Literature Review of Land Use Models

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By RAND *Europe*

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Introduction

In a project for the Transport Research Centre (AVV) of the Dutch Ministry of Transport, RAND Europe has been commissioned to review the literature on state-of-the-art land use models. RAND has a long tradition in land-use modeling, going back to the early work of Lowry in 1964. More recent examples are the work for the thousand friends of Oregon (Gunn, 1991) or the residential choice project in The Netherlands (HCG, 1991). The aim of the present study is to review and evaluate the international models. The idea is that the methods and concepts, applied in the international models, are useful for the development of a new version of the TIGRIS (land-use & transport) model in the Netherlands. TIGRIS is an abbreviation of the Dutch 'Transport Infrastructuur Grondgebruik Interactie Simulatie'.

The current version of TIGRIS is a dynamic spatial allocation model, which models the interaction between land use and transportation. It has been developed as part of the Struwin-project in 1994. The TIGRIS model operates at an (inter-) regional level and can be considered as a strategic model.

This literature review is part of a project that will set out recommendations to improve the current version of the TIGRIS model. The overall project is split into three subprojects:

- A literature review on land use models with respect to TIGRIS, carried out by RAND Europe
- An inventarisation of data sources to calibrate the TIGRIS model, carried out by MuConsult
- Preliminary research to implement an theoretical, economic foundation into TIGRIS carried out by the VU Amsterdam.

This report consists of three parts. Part A presents a quick scan of seven international state-of-the-art land use transportation interaction models. Part A also describes relevant models operational in The Netherlands. Part B describes three models, selected by AVV, in greater detail and discusses the features of the models in the context of TIGRIS and the Netherlands.

Part C addresses an additional question of the AVV. This section specifies the requirements and outlines the features of a transport model for the new TIGRIS.

A. Quickscan

A.1 Introduction

The purpose of part A is to give a brief overview of the available land-use models on the market. The land-use models included in the quick scan were pre-selected in the project plan. The intention is to give a description of the different models, rather than a comparison between the models based on pre-selected criteria. At this stage the final requirements, that the renewed TIGRIS model will have to meet, are still to be determined. Therefore, this part describes the important features of the pre-selected models and will leave the selection of the models open to discussion. In the next part more detail will be provided for a selection of the models.

In this quick scan, the focus is on models simulating the spatial impacts of transport measures and vice versa. This report does not cover all the possible methods and approaches to model the spatial –economic impacts of infrastructure measures. An overview of the range of available methods to estimate economic impacts of infrastructure investments is given in Oosterhaven (2000):

- Micro surveys with firms
- Estimations of quasi production functions
- Partial equilibrium potential models
- Regional and macro economic models
- Land-use & transport interaction models (LUTI)
- Spatial computable general equilibrium models (SCGE)

The estimation of the spatial-economic impacts of infrastructure measures requires a spatial detailed level of operation of the models. This rules out the use of some of the above mentioned models. The two classes of models operating at the required spatial detailed level are discussed in this paper, namely the LUTI models and the SCGE models.

A parallel study of the Free University of Amsterdam (VU) will focus on the spatial economic theory of the labour and housing market. In this study we will also pay attention to the Mobilec model, as an example in the Netherlands of a dynamic, interregional model based on the production function method.

Seven state of the art international LUTI models are included in this quick scan. As described in the proposal, the pre-selected land-use transport models to be considered are:

- MEPLAN
- TRANUS
- Oregon Statewide Integrated Land Use and Transport Model
- URBANSIM
- IRPUD
- MUSSA
- NYMTC-LUM, The New York Metropolitan Transportation Council Land Use Model

Besides the international state-of-the-art LUTI models RAND Europe has been asked to include a short description of relevant models operational in the Netherlands. The following models are included:

- RAEM
- LOV
- MOBILEC

In the quick scan we will treat the MEPLAN and TRANUS models simultaneously based on the similarities in the modelling approach. The Oregon Statewide Model has been developed in the TRANUS framework and is also classified into this group.

IRPUD and UrbanSim have an activity-based background in common. Both of the models focus on a dynamic and spatially detailed approach to simulate the urban processes of change. Despite the common elements of UrbanSim and IRPUD, there are enough differences to justify to describe the models separately. In combination with the IRPUD model, we should also mention the DELTA model (Simmonds, 1994, 1999), because this model has been inspired by IRPUD and is available as a commercial package, which has been applied in several UK metropolitan areas (Edinburgh, Manchester).

The MUSSA and NYMTC-LUM models have the very strong foundation in micro-economic theory in common and both of the models are unified models. The more famous METROPOLIS model of Anas was the underlying model of the NYMTC-LUM.

The LUTI models are by far the most commonly used land-use models. Besides the LUTI, the Spatially Computed General Equilibrium methods and GIS based approaches are used to describe the spatial developments. The SCGE method is part of the new economic geography school and the method is at the beginning of its lifetime. The RAEM model in the Netherlands is described as an example of a SCGE model. The Environment Explorer, in Dutch LeefOmgevingsVerkenner, (LOV) and Ruimtescanner are examples of the GIS based approaches in the Netherlands. In this memo, the LOV is briefly described.

The MOBILEC model is included in the quick scan as an example of a mobility and economy model in the Netherlands. The MOBILEC model is a macro economic model on the level of regions within a country or country part. The model is introduced and the relevance of the MOBILEC model for the new TIGRIS is shortly explored.

This part is set out as follows: Chapter A.2, A.3, A.4 and A.5 will describe land-use transport interaction (LUTI) models, spatial computable general equilibrium (SCGE) models, cellular automata base models and the MOBILEC model, respectively. The last chapter of part A summarizes our findings, indicates trends in land-use transport models.

A.2 Overview of the LUTI-models

A.2.1 MEPLAN, TRANUS

Name	MEPLAN
Model developer	ME&P (Marcial Echenique/Ian Williams)
Spatial scale level	depends on application
Dynamics	equilibrium model with incremental sub-models
Transport model	integrated
Applications	London, Helsinki, Napels, Cambridge, Santiago, Vicenza, San Sebastian, Bilbao, Shanghai and many more
Source	Pagliara(2001), Wegener (1999), EPA (2000), Simmonds(1999b), Williams (1994), Webster (1988)

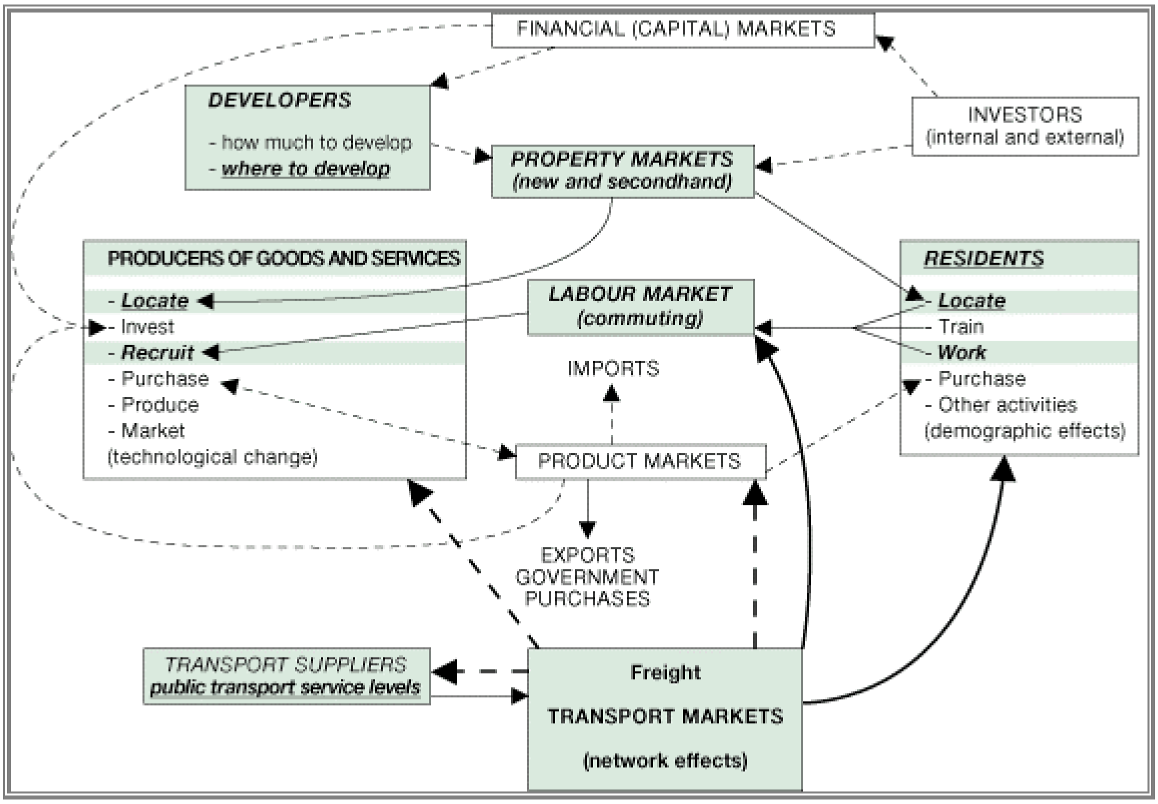
Name	TRANUS
Model developer	Modelistica (De la Barra)
Spatial scale level	depends on application
Dynamics	equilibrium model with incremental sub-models
Transport model	integrated
Applications	Brussels, Valencia, Venezuela, Santo Domingo
Source	De la Barra (1995), De la Barra (1997), Wegener (1999), EPA (2000)

The MEPLAN and TRANUS models can be considered as spatial-economic models and are quite similar. They originate from the research efforts at the Martin Center at the University of Cambridge. These models are based on the (macro–economic) input–output method that simulated flows between sectors. These flows are allocated to zones using the (micro–economic) discrete choice theory. The spatial–economic framework can be transferred to different spatial scale levels, meaning they are capable to model different study areas, e.g. multiple labour and housing markets.

The MEPLAN and TRANUS models contain a land-use as well as a transport model. The models contain all the stages of a conventional four stage transport model, although 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 zones. The so-called trades out of the land-use module are translated in transport flows and input for the mode and route assignment model. The levels of service of the transport model are transferred into disutilities and form an input for the land-use model. In the land-use model the location behavior of households and firms is based on the simulation of competitive markets, with incomes and rents determined endogenously in each time period.

Figure 1 gives an overview of the relationships in the MEPLAN model.

Figure 1. Actors and markets in MEPLAN (LASER)



Source: David Simmonds Consultancy, 1998

In the residential location sub-model of MEPLAN the number of households of a particular category are allocated to a residence zone as a function of the following factors:

- The cost of living for a household locating in that zone (floorspace rent plus costs of services)
- The amount of floorspace the household will consume (a function of the rent and the income of the household)
- The amount of residential floorspace in the zone
- The accessibility to suitable employment opportunities for the employed members of the household (transport costs and times for work trips)
- The accessibility to shopping and services (transport times and costs for non-work trips)

The business location sub-model handles the industrial and commercial businesses in different ways. The location of industrial businesses is an exogenous input and the commercial businesses are endogenously modelled like the allocation of households. The MEPLAN and TRANUS models are calibrated using statistical data for the base year. A longitudinal validation process validates the incremental sub-models in MEPLAN and TRANUS. The components (input –output, spatial choice) in the MEPLAN and TRANUS package are intertwined in a way that they are solved simultaneously for the base year, which is inherently difficult for the user. But the models have been applied in many different regions (e.g. MEPLAN: London, Helsinki, Naples, Sacramento, Edmonton; TRANUS: Caracas, Brussels, Sacramento) and there is a lot of experience in calibrating these models.

