondissements*). To that end, we use MOBILEC-Belgium.

All scenarios are based on the following assumptions:

- technological development of 1.75 % by period (a period in the model contains 3 years); because of differences in innovation, this percentage has been reduced to 1.5 % or raised to 2 % for some regions;
- rise of the share of labour-intensive industries (especially the service sector) in the regional product in a period of 3 years corresponding with $\frac{3}{4}$ of the rise of this share in the preceding period;
- rise of the real wage rate of 1.2 % by year;
- decrease of the average number of passengers by car with 0.3 % by year and increase of the average load by lorry, train and ship with 0.7 % by year.

We make the following additional assumptions for the reference scenario:

- constant capacity of the roads;
- constant real travel-distance cost by kilometre;
- constant travel time by train and ship.

As alternatives, we formulate several extension scenarios where the capacity of the road infrastructure is extended in all regions in such a way that the travel time of the road traffic does not rise in spite of the increasing traffic. We examine eight ways of public financing, so that there are eight extension scenarios. These extension scenarios are compared with the reference scenario.

5.2 Estimating the parameters connected with financing

The parameters in the model MOBILEC are estimated in Van de Vooren (1999) and NEA (1999). Here we explain how the parameters connected with financing are estimated.

The parameter Γ_r in the base period, 1991-1993, is estimated with the help of (7). The values of I_r and Y_r are known in the base period. However, the values of S_r and σ_r are unknown. Assuming $\sigma_r = \sigma_N$ for all regions and approximating σ_N as $S_N/(Y_N - T_{d(N)}) = 0.14$ in the base period, the value of Γ_r can be deduced from (7).

The value of Γ_r changes as a result of the financing of the extension scenarios in the options 2, 4 and 6. For the calculation of $\Delta\Gamma_r$, we need the costs of the extension scenarios and the contribution of the regions to it.

The cost of the extension scenarios is estimated as follows. It applies to any region r (omitting index r):

$$F_t = (V_t - V_{t-1}) f_t \quad (12)$$

- F_t - total construction cost in period t ;
- V_t - capacity of the road infrastructure in period t ;
- f_t - mean cost by unit of capacity of the road infrastructure in period t .

The value of f_t is approximated with the help of:

$$f_t = (\mu Y_{t-1})/V_{t-1} \quad (13)$$

where μ is a parameter ($0 < \mu < 1$). Substitution of (13) into (12) gives:

$$F_t = [(V_t - V_{t-1})/V_{t-1}] \mu Y_{t-1} \quad (14)$$

It applies by definition in the case of the extension scenarios:

$$(V_t - V_{t-1})/V_{t-1} = (U_{t-1} - U_{t-2})/U_{t-2} \quad (15)$$

where U_t represents the utilization of the road capacity in period t , expressed in passenger-car equivalent. Substitution of (15) into (14) gives:

$$F_t = [(U_{t-1} - U_{t-2})/U_{t-2}] \mu Y_{t-1} \quad (16)$$

Equation (16) is applied to any region r . The model generates the time paths of U and Y . With the help of the reference book about economic effects of infrastructure of the Dutch Ministry of Transport, Public Works and Water Management (1996) we estimate $\mu = 0.015$ for 1995.⁴ We use this value for all years.

The contribution of region r to the total (national) cost of the extension of the road capacity in all regions in period t , $F_{r(t)}$, is approximated as follows:

$$F_{r(t)} = [Y_{r(t-1)}/Y_{N(t-1)}] F_t^N \quad (17)$$

Some financing options have additional effects (section 4.4), which are generated by the model. In option 5 we put $\delta = 0.5$ in (9), (10) and (11) for all regions. In option 8 we determine the increase of the levy on mobility needed for financing the total (national) extension cost of F_t^N as follows.

