A POLICY ORIENTED MODEL ABOUT ECONOMY, MOBILITY, INFRASTRUCTURE AND OTHER REGIONAL FEATURES WITH AN APPLICATION TO THE DUTCH PROVINCE OF UTRECHT

FLORIS W.C.J. VAN DE VOOREN
Ministry of Transport, Public Works and Water Management
The Netherlands
Rijkswaterstaat Directie Limburg
Avenue Céramique 125, 6221 KV MAASTRICHT, THE NETHERLANDS

Abstract

The relationship between the economy, mobility, infrastructure and other regional features is described by an interregional dynamic model, named MOBILEC. Its main characteristic is the mutual influencing of the economy and mobility. With the help of MOBILEC time paths of regional product, employment, investment and mobility (passengers and goods; transport modes; transport flows by motive) can be simulated for each region. It is also possible to calculate by region the effects of mobility policy and spatial economic policy on the quantities mentioned. The simulation results of the mobility and the economy of the province of Utrecht are presented.

INTRODUCTION

In political circles transport infrastructure is generally considered as an important factor for economic development of countries and regions. However, it turns out not to be easy to determine the contribution of infrastructure to economic development.[1]
In practice a *traffic model* is often used to examine to what extent the infrastructure has to adapt for conducting the future mobility. In this approach the causal connection between economy and mobility is put in such a way that the economic situation is one of the determinants for the size of mobility.[2] This approach does not allow one to determine the extent to which the construction of new infrastructure or the improvement of existing infrastructure promotes economic development. Neither is it possible to determine to what extent not widening the infrastructure slows down the economic development.
The mutual influencing of the economy and mobility is the main characteristic of an interregional dynamic model, named MOBILEC (MOBILity/EConomy). MOBILEC describes the relationship between the economy, mobility, infrastructure and other regional features. It is a neoclassical growth model, but adapted in such a way that it can generate unemployment. The model is macroeconomic on the level of regions within a country or country parts within Europe. The model contains 37 equations and 37 endogenous variables.
The model takes account of:

(1) the bicausal relationship between the economy and mobility in connection with the difference between productive and consumptive mobility;
(2) the infrastructure as a limiting condition (to change by policy) for the 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;
(3) the geographic situation of the regions in connection with transit traffic;
(4) the importance of regional features for economic development;
(5) intra- and interregional flows of transport; flows of transport are not, as in a traffic model, assigned to specific stretches of infrastructure;
(6) the economic connection between regions;
(7) the economic growth by means of net investment and technological progress, which increase the capacity of production.

With the help of MOBILEC time paths of regional product, employment, investment and mobility (passengers and goods; transport modes; transport flows by motive) can be simulated for each region. It is also possible to calculate by region the effects of mobility policy and spatial economic policy on the quantities mentioned.
The article will give a description of MOBILEC. The model has been applied to three regions of the Netherlands; the simulation results of the mobility and the economy of the province of Utrecht will be presented in this article. It will happen in the form of long-term projections from 2000 to 2030, on the basis of four scenarios[3] of economic environment and five variants of mobility policy.

PRODUCTIVE AND CONSUMPTIVE MOBILITY

There exists a bicausal relationship between economy and mobility, which can be found as follows.
A production function describes the relation between the input of production factors and the output of commodities. Besides the usual production factors labour and capital, the production factor traffic infrastructure can be distinguished. However, one should not admit the size of infrastructure in the production function but the part of it that is utilized for the production. The infrastructure utilized is to identify with the mobility for productive ends, expressed in terms of the number of passengers and the

number of tons of goods which have been moved through this infrastructure.

Transport of goods and business traffic concern *productive mobility*. 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*. Commuter traffic comes into being because of a productive performance outside the residence; for that reason it is a matter of productive mobility. On the other hand it can be posed that commuter traffic is the consequence of the consumptive wish of living in a more attractive environment than where one is working; from this view commuter traffic is to be characterized as consumptive mobility. This difficulty results in a separate equation for commuter traffic in MOBILEC.

The production function contains productive mobility and not consumptive mobility. In accordance with the production function, the direction of the causal connection goes from mobility to economy. In 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.

THE MODEL

MOBILEC contains a Cobb-Douglas production function to which is added the regional *production structure* and the regional *urbanisation*:

$$\mathbf{Y_r} = A_r\ \mathbf{N_r}^{\alpha}\ \mathbf{K_r}^{\beta}\ \left(\prod_{s=1}^{k}\mathbf{Tpi_{sr}}\right)^{\gamma i} \left(\prod_{s=1}^{k}\mathbf{Tpii_{sr}}\right)^{\gamma ii} \left(\prod_{s=1}^{k}\mathbf{Tpiii_{sr}}\right)^{\gamma iii} \left(\prod_{s=1}^{k}\mathbf{Tp1_{rs}}\right)^{\gamma 1}$$

$$\left(\prod_{s=1}^{k}\mathbf{Tp2_{rs}}\right)^{\gamma 2} \left(\prod_{s=1}^{k}\mathbf{Tp3_{rs}}\right)^{\gamma 3} (Yn_r/\mathbf{Y_r})^{\delta}\ \exp(\varepsilon C_r) \tag{1}$$

where:

Y_r - real geographic product of region r;
A_r - state of technology in region r;
N_r - labour volume in region r;
K_r - real private stock of capital goods in region r;
Tpi_{sr} - productive mobility of goods by lorry from region s to region r;
$Tpii_{sr}$ - idem, by train;
$Tpiii_{sr}$ - idem, by ship;
$Tp1_{rs}$ - productive mobility of business traffic by car from region r to region s and back to the region of origin r;
$Tp2_{rs}$ - idem, by train;
$Tp3_{rs}$ - idem, by bus;
Yn_r - real value added of the labour-intensive industries in region r;
C_r - indicator for the extent of urbanisation of region r: share of the population of the municipalities with a head centre of more than 50,000 inhabitants in the total population of the region.

