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Modelling of residential Land-use,
in a joint framework of land-use, transport and economy

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Abstract

An evaluation scheme for transport infrastructure projects, presently adopted by the Dutch government, includes a research challenge to develop a spatial-economic model addressing the indirect impacts of infrastructure measures. Presently several developments in the field of spatial-economic modelling are ongoing in the Netherlands. The Mobilec model is an example of such a development. The Mobilec model is an interregional model, at NUTS3 level, that describes the relationship between productivity, mobility and infrastructure. The current model will benefit of more spatial detail and the explicit modelling of the housing market. The interactions of the Mobilec model and the proposed housing market model are explored in this paper. Furthermore the paper presents a description of the housing market model and reports the current status of the modelling .

1 Introduction

An evaluation scheme for transport infrastructure projects, presently adopted by the Dutch government, includes a research challenge to develop a spatial-economic model addressing the indirect impacts of infrastructure measures. In the Netherlands several developments in the field of spatial-economic modelling are ongoing. The Mobilec model is an example of such a development. The Mobilec model is an interregional model, at NUTS3 level, that describes the relationship between productivity, mobility and infrastructure. The current model lacks spatial detail and an adequate modelling of the housing market and labour market. This research focuses on the development of a housing market model in interaction with the Mobilec model.

The paper gives in chapter 2 an overview of models in the Netherlands, which are used in the economic evaluation of infrastructure projects. Chapter 3 describes the aim of the research and chapter 4 presents the research topic in a wider framework. In chapter 5 the residential location choice model is described and chapter 6 presents some conclusions.

2 Evaluation of infrastructure measures

In this part the text focuses on a description of models assessing the economic and spatial impacts of infrastructure measures. The literature about the regional economic impacts of infrastructure measures is extensive (examples are: Rietveld and Nijkamp 1992, Rietveld en Bruinsma 1998, Vooren 2001, Oosterhaven 2001) and a large variety of research methods exist. Frequently used methods are:

- micro entrepreneurial surveys
- quick scan methods using key figures
- Location models
- input-output models
- inter-regional trade models
- production function approach
- spatial computable general equilibrium models

Another type of models, addressing the spatial impacts of transport measures, is categorized as land-use and transport "LUTI"-models. The integrated land-use and transport modelling systems are often used to estimate the spatial impacts and the environmental impacts of transport and land-use policies. These models are, less commonly, used for the economic evaluation of land-use and transport policies. However some of these models, e.g. Meplan and Tranus (Williams 1994 and Barra 1995), use spatial input-output methods to model the inter-regional economic relations. The LUTI models have been extensively reviewed and overviews of state-of-the-art LUTI models are presented in EPA 2000, Miller 1998, Simmonds 1999, Wegener 1999 and Zondag 2001.

In this section the focus is on three economic models operational in the Netherlands. All three models focus on the economic impacts of major infrastructure measures. The economic impacts of major infrastructure projects in the Netherlands are often analysed by the CPB (Central Planning Agency). The CPB uses the Athena model, as part of a wider analysis, to explore the macroeconomic effects of major infrastructure projects. The Athena model focuses primarily on the medium and long-term effects of policies that affect the sector structure of the economy. The Athena model is an econometric model that distinguishes fifteen branches of industry (Broer 1998, CPB 1990).

The CPB analysis the economic impacts at the country level and does not analyse the regional impacts of infrastructure measures. The impacts at a regional level are important for regional policy makers, national equity strategies or spatial development targets. The impacts of transport measures occur on a local or regional level and a transport measures changes competitiveness between regions.

The RAEM model is a Dutch application of the Spatially Computed General Equilibrium method and has been developed by the Ministry of Public Works, Transport and Water Management. The model is still under development, but a first version of the model has been applied to analyse the spatial-economic impacts of transport measures at a regional level. The SCGE model consists of comparative static equilibrium models of interregional trade and location, based in microeconomics, using utility and production functions with substitution between inputs (Oosterhaven 2000). The SCGE models are theoretically strong in the interregional assessment of

infrastructure measures and the inclusion of producer production and price decisions. The model suffers of practical problems as computation time and problematic estimation of parameters.

A third example is the Mobilec model. The Mobilec model can be described as a modified neoclassical growth model. The Mobilec model describes the relationship between the economy, mobility, infrastructure and other regional features in an interregional dynamic way (Vooren 1998). A main characteristic of the model is the representation of the two-way interaction between economy and mobility. In the traditional transport models transport is estimated as a derived demand of the economical development scenarios. The Mobilec model also determines the contribution of infrastructure to economic development.

