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## Toward a joint modeling of land-use, transport and economy

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# Toward a joint modeling of land-use, transport and economy

41<sup>st</sup> congress of the European Regional Science Association

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## **Abstract**

The paper aims to identify the scope and design of the land-use module in a joint framework for land-use, transport and economy. Such a joint modeling can make a significant contribution in the analysis of the spatial economic impacts of major infrastructure projects. The existing MOBILEC (mobility and economy) model lacks spatial detail to analyze the spatial impacts of infrastructure measures. The idea is to expand the existing modeling package with a land-use model representing the housing and labour market at a spatial detailed level. The design of the land-use model is done based on some comparative studies and by paying attention to the integration with the existing framework and the context of the Netherlands. The modeling of the housing market focuses on the housing preferences of the households and the role of the government in the spatial planning.

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# 1 Introduction

It is widely accepted that spatial settlement and transportation are closely related: land use changes have impacts on the performance of the transportation network and changes in the transport system have impacts on settlement behavior. Integration of land-use and transportation analyses is therefore widely recognized as a requirement to adequately address development options. Modeling such integration poses the challenge to structure the problem and develop a operational model which can address such a complex, long term and highly uncertain system.

At Delft University of Technology a research project has started in the field of integrated land-use and transport modeling. The main focus in this project is on the interaction between the transport measures and the spatial developments. The aim is to model the spatial impacts of large infrastructure measures so that these impacts can be included in the evaluation process.

In the last few years a new model, called MOBILEC, has been developed by Van de Vooren at the Ministry of Transport, Public Works and Water Management in the Netherlands to describe interactions between the transport infrastructure and the economy. A cooperation between Delft University and Van de Vooren has started to integrate the further development of MOBILEC and the land-use research. In this way a model will become available which allows to describe the interactions between transport infrastructure, land-use and the economy. Such an integrated model can make a significant contribution to a structured analysis of the impacts of major infrastructure projects.

The present paper aims to identify the scope of the expanded model and focuses in more detail on the housing market. This is done based on some comparative studies and paying attention to a consistent set up and a balanced level of detail in the different components.

Firstly chapter two presents an overview of some of the state of the art integrated land-use and transport models. An short introduction to the MOBILEC model and the integration with the land-use component is presented in chapter three. The housing and labour market are discussed in more detail in chapter four. The role of the government in the physical planning is described in chapter five. And finally some observations and future developments will be presented in chapter six.

## 2 Overview of land – use transport interaction models

The literature about integrated modeling of land-use & transport is enormous and it is certainly not the intention to cover all of it here. In the past three decades there have been, worldwide, numerous attempts to develop and apply land-use & transport interaction models (so-called 'LUTI' models). Nevertheless only a few packages are currently operational and even fewer have been applied to more than one region. This chapter focuses on some of the operational LUTI packages.

A common feature is the recognition that transport and location decision co-determine each other. The transport system is linked to the land-use system by the accessibility of regions. Accessibility is in all circumstances a relevant parameter in the settlement preferences of the functions, although its relative influence reduces for regions with a dense transport network. Changes in the transport systems will result in a new relative accessibility of zones in a region and in the long term the changes result in a new spatial distribution of functions and their related transport demand. The reason for integrated modeling is that the long-term impacts of spatial or transport measures can only be predicted by analyzing the whole integrated land-use & transport system.

The variety in basic theories for integrated land-use & transport modeling has diminished throughout the years and nowadays almost all 'state of the art' models rely on discrete choice theory to explain and forecast the behaviour of actors such as residents or firms. Another common element in most of the models is that they represent both activities and the space in which they are located. The reason for doing so is that the existing stocks of buildings, which can only be slowly and expensively changed or added to, represents a major set of constraints on urban change; and that much of the planning process acts upon the marginal changes in those stocks, not directly upon the activities which use them (Simmonds, 1999).

Besides the above described common elements in the state-of-the-art models there are significant differences between the models, such as difference in scale level, model structure, dynamics and way of calibration and validation. The land-use transport models selected for description in this chapter are: MEPLAN (DETR 1999, Williams 1994), TRANUS (de la Barra, 1997), DELTA (Simmonds, 1994,1999) and URBANSIM (Waddell, 1998, 2000). The reason for selection is that the models have in common that they are operational and have been applied in multiple studies.