The increase of the levy yields revenues for the financing:

$$R_N = \Delta t_{1N} \sum_{r=1}^k \sum_{s=1}^k \frac{T p i_{sr}}{b p i} d i_{sr} + \Delta t_{1N} \sum_{r=1}^k \sum_{s=1}^k \left(\frac{T p 1_{rs}}{b p 1} + \frac{T c 1_{rs}}{b c 1} + \frac{T w 1_{rs}}{b w 1} \right) d 1_{rs} \quad (18)$$

where:

- R_N - national revenues of the increase of the levy on mobility;
- Δt_{1N} - increase of the national levy on mobility by lorry per kilometre;
- Δt_{1N} - idem, by car;
- $T c 1_{rs}$ - consumptive mobility (number of passengers) by car from region r to region s and back to the region of origin r ;
- $T w 1_{rs}$ - commuter traffic (number of passengers) by car from region r to region s and back to the region of origin r ;
- $b p i$ - average load per lorry;
- $b p 1$ - average number of passengers by car with regard to productive mobility;
- $b c 1$ - idem, with regard to consumptive mobility;
- $b w 1$ - idem, with regard to commuter traffic;
- $d i_{sr}$ - distance by lorry from region s to region r ;
- $d 1_{rs}$ - distance by car from region r to region s and back to the region of origin r ;

Following (18), busses have been exempted from the increase of the levy. By trial and error we can raise the levy as much as that the condition $R_{N(t)} = F_t^N$ is satisfied; note that F_t^N depends – see (16) - on the national product and the growth of utilization of the road capacity in the preceding period and that $T p i_{sr(t)}$, $T p 1_{rs(t)}$, $T c 1_{rs(t)}$ and $T w 1_{rs(t)}$ in (18) fall as a consequence of the increase of the levy.

We formulate the following rules for this trial and error. The increase of the levy is the same for all vehicles: Δt_N . It is calculated as:

$$\Delta t_{N(t)} = F_t^N : \left[\sum_{r=1}^k \sum_{s=1}^k \frac{T p i_{sr(t-1)}}{b p i} d i_{sr} + \sum_{r=1}^k \sum_{s=1}^k \left(\frac{T p 1_{rs(t-1)}}{b p 1} + \frac{T c 1_{rs(t-1)}}{b c 1} + \frac{T w 1_{rs(t-1)}}{b w 1} \right) d 1_{rs} \right] \quad (19)$$

The calculation of $R_{N(t)}$ following (18) on the basis of $\Delta t_{N(t)}$ in (19) can result in $R_{N(t)} > F_t^N$ or $R_{N(t)} < F_t^N$. Increasing road traffic in connection with economic growth leads *eo ipso* to $R_{N(t)} > F_t^N$. Decreasing road traffic because of the rise of the levy leads *eo ipso* to $R_{N(t)} < F_t^N$. It is not to determine *a priori* the result of these two opposing factors. To avoid a structural deficit or surplus of the revenues in relation to the cost, we add the quotient $F_{t-1}^N/R_{N(t-1)}$ to (19):

$$\Delta t_{N(t)} = \frac{F_{t-1}^N}{R_{N(t-1)}} F_t^N \cdot \left[\sum_{r=1}^k \sum_{s=1}^k \frac{Tp_{i_{sr(t-1)}}}{b_{pi}} di_{sr} + \sum_{r=1}^k \sum_{s=1}^k \left(\frac{Tp_{1_{rs(t-1)}}}{b_{p1}} + \frac{Tc_{1_{rs(t-1)}}}{b_{c1}} + \frac{Tw_{1_{rs(t-1)}}}{b_{w1}} \right) d1_{rs} \right] (19)',$$

If the levy in the preceding period proves to be too low (high), the levy in the current period is raised (lowered) by a correction factor in (19)'.

5.3 Quantitative results

We aggregate the quantitative results by arrondissement to Total Belgium and its three composing regions, namely the Flemish Region, the Walloon Region and the Brussels-Capital Region. The results are point estimates. A *sensitivity analysis* is necessary for giving information about the confidence of the estimates. The second author of this paper will pay attention to this subject in his Ph.D. thesis. However, we think that a sensitivity analysis will not affect the ranking of the financial options.

5.3.1 Growth rates of the economy and transport

The tables 2–5 present the growth rates of the economy and transport for the reference scenario and the extension scenarios by option.