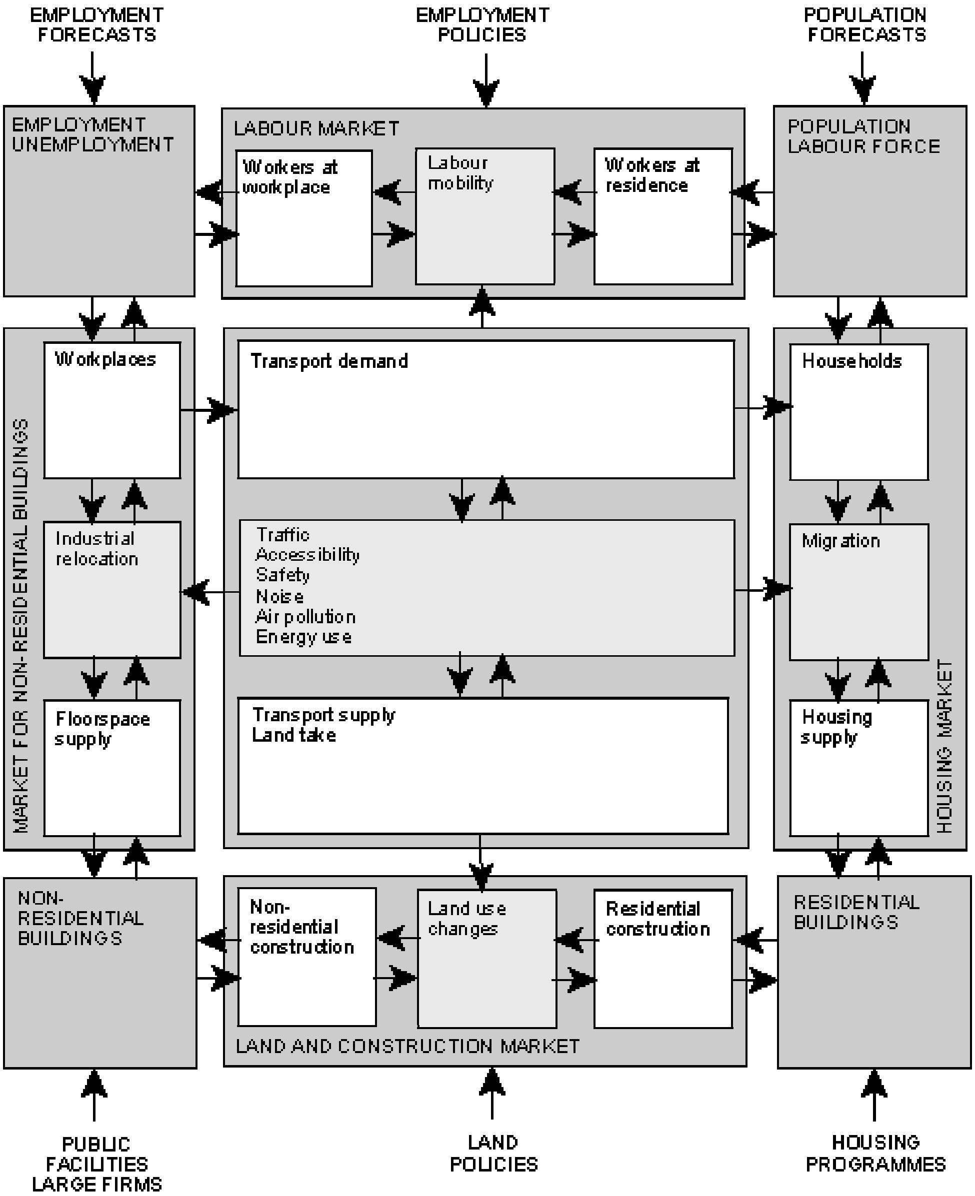
A.2.2 IRPUD

Name	IRPUD
Model developer	Michael Wegener
Spatial scale level	metropolitan regional and local
Dynamics	incremental
Transport model	integrated
Applications	Dortmund
Source	Wegener (1998a-g), Wegener (1999), EPA (2000), Webster (1988)

The IRPUD model of Dortmund, developed by Wegener, contrasts remarkably with many aspects of the MEPLAN and TRANUS model. The model developed in 1985 provided inspiration for the development of more recent models as UrbanSim and to larger extent DELTA. The IRPUD model has a dynamic structure, operates at an intra-regional level and the model has a composite structure of subsystems. Basic idea behind IRPUD and also DELTA is the focus on the representation of urban processes of change rather than on one overall (equilibrium) theory.

The model consists of six interlinked submodels, namely a transport submodel, an ageing submodel, a public programmes submodel, a private construction submodel, a labour market submodel and a housing market submodel. Figure 2 shows how the various models interact. Only the transport submodel is an equilibrium model referring to a single point in time, all the other submodels are incremental and refer to dynamics on a period of time. Typical aspects of the IRPUD model are the attention paid to the time scale of urban processes and the inclusion of search behavior in the modelling of households seeking dwellers and of landlords seeking tenants.

Figure 2. The IRPUD model.



Source: Wegener (1998)

The IRPUD predicts for each simulation period:

- Location decisions of industry, residential developers and households
- Resulting migration and travel patterns
- Construction activity
- Land-use development
- Impacts of public policies as industrial development, housing, public facilities and transport

The DELTA and IRPUD model are not formally calibrated by statistical estimations, but the models are validated on their performance of simulation against observed change over time.

A.2.3 UrbanSim

Name	UrbanSim
Model developer	Paul Waddell (model design and project lead), Michael Noth & Alan Borning (software architecture)
Spatial scale level	urban (grid cells)
Dynamics	incremental
Transport model	not included in the model, should be connected
Applications	Honolulu, Eugene-Springfield, Great Wasatch Front area (Salt Lake City), Puget Sound (Seattle)
Source	University of Washington (2000), Wegener (1999), EPA (2000)

UrbanSim is recently developed by the University of Washington and a first version of the model has been applied in the Eugene-Springfield metropolitan area (Oregon), Salt Lake City (Utah) and Honolulu (Hawaii). The National Science Foundation and the University Initiative Fund of the University of Washington are funding the project. Urbansim is a software-based system designed to be used for integrated planning and analysis of urban development, incorporating the interactions between land use, transportation, and public policy.

The model implements a perspective on urban development that represents a dynamic process resulting from the interaction of many actors making decisions with the urban markets for land housing, non-residential space and transportation. Four types of actors are distinguished in the model:

- Households, making choices about whether to move or not, and if they move, where to locate.
- Businesses, making similar decisions
- Developers, making choices of what properties to develop or redevelop and into what use, at what density and scale.
- Governments, making infrastructure investments, and place constraints on development in the form of land use plans, density constraints, environmentally sensitive land restrictions, urban growth boundaries, and many other policies.

The interactions of the four types of actors produce outcomes representing the distribution of population and employment, as well as the prices, uses, and density of land development.
The key features of the model are:

- Simulates decision of individual urban actors
- Explicit representation of
  - Land, building, occupants
  - Land markets and prices
  - Government policy and infrastructure
- High spatial and sector disaggregation
- Based on random utility theory

The UrbanSim model is linked to existing transport models in the area of study, the model itself does not include a transport model. The output of the Urbansim model is fed into a traditional four-step travel model, that calculates accessibility indices for each zone based on travel times, costs and patterns by mode. The Urbansim model is very dynamic (for its type of model) with time steps of one year, but the interaction with the transport model can occur less frequently. Figure 3 gives an overview of the interactions between the submodels in UrbanSim and the external transport model.

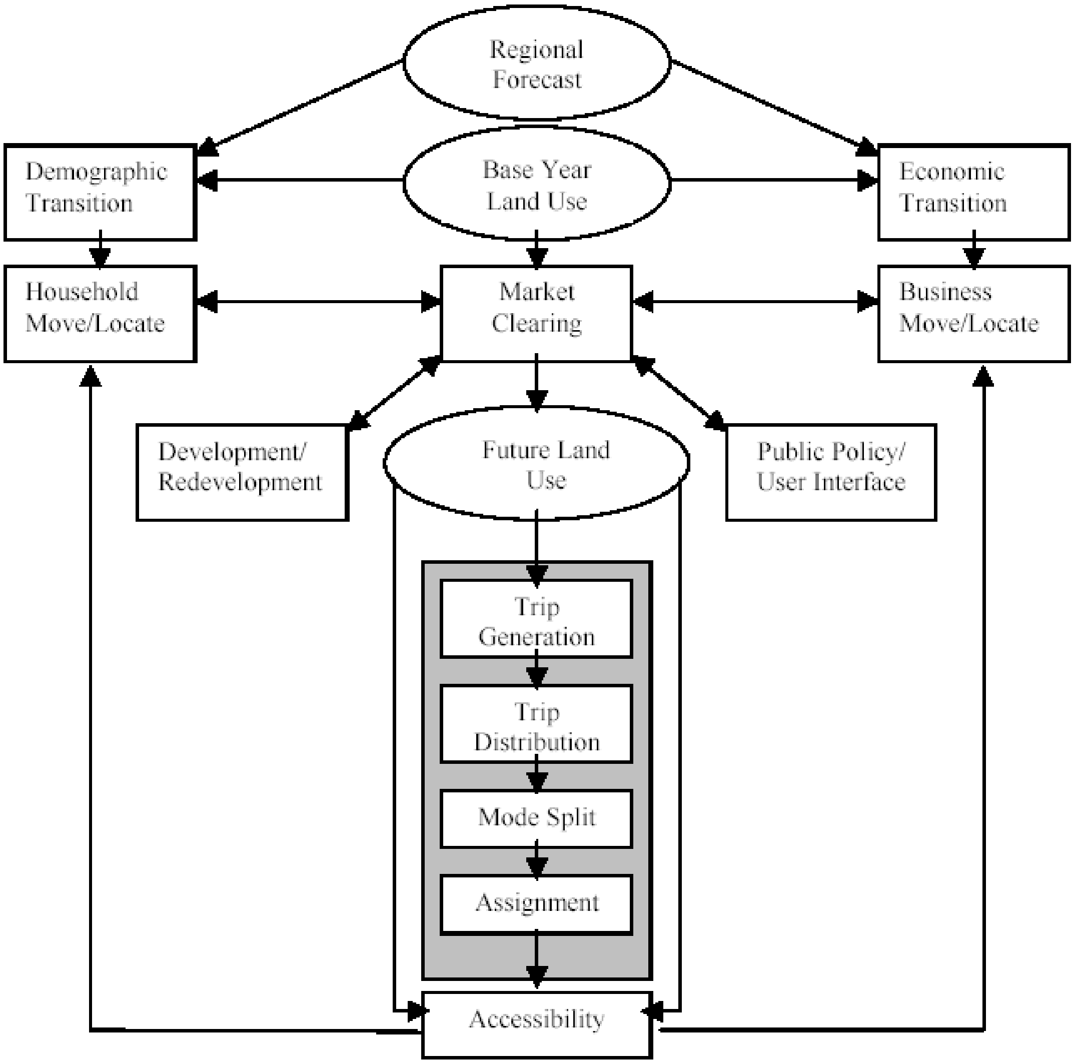


Figure 3. Functional Structure of UrbanSim

A longitudinal validation process has validated the application of UrbanSim for the Eugene-Springfield region. The UrbanSim model is like Delta and IRPUD an incremental model, which is validated by its capability to represent historical urban processes of change, rather than by direct calibration. The data requirements of the model are: detailed land use data, land use plans, development costs, regional control totals, household census data, travel survey and business establishments. The strong points of the model are the foundation in behavioral theory, and the fact that the model addresses the development trend towards high disaggregation of spatial units and sectors.