The endogenous variables are in bold typeface. Greek small letters represent coefficients, which can adopt whether or not region specific values; for the sake of simplicity, they are not equipped with an index r, rs or sr.[4] There are k regions: s = 1, 2, ... r, ... k.[5]

Contrary to what the neoclassical theory teaches, marginal labour productivity does not determine the real wage rate in the model, but the real wage rate, taken exogenously, determines the marginal labour productivity:

$$\frac{\partial \mathbf{Y_r}}{\partial \mathbf{N_r}} = w_r \tag{2}$$

where w_r represents the real wage rate. Because of eqn (2) the model can generate unemployment, contrary to the neoclassical theory with its flexible prices.

The productive mobility of goods by lorry from region s to region r takes such a size that its marginal mobility productivity equals the real price of productive mobility of goods by lorry:

$$\frac{\partial Y_r}{\partial Tpi_{sr}} = ppi_{sr} \tag{3.i}$$

where ppi_{sr} represents the real price per ton of productive mobility of goods for covering the distance by lorry from region s to region r. The same type of equation applies to the productivity of freight transport by train - eqn (3.ii) - and by ship - eqn (3.iii).

Likewise the marginal mobility productivity of business traffic by car from region r to region s and back to the region of origin r equals the real price of productive mobility:

$$\frac{\partial Y_r}{\partial Tp1_{rs}} = pp1_{rs} \tag{3.1}$$

where $pp1_{rs}$ represents the real price per passenger of productive mobility of business traffic for covering the distance by car from region r to region s and back to the region of origin r. The same type of equation applies to the productivity of business traffic by train - eqn (3.2) - and by bus - eqn (3.3).[6]

The stock of capital goods in eqn (1) is measured at the beginning of the period t, $K_{r(t)}$. It is extended by (private) net investment in period t, $I_{r(t)}$, to the stock of capital goods in period t+1:

$$K_{r(t+1)} = K_{r(t)} + I_{r(t)} \tag{4}$$

The time index is only written in those equations where variables refer to different periods.

Regional (private) saving S_r is a function of regional income, which is equated, for the sake of simplicity, to the geographic product:

$$S_r = \sigma \, Y_r^{\upsilon} \tag{5}$$

The level of the national (private) investment I_N is determined by the national (private) saving reduced by the deficit on the state account and the surplus on the balance of payments : $I_N < S_N$.[7] If the state account shows a surplus and the balance of payments a deficit, it holds $I_N > S_N$. The possibility of inequality between national investment and national saving is represented as follows:

$$I_N = \Gamma_N \, S_N$$

where $\Gamma_N < 1$ in case of a deficit on the state account and a surplus on the balance of payments and $\Gamma_N > 1$ in case of a surplus on the state account and a deficit on the balance of payments.

From saving S_r of region r, $\Gamma_r \, S_r$ is used for investment, either in region r or elsewhere in the country. So regional investment equals regional saving $\Gamma_r \, S_r$, increased by the interregional savings balance. In case of a positive interregional savings balance of region r, savings flows on balance from elsewhere in the country to region r: $I_r > \Gamma_r \, S_r$. A negative interregional savings balance of region r implicates a outflow, on balance, of saving from region r to elsewhere in the country: $I_r < \Gamma_r \, S_r$. The possibility of inequality between regional investment and regional saving is represented as follows:

$$I_r = \Phi_r \, \Gamma_r \, S_r \tag{6}$$

where $\Phi_r > 1$ in case of a positive interregional savings balance and $\Phi_r < 1$ in case of a negative interregional savings balance.
A region may expect a positive interregional saving balance, if - compared with other regions - it is financially attractive to invest there. Against this background, the *ratio of the capital rate of return* in region r to the whole country (as a average of all regions) is to consider as a explaining variable for the quantity Φ_r.
In many countries the entrepreneur can obtain a premium on investment under certain conditions. The level of the premium is, among other things, dependent of the region where the investment is realized. The *ratio of the investment premium* in the region r to the whole country (as an average of all regions) is the second explaining variable of the quantity Φ_r.
On the basis of the foregoing the following equation for Φ_r is formulated:

$$\Phi_r = \phi \left(\frac{Y_r - w_r N_r - pp_r Tp_r}{K_r} \Big/ \frac{Y_N - w_N N_N - pp_N Tp_N}{K_N} \right)^{\zeta} \exp(\eta m_r / m_N) \qquad (7)$$

where:

$(Y_r - w_r N_r - pp_r Tp_r)/K_r$	- capital rate of return in region r;
$(Y_N - w_N N_N - pp_N Tp_N)/K_N$	- capital rate of return in the country;
m_r	- investment premium in region r;
m_N	- investment premium as a average of the country.

$pp_r Tp_r$ is a contracted notation for: $\sum_{s=1}^{k} (ppi_{sr}Tpi_{sr} + ppii_{sr}Tpii_{sr} + ppiii_{sr}Tpiii_{sr} + pp1_{rs}Tp1_{rs} + pp2_{rs}Tp2_{rs} + pp3_{rs}Tp3_{rs})$.

$pp_N Tp_N$ is a contracted notation for: $\sum_{r=1}^{k} \sum_{s=1}^{k} (ppi_{sr}Tpi_{sr} + ppii_{sr}Tpii_{sr} + ppiii_{sr}Tpiii_{sr} + pp1_{rs}Tp1_{rs} + pp2_{rs}Tp2_{rs} + pp3_{rs}Tp3_{rs})$.

