Interaction of Transport and Land Use: A Framework for an Integrated Urban Model

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Abstract

The growing general concern over lack of space and other limitations on resources has led to the conviction that policy makers who deal with urban development need to consider their choices carefully, taking into account the effects on urban development on the long term. A useful tool for policy makers are urban models that provide quantitative insight in the effects of possible government policy.

In this paper the framework for an integrated urban model for the Deltametropolis region is presented. It describes the theoretical design of the urban region model and defines the place of research in field of spatial modeling. In the proposed urban model the spatial system (i.e. the urban region) is represented by multiple linked sub-systems. Individual sub-systems are: the housing market, the market for business real estate and the transport system. The main objects of the research are the development and application of modeling techniques for the choice behavior of households and companies as separate entities and their interaction with transport. In addition to an analysis of surveys and demographic databases, a high spatial resolution will be added to the model by using GIS-functionalities, digital land-use maps and infrastructure networks.

INTRODUCTION

It is undisputed that transportation networks influence land use and vice versa. Land use is the spatial distribution of activities. This distribution generates traffic, for people move from one activity to another. Changes in the transportation system effect land use in the long term: due to changes in accessibility residents eventually tend to move to more accessible locations. Integrated land use and transport models are a useful aid to gain insight into these processes and to provide useful support for policy makers (governments). An example of research on this mutual influence can be found in Wegener and Fürst (1999). They describe two two-way interactions between urban land use and transportation by the 'land-use transport feedback cycle'. Several studies have recently been carried out to find out what the future research needs are in the field of integrated urban transport and land-use planning (Wegener, 1999; TRB, 1999).

Although some research has been done in the field of transportation and land-use planning, further research is necessary. In Dutch spatial planning two land-use models are being used: the Living Environment Scanner[1] (de Nijs, 2001) and the Land-use scanner[2] (Scholten, 2001). Both of these models lack the effects of transportation on land use. An international example of an integrated model is the UrbanSim model (Waddel, 2001). UrbanSim is a simulation model that incorporates the interactions between land use, transportation and public policy. The operational models show significant differences with regards to the theoretical foundations and the modeling techniques applied. A good classification for these and next generation integrated models is given by Miller (TRB, 1999) and Zondag (RAND Europe, 2001).

One of the reasons that only a few integrated models have been implemented, is the lack of data and the knowledge about the interaction between land use, transport and the related planning consequences. Research into the mutual influence of land use and transportation can lead to improved land use models (Wegener, 1999), (TRB, 1999).

In Dutch research practice a large amount of data is available that covers a large time span: surveys, demographic databases and land-use maps. For example see: Kemper (1996) or VROM (1999). This research focuses on the analysis of the available data. The objective of the research is to expand the knowledge about the interaction between land use and transport. The results will be applied in an integrated urban region model.

This paper describes the theoretical design of the proposed integrated urban model. Behavioral modeling techniques will be used for simulating the behavior of the actors in the spatial planning process.

DESIGN OF THE URBAN REGION MODEL

The following section gives the design of the urban region model. Each urban market in the urban system is described as well as the parties involved in land-use planning.

Theoretical design of the urban region model: linked urban markets

In operational urban models the urban region is represented as multiple linked markets (Waddell(2001), Wegener (1999)). Each market consists of a supply and demand side. The government and real estate developers influence the supply side of the markets through spatial policy and investments. On the demand side agents (households and companies) react to changes in these subsystems. These reactions expose themselves as individual decisions whether to move to other dwellings or to relocate businesses. This choice behavior of households and companies as entities is the subject of this research. The results will be applied in a simulation model for the development of an urban region.

The residential market consists of the dwellings in the region. Each dwelling can be characterized by a set of attributes: price, size, accessibility, quality. The local government and real estate developers determine these qualities of the dwellings. The demand for specific types of dwellings depends on the households living in the region. The non-residential market consists of office buildings and other commercial real estate. The local government and real estate developers determine the quality of the non-residential real estate. The demand for the non-residential real estate depends on the commercial business and public facilities in the region. The transport market consists of the total network of physical and functional infrastructure, such as highways and railroads. Households and businesses use the infrastructure to undertake activities which are dispersed in space. This generates a transfer demand. The traffic flows on the networks result from the matching of demand and supply.