The table hereunder briefly summarizes the main characteristics of the three models. Please note that the models are still under development and some of the characteristics can be changed.

	Athena	**RAEM**	**MOBILEC**
Type of model	Multi-sector macro economic model	Spatially computed general equilibrium model	Modified neo classical growth model
Economic sectors	Sector disaggregation	Sector disaggregation	One aggregated sector
Dynamic status	Dynamic	Equilibrium model	Dynamic model
Spatial scale level	National	Municipality	COROP (NUTS3)
Complexity of equations	High	High	Moderate
Model estimation	Difficult	Very difficult	Reasonable
Housing market	Not included	Not included	Not included
Interaction transport – economy	One way	One way	Mutual influences
Labour market	Detailed demand side, supply exogenous	Detailed demand, supply simplistic	Simplistic
Policy analysis options	National economic impacts per sector, time path	National and regional economic impacts per sector, projection year	National and regional economic impacts, time path
Understandable	Reasonable	Complex	Reasonable

Table 1: overview of economic evaluation models in the Netherlands

3 Aim of the research

The models oriented on the economic analysis described in the previous chapter often lack spatial detail and a good representation of regional/local features. The modelling of the regional/local characteristics is important because the impacts of transport measures often occur at the local level. A more detailed spatial modelling also gives the opportunity to interact with, and take advantage of, existing national or regional transport models.

This research aims to extend the Mobilec framework with a housing market model and to improve the modelling of the relations between the housing market, labour market, transport and the economy. The research also aims to bring more detail into the labour market modelling. The development of a housing market module and labour market module in the framework of a regional economic model enables the modelling of land-use changes at a detailed spatial scale level. The changes in population or jobs at a local level can be used as social-economic input for more detailed transport models. And vice versa the transport model can generate the travel times and costs of the residents and businesses with more accuracy. The intended result of the research is to make a contribution to the research field of joint modelling of land-use, transport and economy.

4 Framework of economy, labour market, housing market and transport market

As stated before the aim of the research is not make the most advanced housing market model, but to make a contribution to the development of a joint model of land-use, transport and economy. The current Mobilec already includes the interactions between mobility, infrastructure and economy and some regional features at an interregional level. In figure 1 the elements of the Mobilec model are extended with a housing market model and an improved modelling of the labour market. The figure also illustrates the relationship between processes modelled at a local level and processes modelled at a regional level.

Figure 1: Interactions between housing market, labour market, transport and regional economy

The transport market, the housing market, the labour market and the economy all influence each other directly or indirectly. The figure above illustrates the main relations between the markets, there are certainly more relations although mostly indirect, hereunder the key relations are shortly described:

- Economy & transport: The transport costs and times of the productive traffic, business traffic and freight transport, have impact on the economic production. The economic growth is a main driver of the growing demand for transport.
- Labour market & transport: Travel time and cost savings of productive transport can result in additional economic production and jobs. The accessibility of a location is an important parameter in the location choices of firms. The spatial distribution of firms co-determines the volume and performance of the business transport, commuting and freight transport.
- Housing market & transport: The spatial distribution of the houses co-determines the volume and performance of the commuting and leisure transport. The accessibility of a location is an important factor in the residential location choices of the residents.
- Housing market, labour market & economy: The housing market structures the spatial distribution of the population and therefore the labour supply. The transport system sets the spatial constraints of the labour market; almost all the commuting trips are made within a time limit of one hour. The match or mismatch in the regional labour market results in e.g. unemployment, vacancy rates and wage corrections. These factors co-determine the economic performance of a region and the competition between the regions. The migration and settlement of new firms and/or residents depends, among other regional and social factors, on the regional labour market conditions and the regional housing market conditions.

The description of the key relations between the markets illustrates the important role of the spatial distribution of the residents. The distribution of the population influences the transport flows, regional labour market conditions, the location choices of firms and other residents and the economic performance of a region. It is therefore important to analyze the impacts of transport and spatial policies on the residential settlement pattern. A joint framework of economy, land-use and transport can be used to perform such an integrative analysis. The next chapter describes the modelling of residential location choices within such a framework.