The investment premium is to quantify as the weighted average of the current premium percentages in the municipalities of the region in question, with the population of the municipalities as weights.
The consumptive mobility from region r to region s and back to the region of origin r is determined by the income of region r, equated to the geographic product for the sake of simplicity, the price of consumptive mobility, and the regional features *metropolitan character* and *possibities of recreation* in region s in proportion to those in region r:

$$\mathbf{Tc1_{rs}} = \theta 1\, \mathbf{Y_r}^{\iota 1} (\mathbf{pc1_{rs}})^{\kappa 11} (\mathbf{pc2_{rs}})^{\kappa 12} (\mathbf{pc3_{rs}})^{\kappa 13} \left(\frac{B_s/L_s}{B_r/L_r} \right)^{\lambda 1} \left(\frac{R_s/L_s}{R_r/L_r} \right)^{\mu 1} \qquad (8.1)$$

where:

$Tc1_{rs}$	-	consumptive mobility by car from region r to region s and back to the region of origin r;
$pc1_{rs}$	-	real price per passenger of consumptive mobility by car for covering the distance from region r to region s and back to the region of origin r;
$pc2_{rs}$	-	idem, by train;
$pc3_{rs}$	-	idem, by bus;
B_r	-	population in region r;
L_r	-	surface area of region r;
R_r	-	surface area of wood and savage land in region r.

The commuter traffic from region r to region s and back to the region of origin r is determined by the income of region r, the price of commuter traffic, and the per capita employment in region s in proportion to that in region r:

$$\mathbf{Tw1}_{rs} = v1\ \mathbf{Y}_r^{\xi 1}\ (\mathbf{pw1}_{rs})^{\pi 11}\ (\mathbf{pw2}_{rs})^{\pi 12}\ (\mathbf{pw3}_{rs})^{\pi 13} \left(\frac{N_s/B_s}{\mathbf{N}_r/B_r} \right)^{\rho 1} \tag{9.1}$$

where:

$Tw1_{rs}$ - commuter traffic by car from region r to region s and back to the region of origin r;

$pw1_{rs}$ - real price per passenger of commuter traffic by car for covering the distance from region r to region s and back to the region of origin r;

$pw2_{rs}$ - idem, by train;

$pw3_{rs}$ - idem, by bus;

The same types of equations apply to consumptive mobility and commuter traffic by train - eqns (8.2) and (9.2) respectively - and by bus - eqns (8.3) and (9.3) respectively.
The mobility price consists of travel-distance costs and travel-time costs; by lorry or car:

$$\mathbf{ppi}_{sr} = ppdi_{sr}\, di_{sr} + ppti_{sr}\, \mathbf{hi}_{sr} \tag{10.i}$$

$$\mathbf{pp1}_{rs} = ppd1_{rs}\, d1_{rs} + ppt1_{rs}\, \mathbf{h1}_{rs} \tag{10.1}$$

$$\mathbf{pc1}_{rs} = pcd1_{rs}\, d1_{rs} + pct1_{rs}\, \mathbf{h1}_{rs} \tag{11.1}$$

$$\mathbf{pw1}_{rs} = pwd1_{rs}\, d1_{rs} + pwt1_{rs}\, \mathbf{h1}_{rs} \tag{12.1}$$

where:

$ppdi_{sr}$ - real price (per ton) per distance unit of productive mobility of goods by lorry from region s to region r;

$ppd1_{rs}$ - real price (per passenger) per distance unit of productive mobility of business traffic by car from region r to region s and back to the region of origin r;

$ppc1_{rs}$ - idem, consumptive mobility;

$ppw1_{rs}$ - idem, commuter traffic;

di_{sr} - distance by lorry from region s to region r;

$d1_{rs}$ - distance by car from region r to region s and back to the region of origin r;

$ppti_{sr}$ - real price (per ton) per time unit of productive mobility of goods by lorry from region s to region r;

$ppt1_{rs}$ - real price (per passenger) per time unit of productive mobility of business traffic by car from region r to region s and back to the region of origin r;

$pct1_{rs}$ - idem, consumptive mobility;

$pwt1_{rs}$ - idem, commuter traffic;

hi_{sr} - travel time by lorry from region s to region r;

$h1_{rs}$ - travel time by car from region r to region s and back to the region of origin r.

The same types of equations apply to train - eqns (10.ii), (10.2), (11.2), and (12.2) -, to ship - eqn (10.iii) -, and to bus - eqns (10.3), (11.3), and (12.3). Travel time increases, the more the road infrastructure in region r and s and in the regions to pass through is utilized by lorry or car:

$$\mathbf{hi}_{sr(t)} = gi_{sr(t)} \left(1 + \chi i\ \frac{\mathbf{U}_{r(t-1)} + \mathbf{U}_{s(t-1)} + \sum_d \mathbf{U}_{d(rs)(t-1)}}{V_{r(t)} + V_{s(t)} + \sum_d V_{d(rs)(t)}} \right)^{\psi i} \tag{13.i}$$

$$\mathbf{h1}_{sr(t)} = g1_{sr(t)} \left(1 + \chi 1\ \frac{\mathbf{U}_{r(t-1)} + \mathbf{U}_{s(t-1)} + \sum_d \mathbf{U}_{d(rs)(t-1)}}{V_{r(t)} + V_{s(t)} + \sum_d V_{d(rs)(t)}} \right)^{\psi 1} \tag{13.1}$$

where:

gi_{sr} - travel time by lorry from region s to region r, if vehicules do not influence the speed of each other;

$g1_{rs}$	-	travel time by car from region r to region s and back to the region r of origin, if vehicules do not influence the speed of each other;
U_r	-	utilization of the road infrastructure of region r;
$U_{d(rs)}$	-	utilization of the road infrastructure of the regions to pass through between region r and s;
V_r	-	capacity of the road infrastructure of region r;
$V_{d(rs)}$	-	capacity of the road infrastructure of the regions to pass through between regions r and s.