The MEPLAN and TRANUS model are quite similar and originate from the research efforts at the Martin Center at the University of Cambridge. These models combine the (macro – economic) input – output method to simulate the flows between regions and the (micro – economic) discrete choice theory. The spatial – economic framework can be transferred to different spatial scale levels and these two models are capable to model study areas consisting of e.g. multiple labour and housing markets. The DELTA and URBANSIM model lack such a macro-economic approach and are currently more suitable to simulate an urban region.

In a recent study of the British Department of the Environment, Transport and the Regions (DETR, 1999) the DELTA and URBANSIM model are addressed as activity models. Activity based models are defined by their focus on the different processes of change. The land-use change is in this view brought about by a number of different processes and the model is divided in sub-models representing the processes. Another element is the dynamic nature of the models to address slow and rapid processes of change (e.g. change of route or house). In this view the model should work in small rather than long time steps, to allow for a mixture of rapid and slow responses, and the model should not be limited to working in arbitrarily long steps (Simmonds, 1999).

The DELTA and URBANSIM model have further in common that they are designed in such a way that they have to be linked to existing transport models. This differs from the MEPLAN and TRANUS model which each contain a land-use as well as a transport model. The MEPLAN model contains all the stages of a conventional four stage transport model, even though the way in which some of the stages are represented is somewhat different from the conventional four stage approach (Williams, 1994). The main difference is that the land-use model in the MEPLAN framework also estimates the pattern of movement by purpose between the zones.

A key difference between DELTA and the MEPLAN/TRANUS models is that DELTA is incremental, working with the changes in past transport and land-use conditions, while the other models are based upon a cross-sectional calibrated relationship (DETR, 1999). The components (input –output, spatial choice) in the MEPLAN and TRANUS package are so intertwined that they are solved simultaneously for the base year, which is inherently difficult for the user (Simmonds, 1994). Another disadvantage of the cross-sectional base year calibration is that the results rely on one point in time.

The main points to take into account from this literature overview are:

- Model the spatial object (e.g. house) as well as the activity (residential use), because of the differences in lifetime;
- Discrete choice modeling is a well developed and applied method to model the preferences of the actors;
- The modeling of multiple regions (incl. multiple labour and housing markets) sets extra requirements to the modeling;
- The validation/calibration of these long term, complex models remains a key research challenge.

In the LUTI – literature (besides URBANSIM) not much attention has been paid to the role of the Government. Especially in the Netherlands the government has a dominant role in the physical planning and an understanding of the supply side conditions, set by the government and real estate developers, seems crucial to understand the land market (see chapter 6). For this reason the often used perfect market simulation, using land-prices to clear the market, doesn't seem the way to go.

### **3 Framework for a joint modeling of land-use, transport and economy**

This chapter outlines a framework towards a joint modeling of land-use, transport and economy. The goal of this paper is to explore especially the modeling of the housing market in such a framework.

#### **3.1 Introduction MOBILEC (mobility and economy) model**

The MOBILEC model, described in this paragraph, can be addressed as a modified neoclassical growth model. Besides the neoclassical approach there is a large variety of methods to estimate the economical impact of infrastructure. These methods are however not reviewed in this paper, for a review of various methods I refer to the large amount of literature on this subject (see Armstrong and Taylor 1985, Oosterhaven en Knaap 2000, Vooren vd 2001). The MOBILEC model is taken as a precondition and the text focuses on the development of a housing module in the MOBILEC framework rather than on the benefits or disbenefits of the various methods.

The MOBILEC model describes the relationship between the economy, mobility, infrastructure and other regional features in an interregional dynamic way. The main characteristic of the model is the representation of the interaction between economy and mobility. For comparison in the traditional transport models transport is estimated as a derived demand of the economical development scenarios.

The description of the MOBILEC model in this paragraph is based on the work by van de Vooren (1998, 1999), who is the developer of the model. A Cobb-Douglas production function describes the relation between the input of production factors and the output of commodities. In the production function the transport infrastructure is added as an additional production factor besides the usual factors as state of technology, labour and capital.