5 Residential location choices

5.1 Residential location developments and policy in the Netherlands

The Ministry of housing, physical planning and environment is the key player, at the national level, in steering the housing market developments in the Netherlands. Different departments of the Ministry handle issues as the location of residential areas, public housing redevelopments or financial policies. For a long time the focus was on solving the quantitative shortage at the housing market. Sufficient supply of houses, the improved accessibility over the past decades and the good labour market conditions have made the residential environment a more prominent factor in the residential location preferences of the residents in the Netherlands. A growing qualitative mismatch results in over demand for the rural areas, small villages and the city centre. On the other side an over supply is expected in the neighbourhoods around the city centre. At a national level an over demand for private housing is expected in combination with an over supply of rental houses. (Source: VROM 2001)

In response the Government supports policies towards a growing percentage of private houses. The growing number of private houses and privatisation of public housing corporations will result in more free market behaviour in the housing market. The influence of the government in assigning the houses will be reduced. However the Government continues to have a strong influence on the supply side, especially on the location of new residential development. The location choices of the residents are still supply dominated and a qualitative mismatch remains between location preferences of the residents and the residential locations. The qualitative mismatch raises questions as:

- Is the central government capable to control the spatial development direction or are other stakeholders (e.g. residents, local governments) steering the spatial developments in alternative directions?
- Is the qualitative mismatch going to result, under conditions of enough supply at the national level, in high vacancy rates of undesired houses and locations?
- Is the increased free market functioning of the housing market going to result in a clustering of the low income households in the undesired neighbourhoods?

- What are the impacts of the current spatial and housing policy of the government on the transport system and the regional economies? What are the impacts of alternative policies?

The analysis of the first three questions requires a modelling of the residential location choices and an endogenous modelling of housing prices. The analysis of the last question requires an integrative modelling of transport, the housing market, the labour market and the economy.

5.2 Model description

The main finding, of the residential choice project (HCG 1991), is that the level of service of the transport system is of relatively little importance in the decision whether to move or not, while it is of major importance in the choice of the new residential zone conditional on a decision to move. This research aims to assess the economic and spatial impacts of infrastructure measures and therefore the research will focus, in this stage, at the location choices rather than on the migration choices. Future developments can lead to an endogenous modelling of the migration choice and the integration of migration and location choices in a nested logit structure.

Discrete choice theory will be used to model the location choices of the residents and the model structure is the multinomial logit structure (Ben-Akiva 1985). An important advantage of this theory is that it allows variation in taste within a group of decision makers. Another advantage is that characteristics of the decision maker (e.g. income, gender) and of the alternative (e.g. price) are combined within one formula. The utility function of alternative a for decision maker d is:

$$U_{ad} = V_{ad} + \varepsilon_{ad}$$

In the formula V is the systematic component of the utility and å is the random (disturbance) component. The random component contains all parameters, influencing the utility, which are not included in the systematic part (e.g. unknown to the researcher). In the multinomial logit model the assumptions is made that the error term (å) is identically and independently Gumbel distributed.

$$P_d(a) = \frac{e^{V_{ad}}}{\sum_{j \in C_d} e^{V_{jd}}}$$

C_d is the set of all alternatives available for decision maker d.

The formula above calculates the probability that decision maker d (e.g. household) selects alternative a as residential location. Each vacant house is in theory an alternative for the households searching for a new house. Data limitations and computation time considerations make it necessary to aggregate the alternatives (vacant houses) into geographical zones. The probability that a household choose a vacant house has to be independent of the geographical zoning. This is especially the case if the geographical zones differ strongly in size.

In the utility function a logarithm can be used to avoid the impact of differences in zone size. A logarithm of the number of vacant houses in a zone is directly proportional with the probability a certain zone will be chosen. In this case the number of vacant houses functions as a scaling factor. The coefficient in the logarithmic term has to be positive, because a negative probability doesn't exist.

The number of vacant houses in a zone is the result of existing vacant houses, emigration of households, discontinuation of households, and exogenous parameters as residential development and demolishment. The number of vacant houses in a zone is corrected by a parameter describing the relation between the number of housing units and number of households in a municipality, especially in student cities as Groningen (1.16 household/house) or Wageningen (1.43 household/houses) the parameter is significantly different from one. Statistics can be used to analyse residential development and demolishment trends per municipality for the last decade. For future years the demolishment factor per municipality will be based on the past trend, a factor by municipality type (not specific for each of the municipalities) can be used to minimize the impact of specific cases. The future projections of residential development sites in the model can be based on existing plans as the new map of the Netherlands or can be part of alternative policy testing.