A.2.4 NYMTC-LUM (Metrosim)

Name	NYMTC-LUM (Metrosim)
Model developer	Alex Anas & Associates
Spatial scale level	urban (3500 zones)
Dynamics	static equilibrium model
Transport model	connected to MTC travel demand model
Applications	New York
Source	Miller (1998), Wegener (1999), EPA (2000), Simmonds (1999)

The Metrosim model is the underlying model of the New York Metropolitan Transportation Council Land Use Model. The NYMTC-LUM model can be considered as a simplified version of the Metrosim model, both of the models have been developed by Dr. Alex Anas. The Metrosim model is founded in the economic theory and the market behavior is modelled intensively. The model has further been set up as one unified model, where most of the models have a composite structure addressing the various sub-markets. The NYMTC-LUM is now being developed and has not been applied until now (information source: New York State Department).

It is important to note that the NYMTC-LUM model has been developed for public transport related planning. Features of such an application are detailed spatial zones, detailed public transport network and mode choice models.

Other main characteristics of the NYMTC-LUM model are (Miller, 1998):

- The model is a unified model and it simultaneously models the interactions between residential housing, commercial floor space, labour, and non-work travel markets. In each of the markets the supply and demand processes are explicitly represented.
- Housing prices, floor space rents and workers wages are all endogenously determined within the model, and are used to mediate between demand and supply processes within their relevant markets.
- The model uses traffic zones as spatial unit of analysis, this provides a very detailed level of spatial disaggregation (e.g. up to 3500 zones in the New York application).
- The model solves for a static equilibrium in the forecast year, by finding the prices and wages which cause demand and supply in the markets being modelled to become consistent.
- The disaggregation of household, employment and buildings is limited.
- The NYMTC-LUM model is connected to the existing MTC travel demand model in terms of receiving as inputs, model utilities from the MTC mode choice model.

A.2.5 MUSSA

Name	MUSSA
Model developer	Francisco J. Martinez
Spatial scale level	urban (264 zones)
Dynamics	static equilibrium model
Transport model	interacting with ESTRAUS transport model
Applications	Santiago
Source	Martínez (1996), Wegener (1999), EPA (2000)

MUSSA is a land use model, which follows the bid-choice location economic theory and is designed to interact with the 4 stages transport model ESTRAUS. The combined model MUSSA-ESTRAUS represents a 5-stage land use-transport interaction model. MUSSA can interact with other transport models as well, provided that the zoning is consistent. There is, however, no experience with such a combination. Up to now the MUSSA model is only available for the Santiago Metropolitan region in Chili. In theory MUSSA has a lot of similarities to the Anas models (METROSIM) in adopting a unified economic framework. Figure 4 gives an indication of the interaction between the land use and the transportation model in MUSSA.

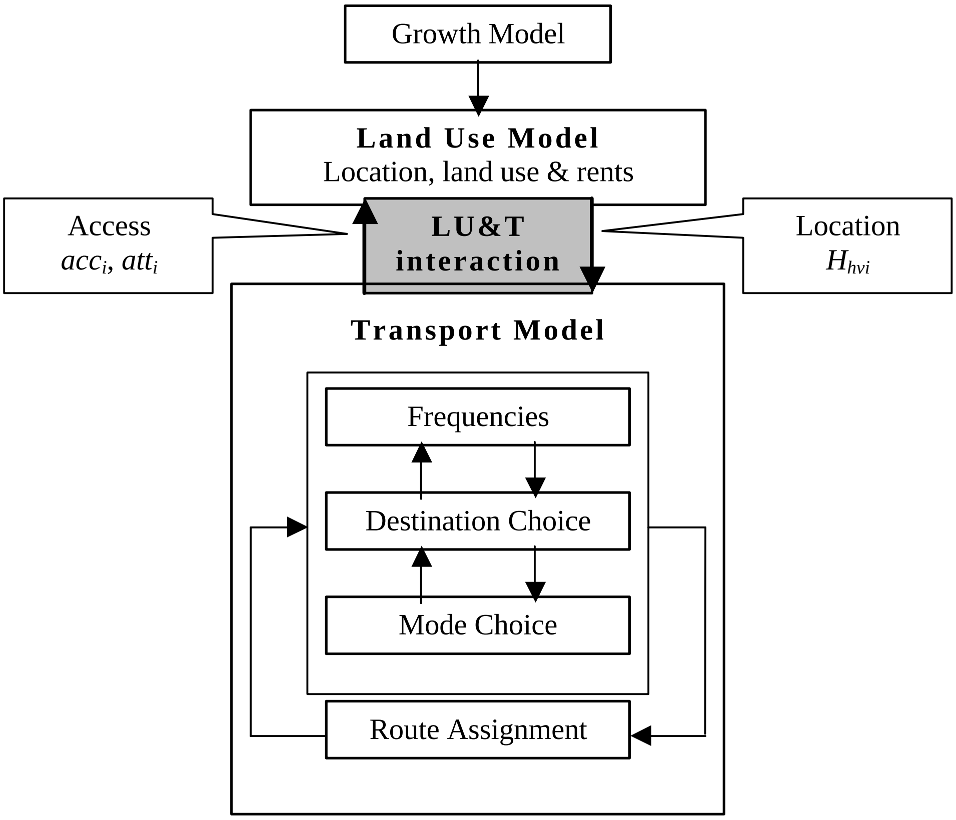


Figure 4. Diagram of the LU&T model.

This approach results in two distinctive economic outputs: land rents, by zones and dwelling type, and a measure of locators' loss in utility, which are available for each forecasting year by household and firm cluster. Competition for land is open for residential and non-residential purposes, with land being allocated to the highest bidders, hence no arbitrary segmentation of the market is required. The approach is based on microeconomic theory and can be described as a fully disaggregated, stochastic and behavioral framework, which pursues static equilibrium.

The data used in the Santiago application of MUSSA are:

- Households (65 clusters), taken from an origin-destination survey.
- Firms, segmented into five sectors
- Dwellings, categorized into buildings and house types
- Zones, 264 ESTRAUS zones
- Access measures, obtained from ESTRAUS for households/firms by zone

The MUSSA model has been developed and applied in an unregulated land market and the highest bidder will be allocated. The MUSSA framework seems to be less qualified to operate in a strongle regulated market as in the Netherlands. The location choices in the MUSSA model are calibrated independently of other choices (e.g. trip destination), in this way more sophisticated calibration procedures and function specifications can be used.

Unlike other models, MUSSA is not an incremental model. It forecasts location choices for a given future year using a static equilibrium approach.

A.2.6 Overview of urban subsystems in international LUTI-models

Table 1 shows eight types of major urban subsystems categorised by the speed of how the systems change. The subsystems are ranked from slow to fast. A '+' indicates that the subsystem is present within the model.

Very slow changes: networks, land use. Urban transport, communications and utility *networks* are the most permanent elements of the physical structure of cities. The transport network changes meant here are major changes in physical network. The *land use* distribution is equally stable.

Slow changes: workplaces, housing. Workplaces (non-residential buildings) such as factories, warehouses, shopping centres or offices, theatres or universities exist much longer than the firms or institutions that occupy them, just as *housing* exists longer than the households that live in it.

Fast changes: employment, population. Households are created, grow or decline and thus influence the *population*. *Employment* is determined by firms who create new jobs or make workers redundant and number of employees is directly related to the distribution of the population.

Immediate changes: goods transport, travel. The location of human activities in space give rise to a demand for spatial interaction in the form of *goods transport* or *travel*. These interactions are the most flexible phenomena of spatial urban development.

Table 1. Urban subsystems represented in international LUTI models

Models	Speed of change							
	Very slow		Slow		Fast		Immediate	
	Networks	Land use	Work places	Hous ing	Employ-ment	Popula-tion	Goods transport	Travel
DELTA/START	+	+	+	+	+	+	+	+
IRPUD	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	+	+			+	+		+
TRANUS	+	+	+	+	+	+	+	+
URBANSIM		+	+	+	+	+		+

Source: Wegener (1999)

A.3 Overview of the Spatial Computable General Equilibrium model

A.3.1 RAEM

The RAEM model is a Dutch application of the Spatially Computed General Equilibrium method. The model is still under development, but a first version of the model has been applied to estimate the spatial economic impacts of a new magnet high speed rail connection between the West and the North of the Netherlands. The number of applications of the SCGE approach is still limited due to empirical and computational problems. At the moment there are no mature (long running and often applicated) SCGE models on the market, but, like the RAEM model, efforts are made to create such a model.

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. The SCGE models are theoretically strong in the interregional assessment of infrastructure measures and the inclusion of producer production and price decisions. The RAEM model operates at the municipality level for the whole of the Netherlands and the business sector is disaggregated into 14 sectors. The representation of the households in the RAEM model is limited to one type of household. The inclusion of a detailed representation of the housing market is missing in the current version of the RAEM model.

The calibration of the SCGE models is problematic because of the high non-linear character of the behavioral equations. The consistent estimation of all the necessary consumers' and producers' substitution elasticities is problematic, because of the lack of adequate data and the lack of tradition of estimating such elasticities at the regional level. The parameters in the RAEM application are estimated based on expert judgement, econometric estimations and derived from bi-regional input-output models.

A.4 Overview of the cellular automata based model

A.4.1 Environment Explorer (LOV)

The Environment Explorer was developed for rapid integrated assessments of the effects of different spatial policy options based on economic, social and ecological values. The National Institute of Public Health and the Environment owns the LOV and the model is still under development. The model is GIS based and has been set up for the whole of the Netherlands, the basic spatial unit of analysis are cells of 500 by 500 m. The model has a three layer structure:

- National level; demographic and economic scenarios as exogenous input
- Regional level: spatial interaction model (40 economical regions in the Netherlands)
- Local level: cellular automata model (cells of 500 by 500 m)

The model is dynamic and the model uses time steps of 1 year. The regional and local level interact with each other through time. At the regional level, a spatial interaction model distributes the national developments as changes in employment or population between the regions. The division between the regions is based on regional and local features. At the local level the LOV follows the approach developed from the theory of cellular dynamics. Cellular Automata are objects associated with areal units or cells. The method follow simple stimulus-response rules whether to change or not change the state of a cell, based on the state of adjacent or near-by cells. By adding random noise to the rules, complex spatial patterns can be generated.

Currently, a project has started to model transportation within the LOV. The objective is to model the effects of land use on the number of car and public transport trips. Trips are calculated between zones, which are an aggregation of the 345 LMS-zones. The transport model also aims to improve the accessibility measures in the land-use model. The number of interactions between land use and transportation can be specified by the user, but will depend on major changes in the transportation infrastructure.

Strong points of the method in the LOV model are:

- The LOV takes full advantage of the available data in GIS systems
- The model has a very short running time
- The LOV model is a user-friendly system with a strong geographical user interface
- The model enables visual analyses of the evolution of spatial developments through time.

The model is suitable for sketching exercises and the short calculation time makes it very practical for fast evalution of imposed policies. But some theoretical gaps seem to make the instrument less qualified for the evaluation of policy measures. The basic criticism on the LOV consist of the following elements:

- Lack of behavioral theory, the method of the LOV is not founded in the modern theories of spatial choice behavior.
- The decision rules are not calibrated on statistical data.
- Lack of distinction between land, houses and population. The urban processes as construction or moving operate at different time scales.
- Lack of economic modelling at a regional level. Economic features as wages or investments are not included in the regional interaction model.
- Unstable processes that may lead to diverging outcomes.

A.5 The MOBILEC model

The MOBILEC model can be described as a modified neoclassical growth model. The description is based on articles of the developer F. van de Vooren (1998, 1999). 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 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.

In MOBILEC a modified Cobb-Douglas production function describes, at a regional level, the relation between the input of production factors and the output of commodities. The transport infrastructure is added in the production function as an additional production factor besides the usual factors as state of technology, labor and capital. It should be noted that it is not the capacity of the infrastructure that is included as production factor but the part of it that is utilized for the production.