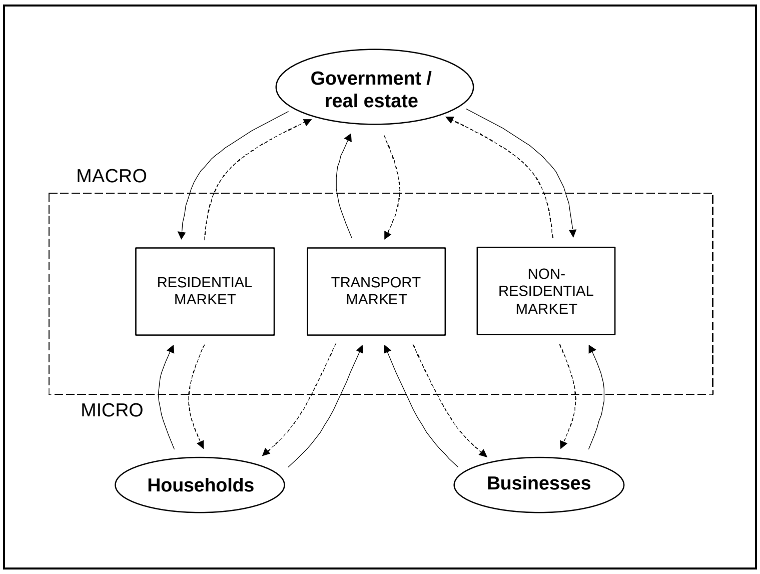

Figure 1 Linked urban markets

The urban markets have a strong coherence as a result of the spatial relations of each agent. These relations play a determining role in the choice behavior of households and companies, and are quantified by analyzing the transportation facilities. Therefore the transport system plays a central role in the urban region model. Accessibility measures can be a means for quantifying the commercial properties of a location, each measure regarding the position on the transport market (Geurs and Ritsema van Eck, 2001).

Key actors in land-use planning

Key actors in the planning of land use are governments, real estate developers and agents (Waddell, 1998). Each key actor operates at a different scale level (TRB, 1999). Figure 2 describes these different urban scales, the key actors and their activities. Top down in the process of land-use planning, the government influences land use as the director of the use of the issued land. On the meso level investors determine the attributes of the real estate (floorspace, price, quality etc.). Agents, finally, determine where to work and live on micro level.

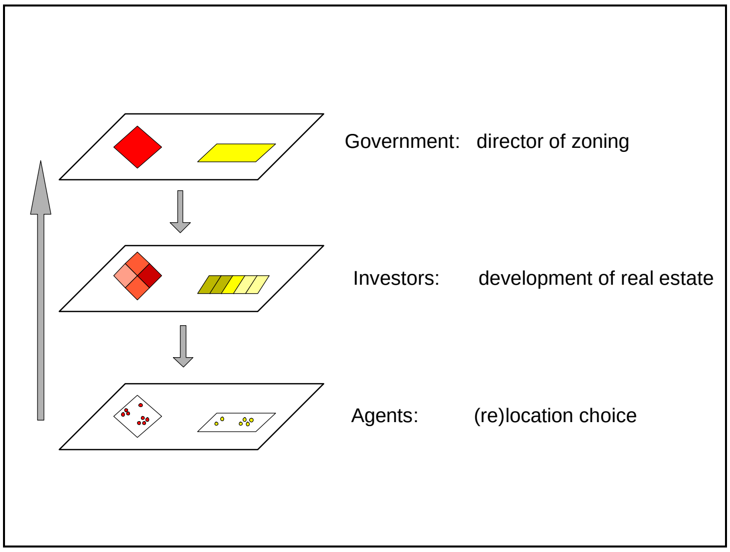

Figure 2 Urban scales, actors and activities

Governments (Macro level)

Particularly in the Netherlands, the government influences the land market strongly as the director of the issue of arable land. The government also determines the use of the issued land. Therefore the spatial development in the Netherlands can be considered as strongly guided (Zondag, 2001). The manner in which governments (local and national) create their zoning policy is mainly based on suitability (VROM, 2001). The urban region model needs to translate the zoning policy of the government sufficiently. An exploration of the past policy plans could give more insight in the effectiveness of the spatial policy. The necessary data will consist of (historical) policy zoning plans, land use schemes, policy documents and interviews with (former) policy makers.