At the demand site of the housing market three subgroups of households are distinguished:

- Immigrants; new immigrants into the country
- Movers; household moving from one house to another
- Starters; new households not leaving a house behind

For each of the subgroups a utility function will be estimated by using disaggregated data of the national housing market survey (WBO) as a basis. The parameters in the utility function of the movers and starters are similar; the utility function for starters is as follows:

$$U_{sr} = \alpha_1 * A_{sr} + \alpha_2 * D_{sr} + \alpha_3 * Ucat1_{sr} + \alpha_4 * Ucat2_{sr} + \alpha_5 * Ucat3_{sr} + \alpha_6 * Ucat4_{sr} + \alpha_7 * Ucat5_{sr} + \alpha_8 * Pinc1_{sr} + \alpha_9 * Pinc2_{sr} + \alpha_{10} * Pinc3_{sr} + \alpha_{11} * Pinc4_{sr} + \alpha_{12} * Pinc5_{sr} + \alpha_{13} * S_{sr} + \varepsilon_{sr}$$

with:

α	coefficients, read β for movers
A_{sr}	accessibility zone r
D_{sr}	distance between zone of origin household s and zone r
$Ucat_{sr}$	residential density indicator for zone r, five categories
$Pinc_{sr}$	price indicator for different income classes of household s in zone r
S_{sr}	Social-cultural services in zone r
ε_{sr}	Error term household s zone r

The utility function of the movers and starters includes a distance parameter. This parameter addresses the fact that household removals are strongly distance related (HCG, 1991). A variety of reasons can be named as social relations, workplace and limited information of opportunities far away. The distance parameters has a different influence on households moving to improve their residential living conditions or households moving after a job change of one of the household members (ABF 2000). The analysis will pay attention to this phenomenon and, if possible, an additional subdivision of the household groups starter and movers is considered.

The influence of the average house price in the location choice is different for five income categories. The other variables are equally important to all the households in the current modelling; see description of the explanatory variables in 5.3.

The formula for the immigrants is quite similar to the formula of the other categories except the distance parameter is not included.

$$U_{ir} = \beta_1 * A_{ir} + \beta_2 * Ucat1_{ir} + \beta_3 * Ucat2_{ir} + \beta_4 * Ucat3_{ir} + \beta_5 * Ucat4_{ir} + \beta_6 * Ucat5_{ir} + \beta_7 * Pinc1_{ir} + \beta_8 * Pinc2_{ir} + \beta_9 * Pinc3_{ir} + \beta_{10} * Pinc4_{ir} + \beta_{11} * Pinc5_{ir} + \beta_{12} * S_{ir} + \varepsilon_{ir}$$

Allocation

In the model the price mechanism is used to match the housing demand and supply, the development of the average house price in a zone is endogenously determined in the model. The demand/supply ratio per zone determines the price adjustments. The price adjustment can be part of an iterative process within one time step (year) or the price adjustments can be made between the time steps. The computation time of the second option is preferable, but the method has a risk of allocation more households to a zone than vacant houses in a zone. Test runs with the model can help to determine the preferred method. The adjusted prices are a parameter in the utility function of the households.

The functioning of the price mechanism in the strongly regulated housing market of the Netherlands is limited. For example a high average house prices in a region will not lead to extra supply of houses and conversion of agricultural land into residential land. However the price setting of the private ownership houses and private rent houses seems to work quite reasonable. In the public rent market the price mechanism is not working, public housing corporations often use age or waiting time criteria to allocate the vacant houses. The modelling of sub-markets (private ownership, private rent and public rent), with their own mechanism, is an option to address the specific condition in a better way. International examples of similar regulated situations are described in Anas (1987) and Pagliara (2001).

5.3 Description of explanatory variables

This section shortly describes the explanatory variables in the utility functions of the residential location choice. The thematic maps (page 13) show the values of the

variables for all the municipalities, according to the 1997 municipality definition there are 572 municipalities in the Netherlands.

Accessibility of workplaces

The accessibility variable in the model describes the access to the job locations in a type of gravity formula. Each of the zones has an accessibility potential to the labour market. The travel time matrices for car, train and bus and the employment figures of the Mobilec model are used as input data in the accessibility formula.

$$A_c = \sum_{meC_m} \sum_{seC_s} per_{mc} * \left(\frac{Empl_s}{T^a_{csm}} \right)$$

C_m, C_s Collection of all modes (m) and all zones (s)

A_c Accessibility potential of zone C

per_{mc} Modal split commuting of mode m in zone c

$Empl_s$ Employment in zone s

T_{csm} Travel time between c and s for mode m (incl. Congestion)

The accessibility variable is update every three years in line with the time periods of the Mobilec model. The time step of three year in contrary to the yearly steps of the residential location choice model is not a problem, considering the slow changes in accessibility potentials. The long-term aim is to use the Mobilec model in combination with a more advance transport model. The travel time and modal split predictions will certainly benefit of such a combination.