The casual relation between the economy and the mobility has two directions. The so-called productive mobility (goods and business transport) is used as input factor in the economic production function. But the consumptive mobility depends on the income and is the result of the economic development of a region. The MOBILEC model has been used to make multi-regional long term projections (2030). The model is dynamic and it uses time steps of three years. The present spatial scale level is at the COROP-region level. The Netherlands is subdivided in 40 COROP-regions (European NUTS 3 zones).

#### **3.2 Extension of the framework**

The current MOBILEC framework will be used as basis for the further extension of the modeling with a housing market. Key conditional characteristics for the future extension are the inter-regional and dynamic structure. The housing module and the current MOBILEC model are linked to each other through the labour market (see figure 1). The MOBILEC model calculates the employment demand for the COROP-regions and the housing module calculates the spatial location of the residents (supply of labour). Figure 1 presents a flow diagram of the extended model and the figure illustrates how the model evolves in time. For one time interval the basic endogenous and exogenous elements and their interactions are presented. The aim of the overall framework is to analyze the spatial economic impacts of infrastructure measures.

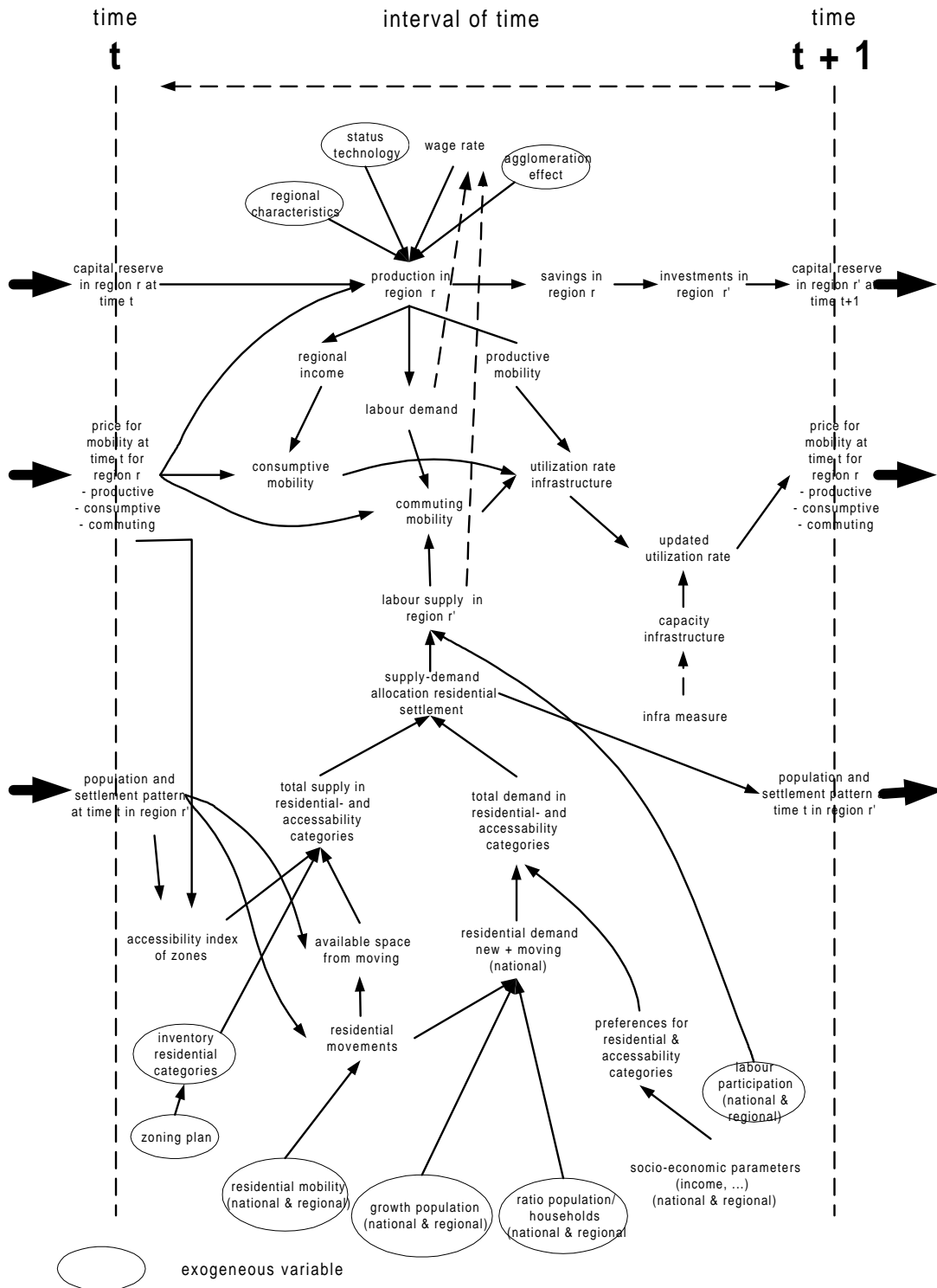
A transport measure, change in the transport infrastructure of region x (e.g. increased capacity), has impact on the regional product as well as on the housing market. The lower transport costs will result in a higher production for region x (extra labour demand) and in an increased accessibility for the residential sites in region x. A long term effect is that the region becomes, if vacant houses are available, more attractive to migrate to. Surrounding regions within commuting distance of region x will also benefit of the changes in the region, especially when the land resources are limited in region x. Both cases, the settlement of new residents