Table 2 Average growth per year (%) of the real domestic product, employment and transport of goods and passengers by transport mode in Total Belgium in the period 2000-2030 (a)

	Reference scenario	Extension scenarios				
		options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Domestic product	1.95	1.99	1.96	1.98	1.82	1.98
Employment	0.67	0.70	0.68	0.70	0.54	0.70
Transport of goods						
· by lorry	1.36	1.72	1.69	1.71	1.54	1.67
· by train	1.50	1.53	1.51	1.52	1.42	1.52
· by ship	1.81	1.84	1.83	1.84	1.75	1.84
Transport of passengers						
· by car	0.38	0.78	0.76	0.77	0.68	0.65
· by train	0.16	0.05	0.05	0.05	0.05	0.07
· by bus (b)	-0.34	0.05	0.05	0.05	0.05	0.08

(a) Transport growth has been calculated on the basis of the number of passengers or quantities of tons.

(b) Including tram and metro.

Table 3 Average growth per year (%) of the real regional product, employment and transport of goods and passengers by transport mode in the Flemish Region in the period 2000-2030 (a)

	Reference scenario	Extension scenarios				
		options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Regional product	2.24	2.28	2.26	2.27	2.12	2.27
Employment	0.97	1.01	0.99	1.00	0.85	1.00
Transport of goods						
· by lorry	1.52	1.91	1.88	1.90	1.75	1.85
· by train	1.71	1.74	1.73	1.74	1.63	1.74
· by ship	1.96	1.99	1.98	1.98	1.89	1.98
Transport of passengers						
· by car	0.47	0.91	0.90	0.91	0.82	0.79
· by train	0.15	0.04	0.04	0.04	0.04	0.07
· by bus (b)	-0.40	0.05	0.05	0.05	0.05	0.08

(a) and (b): see under table 2.

Table 4 Average growth per year (%) of the real regional product, employment and transport of goods and passengers by transport mode in the Walloon Region in the period 2000-2030 (a)

	Reference scenario	Extension scenarios				
		options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Regional product	1.31	1.32	1.29	1.32	1.06	1.32
Employment	0.03	0.05	0.01	0.04	-0.20	0.04
Transport of goods						
· by lorry	1.01	1.29	1.25	1.28	1.07	1.24
· by train	1.02	1.03	1.02	1.03	0.92	1.03
· by ship	1.04	1.05	1.04	1.05	0.95	1.05
Transport of passengers						
· by car	0.17	0.45	0.42	0.44	0.32	0.33
· by train	0.21	0.06	0.06	0.06	0.06	0.09
· by bus (b)	-0.20	0.04	0.04	0.04	0.04	0.07

(a) and (b): see under table 2.

Table 5 Average growth per year (%) of the real regional product, employment and transport of goods and passengers by transport mode in the Brussels-Capital Region in the period 2000-2030 (a)

	Reference scenario	Extension scenarios				
		options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Regional product	1.72	1.74	1.72	1.73	1.64	1.73
Employment	0.49	0.50	0.49	0.50	0.41	0.50
Transport of goods						
· by lorry	1.29	1.63	1.62	1.63	1.52	1.59
· by train	1.66	1.67	1.66	1.67	1.59	1.67
· by ship	1.76	1.77	1.76	1.77	1.68	1.77
Transport of passengers						
· by car	0.36	0.75	0.74	0.75	0.70	0.63
· by train	0.21	0.04	0.04	0.04	0.05	0.07
· by bus (b)	-0.35	0.04	0.04	0.04	0.04	0.07

(a) and (b): see under table 2.

Reference scenario

The reference scenario shows an average economic growth in Total Belgium of 1.95 % by year in the period 2000-2030. It is accompanied with an average growth of employment of 0.67 % by year. The transport of goods by train and ship grows more than that by lorry. The transport of passengers by car and train increases and that by bus (including tram and metro) decreases. The growth rates in the Flemish Region are higher and those of the Walloon Region and the Brussels-Capital Region are lower than on the federal (national) level, with the exception of the growth rates of public transport. The lower the economic growth, the higher are the growth rates of public transport.