Real estate developers/private investors (Meso level)

Real estate developers and private investors play an important role in translating new zoning policy for new or existing urban areas into new real estate. These real estate developers are most often private and commercial companies that design and construct the real estate for these new residential or commercial areas. Therefore real estate developers play an important role in determining the qualities of the real estate. To create a coherent and architecturally sound plan developers work with spatial (town) planners of their own or from a local government. The aim of developers is profit maximization. By estimating possible benefits and costs, investors determine their expected profit. A bid-rent function is an often applied concept for modeling rent prices. These economic considerations need to be taken into account for in the urban region model. The most important data to retrieve is information about the amount of available floorspace, the quality and age of current dwellings and business accommodations and the prices of these buildings.

Agents: Households and businesses (Micro level)

Agents are the actual users of dwellings and buildings which are offered by the parties described above. The choice behavior of these agents is an important part of this research. In a society there are numerous groups of agents, all of whom have their own preferences, possibilities and attributes. This research distinguishes two main groups of users: households and businesses. Households demand residential buildings (dwellings) and businesses demand non-residential buildings and real estate.

The location choice behavior of households and businesses differ fundamentally. Households have to decide where to live and work and take part in social activities like shopping, leisure, education or medical services. Businesses have other concerns, such as the location of labor, suppliers and customers. The choice behavior of businesses can be considered as a rational choice, based on economic motives. The choice behavior of households, on the other hand, is considered to be more emotional, reflecting the life-style of agents. In addition to commuter distances, the accessibility of different (public) services plays an important role in the choice behavior of households.

In contrast to the zoning motives of governments, which are based on suitability, agents (residents, businesses and services) tend to make their decisions of where to settle based on attractiveness and utility. This behavioral approach to decision making has been applied for a long time in research on land use. Alonso (1964) described land use using bid-rent functions. Later, random utility theory was introduced in the discrete choice models (Ben-Akiva, 1985). Martinez (1992) combined bid-rent functions and discrete choice theory, which approach is applied in the UrbanSim model (Waddell, 1998).

The difference in scales is reflected on the model in several ways: the collection and processing of data and the most suitable modeling technique. The data and possible model techniques will be discussed in the next sections when the urban markets are described.

MODELING AGENT BEHAVIOR

Household behavior on the residential market

During the past decades several researches have studied the behavior of households. These studies can be divided into two main groups: sectorial and integrated. Sectorial models describe only a certain social-economic sector, like the residential, business and transport market. These models have a large history in the Netherlands in providing versatile information for government policy, for example PRIMOS[3] (household-demography; (Heida 2000)), SOCRATES[3] (simulating residential market) and the National Model System[4] (transport modeling). Because of their sectorial approach, the models tend to focus on a specific part or aspect of the subject. The PRIMOS model, for example, merely matches the demand and supply sides of the residential market based on the qualities of dwellings and the wishes of households. A spatial factor, like the location of the workplace or services, is not taken into account. These sectorial models also have important advantages. A high level of detail and disaggregation can be achieved and the results of the model can be calibrated on large datasets with large time spans.

The other group of household behavior models, the integrated models, tries to take into account more aspects of the behavior on the residential market. An example of this approach is given by Borgers (1991). Developing an integrated model, brings along certain issues and difficulties:

a. The complexity of integrating different aspects and scale levels - spatial processes work on different scales, as well in time as in space.
b. The choice of the correct modeling technique – through the last decades various modeling techniques have been developed and applied.
c. The collection and processing of large datasets – to find, produce and/or keep data up to date for one sector is already a tedious task, let alone for an integrated model.
d. The calibration and validation of the results – partly caused by collecting the right data and partly by the complexity of the combined processes. It is much more difficult to calibrate an integrated model than a sectorial model, because many processes are working together, each generating results which need to be calibrated and validated.

One of the research's new approaches in the research field of land use modeling lies in the use of households as individually acting agents. According to Imhoff e.a. (1995), the choice for using households can be justified by three factors:

i. Demographic processes are to a large degree dependent on the household situation of the individuals involved.
ii. In many social, economic and cultural processes, the household rather than the individual is the relevant unit of analysis.
iii. The developments as such in the number and composition of households in many countries, especially in Europe, over the past three decades have been impressive.

The explicit usage of households in a land use model brings along two important issues: household classification and the household's internal relationships. A large amount of household classifications is known. Households can differ in:

- Structure and size; number of members, number of children, age of the members, etcetera.
- Social-economic situation; Wealth, education, line of work, etcetera.
- Car ownership; none, one or more.

On the other hand, compared to the single person utility experience and decision-making, the complex relationships and relative power in a household are fairly unknown areas in behavioral land use modeling. Social household studies could bring more insight into this matter.