in region x or surrounding regions, result in extra travel demand and possible extra congestion. The extra travel costs will have a negative impact on the regional product and the accessibility of the region (agglomeration disbenefit).

The MOBILEC model is currently a disaggregated model at the COROP-zone level (40 zones in the Netherlands, NUTS 3). But for the evaluation of the impacts of infrastructure measures on the housing market more spatial detail is needed. This need for spatial detail in the evaluation of infrastructure measures has been summarized by Vickerman (2000) as follows “it is increasingly clear that there are too many conflicting forces to be able to distinguish all these effects at an aggregate level, even at an aggregate regional level”. The detailed zonal representation can be chosen in such a way that the land-use model uses the level of traffic analysis zones of the existing National or Regional modeling systems in the Netherlands. In this way the land-use model can use travel times and costs of existing transport models.



**Figure 1 : Flow diagramme extended Mobilec**



## 4 The labour and housing market

### 4.1 Interactions labour and housing market

This chapter describes a concept for modeling of the housing and labour market, the plan is to add these modules to the MOBILEC framework. The concept is based on comparative studies and practical considerations on model development, keeping in mind that the model has to be operational at a spatially detailed level. The application area of the final model will be the whole of the Netherlands, but for a first version one or a few of the 40 COROP regions will be studied in more detail. The proposed spatial scale level, the integration within the MOBILEC framework and context of the Netherlands result in different conditions for the new land-use model in comparison with the land-use models described in the overview in chapter 2. However some elements of the reviewed models in chapter 2 remain interesting for the new modeling concept. Two especially interesting lessons are:

- the modeling of the spatial object (e.g. house) as well as the activity (e.g. resident)
- the use of discrete choice methods to model the preferences of the actors

The point of view towards the labour and housing market is that the labour market cannot be treated independent from the housing market. The question ‘Do jobs follow the people or do people follow the jobs?’ illustrates the unsolved causality. The two-way interaction can be shortly described as:

- If people moving out of an area, for example for quality of life reasons (rural areas, type of housing), the effects for the firms are less supply of labour and/or higher commuting costs. A decreased supply of labour results in higher wages and less qualified employees, especially in highly specialized sectors. The higher commuting costs are often partly the burden of the employer and partly of the employee. Both effects (less labour supply and travel costs) are incentives to the firms to follow the settlement pattern of the residents.
- If a new firm locates in a region the labour demand will increase, in a market with low unemployment figures the competition can lead to higher wages. The new job vacancies and/or higher wages will attract people to migrate or commute to this region. In the longer term the long distance commuters can also chose to migrate to the region to diminish their commuting costs.

The relation between commuting, migration and labour participation has been handled in a dissertation study of Evers and van der Veen (1986). Nowadays it seems that the constraints of the supply side of the housing market play an important role in the migration pattern in the Netherlands. For the preferred type of houses (rural environment, own garden), which are not available near the main business districts, people are even willing to increase their commuting costs. Vickerman (2000) refers to recent evidence for the UK (Cameron and Muellbauer, 1998) which suggests that the housing market has a strong effect on decisions to migrate between regions. The modeling of the housing market has to emphasize the importance of housing preferences in the migration choices.