Extension scenarios, options 1, 3 and 7

As a result of the extension of road capacity, the travel time costs of the lorry, car and bus do not rise any longer, what has a positive effect on the growth of the regional product, employment and transport by lorry, car and bus. Thanks to the higher economic growth, the transport of goods by train and ship also profit. Only the growth of transport of passengers by train decreases; the positive effect of economic growth is smaller than the negative effect of substitution (shift in the modal split). The effects are the highest in the Flemish Region and the lowest in the Walloon Region, with the exception of transport of passengers by train. The other options show this pattern too. The results of the options 1, 3 and 7 are equal, what is consistent with table 1 in section 4.4.

Extension scenario, options 5 and 8

Judging an option only on the basis of economic growth, options 5 and 8 have the second preference after the options 1, 3 and 7. The difference in economic growth with the options 1, 3 and 7 is not visible in the Walloon Region as a result of rounding off. The options 5 and 8 differ in the growth rates of transport of goods and passengers. The modal split in option 8 develops more favourable for train, ship and bus. That may be an argument for preferring option 8 to option 5.

Extension scenarios, options 2 and 4

Options 2 and 4 have the third preference judging on the basis of economic growth. These options result in lower growth rates than the options 1, 3, 5, 7 and 8. Options 2 and 4 are not attractive for the Walloon Region, where the economic growth is lower than in the reference scenario.

Extension scenario, option 6

Option 6 is not interesting from the point of view of economic growth compared with the reference scenario. Moreover the growth rates of transport by lorry and car are higher.

We conclude that the ranking of the options on the basis of economic growth is consistent with the general ranking on the basis of $\Delta\Gamma$ and fixed cost F in section 4.4. However, the options 1, 3 and 7 are now preferred to the options 5 and 8. Moreover, option 8 is preferred to option 5 if one judges the modal split of option 8 more attractive than that of option 5. Option

6 is not interesting from the point of view of economic growth and so are options 2 and 4 for the Walloon Region.

5.3.2 Absolute differences in value-added and employment

The differences in growth rates with regard to value-added and employment between the scenarios are small, but it concerns average growth rates by year over the period 2000-2030. In 2028 the absolute differences have become considerable, as tables 6 and 7 show.

Table 6 Absolute differences in value-added between the extension scenarios by option and the reference scenario in 2028 (million of euros, price level 2000)

	options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Total Belgium	4654	1920	2930	-13892	3531
Flemish Region	3883	2227	2723	-7457	2953
Walloon Region	489	-385	136	-5307	373
Brussels-Capital Region	282	78	71	-1128	205

Table 7 Absolute differences in employment between the extension scenarios by option and the reference scenario in 2028 (thousands of jobs)

	options 1, 3, 7	options 2, 4	option 5	option 6	option 8
Total Belgium	56.5	23.2	30.3	-170.2	42.8
Flemish Region	46.2	26.4	29.3	-89.4	35.0
Walloon Region	6.2	-4.4	0.7	-64.2	4.8
Brussels-Capital Region	4.1	1.2	0.3	-17.6	3.0

The ranking of the options on the basis of absolute differences in value-added and employment in 2028 is consistent with the general ranking in section 4.4, on the understanding that now the options 1, 3 and 7 are preferred to option 8 and that option 8 is preferred to option 5. This ranking corresponds with the ranking on the basis of economic growth and modal split in the preceding subsection. Option 6 is not interesting from the point of view of value-added and employment and so are options 2 and 4 for the Walloon Region.

5.3.3 Cost-benefit analysis

From the point of view of the Pareto welfare theory, the ranking of the options must be based on social costs and benefits. We use the *profitability index* as criterion. The profitability index is defined as the ratio between the net benefit (= benefit – cost) and the claim that the option makes on the budget (Blauwens, 1976 and De Brucker et al, 1998). We equate this claim with the cost. The benefits are the additional value-added of an option compared with the reference scenario. The costs are calculated with the help of (17). Costs and benefits are generated since 1995. The real discount rate is put at 4 %. The results are presented in table 8.