The characteristics of a household determine the activity pattern of a household and the experienced utility, derived from these activities. A household's main activities are working and living. To perform these activities the members have to commute. From studies it has become clear that employment is the major determinant of residential location (Harvey, 1996). Other issues that influence a household's activity pattern are social bounds like the presence of relatives and the location of the children's school and sporting facilities. The derivation of a household's utility experience and activity patterns can be based on behavior and preference research, surveys and statistical data.

This research strives for the highest level of detail as possible. This level depends on the accessibility of different types of data, the assumed relevant level of detail and the available spatial modeling techniques. For this last issue the observed properties from the residential market, which lead the conceptual model of the market, are an important influence. It is likely that a highly disaggregated discrete choice model or a kind of micro-simulation turns out to be satisfactory. An important factor in the residential market is the relation with transport, which will be clarified later in the paragraph on the transport market. The availability and properties of the data is a very important issue. One of the most relevant data-resources is the Housing Demand Survey[5] (VROM, 1999). This is a large scale national housing survey of the Netherlands.

Firm behavior on the non-residential market

The choice which modeling technique to use for simulating the non-residential market is important. It must be able to simulate the firms' choice of location. For this choice different approaches on locational theory are available. An historical classification is given by Lambooy (1997). He distinguishes four theories:

- Classic theories: minimizing costs;
- Neo-classic location theories;
- Behavioral theories;
- Strategic theories.

As stated in the design of the urban region model, this research focuses on the locational choice behavior of agents on urban markets. On the non-residential market the choice behavior of individual firms is simulated. Within this context behavioral theories can be assumed to be the best suited modeling technique. Behavioral theories describe the location choice behavior of firms and the driving motives behind it. Important issues are the motives for the decisions of firms and the information on which this decision is made. The demography of firms approach can be mentioned as a research approach based on a behavioral approach.

The demography of firms approach started with a study of David Birch of the Massachusetts Institute of Technology into the 'job generating process' (Birch 1979). In the Netherlands the demography of firms approach is adopted by researchers of various disciplines, like regional sciences and economics (Pellenbarg 1985; van Wissen 1997;

Dijk et. al. 1999). The theory describes economic development by birth, death and migration of firms. It tries to explain and predict these processes from a bottom up view, beginning with individual firms.

Next to the demography of firms technique, other examples of behavioral location theories are known. Witlox (1998), for example, explains site selection by industrial firms using fuzzy decision tables. The last modeling technique to be mentioned is discrete choice modeling. This is often applied in transportation modeling or residential choice behavior but much less in non-residential location theory. An elaborate exploration of choice location theories and possible modeling techniques can lead to the choice for the optimal modeling technique.

The agents on the non-residential market exist from a large variety of firms. They can be divided in multiple sectors, each with specific production factors and business preferences. Logistic firms for example have a strong relationship with suppliers and customers. Business services on the other hand have a strong relation with customers and attach more value to the charisma and quality of the real estate.

The definition of an appropriate classification is the first step in modeling business behavior on the non-residential market. The settlement choice of each sector is dependent on multiple factors and differs per type of business. Determination of relevant choice factors and the calibration of the choice behavior is part of the research. Special attention is given to the influence of infrastructure on the choice behavior and the quantification of this influence.

When studying choice behavior, the availability of data is an important issue. The choice behavior can be distilled either from stated (surveys) or revealed (statistical) data, depending on the availability of data. Surveys on company preferences are scarce, because collecting these data is difficult. First of all it is difficult to find the person responsible for the settlement choices, especially in large firms. Secondly, personnel and managers of a company are often busy or time is too expensive to cooperate in a survey.

In some cases, though, regional surveys are available (Dijk et. al. 1999). The possibilities for stated preference will be explored in the theoretical research. On the other hand, revealed preference requires historical data on the spatial devision of firms and the quality of the real estate. These data can be gathered by combining data from different sources (Kemper 1996). Possible sources are: the Central Bureau of Statistics, the National Information System on Labour facilities[6], the Chamber of Commerce and different real estate investors. In order to create a consistent database, the disparities in the data must be handled. ABF Research, an associated company to the research, provides the data and contacts necessary to assemble the database.