### 4.2 Main processes of land-use change

There are a number of different processes which have to be specified and combined to understand spatial change. The main processes of change can be discerned as being:

- Demographic developments (exogenous data)
- Social-economic developments (MOBILEC and exogenous data)
- Household mobility and preferences to locate (land-use model)
- Firm mobility and preferences to locate (MOBILEC and land-use model)
- Real estate developers (see chapter 5)
- Public policy, transport infrastructure and land use planning (see chapter 5)

*Demographic and social-economic developments*

Developments as aging of the population, household formation, immigration-emigration for the Netherlands, labour participation and car ownership rates are exogenous scenario inputs in the modeling. The scenario figures will be derived from institutions as the National Planning Agency (CPB). Economic developments as the geographic product of the COROP regions, (un-) employment and wages are endogenous modeled in the extended MOBILEC model.

#### *Household mobility and supply of houses*

The demand for a specific type of houses depends on the volume of the house seekers (mobility, immigrants-emigrants volumes for the Netherlands) and the preferences of the house seekers. The supply of houses depends on new construction, demolition, mobility rates (new vacancy) and existing vacancy. At average the household mobility in the Netherlands is around one move in the seven years. For an individual household this average figure is differentiated based on characteristics of the household and characteristics of the current type of residential area. For example in the mobility module of the URBANSIM model (University of Washington, 1998) reflects differential mobility rates for renters and owners, and for households with and without children, etc. The forecasts will benefit of a disaggregation of the household types, for example by income or by household size. At the supply side construction and demolition decisions are made by the government, the next chapter describes the role of the government in the housing market.

In the Netherlands the PRIMOS model is used to forecast the housing demand at a regional/local level. A disadvantage of this model is that it only calculates the quantitative demand and not the qualitative demand (type of residential location). Nowadays in the Netherlands the problems with the housing market are changing from a quantitative shortage into a qualitative shortage. Especially for future projections the mismatch between qualitative supply and demand preferences is going to be an important problem in the housing market. The QUATRO model in the Netherlands focuses on the qualitative demand (VROM, 1989), but this model operates only at the aggregated level of the whole country. The challenge is to develop a model for the housing market, which contains the quantitative as well as the qualitative supply and demand at a spatial disaggregated level.

#### *Household location choice*

The household location choice is the result of the preferences of the household and the available supply of houses. As mentioned before discrete choice theory (see Ben-Akiva, 1985) can be used to model the preferences of the households. Characteristics of a household are used to estimate the change that a household prefers a certain location. A multinomial 'logit' model can be used as method to estimate the preferences of the households in function of characteristics such as household size, income, car ownership. At the supply side the number and type of houses are administrated by zones (traffic analysis zones, (sub-) municipality level)

The choice set in the model consists of alternative location types. Alternative location types are defined by the combination of an accessibility category and type of house. Vacant houses of the same type in different zones classified in the same accessibility category are summarized as one alternative location type. The accessibility index is calculated at a zonal level and counts for all the houses in a zone.

The accessibility Index for employment is calculated as follows:

$$B_i = a \sum_j M_j f(c_{ij})$$

$B_i$	Accessibility index
$a$	constants
$M_j$	Number of jobs in j
$c_{ij}$	transport costs between i and j (incl. time)
$f(c_{ij})$	spatial interaction function (higher costs result in less interaction)

The transport costs between i and j are a combination of travel costs and travel time, the travel time component can be expressed in costs by using value of time figures. The spatial interaction function is non-linear and for the commuting purpose a strong decrease in interaction can be observed above travel times of one hour. For all the zones the accessibility index for employment is calculated and the accessibility index of each zone is used to classify the zones in an accessibility category (e.g. five categories).