The utilization of the road infrastructure concerns the *expected* utilization in period t; it is equated to the *actual* utilization in period t-1. So $hi_{sr(t)}$ and $h1_{rs(t)}$ represent the expected travel time in period t. The same type of equation applies to the travel time by bus: (13.3). It is assumed that the distribution of mobility over time - peak and low hours; working days, Sundays and holidays - is constant. The utilization of railway infrastructure does not determine directly travel time by train because of its blocksystem. Waterway infrastructure has an overcapacity for transport by ship. Therefore travel times by train and by ship are considered as exogeneous quantities.
The utilization of the road infrastructure in region r is calculated as:

$$\begin{aligned} U_r = & \sum_{s=1}^{k} ei \frac{Tpi_{sr}}{bpi} + \sum_{\substack{s=1 \\ s\neq r}}^{k} ei \frac{Tpi_{rs}}{bpi} + \sum_{u,v} ei \frac{Tpi_{uv(r)}}{bpi} + 2\sum_{s=1}^{k} \frac{Tp1_{rs}}{bp1} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} \frac{Tp1_{sr}}{bp1} + 2\sum_{u,v} \frac{Tp1_{uv(r)}}{bp1} + \\ & 2\sum_{s=1}^{k} \frac{Tc1_{rs}}{bc1} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} \frac{Tc1_{sr}}{bc1} + 2\sum_{u,v} \frac{Tc1_{uv(r)}}{bc1} + 2\sum_{s=1}^{k} \frac{Tw1_{rs}}{bw1} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} \frac{Tw1_{sr}}{bw1} + 2\sum_{u,v} \frac{Tw1_{uv(r)}}{bw1} + \\ & 2\sum_{s=1}^{k} e3 \frac{Tp3_{rs}}{b3} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} e3 \frac{Tp3_{sr}}{b3} + 2\sum_{u,v} e3 \frac{Tp3_{uv(r)}}{b3} + 2\sum_{s=1}^{k} e3 \frac{Tc3_{rs}}{b3} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} e3 \frac{Tc3_{sr}}{b3} + \\ & 2\sum_{u,v} e3 \frac{Tc3_{uv(r)}}{b3} + 2\sum_{s=1}^{k} e3 \frac{Tw3_{rs}}{b3} + 2\sum_{\substack{s=1 \\ s\neq r}}^{k} e3 \frac{Tw3_{sr}}{b3} + 2\sum_{u,v} e3 \frac{Tw3_{uv(r)}}{b3} \end{aligned} \quad (14)$$

where:

ei	-	parameter for transforming the number of lorries into passenger-car equivalent;
e3	-	parameter for transforming the number of busses into passenger-car equivalent;
bpi	-	average load per lorry;
bp1	-	average number of passengers per car with regard to productive mobility;
bc1	-	idem, consumptive mobility;
bw1	-	idem, commuter traffic;
b3	-	average number of passengers per bus;
$Tpi_{uv(r)}$	-	productive mobility of goods by lorry between regions u and v via region r because of the geographic situation.

The factor 2 in eqn (14) indicates that in general passenger traffic uses road infrastructure twice: going out and returning.
The following identities are to add to the model for completing:

$$Y_N = \sum_{r=1}^{k} Y_r \quad (15)$$

$$N_N = \sum_{r=1}^{k} N_r \tag{16}$$

$$K_N = \sum_{r=1}^{k} K_r \tag{17}$$

The model works as follows. The geographic product/regional income in period t determines regional saving according to eqn (5). According to eqns (7), (15), (16), and (17), the geographic products, the labour volumes and the stock of capita goods of all regions together determine $\Phi_{r(t)}$ given the real wage rates and investment premiums. Given the value of $\Gamma_{r(t)}$, regional investment is fixed according to eqn (6) and so the stock of capital goods at the beginning of period t+1 according to eqn (4). The exogenous real wage rate and the price of productive mobility in period t+1 fix the marginal labour productivity and the marginal mobility productivity in period t+1 according to eqns (2) and (3). These marginal productivities and the stock of capital goods at the beginning of period t+1 determine, according to eqn (1), simultaneously labour volume, productive mobility and geographic product in period t+1, given the state of technology, the production structure and the urbanisation. At the same time consumptive mobility and commuter traffic are calculated with the help of eqns (8) and (9) respectively. Then the process starts again: the geographic product/regional income in period t+1 determines regional saving in period t+1 according to eqn (5), etc. In this continuous process of development of economy and mobility, eqns (10) - (14) fix the mobility prices.

SIMULATION OF TIME PATHS

In order to simulate time paths of geographic product, employment, investment and mobility and to calculate policy effects on these quantities, it is necessary to deduce the reduced-form equations of the model. The coefficients of the reduced-form equations can be estimated by econometric methods. To limit the quantity of statistical data, cross-section analysis is to prefer to time-series analysis. Moreover, a cross-section analysis reveals better the influence of regional features, because they change in general to a small degree in the course of time, while their differences between regions often are significant.
As experiment, MOBILEC has been applied to 3 of the 40 Dutch regions, so that a cross-section analysis is not possible as yet. Therefore we shall assign values to the coefficients on the basis of economic theory and empirical results in other studies.
Substitution of eqn (1) into eqns (2), (3.i), and (3.1) gives respectively:

$$\ln \mathbf{N}_r = \ln \mathbf{Y}_r - \ln w_r + \ln \alpha \tag{18}$$

$$\ln \mathbf{Tpi}_{sr} = \ln \mathbf{Y}_r - \ln \mathbf{ppi}_{sr} + \ln \gamma i \tag{19.i}$$

$$\ln \mathbf{Tp1}_{rs} = \ln \mathbf{Y}_r - \ln \mathbf{pp1}_{rs} + \ln \gamma 1 \tag{19.1}$$