The so-called productive mobility (goods and business transport) is expressed in terms of passengers and the number of tons of goods. The causality of the consumptive mobility is the other way around. 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). Besides the model for the Netherlands, the MOBILEC model has also been applied in Belgium. The University of Antwerp has developed the model for Belgium and an extension to include Luxembourg is on the way.

Strong points of the model are:
- The inter-regional structure. The interdependency of the regions is simulated by the ratio of the capital rate of return. Savings in a region r can flow to other regions where the capital rate of return is better;
- The dynamic structure of the model enables the user to analyze how the system evolves;
- The inclusion of the mutual influencing of the economy and mobility;
- The identification of productive and consumptive transport;
- The fact that the model is operational in two countries and has been applied to several case studies in the Netherlands is another important achievement.

Points of criticism are:
- The model only includes one-sector of economic activity. The model is not capable to represent the very different impacts of transport changes for the different sectors in the economy;
- The model fails to recognize the importance of demand factors on the regional growth;
- The production function approach tends to overestimate the contribution of the infrastructure to the economic growth. The production elasticities of the mobility in MOBILEC (between 0.03 –0.07) are modest in comparison with international literature on production functions;
- The transport modeling approach is so basic (no network, COROP as zone level), that the transport results are not very reliable.

The MOBILEC model does not aim to model the land-use changes, whence it should not be considered as a land-use transport interaction model. The model misses, in comparison with the LUTI models, spatial detail and the modeling of the housing and labor market. The transport modeling in MOBILEC is also very simplistic. But the MOBILEC model can be valuable in connection with a transport model and a spatial model representing the housing and labor market. Especially when the modeling of generative impacts of transport measures is considered to be important for the new TIGRIS model. In this case the new TIGRIS/MOBILEC modeling package can be considered as a joint modeling of transport, land-use and the economy.

A.6 Discussion of the LUTI models

A.6.1 Discussion of characteristics

The three described modelling methods in this memo, namely LUTI, cellular automata and SCGE, all have their pros and cons. The LOV model seems to be a useful tool for sketch planing in a decision room environment, but the model is less qualified to evaluate policy options. The SCGE method is a relative new method well suited in the new economic geography school, the method is capable of incorporating economic processes as imperfect markets and economies or diseconomies of scale. The method seems to be theoretically sound but the practical application of the method is still in its infancy. Many empirical and computational problems of the SCGE method are still unsolved. The most common modelling practice at the moment are the LUTI models. The practical feasibility of the LUTI models is large and a mature methodology has been established. Therefore, the rest of the discussion focuses on the LUTI types of models.

Besides differences between the LUTI models, e.g. in model structure, dynamics, scale level, interaction with transport model and way of validation and calibration, there are common elements in the state-of-the-art LUTI models. As general characteristic of the LUTI models the following elements can be mentioned:

- The variety in basic theories for integrated land-use & transport modelling has diminished throughout the years and nowadays almost all ‘state of the art’ models rely on discrete choice theory to explain and forecast the behavior of actors such as residents or firms. In the case of this quick scan all models rely on discrete choice theory to explain the behavior of the actors.
- Another common element in most of the models is that they represent both activities and the space where they are located. The reason for doing so is the difference in life time of urban processes as house construction or moving of residents.
- In the LUTI models the focus is on the distributive impact of infrastructure measures rather than on the generative impacts. In other words the focus is on the redistribution of employment instead of on the generation of employment.
- All of the LUTI models in the study are predictive models and not optimizing models.
- The location of households and service activities can be explained much better than the location of industrial activity.
- The power of LUTI models in estimating interregional location effects of transport measures is much less than that of estimating the impact on intra-regional location decision. The interregional element can be improved by integrating a LUTI model and a regional economic model.

To support the discussion, Table 2 and Table 3 give an overview of the policy relevance of the presented LUTI models in this memo. These table were reported in the project TRANSLAND by Michael Wegener in 1999. Note that transport policies in URBANSIM can’t be modelled, due to the lack of a transport model.

Table 2. Land-use policies that can be studied with land-use tranport models

	Land-use policies											
	Investment and services			Planning		Regulation		Pricing and subsidies			Information	
Models	Facilities	Workplaces	Housing	General land-use plan	Detailed	Land-use plan	Building standards	Building permits	Taxes and subsidies	Development charges	Education	Marketing
DELTA/START	+	+	+	+								
IRPUD	+	+	+	+								
MEPLAN	+	+	+	+								
METROSIM	+	+	+	+								
MUSSA	+	+	+	+								
TRANUS	+	+	+	+								
URBANSIM	+	+	+	+								

Source: Wegener (1999)

Table 3. Transport policies that can be studied with land-use tranport models

	Transport policies											
	Investment and services			Regulation			Pricing and subsidies			Information		
Models	Roads	Public transport	Public transport operation	Parking	Traffic regulation	Parking regulation	Road pricing	Parking fees	Fuel taxes	Public transport fares	Education	Marketin
DELTA/START	+	+	+	+	+	+	+	+	+	+		
IRPUD	+	+		+	+	+	+	+	+	+		
MEPLAN	+	+	+	+	+	+	+	+	+	+		
METROSIM	+	+	+		+		+		+	+		
MUSSA	+	+	+		+		+		+	+		
TRANUS	+	+	+	+	+	+	+	+	+	+		
URBANSIM												

Source: Wegener (1999)

A.6.2 Trends in land-use transport models

Nowadays more and more LUTI models are available as user friendly software packages which can run on a desktop computer. Of the LUTI models in this memo the DELTA, MEPLAN, TRANUS and METROPOLIS models are available as commercial packages. The URBANSIM model is freely available and can be downloaded on the Internet and can be used under the General Public License rules (USA). The MUSSA and IRPUD model are not available as commercial packages.

The older Martin Centre models (MEPLAN, TRANUS) are integrated models consisting of a land-use and transport model. The more recent land-use models as DELTA, URBANSIM, NYMTC-LUM, MUSSA are independent land-use models and conversion modules are used to link the land-use model with an existing transport model in the study region. Another example of this trend is the effort of Marcial Echenique & Partners (ME&P) to develop a land-use model (MENTOR) that can easily be linked to existing transport models in the UK. The main reason for this trend is the enormous growth in operational transport models; nowadays almost all the metropolitan areas have a transport model operational.

There is a trend towards more disaggregation of spatial units of analysis and disaggregation of 'behavioral units' (e.g. households, firms). Growth in computing power, estimation techniques and data availability are the driving forces behind this trend. In most applications discrete choice theory seems to remain the way to represent the choice behavior of actors. Advantages are that the theory is in a mature state and that estimation packages are commercially available.

Another more recent trend is the attention for activity based models. The activity-based method is moving from the stage of theory into the stage of practice. An example of the integration of an activity-based model system and a residential location model can be found in Ben-Akiva and Bowman 1998. For the integrated land-use and transport models future developments can be expected in the field of integrating long term lifestyle decision and daily activity decisions (Waddell 2000). A first step can be to use activity-based accessibility parameters.

B. Detailed description of IRPUD, UrbanSim and MEPLAN

B.1 Introduction

Part A was descriptive, presenting an overview of internationally available packages and two other relevant Dutch models. Part B will follow a more prescriptive oriented approach, describing in more detail which features are in the model, and which elements can be useful for the new TIGRIS model. The most promising models, with respect to the new TIGRIS model, described in the quick scan in part A, are the focus of this part of the report.

In a meeting with the Transport Research Center (in Dutch 'Adviesdienst Verkeer en Vervoer, AVV') the results of the quick scan were evaluated, and the AVV selected three models for a more detailed description. These three models are:

- MEPLAN
- URBANSIM
- IRPUD/DELTA

The above mentioned models will be described using a fixed format, which makes a comparison more easy. At the end of the description an example of an application of each model will be given.

The IRPUD and DELTA models are much alike. Therefore, we will only describe the IRPUD model extensively, because this is the more complex one of the two. A short description and the main differences between the DELTA model and IRPUD are discussed in B.2.7.

This part is set out as follows: B.2, B.3 and B.4 will describe the three selected models in detail. B.5 summarizes our findings of the selected models with respect to the new TIGRIS model.

B.2 IRPUD

Literature: Wegener (1998a-g), Wegener (1999), Simmonds (1999a), Simmonds (1999b), EPA (2000), Webster (1988), Pagliara (2001)

B.2.1 General description

The IRPUD model of Dortmund was developed by Wegener in 1985. It has a dynamic structure, operates at an intra-regional level and the model has a composite structure of subsystems. The basic idea behind IRPUD and also DELTA is the focus on the representation of changing urban processes rather than on one overall (equilibrium) theory.

The IRPUD predicts for each simulation period:

- Location decisions of industry, residential developers and households
- Resulting migration and travel patterns
- Construction activity
- Land-use development
- Impacts of public policies as industrial development, housing, public facilities and transport

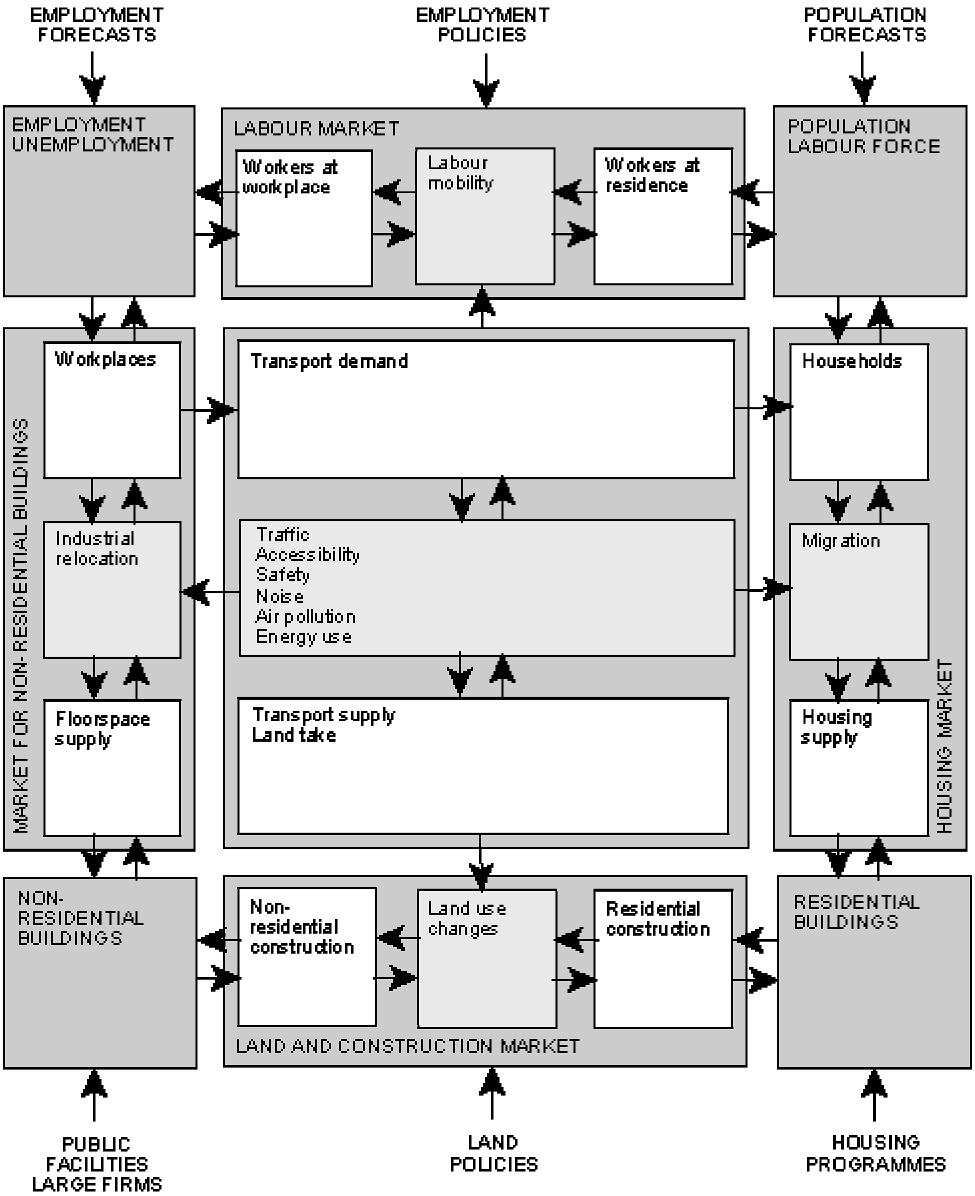
Typical aspects of the IRPUD model are the attention paid to the time scale of urban processes and the inclusion of search behavior in the modelling of households seeking dwellers and of landlords seeking tenants.