The multinomial logit model predicts the probability an individual household will prefer a certain location type. The probability of choosing an alternative location type 'a' is:

$$P(a) = \frac{e^{V_a}}{\sum_a e^{V_a}}$$

P(a) is the probability of choosing alternative a  
 $V_a$  systematic component of the utility of alternative a

A potential specification of the systematic component is:

$$V_a = \alpha_1 + \alpha_2 HS + \alpha_3 I + \alpha_4 C$$

$\alpha$  Weights  
 HS Household size, variable for household with or without children  
 I Income level of the household  
 C Car ownership household (0,1,2+)

A scarcity of housing supply makes an iteration process necessary, under perfect market conditions prices are used to clear the market. In the strongly regulated and supply dominated housing market of the Netherlands it is complicated to clear the market by prices. A possible way to allocate the demand in this situation is to fill-up the most popular location types in the first round and to exclude these sites of the second allocation phase, and so on. If an alternative location type is not completely filled-up the households are proportionally divided to the zones, having vacant houses in the location type (combination accessibility category and type of house), based on the number of vacant houses in the zone.

#### *Regional employment, mobility of firms and location choice*

Regional changes in the employment are represented per region (COROP – region) by the regional macro-economic production function in the MOBILEC model. The employment changes at a macro level are the result of processes at a micro level, examples of these micro level processes are the growth or decline of existing firms or the settlement or move of firms. In other words the change of employment at a regional level is the result of the decisions made at the level of individual firms. In the proposed concept the macro level formula is used to model the overall performance of the firms in a region.

A simple method, a multi-criteria-analysis with the weights based on expert judgement, will be used to disaggregate the change of employment to the zones within a region. The attractiveness potential combines location characteristics as accessibility to other businesses, accessibility to employees, available land at the location, etc. A lack of available land for business development in a region will result in a move of the employment growth to the surrounding regions. In general the calculated employment change will be realized in the region itself but scarcity of resources can result in a flow to the surrounding regions.

## 5 The role of the government in spatial planning

In the analysis of the development of a region a differentiation can be made between autonomous and guided development. “Autonomous” refers to the development of the region as result of the working of the free markets and “Guided” refers to steering of the development through governmental planning and regulations. An actual situation will usually be a mix of the two. The level of guidance by the government depends on the political involvement and the available regulatory apparatus to guide. The situation differs strongly for different regions and countries. The spatial development in the Netherlands can be considered as strongly guided in the international comparison.

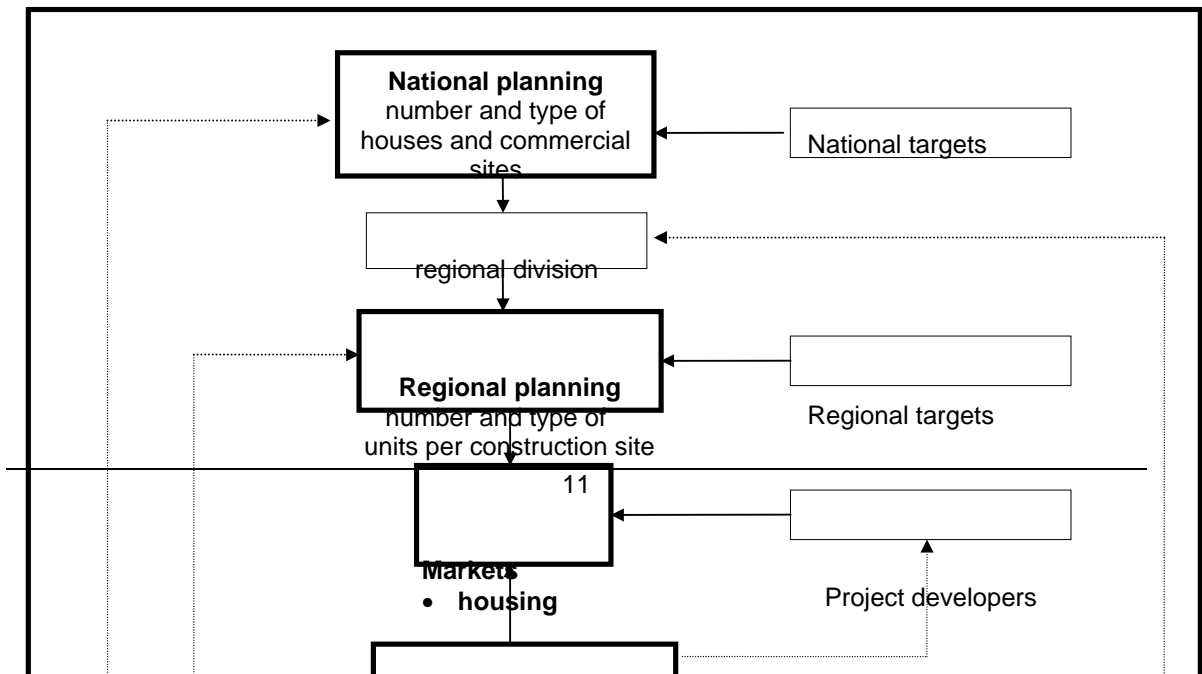
The description and understanding of the trends in the functioning of the spatial developments is a continue part of study. Changing spatial policies set new conditions for the functioning of the housing market, and therefore in the functional specification of the model. Key elements in the description are the consideration of scale levels, the involvement of various actors and their behavior, a sufficient separation of autonomous versus guided development and the regulatory and market situation.