House price index

The 1997 average house price per Municipality, in the municipality statistic of the National Statistical Agency (CBS), has been used as base year input in the modelling. It should be mentioned that extreme differences in house prices in a municipality exists, especially in large municipalities like e.g. The Hague. The average house prices are used as an index of the housing costs in a zone. The house price variable is further endogenous and the average housing price index of a municipality is update every year based on the demand/supply factor for the specific zone. The price index is used to match supply and demand in the modelling.

Residential Density

Statistical data at the municipality level of the national statistical agency (CBS) has been collected to allocate the municipalities into five categories of residential density. The CBS addresses the residential density in a municipality by the average number of houses in the surrounding of a house. For each house in a municipality the number of houses within a distance of 1 km are calculated and the average value of all houses in a municipality determines the residential density. The dynamic change of the variable value is expected to be long term and small, the parameter is therefore a fixed variable in the modelling. The housing density parameter gives an indirect indication of the possible, most likely, types of residential environment.

Social – cultural Services

This variable is, like the other variable, obtained from the National Statistical Agency. The variable expresses the number of hectares in a municipality, which are used by services as cultural centres, hospitals, secondary education and higher, etc. In the model the variable is used as an indicator for the accessibility of services. The variable includes only the social-cultural services in the municipality of residence.

5.4 Current status; interactions with Mobilec

An illustrative version of the residential model is already developed to show the interactions between transport, the housing market and the regional economy. The work has concentrated on the program structure, data collection and the linkage with the Mobilec model. The test version of the residential model lacks an adequate modelling of the residential behaviour, in the test version expert weights are used to calculate the attractiveness of zones for residential allocation. The house seeking household are allocated proportional to the attractiveness of zones (corrected for the number of vacant houses) or the user can choose to fill-up the most attractive zone than the second, etc.

In this stage the Mobilec model and the residential location (RL) model operate as two separate models with an external linkage. Both of the models are dynamic in nature, however the time steps are different; the Mobilec model has time periods of three years

and the residential location model has time periods of one year. Figure ?? illustrates the dynamic linkage and the data exchange between the two models.

Figure ???

Figure 2: Interaction between Mobilec and residential location choice model

In the Mobilec model the average wages in a region are taken exogenously and the real wage determines the marginal labour productivity. The neoclassical theory has been modified in the Mobilec model to generate unemployment. In the Netherlands the differences in wages and local prices are limited and the collective labour agreements are negotiated at a national level. Although the differences are limited it would be interesting, not at least from a perspective of alternative policy analyses, to model the interaction between the wages and the ratio labour supply and labour demand. Differences between regions in unemployment or wages can also be tested as explanatory variable in the utility function of the households searching for a house. Research at this point is ongoing. Other research (Broersma 2001) emphasizes the strong relation in the Netherlands between labour demand changes and labour participation.

6 Conclusions

This paper has presented a brief overview of different models in the Netherlands addressing the economic impacts of transport policies. The Mobilec and RAEM model have a regional focus and the impacts can be assessed at a regional level. However the Mobilec model will benefit of more spatial detail and an extension of the model with the modelling of the housing market and an improved representation of the labour market. This research focuses on the development of a housing market model in interaction with the Mobilec model. The intended result of the Mobilec plus version is a better assessment of the economic impacts. Another intended result is the opportunity to assess the spatial impacts of transport and land-us policies at a detailed spatial scale level. Specific characteristic of the Mobilec plus model in comparison with other models is the endogenous modelling of the interactions between the housing market, labour market, transport and economy.

The paper further describes a first version of the residential location choice model. The main characteristics of the model are discrete choice modelling at the demand side and the price mechanism as market mechanism. The residential location module is linked with the existing Mobilec model and the models interact in a dynamic way. Important research questions regarding the residential location choice model are:

- How to incorporate the migration move/stay choice in the modelling and what is the impact of transport measures on this choice?
- Is it necessary to model sub-markets in the housing market for private ownership, private rent and public rent house? What is the best allocation mechanism for each of the sub-markets?
- How do the labour market choices and the housing market choices interact? Is it necessary to include labour market choices in the residential location choice model or should the labour and residential choices be modelled in an integrated way?
- What is the impact of transport measures on the residential location choices and vice versa what is the impact of location choices on the transport performance and the regional economy? Is it possible to assess these impacts adequately with the Mobilec plus model?

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