The guiding role of the transport market

As stated in the previous paragraphs, transport is an important factor in the development of land use. The location choice of agents is influenced by the changes on the transport market. These changes occur when the land use alters (e.g. changes in spatial division of agents) or when changes are made to the networks (e.g. new infrastructure) and transport legislation (e.g. road pricing). This can lead to new or different mobility effects, like traffic jams and pollution.

The quantification of these effects is important for the evaluation of government's spatial policy scenarios. One of the most used and acclaimed research projects in the Netherlands on this subject is the National Model System (in Dutch: Landelijk Model Systeem; LMS). This model is an instrument that makes prognoses on a national scale for the development of the mobility of persons on an average working day. The basis principle of the LMS is the forecasting of changes according to a base year (Hague Consulting Group, 1997).

There are two time scales in the transport and land use relation: short and long term.

- Short term: the daily commuting and visits to services, which is determined by the land use. For example: a new shopping mall, situated close to an urban area, will immediately generate traffic between residential areas and this mall. An unluckily chosen location for the mall could lead to an overburdening network, less visits and subsequently a commercially failure of the mall.
- Long term: the yearly migration of households and businesses, which is determined by the construction of new infrastructure. For example: a new high-speed railroad improves the accessibility of an arable area. When investors (project developers and companies) find this area appealing enough, they will reclaim this land. The consequences by these events finally affect the land use,

but on a longer term (the development of new urban locations will at least cost about ten years). After this, migration flows set in and traffic streams develop.

For both time scales, human choice behavior in living, working and moving controls the changes. To model this behavior, a theoretical framework for integrating urban economic models and transportation models describing the complex interaction in the urban area will be developed firstly.

The way transport currently plays a role in Spatial Modeling is usually through accessibility measures, like the classical potential accessibility. This measure is expressed in means of infrastructure-based accessibility, describing for example the amount of effort for a person to reach one or more locations, reflected by the "average speed on the road network", "level of congestion" or "average delays". The measures then influence a location's attractiveness for an agent. Because of the somewhat roughly generated measure, this attractiveness works on an aggregated level. Recently Geurs and Ritsema van Eck (2001) have applied different measures of accessibility in their accessibility studies. Two examples with a more individual accessibility approach than the potential accessibility are:

- Activity-based/Time-space: Analyses the accessibility measure on a micro-level en include the activities in which an individual can participate at a certain time.
- Utility based: With these measures the benefits that individuals derive from the land use transport system can be analyzed.

The application of one of these measures, or a combination of both, could be beneficial to model the transport part of the agent behavior. Particularly for the household's utility maximization, an individual approach could be appropriate. Future research will determine which accessibility measure is most suitable.

OBSERVATIONS AND FUTURE DEVELOPMENTS

This chapter provides some additional observations and describes possible future developments of the research. The observations relate to the more general aspects of the urban region model, such as a description of the region for which the model is developed, the results expected and the data required.

Region of interest: Deltametropolis

The research focuses on the central urban region in the Netherlands: the Deltametropolis. This region can be seen as one poly-centric urban system with a sufficient size to take into account the urban scales in land-use planning. In addition, this region provides an interesting variety in living- and working environments. The Deltametropolis consists of the four major cities in the Netherlands: Amsterdam, Rotterdam, The Hague and Utrecht. The region is strongly urbanised and characterised by traffic problems (e.g. congestion and inadequate public transport) and a large claim on open land for new urban areas and infrastructure (e.g. the HSL-Zuid, a HighSpeedTrain-track connecting Amsterdam and Rotterdam to the European HST-network).