Substitution of eqns (18), (19.i) - (19.iii) and (19.1) - (19.3) into eqn (1) gives:

$$\begin{aligned}\ln \mathbf{Y}_r = {} & [1/(1 - \alpha - k\,\gamma i - k\,\gamma ii - k\,\gamma iii - k\,\gamma 1 - k\,\gamma 2 - k\,\gamma 3)]\,[\ln A_r + \alpha \ln \alpha + \\ & k\,\gamma i \ln \gamma i + k\,\gamma ii \ln \gamma ii + k\,\gamma iii \ln \gamma iii + k\,\gamma 1 \ln \gamma 1 + k\,\gamma 2 \ln \gamma 2 + k\,\gamma 3 \ln \gamma 3 + \\ & \beta \ln \mathbf{K}_r - \alpha \ln w_r - \gamma i \sum_{s=1}^{k} \ln \mathbf{ppi}_{sr} - \gamma ii \sum_{s=1}^{k} \ln \mathbf{ppii}_{sr} - \gamma iii \sum_{s=1}^{k} \ln \mathbf{ppiii}_{sr} - \\ & \gamma 1 \sum_{s=1}^{k} \ln \mathbf{pp1}_{rs} - \gamma 2 \sum_{s=1}^{k} \ln \mathbf{pp2}_{rs} - \gamma 3 \sum_{s=1}^{k} \ln \mathbf{pp3}_{rs} + \delta \ln (Yn_r/Y_r) + \varepsilon\, C_r]\end{aligned} \tag{20}$$

There are still some endogenous variables in eqn (20): the stock of capital goods at the beginning of the period considered and the prices of productive mobility.

The stock of capital goods depends of the stock of capital goods and the investment in the preceding period. The value of the stock of capital goods in eqn (20) can be determined with the help of eqn (4), as soon as the investment is known. As the experiment with MOBILEC only concerns 3 of the 40 Dutch regions, we assume, for the sake of simplicity, that the *ratio of the capital rate of return* in Utrecht to that in the whole country (as an average of all regions) does not change in the course of time. In Utrecht *investment premiums* are not applied. Then it follows from eqns (5), (6), and (7):

$$\ln \mathbf{I}_r = \ln E_r + \upsilon \ln \mathbf{Y}_r \tag{21}$$

where E_r contains all quantities which are supposed to be constant.

The mobility prices depend of exogenous quantities and the expected utilization of the road infrastructure, which is equated to the actual utilization in the preceding period. However, we cannot use eqns (13.i) and (13.1) because of the application of the model to only three regions. Moreover, it is difficult to quantify V_r. As alternative, the increase of travel time by lorry and car is calculated as:[8]

$$(\mathbf{hi}_{sr(t)} - \mathbf{hi}_{sr(t-1)})/\mathbf{hi}_{sr(t-1)} = \omega i\,[(\mathbf{U}_{r(t-1)} - \mathbf{U}_{r(t-2)})/\mathbf{U}_{r(t-2)} - (V_{r(t)} - V_{r(t-1)})/V_{r(t-1)}] \tag{22.i}$$

$$(\mathbf{h1}_{rs(t)} - \mathbf{h1}_{rs(t-1)})/\mathbf{h1}_{rs(t-1)} = \omega 1\,[(\mathbf{U}_{r(t-1)} - \mathbf{U}_{r(t-2)})/\mathbf{U}_{r(t-2)} - (V_{r(t)} - V_{r(t-1)})/V_{r(t-1)}] \tag{22.1}$$

The same type of equation applies to the increase of travel time by bus: (22.3).

U_r is calculated with the help of eqn (14), in which we leave aside, for the time being, the terms in the right-hand side of eqn (14) concerning transport of goods from Utrecht to other regions, transport of passengers from other regions to Utrecht and back to the other regions of origin and transit transport through Utrecht. Leaving aside these terms in eqn (14) is not a serious problem in our experiment, because we are interested in the *relative* mutation of U_r; see eqn (22).

In the experiment of the three regions, the regional features *metropolitan character* and *possibilities of recreation* in eqn (8) and the *comparative per capita employment* in eqn (9) are supposed to be constant in the course of time.

The values of the coefficients in the equations for the time paths are obtained as follows. The values of a, γi, γii, γiii, γ1, γ2 and γ3 are to deduce from eqns (18) and (19) applying to Utrecht in the period 1991-1993: $\alpha_U = .72$ and $\sum_s \gamma i_{sU} + \sum_s \gamma ii_{sU} + \sum_s \gamma iii_{sU} + \sum_s \gamma 1_{Us} + \sum_s \gamma 2_{Us} + \sum_s \gamma 3_{Us} = .04$.[9] Assuming constant returns to scale, $\beta_U = .24$.