B.2.2 Model specifications

B.2.2.1 Model structure

The model consists of six interlinked submodels, namely a Transport Submodel, an Ageing Submodel, a Public Programmes Submodel, a Private Construction Submodel, a Labour Market Submodel and a Housing Market Submodel. Figure 5 shows how the various submodels interact.

Figure 5. The IRPUD model.



Source: Wegener (1998)

The four square boxes in the corners of the figure show the major stock variables in the model. Each of the stock variables are represented by actors: the population by individuals or households, employment by workers, residential buildings by housing investors and non-residential buildings by firms.

The five markets in the model are presented in the figure, where the demand and supply is shown for each market. The large arrows indicate the exogenous input that are forecasts of regional employment and population or policies.

B.2.2.2 Spatial unit of analysis

The present IRPUD model uses 30 zones to examine the location and mobility decisions. These zones are connected by transportation networks (e.g. roads and public transportation lines). In the new revision of the model (PROPOLIS project) the spatial resolution will be extended to 300 zones.

B.2.2.3 The dynamic structure of the model

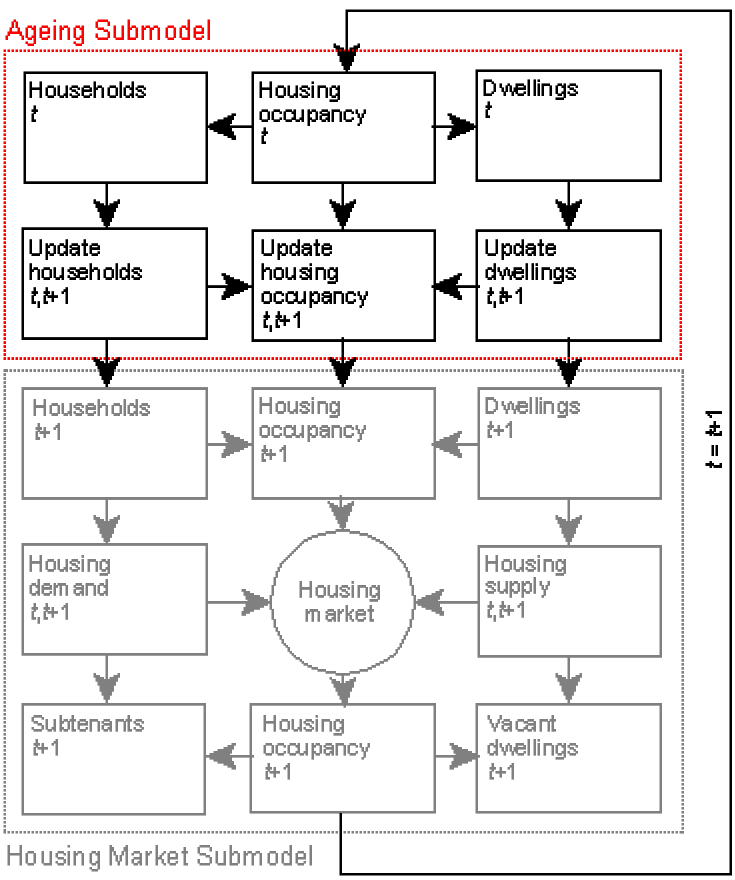
The transport model within IRPUD is an equilibrium model referring to a point in time. The other submodels are incremental and refer to a period of time. The Ageing, Public Programmes, Private Construction, Labour Market and Housing Market Submodels are executed sequentially once in each simulation period. Each submodel passes information to the next submodel in the same period and to itself in the following period. The Transport Submodel runs at the beginning and the end of each simulation period (where the run at the end of a period is the same as the run at the beginning of the next period).

B.2.3 Demographic and socio-economic developments

B.2.3.1 Demographic developments

The number of persons and households in IRPUD is modelled by the Ageing Submodel. The distribution of the population over zones due to migration into, out or within zones is determined by the Housing Market Model (discussed in paragraph B.2.4.3).
Figure 6 shows the interaction between the two models.

Figure 6. Household and housing change in the Ageing Submodel and Housing Market Submodel.



Source: Wegener (1998)

The population is categorized by five year age groups and sex, and transition rates between groups are exogeneously determined as well. The change of population is modelled per zone as a result of fertility and mortality rates, which are calculated based on a cohort-survival model. The rates of fertility and mortality are exogenously fed into the model.

The demographic changes of households and housing, that are time dependent, are modelled in the Ageing Submodel. Households are classified by nationality, age of head, income/skill and size. Changes in households can result from the life cycle of a household and the change of the household status, changes in housing include deterioration by ageing and demolition as a result of ageing. Demolotion may occur due to planning of other land uses. This is modelled in the Private Construction Submodel.

For each household and dwelling in a zone a transition rate is defined as probability that a change to another type will occur during the simulation period from time t to time t+1. The probabilities are exogeneously given or are taken from the demographic submodel for population change. The number of new households without a dwelling are created through marriage or divorce, or the demolition of a dwelling. Vacant dwellings are generated by the dissolution of a household.

B.2.3.2 Social-economic developments

Households are divided into four income groups (low, medium, hig and very high) which correspond to the four skill levels of workers. Household incomes and housing, travel and shopping budgets of the four income groups are specified exogenously. The income is constant irrespective of their location in the region.

The regional employment and unemployment forecasts are exogenous input for the model.

B.2.4 Markets in the model

B.2.4.1 Land market

The Private Construction Model determines the land price as a function of the demand for land of the land use category in the zone in the period just completed. Prices are updated annually meaning that IRPUD does not attempt to reach equilibrium land prices within a year. The price adjustment model reflects price adjustment behaviour by land owners.

B.2.4.2 Labour market

The labour market in IRPUD is modelled in the Labour Market Submodel. The labour market depends solely on demand, meaning that firms employ and release workers according to their needs. The change of employment is modelled in three other submodels:

- The Ageing Submodel calculates the decline of zonal employment resulting from a sectoral decline, lack of building space and firms that relocate to another region:
- Shifts in zonal employment due to the location or removal of large plants can be exogenously specified by the user in the Public Programmes Submodel;
- In the Private Construction Submodel the change of zonal employment due to new jobs in vacant buildings or new construction is modelled.

The Labour Market Submodel models the change-of-job utility, which is assumed to depend on the distance between the old and the new workplace and the assumption that a job nearer to home is more preferable than a job farther away. The propensity to change job relates (inversely) to the trip utility of the work trip modelled in the Transport Submodel.

The changes in income distribution are modelled in this submodel. It is assumed that whenever a household turns unemployed, it drops from one income group to the next lower one. A household that becomes employed will move to a higher income category.

B.2.4.3 Housing market

The Housing Market Submodel models the intraregional migration of households as a result of the search from households for a certain dwelling. Housing of each zone is represented as a four-dimensional distribution of dwellings classified by type of building (single-family, multi-family), tenure (owner-occupied, rented, public), quality (very low, low, medium, high) and size (1,2,3,4,5+ rooms).

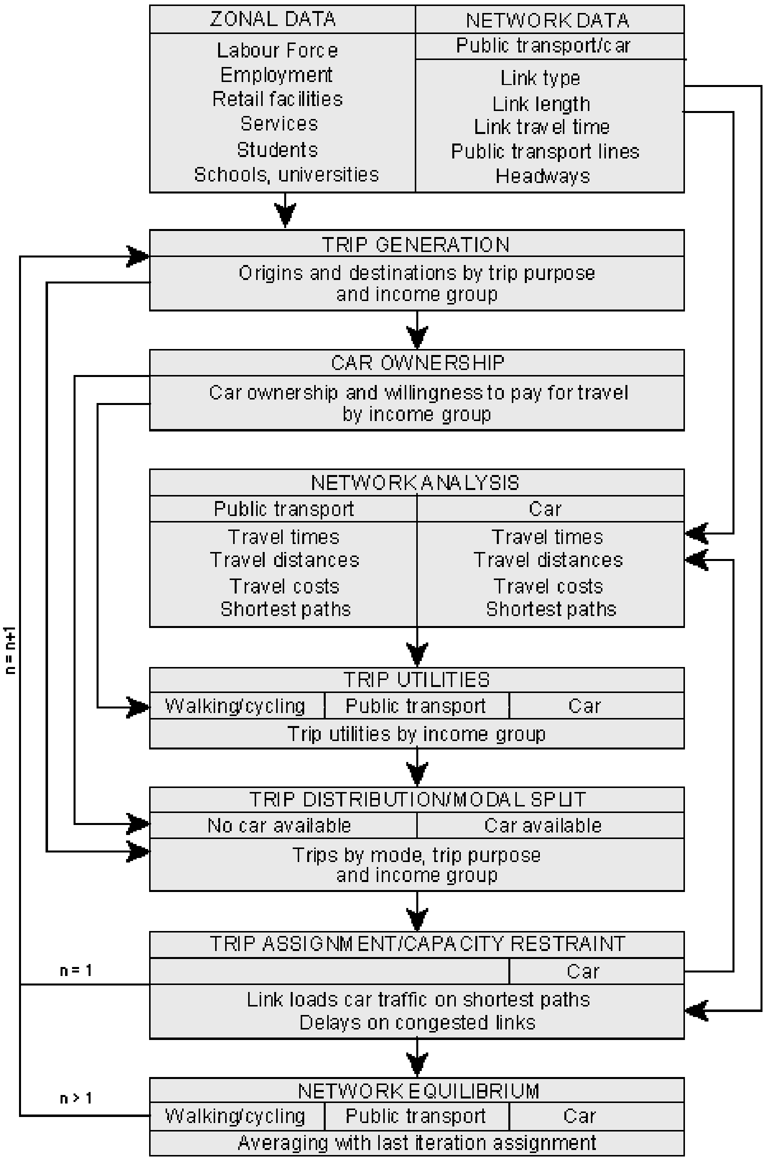
The migration submodel is a Monte Carlo micro-simulation of a sample of representative housing market transactions. There are four phases in the micro-simulation: the **sampling phase** determines a household looking for a dwelling or a landlord looking for a tenant. In the **search phase** the selected household or landlord searches for a suitable dwelling or tenant. The decision whether or not to accept the dwelling is made in the **choice phase**. A household will try to maximize its utility and will search for a dwelling that increases the utility marginally. The attractiveness of a dwelling per zone depends of a weighted aggregate of the housing attributes. The accessibility of a zone, expressed as mean trip utility calculated in the transport model, is reflected in the attractiveness of a dwelling as well. If the household does not find a suitable dwelling the search is stopped for the current period. Eventually, in the **aggregation phase**, transactions are made and all changes of households and dwellings are performed, multiplied by a sampling factor. This leads to intraregional migration flows of households by household types between dwellings by type in the zone. Both the sampling phase and the search phase are controlled by multinomial logit choice functions.