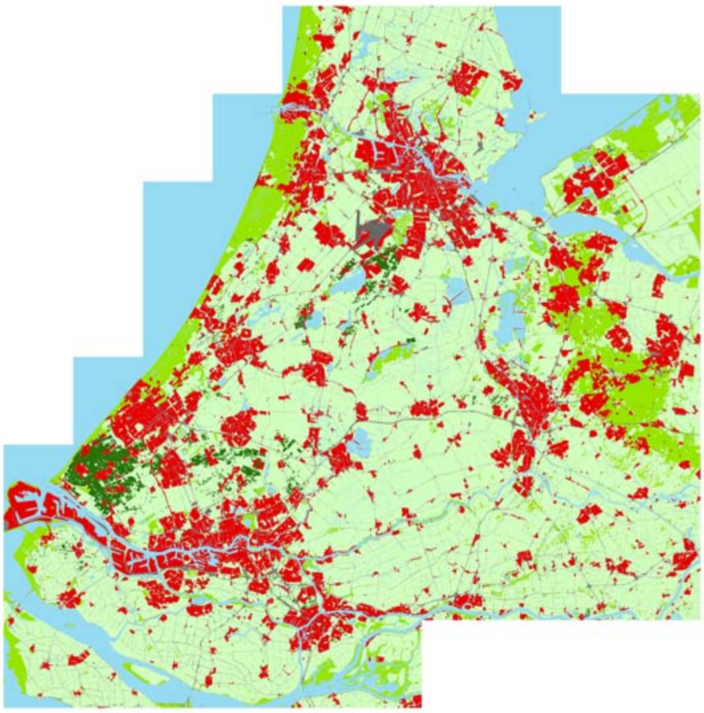

Figure 3: The Deltametropolis

Expected Results

The expected outcome of the research is an urban region model which predicts the (re)locational behavior of firms and households. General assumption underlying the model is the guiding role of infrastructure in the locational preferences of firms and households. The purpose of the model is to evaluate spatial policy scenarios.

Spatial policy scenarios can be evaluated on different criteria using the outcomes of the urban model. These outcomes consist of a detailed description of the traffic streams (in terms of congestion and modal split), migration (long term transfers) and characteristics of the new urban areas (in terms of density of land use, locational quality of the real estate, quality of the environment, etcetera). The outcomes of the urban region model can be evaluated from two angles:

- Agential: the profit or average income of households and/or firms.
- Governmental: for example in terms of mobility, the modal split and auto mobility, and in terms of nature preservation, the area of high quality nature and cutting up of nature areas.

The results of a model are permanently up for discussion, which may concern the validity or the implications of the results. This applies especially to the research field of spatial modeling. The results of a spatial model consist of predictions of the future, and cannot directly be verified. On the other hand, the users of the model (i.e. policy makers) would like to know the outcome of proposed policies. This kind of models should be able to predict these effects and help the policymaker in judging his plans: the ex-ante evaluation.

The planned calibration/validation-process for the development of the individual model components is to be carried out parallel. This means that each sub-system or module is tested separately. In this way the total outcome of the model has a causality which can be assumed to be correct. This approach is more realistic and scientifically sound than an integrated calibration method, since this method can result in an outcome that fits historical data by adapting the parameters of the model. However, it is likely that the causality, which is important for the simulation of future outcomes, is lost.

Data requirement

In general the research consists of analysis and combination of a large amount of data of different types. In addition to an analysis of surveys and demographic databases, a high spatial resolution will be added to the model by using GIS-functionalities and digital land-use maps and infrastructure networks. The role and nature of the required data is described in chapter three. Availability of the data is guaranteed through the co-operation of various parties.

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- Spatial Planning Bureau[7] – Bureau that performs independent analysis's, prognoses and explorations in the framework of spatial policy for the Dutch national government. One of the two Ph.D. students works part-time for the Spatial Planning Bureau.

- ABF Research – A commercial research agency that collects and processes statistical data on the subject of living, working and servicing for local and national governments. One of the two Ph.D. students works part-time for ABF Research.

- Delft University of Technology, Faculty of Civil Engineering and Geosciences, department of Geodetic Engineering – The Geographic Information System software of ESRI, applied in the research, is used within the framework of the Geo-Database Management Center, a research center located in the Netherlands.

FOOTNOTES

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[1] In the Netherlands the Living Environment Scanner is known as the 'LeefOmgevings-Verkenner (LOV)'

[2] In the Netherlands the Land-use scanner is known as the 'Ruimtescanner (RS)'

[3] For more information, see www.abfresearch.nl

[4] In Dutch: Landelijk Model Systeem (LMS).

[5] In Dutch: Woningbehoefte Onderzoek (WBO). Also see: www.wbo.nl

[6] In Dutch: Landelijk Informatie Systeem Arbeidsvoorzieningen (LISA)

[7] In Dutch: Ruimtelijk Planbureau (RPB).

REFERENCES

Alonso, W. (1964), *Location and Land Use*, Harvard University Press, Cambridge, Mass., United States of America.

Ben-Akiva, M. and Lerman, S. R. (1985), *Discrete Choice Analysis: Theory and Application to Travel Demand*, Cambridge, MIT Press, Massachusetts, United States of America.

Birch, D.L. (1979), *The job generating process*, Cambridge University Press, Cambridge, Mass., United States of America.