Table 1 - Values of the coefficients in the equations for the time paths

(20):	$\delta/(1 - \alpha - k\gamma i - k\gamma ii - k\gamma iii - k\gamma 1 - k\gamma 2 - k\gamma 3) = .50$				(21): $\upsilon = 1.00$			
	$\varepsilon/(1 - \alpha - k\gamma i - k\gamma ii - k\gamma iii - k\gamma 1 - k\gamma 2 - k\gamma 3) = -.10$				(22): $\omega i = .50$	$\omega 1 = .50$	$\omega 3 = .50$	
(8.1) →	(23.1):	$\iota 1 = .50$	$\kappa d11 = -.61$	$\kappa d12 = .01$	$\kappa d13 = .02$	$\kappa t11 = -1.00$	$\kappa 12 = .02$	$\kappa d13 = .04$
(8.2) →	(23.2):	$\iota 2 = 0$	$\kappa d21 = .09$	$\kappa d22 = -.99$	$\kappa d23 = -.04$	$\kappa t21 = .13$	$\kappa t22 = -1.49$	$\kappa t23 = -.30$
(8.3) →	(23.3):	$\iota 3 = 0$	$\kappa d31 = .12$	$\kappa d32 = -.05$	$\kappa d33 = -.82$	$\kappa t31 = .17$	$\kappa t32 = -.08$	$\kappa t33 = -1.28$
(9.1) →	(24.1):	$\xi 1 = .50$	$\pi d11 = -.20$	$\pi d12 = .01$	$\pi d13 = .02$	$\pi t11 = -1.40$	$\pi t12 = .02$	$\pi t13 = .04$
(9.2) →	(24.2):	$\xi 2 = 0$	$\pi d21 = .15$	$\pi d22 = -.50$	$\pi d23 = 0$	$\pi t21 = .80$	$\pi t22 = -1.68$	$\pi t23 = -.19$
(9.3) →	(24.3):	$\xi 3 = 0$	$\pi d31 = .17$	$\pi d32 = -.01$	$\pi d33 = -.37$	$\pi t31 = .89$	$\pi t32 = -.07$	$\pi t33 = -2.02$

Table 1 represents the values of the coefficients which cannot be deduced from the model. The values of the coefficients $\delta/(1 - \alpha - k\gamma i - k\gamma ii - k\gamma iii - k\gamma 1 - k\gamma 2 - k\gamma 3)$ and $\varepsilon/(1 - \alpha - k\gamma i - k\gamma ii - k\gamma iii - k\gamma 1 - k\gamma 2 - k\gamma 3)$ have been taken from Van de Vooren & Wagenaar (1987). The negative value of ε indicates that agglomeration diseconomies exceed agglomeration economies. The assumption of $\upsilon = 1$ implies a linear saving function. We suppose $\omega i = \omega 1 = \omega 3 = .5$ in the first instance.
The values of the elasticities in eqns (8) and (9) in table 1 have been taken from Van der Waard (1990). However, we revised the values of income elasticities in connection with substitution effects for other transport modes. Further, Van der Waard mentions values of elasticities with regard to distance-travel costs and travel time. For this reason eqns (8) and (9) are adapted as follows:

$$\ln \mathbf{Tc1}_{rs} = \ln F1_{rs} + \iota 1 \ln \mathbf{Y}_r + \kappa d11 \ln pcd1_{rs} + \kappa t11 \ln \mathbf{h1}_{rs} + \kappa d12 \ln pcd2_{rs} + \kappa t12 \ln h2_{rs} + \kappa d13 \ln pcd3_{rs} + \kappa t13 \ln \mathbf{h3}_{rs} \qquad (23.1)$$

$$\ln \mathbf{Tw1}_{rs} = \ln G1_{rs} + \xi 1 \ln \mathbf{Y}_r + \pi d11 \ln pwd1_{rs} + \pi t11 \ln \mathbf{h1}_{rs} + \pi d12 \ln pwd2_{rs} + \pi t12 \ln h2_{rs} + \pi d13 \ln pwd3_{rs} + \pi t13 \ln \mathbf{h3}_{rs} \qquad (24.1)$$

Eqns (23.1) and (24.1) are adaptations of eqns (8.1) and (9.1), in which $F1_{rs}$ and $G1_{rs}$ contain all quantities are supposed to be constant. Likewise eqns (8.2), (8.3), (9.2) and (9.3) are adapted to eqns (23.2), (23.3), (24.2) and (24.1) respectively.
A_r in eqn (20) and the intercepts in eqns (21), (23) and (24) have been assigned such a value that the respective equation gives the actual value of the dependent variable in the period 1991-1993. A period of MOBILEC encloses three years.

SCENARIOS AND MOBILITY POLICY

We want to make projections about the economy and mobility till 2030, but we do not have the gift of prophecy. Because of the fundamental uncertainty about future, four scenarios of economic environment are distinguished. To each scenario five variants of mobility policy are coupled. Tables 2 and 3 give a description.

Table 2 - Four scenarios of economic environment

	A_r	Yn_r/Y_r	coeff. C_r	w_r
Post-industrial economy	2%	a=.50	constant	1%
Innovative post-industrial economy	2.5%	a=.50	+ .005	1%
Service economy	2%	a=.75	constant	1%
Innovative service economy	2.5%	a=.75	+ .005	1%

According to table 2 the rate of technological development is 2% and 2.5% per period respectively (a period of MOBILEC encloses three years). The regional production structure changes per period t as follows:

$$(Yn_r/Y_r)_t = (Yn_r/Y_r)_{t-1} + a\,[(Yn_r/Y_r)_{t-1} - (Yn_r/Y_r)_{t-2}]$$

where a = .50 respectively .75. The coefficient of C_r in eqn (20) remains constant (-.10) or increases by .005 points per year because of a rising vitality of urban agglomerations. In the last case the coefficient of C_r becomes finally positive: agglomeration economies will exceed agglomeration diseconomies. The real wage rate increases by 1% per year.

Table 3 - Five variants of mobility policy

	Capacity of road Infrastructure	Real travel-distance costs per km	Travel time
Null variant	constant	constant	ship constant train constant
Road variant	extension = increase of utilization	constant	ship constant train constant
Tariff variant	constant	car/lorry 3% ship 1% train 1% bus 1%	ship constant train constant
Public-transport variant	constant	constant	ship constant train -1% bus -1%
Total variant	extension = increase of utilization	car/lorry 3% ship 1% train 1% bus 1%	ship constant train -1% bus -1%

The null variant (no new measures) in table 3 functions as reference for the other variants; the travel time of ship and train is assumed constant, where as the travel time of lorry, car and bus is the result of the model. The road variant implies constant travel time for lorry, car and bus too; see eqn (22). The increase of travel-distance costs per km and the decrease of travel time concern percentages per year. In the public-transport variant the increase of travel time for car and bus corresponds no more, as a result of priority measures, special strips etc. for bus. The total variant contains all measures of the other variants.