In the Housing Market Submodel, the price and rent of a dwelling are determined by the demand for housing in the previous housing market simulation. The demand for housing is expressed as a function of the proportion of vacant units. The supply side of the housing market, i.e. changes in the composition of the housing stock, is determined in the Private Construction Submodel. Newly developed and renovated dwellings are more expensive than existing ones. Housing in zones with much building activity become more expensive than ones with few new dwellings.

B.2.4.4 Transport model

The Transport Submodel within the IRPUD Model calculates work, shopping, service and education trips for four socio-economic groups and three modes: walking/cycling, public transport and car/motorcycle. The model seeks to determine a user-optimimum set of flows where car ownership, trip rates, modal split and route choice are in equilibrium subject to congestion in the network. Figure 7 shows the linkage between the various components within the Transport Submodel. The Transport Submodel models the mobility pattern in the region and provides accessibility measures for the land-use parts of the model, which are input for attractiveness functions in the Public Programmes and Housing Market submodels.

Figure 7. Transport Submodel within IRPUD.



Source: Wegener (1998)

The transport supply is represented by two explicit transport networks, public transport and road, and one implicit network, walking and cycling. For each mode travel times and costs are calculated differently.

Car ownership is a function of household travel budgets and expected travel expenditure. The car ownership level is categorised for each income group and for each zone. Parking limits in high density areas will influence ownership through a monthly penalty cost and will result in extra time and money penalties for trips ending in such areas. Car ownership is not influenced by the availability of public transport.

IRPUD simulates all outgoing home-based trips during a four-hour morning peak period. Return trips and non-home-based trips are not considered. Destination choice for work trips is performed only in the base year: in all subsequent years the work trip matrix is updated as a result from shifts in the housing market. Only the modal split is adjusted by the transport model.

The level of service coded in the public transport network (train/bus frequencies) apply to the four hour morning peak period. Frequency of public transport serivce is integrated into travel time in the form of waiting time. Travel time is not converted into transport cost by value-of-time coefficients, but are valued by a common utility function. The link travel times coded in the road network refer to non-congested travel. The Transport Submodel calculates congestion depending on the transport flows in an iterative process. Differences between modes besides time and money are reflected in different value functions for the three modes.

The detailed input for the transport model as well as the outputmatrices are described in Appendix A.

B.2.5 Calibration and validation of the model

B.2.5.1 Method

The model parameters to be calibrated can be classified into six groups:

- Demographic parameters
- Household parameters
- Housing parameters
- Technical parameters
- Monetary parameters
- Preference parameters

The IRPUD model was partly calibrated by manual fine-tuning in a long, interactive process.

B.2.5.2 Validation

IRPUD model is validated on its performance of simulation against observed change over time.

B.2.6 Policy measures

Within IRPUD, global and local policies can be modelled.

Global policies affect the economic or institutional environment of urban development in the whole region:

- Global economic policies: changes in tax laws and subsidies; forecasts of employment and immigration and outmigration for the total region.
- Global housing policies: taxation and subsidies in the housing sector or new regulations governing land use or construction activity.
- Global transport policies: taxes or subsidies resulting in changes to petrol prices, parking fees or public transport fares; general speed limits or road pricing schemes.

Local policies are regulatory or direct zone-specific:

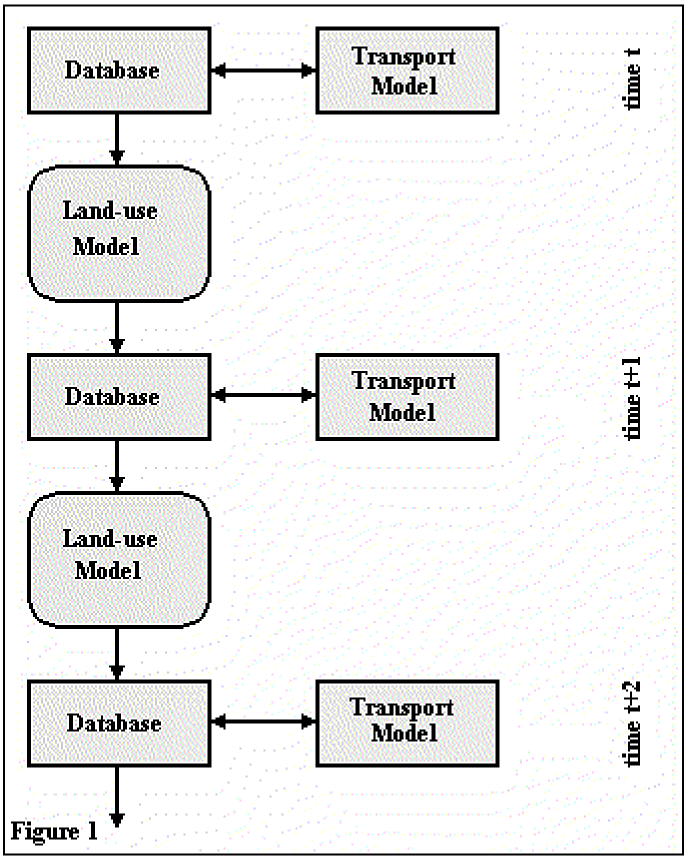
- Local land-use planning: a land-use or zoning plan for each zone.
- Local economic policies: new industrial locations, relocations of firms, or plant closures.
- Local housing policies: new housing or urban renewal projects in specific zones.
- Local public facilities: schools , hospitals, rreation facilities etc.
- Local transport policies: additions, deletions, or modifications of network links or public transport lines.

B.2.7 The DELTA Model

The DELTA model was developed by David Simmonds Consultancy, the MVA Consultancy and the Institute for Transport Studies (ITS) during the period 1995-1996. The work is an extension of the existing START model of Edinburgh designed by MVA. The underlying theoretical foundation is the IRPUD model by Wegener. As mentioned before, the DELTA model is a less complex, but more practical model than IRPUD. In this paragraph we will outline DELTA briefly and discuss the differences with IRPUD.

The name DELTA stands for Development, Employment, Location, Transition or growth, and Area quality. These are the five submodels in the land use part of DELTA. In addition, in each period the land use model interacts with a transport model. The overall structure is given in Figure 8.

Figure 8. The DELTA Model



Source: Simmond (1999)

In contrast with IRPUD the DELTA model has a connected transport model, rather than an endogenous one. This makes it more applicable to various areas working with their own transport model.

The five submodels mentioned above model the same attributes as the submodels within IRPUD. The major differences between DELTA and IRPUD are that IRPUD uses Monte Carlo simulation for the housing market. The modeling of the housing market in DELTA does not use a micro-simulation. Both of the models use the utility theory. The underlying theory of the IRPUD submodels is more complex. However, DELTA has a specific submodel for the area quality, which attempts to capture the influence of the neglect of buildings and gardens, long-term vacant properties or the use of residential property for ‘industrial’ purposes as a negative aspect.

The dynamics of DELTA is virtually the same as for IRPUD. All the submodels are incremental and are processed (annually) in a specific order. The interaction between DELTA and the transport model may be each year, but can be less frequent when the computation time is limited.

B.3 Urbansim

Literature: University of Washington (1999), University of Washington (2000), Wegener (1999), EPA (2000), Waddell (1998), Waddell (2000), Waddell (2001a), Waddell (2001b), Noth (2001)

B.3.1 General description

UrbanSim is recently developed by the University of Washington and a first version of the model has been applied in the Eugene-Springfield metropolitan area (Oregon), Salt Lake City (Utah) and Honolulu (Hawaii). The National Science Foundation and the University Initiative Fund of the University of Washington are funding the project. Urbansim is a software-based system designed to be used for integrated planning and analysis of urban development, incorporating the interactions between land use, transportation, and public policy.

The model implements a perspective on urban development that represents a dynamic process resulting from the interaction of many actors making decisions with the urban markets for land housing, non-residential space and transportation.

UrbanSim can evaluate the long-term results of policies with regard to housing, business and economic development, sprawl, open space, traffic congestion, and resource consumption.

B.3.2 Model specifications

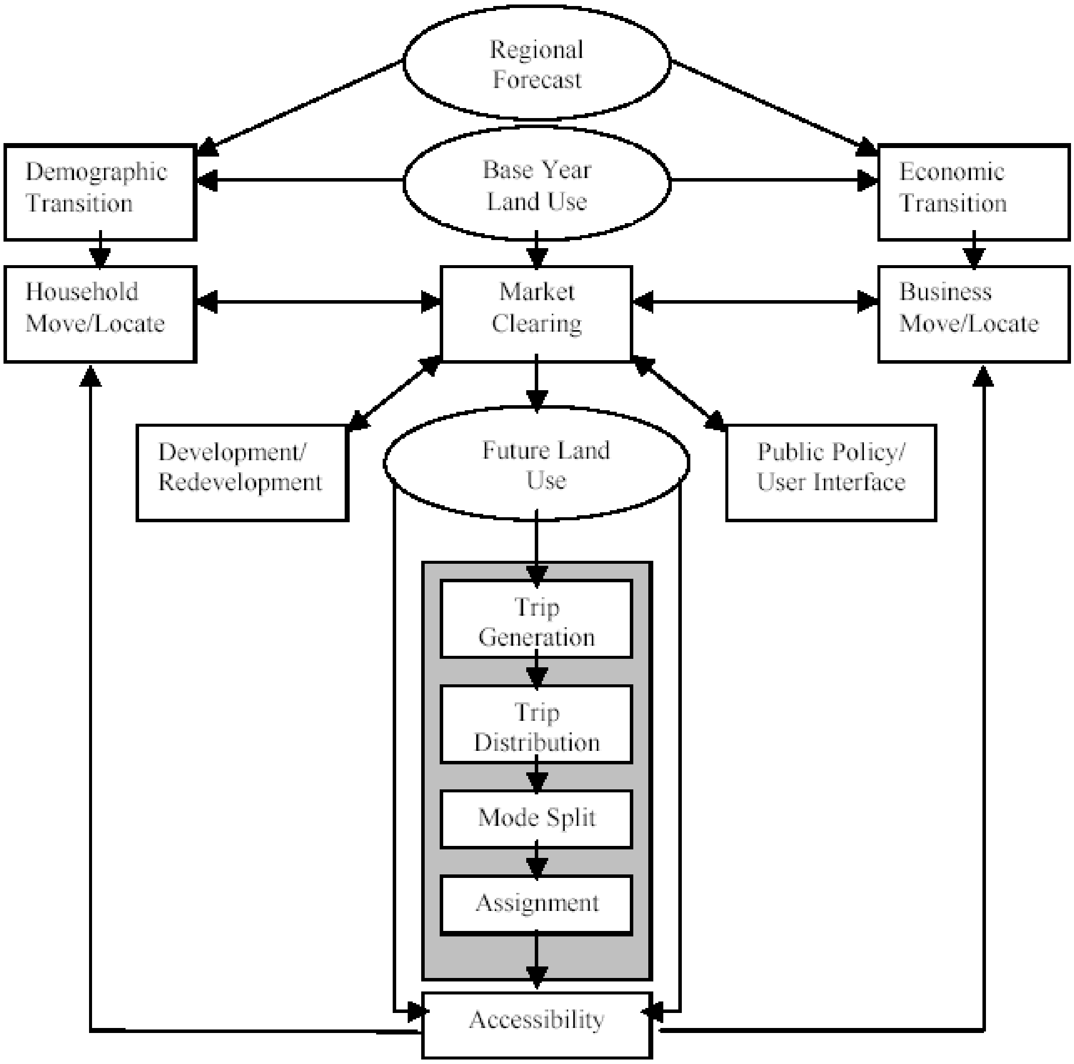
B.3.2.1 Model structure

UrbanSim is a composite model, meaning that all the submodels have their own independent structure and are loosely coupled with each other. The model consists of nine submodels and a transport model, that is connected with UrbanSim but can be different for each application. The following nine submodels are integrated in UrbanSim, each of them will be described in B.3.4:

- Economic Transition Model
- Demographic Transition Model
- Employment Mobility Model
- Employment Location Choice Model
- Household Mobility Model
- Household Location Choice Model
- Land Price Model
- Accessibility Model

Figure 9 gives an indication of the interactions between the submodels in UrbanSim and the connected transport model.