The cost-benefit analysis neglects microeconomic and non-priced aspects of the extension scenarios. Therefore its results must be regarded as a first indication of the profitability indices.

Table 8 Profitability indices of the extension scenarios by option for Total Belgium in the period 1995-2030

options 1,3,7	options 2,4	option 5	option 6	option 8
12.7	5.6	5.8	-39.3	10.4

The ranking of the options on the basis of the profitability index for Total Belgium is consistent with the general ranking in section 4.4, on the understanding that now the options 1, 3 and 7 are preferred to option 8 and that option 8 is preferred to option 5.⁵ This ranking corresponds with the rankings on the basis of economic growth and modal split and on the basis of absolute differences in the preceding subsections. Option 6 is not interesting from the point of view of a cost-benefit analysis.⁶

6 Conclusions

In traffic models the economy, taken exogenously, influences transport. In other transport models it is transport that influences the economy. The model MOBILEC (MOBILity/EConomy) takes into account the interaction between transport and economy; it is a dynamic, interregional model about the economy, mobility, infrastructure and other regional features. We apply MOBILEC-Belgium for estimating the spatial effects of improving infrastructure. The way of financing such an improvement influences the spatial effects. In this connection we extend the model with relations to the parameter Γ and we adapt the equilibrium conditions for the marginal productivity of labour and mobility.

We consider the following options of public financing:

- (1) reduction of other government spending, especially government consumption;
- (2) increase of direct autonomous taxes;
- (3) increase of indirect autonomous taxes;
- (4) increase of the direct tax rate;
- (5) increase of the indirect tax rate;
- (6) increase of the government deficit, financed by domestic resources;
- (7) increase of the government deficit, financed by foreign resources;
- (8) increase of the levy on mobility.

Instead of the government, a private enterprise can improve the infrastructure. The first case is private financing without paying back by the government. In that case the financial options 1 (reduction of private investment not concerning infrastructure), 6 (financing by domestic resources), 7 (financing by foreign resources) and 8 (financing by a levy on mobility, utilized the improved infrastructure) are available, whereas the options 2–5 do not apply. The second case is private financing with paying back by the government.

There is no principal difference between public and private financing in macroeconomic respect, except in option 1 if there is no paying back by the government. However, a government may prefer private financing, for it relieves its financial situation. Our analysis

neglects possible microeconomic advantages and disadvantages of improvement of infrastructure with private financing compared with public financing.

In a scenario analysis, we present the quantitative effects of the eight financing options in terms of:

- (a) growth rates of the economy and transport;
- (b) absolute differences in value-added and employment;
- (c) profitability indices in the framework of a cost-benefit analysis.

The options 1-5 and 7-8 generate positive effects on the growth of the regional product and employment in Total Belgium and its three composing regions, namely the Flemish Region, the Walloon Region and the Brussels-Capital Region, with the exception of the options 2 and 4 for the Walloon Region. Option 6 give negative effects for Total Belgium and each of its composing regions. The absolute differences in value-added and employment as a result of the options reflect the same pattern. The profitability indices of the options 1-5 and 7-8 are higher than 1 and the profitability index of option 6 is negative. It applies to all options that the effects on the growth rates of the economy and transport are the highest in the Flemish Region and the lowest in the Walloon Region, with the exception of transport of passengers by train.

We conclude that these three points of view result in the same ranking of the financial options:

- 1st preference: options 1, 3 and 7;
- 2nd preference: option 8;
- 3rd preference: option 5;
- 4th preference: options 2 and 4.

Option 6 is not interesting, because it results in negative effects compared with the reference scenario and so are the options 2 and 4 for the Walloon Region. We leave some effects aside in our analysis, for instance an increase of the interest rate. In reality, the final ranking of the ways of financing is also based on non-economic judgments.

Notes

1. The exogenous wage rate can be assigned such values that the model, contrary to neoclassical theory with its flexible prices, can simulate unemployment.