PROJECTIONS UTRECHT 2000-2030

Table 4 represents some quantitative results for the province of Utrecht obtained with the help of MOBILEC on the basis of the scenarios and policy variants as described above. In this table, the transport of goods contains the intraregional transport in Utrecht and the interregional transport from other regions, including foreign countries, to Utrecht. The transport of passengers contains the intraregional transport in Utrecht and the interregional transport from Utrecht to other regions and back to Utrecht as region of origin. The lacking interregional transport flows and the transit transport through Utrecht can be taken into consideration, when MOBILEC has been applied to all 40 regions.

Table 4 shows relatively small differences in economic growth between the policy variants per scenario. Small differences also arise between the scenarios "post-industrial economy" and "service economy" and between the scenarios "innovative post-industrial economy" and "innovative service economy". Nevertheless the differences should not be underestimated. It concerns differences between yearly growth rates as an average over a period of 30 years. At a economic growth rate of about 2.5% per year, .01 percentage point more growth means: 6600 jobs (labour years) more in 2030, i.e. 1.6% of the average employment per year in Utrecht in the period 1991-1993. At a economic growth rate of about 4% per year, .01 percentage point more growth means 11,000 jobs more in 2030, i.e. 2.6% of the employment.

In the *null variant*, the transport of goods by train and ship shows a relatively high growth compared to that by lorry. The transport of passengers by car increases, whereas that by train is roughly constant and that by bus decreases.

Table 4 - Province of Utrecht, average growth per year (%) of the geographic product and the transport of goods and passengers by transport mode in the period 2000-2030 (a)

	Null variant	Road variant	Tariff variant	Publ-tr. variant	Total variant
Post-industrial ec.					
Geographic product	2.56	2.63	2.37	2.58	2.38
transport of goods					
* by lorry	1.57	1.91	.71	1.60	.71
* by train	2.52	2.60	1.40	2.62	1.46
* by ship	2.36	2.43	1.68	2.38	1.69
transport of pass.					
* by car	1.27	1.63	.26	1.22	.22
* by train	-.02	.01	-.65	1.85	.94
* by bus	-.41	.04	-.08	1.76	1.31
Innov. post-ind. ec.					
geographic product	4.02	4.15	3.83	4.05	3.86
transport of goods					
* by lorry	2.80	3.42	2.00	2.84	2.09
* by train	3.99	4.12	2.84	4.08	2.92
* by ship	3.82	3.95	3.13	3.84	3.16
transport of pass.					
* by car	1.78	2.46	.78	1.73	.87
* by train	.04	.11	-.58	1.95	1.03
* by bus	-.58	.21	-.21	2.00	1.50
Service economy					
geographic product	2.64	2.71	2.45	2.66	2.46
transport of goods					
* by lorry	1.64	1.99	.78	1.73	.87
* by train	2.60	2.68	1.47	2.69	1.53
* by ship	2.44	2.51	1.75	2.45	1.76
transport of pass.					
* by car	1.29	1.68	.28	1.24	.25
* by train	-.02	.02	-.65	1.85	.94
* by bus	-.42	.05	-.09	1.77	1.32
Innov. Service ec.					
Geographic product	4.11	4.24	3.92	4.13	3.95
transport of goods					
* by lorry	2.87	3.51	2.08	2.91	2.17
* by train	4.07	4.21	2.93	4.17	3.01
* by ship	3.90	4.04	3.21	3.93	3.24
transport of pass.					
* by car	1.81	2.51	.81	1.76	.91
* by train	.05	.12	-.57	1.96	1.04
* by bus	-.59	.22	-.22	2.01	1.51

(a) The table does not contain all interregional transport flows nor transit transport through Utrecht; see text. Transport growth has been calculated on the basis of number of passengers or quantities of tons.

The *road variant* stimulates substitution in favour of lorry, car and bus but thanks to the higher economic growth other transport categories also profit.

As a result of the rise of all mobilities prices, economic growth falls in the *tariff variant*, by which the growth of all transport categories decreases, except bus. The transport of passengers by train and bus (consumptive mobility and commuter traffic) is confronted with a high tariff elasticity and a low cross elasticity in relation to distance costs by car. Nevertheless the bus profits from the tariff variant because of the lower utilization of road infrastructure, what makes possible a higher velocity. The negative effect of the tariff variant on economic growth can be compensated by a tax reduction.

The *public-transport variant* exerts a positive effect on the transport of passengers by train and bus. However, the downward effect on the transport of passengers by car is marginal. The growth rate of the

However, the downward effect on the transport of passengers by car is marginal. The growth rate of the transport of goods by lorry is even somewhat higher than in the null variant.

In the *total variant* the negative effect of the tariff variant on the economic growth and the positive effect of the public-transport variant on the public transport are clearly reflected.

The difference in economic growth between the *innovative* post-industrial/service economy on the one hand and the post-industrial/service economy on the other hand is accompagnied by a smaller difference in mobility growth by lorry (not in the road variant), car, train (passengers) and bus. This can be explained by the higher utilization of road infrastructure by lorry, car and bus in the innovative scenarios and the low income elasticities of consumptive mobility and commuter traffic (.5 with regard to car and 0 with regard to train and bus).

As sensitivity analysis, we replace the value of .5 for $\omega i = \omega 1 = \omega 3$ by the value of .75. By definition, the results of the road variant are not influenced by this replacement. It was found that the growth rates of the other policy variants nearly change.