Borgers, A.,H. Timmermans en P. van der Waerden (1991), *Een model voor gezamenlijk keuzegedrag: een studie naar het woonlocatiekeuzegedrag van huishoudens*, Technische Universiteit Eindhoven, Eindhoven, the Netherlands. [in Dutch]

Dijk, J. et.al. (1999), *Determinants of firm migration in The Netherlands, an exercise in the demography of firms approach*, In: Demography of Firms: Spatial Dynamics of Firm Behavior, Netherlands Geographical Studies 262, Utrecht/Groningen, the Netherlands.

Geurs, K.T. and Ritsema van Eck, J.R. (2001), *Accessibility measures: review and applications*, RIVM (National Institute of Public Health and the Environment), Bilthoven, the Netherlands.

Hague Consulting Group (1997), *Het Landelijk Model Systeem*, Adviesdienst Verkeer en Vervoer, Rotterdam, the Netherlands. [in Dutch]

Harvey, J. (1996), *Urban Land Economics*. Macmillan, Houndsmills.

Heida, H. and H. den Otter (2000), *Primos prognose 1999: de toekomstige ontwikkeling van bevolking huishoudens en woningbehoefte,* VROM (Ministry of Housing, Spatial Planning and the Environment), Den Haag, the Netherlands. [in Dutch]

Imhoff, E., A.Kuijsten, L. Van Wissen (1995), *Introduction*, In: Household Demography and Household Modeling, Plenum Press, New York, United States of America, p.1-15

Kemper, J., et. al. (1996), *Databronnen voor economische demografie*, In: Planning: methodiek en toepassing, TNO-INRO, Delft, the Netherlands, p.3-11. [in Dutch]

Lambooy, J.G., et.al. (1997), *Ruimtelijke Economische Dynamiek*, Coutinho, Bussum, the Netherlands. [in Dutch]

Martinez, F. (1992), *The bid-choice land use model: an integrated framework*, In: Environment and Planning A 24, p.871-885.

Nijs, T. de, et.al. (2001). *De LeefOmgevingsVerkenner: Technische Documentatie*, RIVM-report 408505007|2001, Bilthoven, the Netherlands. [in Dutch]

Pellenbarg, P.H. (1985), *Bedrijfsrelocatie en ruimtelijke kognitie*, PhD thesis, Groningen, the Netherlands. [in Dutch]

RAND Europe (2001), *Literature Review of Land Use Models*, RAND Europe, Leiden, The Netherlands.

Scholten, H.J. et.al. (2001). *Ruimtescanner: Informatiesysteem voor de lange termijnverkenning van ruimtegebruik*. Netherlands Geographical Studies 242, Utrecht/Amsterdam, the Netherlands. [in Dutch]

TRB (1999), *Integrated Urban Models for Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use*, TCRP Report 48, Transportation Research Board, Washington, D.C., United States of America.

VROM (1999), *WoningBehoefte Onderzoek: vragenlijst*, VROM (Ministry of Housing, Spatial Planning and the Environment), Den Haag, the Netherlands. [in Dutch]

VROM (2001), *Vijfde Nota over de Ruimtelijke Ordening (Fifth Policy Document on Spatial Planning for the Netherlands)*, VROM (Ministry of Housing, Spatial Planning and the Environment), Den Haag, the Netherlands. [in Dutch]

Waddell, P. (1998), *Simulating the Effects of Metropolitan Growth Management Strategies*, Conference of the Association of Collegiate Schools of Planning, California, United States of America.

Waddell, P., A. Borning, M. Noth, N. Freier, M. Becke, and G. Ulfarsson (2001). *UrbanSim: A Simulation System for Land Use and Transportation*. Available from http://www.urbansim.org.

Wegener, M., F. Fürst (1999), *Land-Use Transport Interaction: State of the Art*, TRANSLAND Integration of Transport and Land Use Planning Deliverable D2a, University of Dortmund, Dortmund, Germany.

Wissen, L. Van (1997), *SIMFIRMS: Firmografische Microsimulatie van Bedrijfsvestigingen in Nederland. Deel 2: Toepassing en evaluatie*., NIDI, Den Haag, the Netherlands. [in Dutch]

Witlox, F. (1998), *Modelling site selection: a relational matching approach based on fuzzy decision tables*, University of Technology Eindhoven, Eindhoven, the Netherlands.

Zondag, B. (2001), *Toward a joint modeling of land-use, transport and economy*, 41st congres of the European Regional Science Association, Zagreb, Croatia.