### *Scale levels and actors*

Practically the spatial planning can be divided into three scale levels, the national planning, regional (provincial) planning and the township planning. Each of the levels has its own institutions and planning characteristics. The role of the governmental institutions differs greatly between countries as described above. A less dominant role for the government results in a stronger position for private parties as real estate developers and land speculators. These private parties will follow the preferences of their customers (the land demanding functions) and the most valued function will settle first. The role of the government in guided circumstances is to realize a spatial development according to the national or regional targets.

A totally guided spatial development is supply dominated. The government determines the choice set of the functions, in the most limited form there is only one option. The completely guided situation, according to the government targets, is undermined by the following processes:

- The land demanding functions are putting pressure on the government to change the policy. The firms or residents can reject the planned locations and often they are capable to find alternative locations (e.g. other municipalities or international options).
- The hierarchical sequence of targets from national targets, regional targets to local targets is not uniform. Governmental institutions are in competition to meet their own targets. This competition occurs between different scale levels but it also occurs within a scale level. For example a national target for a balanced spatial distribution of social classes is in conflict with municipality targets to attract the high income group. Another example is the competition between regions to attract the settlement of new companies.



### Figure 2: Overview of spatial planning process

The supply of available land and the land demanding functions meet each other in the land market. Actors in this land market are the government, real estate developers and land demanding functions. As previously described the government and the real estate developers regulate the level and kind of supply. The settlement choice of the land demanding functions is based on the preferences of the functions (see chapter 4). The government can steer the development in the desired direction by regulating the supply side or by measures influencing the preferences. The future role of the government and the interactions with the residents and real estate developers have to be incorporated in the modeling. It seems arbitrary to model this model and a more realistic approach is to explore the governmental policy options by using different policy scenarios.

## 6 Observations and future developments

From this exploration of the planning problem and formulation of a first concept it is concluded that the problem is of such complexity that model development necessarily has to progress in stages and that care has to be taken that the modeling remains “practical”. Further work will concentrate on including market behavior for the labour and housing market at a spatial disaggregated level in the extended MOBILEC model.

Key elements of such a complex land-use – transport – economy modeling are:

- A differentiation of Macro- and micro level modeling. For an inter-regional model it is necessary to model the macro economic processes (link of activities in the region to the regional product) as well as micro economic processes (representing choices of actors). The integration of the regional housing market in the overall framework is a key subject of research.
- Spatial detail, as stated in this paper is important to model the labour market and in particular the housing market. A disaggregated zoning even at a regional level is necessary to address the local differences.
- Orientation on evaluation of measures. The final objective of the modelling is to improve the integrated evaluation of major infrastructure measures. The model concept focuses on the processes which change as a result of infrastructure measures. The concept focuses for example on changes in accessibility of locations or changes in the location preferences of households rather than on other relevant topics as immigration or household size changes.
- Calibration for the dynamic and spatially differentiated model is considered especially challenging. Design of an appropriated model structure and a concept to conduct sensitivity tests will be needed.
- Housing market representation, special attention has to be paid to the role of the government in the housing market. The housing market in the Netherlands is strongly regulated and can not be modeled by simply clearing the market with prices.

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