NOTES

1. See for a survey for example: Vickerman, ed. (1991), Munnell (1992), Bruinsma & Rietveld (1993), Gramlich (1994), Bannister, ed. (1995), Gillen & Waters, eds. (1996) and Gomez-Ibanez & Maddrick (1996). See for a discussion for example Toen-Gout & Jongeling (1993) vs. Hakfoort et al. (1993); see also Bomhoff (1995). Blauwens et al. (1996) do not exclude a drain effect of new infrastructure on the economy of some regions.

2. This approach is followed for example in the New Regional Model (NRM) of the Dutch Ministry of Transport, Public Works and Water Management. See also Meersman & Van de Voorde (1991) and Van de Voorde & Meersman (1997).

3. Scenarios are not predictions but constructed pictures of the future. They are intended for founding long-run decisions in a situation of uncertainty.

4. The values of the exponents γi, γii, γiii and $\gamma 1$, $\gamma 2$, $\gamma 3$ respectively can differ between modes of transport because of the correlation between mode of transport and sort of freight/passengers.

5. The consequence of the choice for a Cobb Douglas production function is that it does not allow any transport flow to be zero. This would imply that the geographic product also equals zero. Therefore transport flows of zero are ignored. This implies in practice that the number of regions, k, depends on any region r and differs between modes of transport.

6. According to eqn (3) the entrepreneur compares the price of productive mobility with the value added, generated by an additional unity of productive mobility. Such a comparison does not apply to commuter traffic assuming that it is the commuter himself who pays for his mobility. However, in practice the entrepreneur often pays a minor contribution.

7. It applies in an open economy: $Y = C + S + T$ (1) and $Y = C + I + G + X - M$ (2), where Y - national income, C - private consumption, S - private saving, T - taxes, I - private investment, G - state expenditures, X - export, and M - import. It follows from eqns (1) and (2): $I = S - (G - T) - (X - M)$; i.e. private investment corresponds to private savings reduced by the deficit of the state and the surplus of the balance of payments. The surplus of the balance of payments corresponds to net capital export plus net increase of gold and foreign exchange.

8. It follows from eqn (13.i), leaving aside U_s, $\sum_d U_{d(rs)}$, V_s and $\sum_d V_{d(rs)}$:

$$\frac{dh_{sr}}{dt}\frac{1}{h_{sr}} = \psi i \, \frac{\chi i \, U_r/V_r}{1 + \chi i \, U_r/V_r} \left(\frac{dU_r}{dt}\frac{1}{U_r} - \frac{dV_r}{dt}\frac{1}{V_r} \right)$$

The higher the utilization of the road capacity, the larger is the effect of increasing utilization on travel time. However, we postulate, for the sake of simplicity:

$$\omega i = \psi i \frac{\chi i\, U_r/V_r}{1 + \chi i\, U_r/V_r}$$

The same type of reasoning applies to eqns (13.1) and (13.3).

9. Σ_s: sum over the relevant regions s, including foreign countries, in connection with Utrecht. The relevancy of the regions depends on the size of the transport flows by transport mode.

REFERENCES

Bannister, D., ed. (1995) **Transport and Urban Development**. Spon, London etc.

Blauwens, G., Debaere, P. and Van de Voorde, E. (1996) **Vervoerseconomie**. MIM. Antwerp, 353-354.

Bomhoff, E.J. (1995) **"Met de spade op de schouder", Infrastructure en economie.** Nijenrode Forum for Economic Research, Breukelen.

Bruinsma, F.R. and Rietveld, P. (1993) De structurerende werking van de transportinfrastructuur; een survey betreffende de invloed van infrastructuur en bereikbaarheid op de ruimtelijke spreiding van activiteiten. **Tijdschrift Vervoerswetenschap 29**, 279-302.

Gillen, D.W. and Waters, W.G., II, eds. (1996) Transport Infrastructure Investment and Economic Development, **The Logistics and Transportation Review 32/no. 1.**

Gomez-Ibanez, J.A. and Madrick, J. (1996) **Economic Returns from Transportation Investment.** Eno Transportation Foundation, Lansdowne (VA).

Gramlich, E.M. (1994) Infrastructure Investment: A Review Essay, **Journal of Economic Literature 32.** 1176-1196.

Hakfoort, J.R., De Haan, J. and Sturm, J.E. (1993) Discussie: investeringen en economische groei, **Economisch Statistische Berichten 78**, 670-673.

Meersman, H. and Van de Voorde, E. (1991) De vraag naar personen- en goederenvervoer, **20e Vlaams wetenschappelijk congres, Verkeer in België in 2000: mobiliteit of chaos?** MAKLU Uitgevers, Antwerp and Amersfoort, 3-63.

Munnell, A.H. (1992) Policy Watch: Infrastructure Investment and Economic Growth. **Journal of Economic Perspective 6/no. 4**, 189-198.

Toen-Gout, M.W. and Jongeling, M.M. (1993) Investeringen in infrastructuur en economische groei. **Economisch Statistische Berichten 78**, 424-427.

Van de Voorde, E. and Meersman, H. (1997) **Is Freight Transport Growth Inevitable?** 14th International Symposium on Theory and Practice in Transport Economics, Innsbruck.

Van de Vooren, F.W.C.J. and Wagenaar, S. (1987) Croissance économique régionale aux Pays-Bas, in: Guesnier, B. and Paelinck, J.H.P. (eds.) **Modélisation spatiale; théorie et applications.** Librairie de l'Université, Dijon, 363-387.

Van der Waard, J. (1990) **Concept Handboek Elasticiteiten.** Adviesdienst Verkeer en Vervoer (Ministry of Transport, Public Works and Water Management), Rotterdam.

Vickerman, R.W., ed. (1991) **Infrastructure and Regional Development.** Pion, London.