Figure 9. Functional Structure of UrbanSim



Source: UrbanSim Reference Guide 0.9.

B.3.2.2 Spatial unit of analysis

UrbanSim uses 150 by 150 meter grid cells to specify an area, although the user can adjust the size of the cells. Development and redevelopment of housing can be specified at the detailed level of land parcels, which is the most detailed model to date. At the demand side the model uses the spatial zones of the transport model, which means that the scale level depends on the application. E.g. 271 zones in the Eugene-Springfield application, 761 in Honoulu and 1,000 in Salt Lake City.

B.3.2.3 The dynamic structure of the model

UrbanSim is a dynamic disequilibrium model that runs each year, where the supply component is the developing and redeveloping of individual land parcels based on expected profits or losses. Prices of the last year will determine expected revenues or losses, and new construction will be available in the subsequent year. Demand is based on current supply and last year's prices. Prices are adjusted in the Land Price Model.

The interaction with a connected transport model could be annually, but in practice it occurs on a less frequent basis.

B.3.3 Demographic and socio-economic developments

B.3.3.1 Demographic developments

In UrbanSim, the demographic development is modelled by the Demographic Transition Model. The changes in the distribution of households by type that result in reality, from a complex set of social and demographic change, are calculated over time. The model uses external control totals of population and households by type (when available) to approximate the net results of these changes. Only for the first and last year of the simulation population totals are required, at a minimum, but it is possible to implement them each year. For intermediate years, where data is not available, values are interpolated. When the change in the distribution of the households by type is not given exogenously, the model assumes the distribution will remain constant throughout the years.

UrbanSim will add a new household (so-called household birth) to the list of movers, which will be located by the Houshold Location Choice Model. Households that disappear (so-called household death) will be removed from the household stock, and the vacancies, as a result of their departure will be accounted for.

B.3.3.2 Social-economic developments

Aggregate forecasts of economic activity and sectoral employment is an exogenous variable in UrbanSim, which the user has to define. A range of ten to twenty sectors can be specified, depending on the level of detail of the local economic structure. The sectoral distribution remains constant throughout the years, if it is not specified by the user. Totals have to be defined for the start and end year of the forecasting horizon, and if possible for intermediate years. When data is unavailable control totals will be interpolated.

The Economic Transition Model calculates the sectoral growth or decline by integrating the exogenous forecasts with the model database. Jobs are added to the following year location component for growing sectors. However, new jobs are not immediately assigned a location, but are added to the database and assigned a null location, to be resolved by the Employment Location Choice Model. When sectors show a decline, jobs will be removed proportional to the spatial distribution of that sector. The space that becomes vacant, will be placed in the location component of the model and can be occupied by other jobs. Income (wages) is exonegously given.

B.3.4 Markets in the model

B.3.4.1 Land market

UrbanSim uses a Land Price Model to set the price of land at different locations and with different development types, and of the relative market valuations for attributes of housing, nonresidential housing, and location, balancing between demand and supply. Land prices will influence the location choice for jobs and households. An adjustment of the price will alter the location preferences of occupants, as well as developers to build new constructions.

The Land Price Model is based on the assumptions that households, businesses, and developers are all price-takers and market adjustments are made by the market in response to aggregate demand and supply relationships. Location preferences and demand-supply imbalances are

capitalized into land values. Furthermore, a structural vacancy rate is held as relevant threshold to consider for price adjustment. Apart from locational and site attributes, the current vacancy rate determines the price per acre of development type at a location each year. When the current vacancy rate is below the structural rate, prices are relatively high, and vice versa. Prices are updated annually, after all construction and market activity is completed. The price level of this year is the reference price for market activities in the next year.
The independent variables that influence land prices are:

- Site characteristics
  - Development type
  - Land use plan
  - Environmental constraints
- Regional accessibility
  - Acces to population and employment
- Urban design-scale
  - Land use mix and density
  - Proximity to highway and arterials
- Market condition
  - vacancy rates

B.3.4.2 Labour market

In UrbanSim the labour market is divided into two submodels:

- Employment Mobility Model
- Employment Location Choice Model

The decisions in both models are in reality made by firms. UrbanSim uses individual jobs as the units of analysis, which is equivalent to model business decisions as individual choices about the location of each job.

The Employment Mobility Model predicts the probability that jobs of each type will move from their current location or stay during a particular year. The transitional changes are an indication of job turnover by employees, layoffs, business relocations or closures. The losses in declining sectors are proportional to the spatial distribution of jobs in the sector. The buildings they occupied before the job losses will be made available as vacant space and be relocated to unallocated new jobs in the employment location choice model. When a sector grows, the added jobs are all managed through the employment location model.

The Employment Location Choice Model predicts the probability that a job that is either new (from the Economic Transition Model), or has moved within the region (from the Employment Mobility Model), will be located at a particular site. The model is specified as a multinomial logit model, with separate equations estimated for each employment sector. When the probabilities per alternative for the current job are estimated, the decision, where to locate the job among alternatives, is determined by Monte Carlo simulation.

The stock of available space is assumed to be fixed in the short run of the intra-year period of the simulation, implicating that locators are price-takers. Each locating job or household is not powerful enough to influence the market and must accept the current market price as given.

The independent variables used in the employment location choice model can be grouped into the following categories:

- Real estate characteristics
  - Prices
  - Development type (land use mix, density)

- Regional accessibility
  - Acces to population
  - Travel time to CBD, airport
- Urban design-scale
  - Proximity to highway, arterials
- Local agglomeration economies within and between sectors: center formation

B.3.4.3 Housing market

In UrbanSim the housing market can be divided into three submodels:
- Household Mobility Model
- Household Location Choice Model
- Real Estate Development Model

The Household Mobility Model estimates mobility rates for each type of household. The model is identical in form to the Employment Mobility Model. Mover households by type are subtracted from the housing stock by cell and added to the pool of new households by type estimated in the Demographic Transition Model. The new and moving households are relocated by the Household Location Choice Model. The housing that becomes available for occupation from moving households is redistributed in the location and housing type choice model.

The Household Location Choice Model is very similar to the Employment Location Choice Model in that it predicts probabilities for a household, that is new or has decided to move, which particular location to choose defined by a grid cell. The form of the model is a multinomial logit, where the alternatives of available housing is randomly sampled.

UrbanSim is not a general equilibrium model which assumes perfect information to clear the market assigning households and jobs to available space. The solution is based on the expectation of imperfect information and nontrivial transaction and search costs, where movers obtain the location with the highest utility available. Prices respond at the end of the year to the balance of demand and supply at each location.

The independent variables used in the household location choice model can be grouped into the following categories:
- Housing characteristics
  - prices (interacted with income)
  - development types (density, land use mix)
  - housing age
- Regional accessibility
  - job accessibility by car ownership group
  - travel time to CBD and airport
- Urban design-scale (local accessibility)
  - neighborhood land use mix and density
  - neighborhood employment

The Real Estate Development Model simulates the construction of new real estate. Each grid cell (150 by 150 meter) is classified as a development type: residential, commercial, mixed residential and commercial, industrial, vacant for development or undevelopable. Within the categories, groups are defined resulting in a total of 25 development types. Transition rates of a grid cell to change from one development type to another or the intensification of development within a year are modelled using a multinomial logit model. Depending on the price determined in the Land Price Model a real estate developer or landowner will choose to change the development type.

The independent variables used in the real estate development model can be grouped into the following categories:

- Site characteristics
  - existing development characteristics
  - land use plan
  - environmental constraints
- Urban design-scale
  - proximity to highway and arterials
  - proximity to existing development
  - neighborhood land use mix and property values
  - recent development in neighborhood
- Regional accessibility
  - access to population and employment
  - travel time to CBD, airport
- Market Conditions
  - vacancy rates

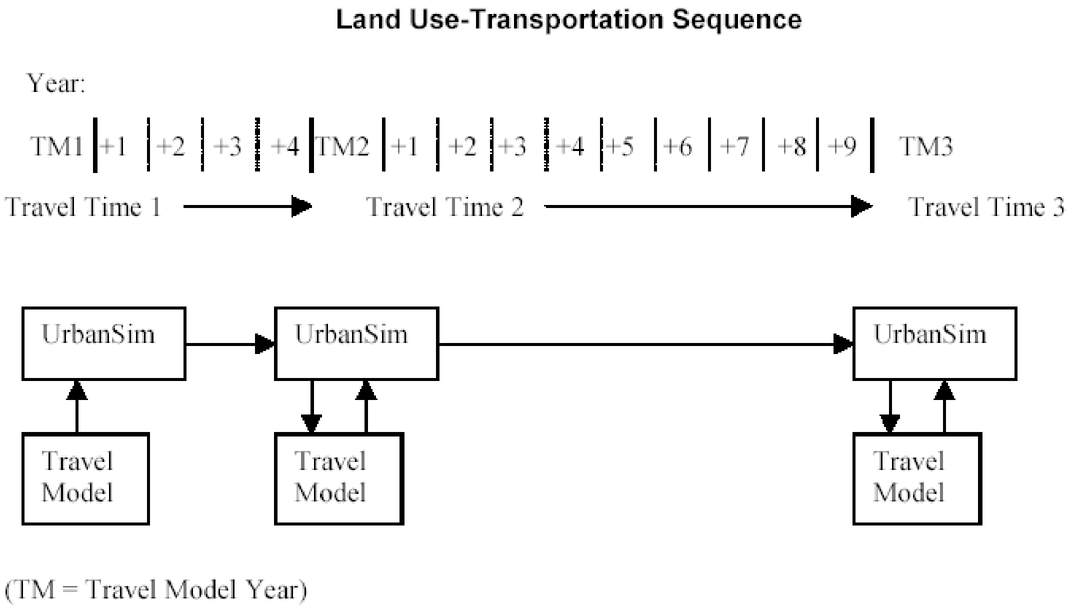
The user can specify development events by adding a special input file, which is processed by the model as though they were generated by simulation.The details of the project must be given by grid cell and a probability of certainty can be given for each project. Special care should be taken here, because the model itself will generate development events for the same year endogenously. An over-prediction of real estate development is likely.

B.3.4.4 Transport model

There is no specific transport model assigned to UrbanSim. The idea is that the Land Use model of UrbanSim interacts with an independent transport model.

The urban simulation model integrates with travel forecasting models through a longer-term temporal dynamic to account for changes in the transportation system, and reflects these through the accessibility indices in the model. Figure 10 illustrates the interaction between UrbanSim and a transport model.

Figure 10. Interaction of a transport model with UrbanSim



Source: UrbanSim Reference Guide 0.9.

Ideally, UrbanSim interacts with the transport model on an annual basis, which is possible, but increases the run time significantly. A period of five year is common to interact with a transport model.

The travel times and utilities are only updated when the travel model is run, however the accessibility indices to measure the relative accessibility to various activities from each potential location are updated annually according to the changing distribution of activities. Because major transportation improvements are likely to be fairly discrete in time, the user can determine the appropriateness of the travel model years with respect to the significance of the transportation system changes in the intervening years.

To capture the effects of transportation policy changes on real estate and household and employment location, Urbansim needs three sets of outputs from a travel model:

1. composite utilities of travel from zone to zone by car ownership from the mode choice model
2. the car ownership probabilities from the vehicle ownership model
3. the am peak travel times for home based work trips

Each set is described briefly below.

The primary influence of transportation access on real estate develoment, household and employment location is captured through access indicators generated by interacting the spatial distribution of activities with the composite utilities of travel to those activities. In the mode choice model, the utilities for different car ownership groups and transit modes are calculated to travel from one zone to another. The composite utility measure is the logsum, which serves as a proxy for the accessibility between zones.