2. It applies in an open economy: the identity $Y = C + S + T_d$ (1) and the equilibrium equation $Y + T_i = C + I + G + X - M$ (2), where Y – national income, C – private consumption, S – private saving, T_d – direct taxes, T_i – indirect taxes, I – private investment, G – government spending, X – export and M – import. It follows from (1) and (2): $I = S - (G - T) - (X - M)$, where $T = T_d + T_i$. So private investment corresponds to private savings reduced by the government deficit and the surplus of the balance of payments.

3. Equation (10) is deduced as follows. There are two situations: situation 0 is the point of departure and situation 1 shows a rise of the VAT compared with the situation 0. It applies to situation 1 with regard to labour:

$$\left(\frac{\partial Y}{\partial N}\right)_1 = \frac{w_1'}{p_1} = w_1 \quad (1)$$

where:

w_1' - nominal wage rate in situation 1;

w_1 - real wage rate in situation 1;

p_1 - price level of geographic product at factor costs in situation 1.

The price including VAT is represented by r . It applies $p(1 + \tau) = r$ where τ represents the VAT. On this basis, (1) can be rewritten as follows:

$$\left(\frac{\partial Y}{\partial N}\right)_1 = \frac{w_1'}{p_0} \frac{p_0}{p_1} = \frac{w_1'}{p_0} \frac{r_0}{r_1} \frac{1 + \tau_1}{1 + \tau_0} \quad (2)$$

The exogenous nominal wage rate and the exogenous price level excluding VAT are in both situations the same: $w_1' = w_0'$ and $p_0 = p_1$. Further is $\tau_0 + \Delta\tau_1 = \tau_1$. Finally, it applies $p_0(1 + \tau_0 + \delta\Delta\tau_1) = r_1$ where δ concerns the extent in which an increase of the VAT can be passed on into sales prices. Substitution of these equations into (2) gives:

$$\left(\frac{\partial Y}{\partial N}\right)_1 = \frac{w_0'}{p_0} \frac{p_0(1 + \tau_0)}{p_0(1 + \tau_0 + \delta\Delta\tau_1)} \frac{1 + \tau_0 + \Delta\tau_1}{1 + \tau_0} = w_0' \frac{1 + \tau_0 + \Delta\tau_1}{1 + \tau_0 + \delta\Delta\tau_1} \quad (3)$$

Rewriting of (3) gives (10). Equations (11) and (12) are deduced in the same way.

4. We estimate μ as follows. The reference book about economic effects of infrastructure says that the construction of motorway with 2x2 lanes costs 10.5 million guilders per kilometre (variant II, excluding additional large constructions works, p. 25): $f_t = 10.5$. $Y_{94-96} = 1,794,591$ (period 1994-1996, million guilders). The length of the Dutch motorway network amounts to 2173 km in 1995. It follows from (15) that $\mu = 0.013$.

Our extension scenarios concern the whole road network. The question is, whether $\mu = 0.013$ also applies to the whole road network. The problem is that a value of f_t is not available for the whole road network. However, it can be demonstrated indirectly that $\mu = 0.013$ is not unlikely for the whole road network. The length of the whole paved road network in The Netherlands, open for four-wheel vehicles, amounts to 110.556 km in 1995, so that $f_t = 211,021$ guilder per km. This seems a likely estimate for the whole road network.

These amounts do not contain additional large constructions works. So $\mu = 0.013$ is a minimum estimate. Therefore we put $\mu = 0.015$.

5. Option 5 shows negative effects in the first years compared with the reference scenario. Adding years after 2030 in the cost-benefit analysis, the difference between the profitability index of the options 2 and 4 at the one hand and that of option 5 at the other hand increases in favour of option 5.

6. The positive profitability indices seem rather high. Perhaps the estimate of $\mu = 0.015$ is too low, which results in too low construction costs; see (18). If we put $\mu = 0.030$, the benefits of

the options 2, 4, 5, 6 and 8 decrease and the costs of all options increase. The profitability indices become lower but those of the options 2 and 4 become negative (as option 6). So the options 2 and 4 are at $\mu = 0.030$ not only unfavourable for the Walloon Region but also for Total Belgium. However, the ranking of the options does not change.

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