Car ownership probabilities are calculated as a function of household size and income distribution, at a minimum, but may depend on many more variables such as density, parking costs and the availability of transit alternatives. UrbanSim will use these probabilities to assign a car ownership to each household, consistent with the probabilities of the transport model, to capture the interdependence between car ownership and residential location.

Highway travel times during the am peak are used to measure travel times to key regional destinations. These variables may be used as independent variables in the employment or residential location choice models.

B.3.5 Calibration and validation of the model

B.3.5.1 Method

The Land Price Model is a hedonic regression of land value on attributes of the land and its environment. The hedonic regression can be estimated using sales transactions if sufficient data is available for all property types, on the lot and its location. Or estimation can be based on tax assessor records on land values, which are part of the database typically assembled to implement in the model.

The Employment Mobility Model is calibrated using available data to calculate transition rates. In the future, with more appropiate data, mobility probabilities might be estimated using binary or nested logit models. In this way, the model could use information about the relative utility of alternative locations to the utility of the current location in predicting whether jobs will move.

The Employment Location Choice Model is calibrated with a geocoded establishment file. A sample of geocoded jobs in each sector is used to estimate coefficients. The model produces demand by each employment type for cell locations.

The Household Mobility Model is calibrated using household surveys, that reflect differential mobility rates for renters and owners, and households with and without children, etc. Logit models can be estimated to predict probabilities of household mobility depending on independent variables based on household characteristics. More advanced logit models such as binary or nested logit can be estimated when data is available and suitable.

The Location Choice Model may be estimated using households by income level, by the number of children or by other life-cycle characteristics. Opposed to such a stratified estimation, the current model is a single model estimation, where these effects are estimated through interactions of the households characteristics with the characteristics of the alternative locations. Calibration of the model is based on the use of a random sample of alternative locations, providing consistent coefficients. Households are modelled individually and are assigned an alternative, using Monte Carlo simulation after a sample of alternatives has been established.

The Real Estate Development Model is estimated using data derived from preprocessing the parcel and grid data, where the year built values of the existing development is given in the assessor records. Missing data is filled by examining the surrounding cells of the same type. New constructions or intensification of the development in the examined years can be determined. Demolition of buildings is currently not modelled within UrbanSim. From this analysis, observed transition rates between any two pairs of development types or intensification of a type within each year can be specified.

B.3.5.2 Validation

The first project where UrbanSim was fully integrated was in the Eugene-Springfield area in Oregon, which was funded by the Oregon Department of Trnasportation TLUMIP project. It is a relatively small size metropolitan area, which has data available for model application. The

base year for the model was 1994. After calibration of the model a database was developed for 1980. From 1980 to 1994 an annual run was made and compared with the 1994 statistics.
The transportation model comprised 271 analysis zones, which was subdivided into 15,000 grid cells of 150 by 150 meters for spatial analysis in the residential location, employment location, realestate development, and land price models. An Urban Growth Boundary was superimposed as a policy. Predictions of the model were fairly good; household and employment change was predicted with an error of 200 or less households or jobs in 89% and 76% of the zones, respectively. Employment change was not predicted as well as household change, because employment tends to be more concentrated and volatile.
Isolated events such as a significant downsizing of a plant in Springfield and the opening of a mall could not be predicted. However, these kind of large-scale events can not be modelled by any model system.

B.3.6 Policy measures

Within UrbanSim the user can define scenarios to evaluate the implications of policies by specifying policy inputs and assumptions.

UrbanSim can model two types of policies: land use policies and policy overlays. These policy instruments include a comprehensive land use plan, which proposes a long-range future urban form as a pattern of prescribed land use designations. Each zone or grid cell is allowed to be (re)developed in one of the classifications described by the user being retail, office, industrial, residential, open spaces or public land uses. In addition the density of development may also be constrained. Other available instruments include regulatory overlays such as the rules regulating development outside an urban growth or urban service boundary, and of environmentally sensitive lands, or within any special planning overlays designated by the user. The overlays are very flexible in that they can be applied to separate counties, cities or regions.

Transportation policies can be incorporated through the connected transport model, but they are not part of UrbanSim.

B.4 MEPLAN

Literature: Pagliara (2001), Wegener (1999), EPA (2000), Simmonds (1999b), Williams (1994), Simmonds (1994), Rohr (1994)

B.4.1 General description

MEPLAN is a multi-purpose software package developed originally by ME&P (UK) in 1984. The software is designed as a general abstract modelling framework to represent social-economic phenomena with a spatial dimension. The MEPLAN framework has been used in planning studies at all spatial scales, ranging form town planning to international models. The MEPLAN model is not a model in the conventional sense, but rather it is a shell which provides facilities to develop the type of model that is appropriate to the needs of a specific study area. In this chapter the structure of the MEPLAN framework is described and characteristics of the applications of MEPLAN in London and South - East England and Naples are used in the description. These models are examples of applications at a metropolitan and regional scale. In the modelling there is particular attention on the location of residences and on the patterns of journey to work, shopping and school.

B.4.2 Model specifications

B.4.2.1 Model structure

The MEPLAN model contains a land-use as well as a transport model. The models contain all the stages of a conventional four stage transport model, although 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 zones. The so-called trades out of the land-use module are translated in transport flows and input for the mode and route assignment model. The levels of service of the transport model are transferred into disutilities and form input for the land-use model.

The land-use model in the MEPLAN framework is characterized by a spatial input-output framework as the means of generating the interactions between places and hence the demand for transport. In the framework three components can be identified:

- The input-output framework, describes the relationships between activities
- Spatial choice models, distributing the relationships across space, the disutilities generated in the transport model are included in the spatial choice models
- A system of constraints representing, through rents and utilities of location, the influence of land-use controls

The three components are integrated and a model run solves the three components simultaneously. The land-use model can be described as a unified model and the spatial choice model and constraints are modelled within the iterations of the input-output model. A first iteration of the input – output generates a set of demands and the spatial choice model distributes the demands to the supply zones. The total supply from each zone is summed and checked against constraints, the production costs are adjusted and the input-output model runs again to generate a new set of demands.

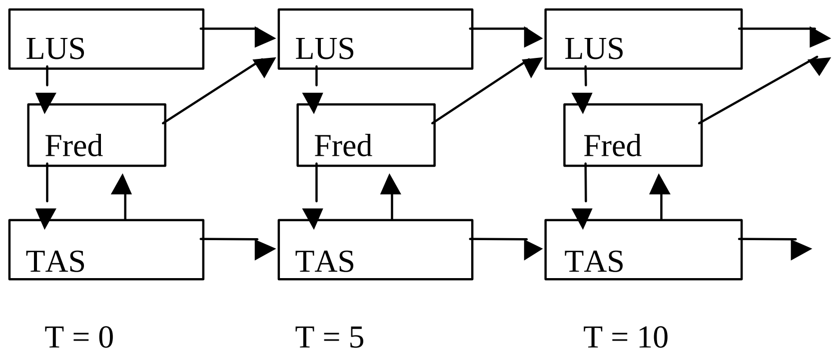
B.4.2.2 Spatial scale level and unit of analysis

The spatial scale level of MEPLAN is flexible and the best illustration is the range in applications at different spatial scale levels, ranging from local town studies to international studies. In general the MEPLAN applications are constructed for strategic analysis and less for local analysis. The main reason for this is the mostly coarse level of spatial resolution. The spatial unit of analysis is also flexible in the modelling, but the high data requirements for an advanced application of the framework are a constraint to the spatial resolution. In one of the most advanced application of the MEPLAN software for London and the South - East 126 spatial units are included. In a new version of the LASER model the number of zones will be extended to 335 zones.

B.4.2.3 The dynamic structure of the model

The modules in the MEPLAN framework operate on a time period by time period basis with feedback between transport and land-use taking place from one period to the next. The user can define the time steps, but in general the model operates through time in steps of the order of five years from a base year to a forecast horizon.

Figure 11. The dynamic structure of the model



LUS Land –use module
FRED Interface module
TAS Transport module

Source: Williams (1994)

B.4.3 Demographic and social-economic developments

B.4.3.1 Demographic developments

The population in MEPLAN is categorized in different social-economic household categories. The economic active and economic inactive households are treated differently in the modelling. The number of economic inactive households depends on exogenous forecasts for the study region. The changes in the number of economic active households are calculated in the spatial choice model and depend on the changes in basic employment of a region. In the modelling, the aging of the population is not endogenously included.

B.4.3.2 Social-economic developments

The import/export figures by industrial sector are exogenous inputs. The decline and growth of basic employment are also exogenous scenario figures. The number of unemployment persons in the region is also an exogenous projection like retired households. The labour participation per type of economic active households is fixed. The labour costs depend on the costs of living in the zones.

B.4.4 Markets in the model

B.4.4.1 Land market

In the MEPLAN model there is no explicit representation of the land-market. The land supply for the residents of firms is modelled through the availability of floorspace. The capacity of land available for development in a zone serves as an attractor in the allocation of additional floorspace in the incremental model. Other types of land-use are modelled indirectly and can be incorporated in the attractiveness of zones.

B.4.4.2 Labour market

The estimation of the location of businesses is carried out in two types of models. The basic employment firms, defined as firms engaged in production for the non-local market in manufacturing and services, are allocated in a incremental model. The incremental model estimates the increment of growth or decline for a activity in each zone between one time period and the next. A study area wide change is assigned to the zones based on the previous employment in the zone and the cost of rent and labour in the zone. An exception are openings or closures of new industries, these are incorporated exogenous in the model.

The firms catering for the local market are allocated in a spatial allocation model and represent the pattern of location art one point in time. In the spatial allocation model the input-output framework and utility and demand functions interact in an iterative way. The travel disutilities and rents are incorporated in the spatial allocation model. The demand functions for employment activities are a simplified version of the household functions. Employment activities have fixed labour inputs and the wages are related to the costs of living. The demand of floorspace can be variable depending on changes in rent. The supply of labour depends on the settlement of the households, the travel disutilities and a calibrated spread factor.

B.4.4.3 Housing market

The residential model includes the households contributing to the economy. The households are for example (application in Naples) classified into five groups: agriculture, white collar or self-employed, owners of firms or managers, blue collars and others. Location choices of unemployed and retired people are not included in the residential module and these households are treated like exogenous inputs. All residential property is assumed as rented. In the case of Naples there is a relatively large public housing sector and two types of floorspace, public and private, has been defined.

In the residential location sub-model of MEPLAN the number of households of a particular category are allocated to a residence zone as a function of the following factors:

- The cost of living for a household locating in that zone (floorspace rent plus costs of services)
- The amount of floorspace the household will consume (a function of the rent and the income of the household)
- The amount of residential floorspace in the zone
- The accessibility to suitable employment opportunities for the employed members of the household (transport costs and times for work trips)
- The accessibility to shopping and services (transport times and costs for non-work trips)

The actual stock of building tends to be stable trough time and the changes are slow. The changes in the supply of residential floorspace per zone are estimated by:

- Development plans, redevelopment, or demolition are assigned exogenously to the zones

- The zonal construction and demolition rates depends on macro-economic forecast for the study region as a whole

B.4.4.4 Transport module

The transport modelling in MEPLAN includes all of the standard features of the traditional four stage transport model. Only the trade generation and distribution are determined in the land-use module of the model. In the interface module the trades are transformed into peak or off-peak trip origin-destination matrices by purpose and social-economic group. In both sub-modules (land-use and interface) the travel disutilities are included in the decision making. The transport module itself executes the last two stages, namely the mode split and route assignment.

The three main elements of the transport model are:
1. The supply of transport – represented by an integrated network of nodes and links for road and rail
2. The demand for transport – represented by a matrix of O-D flows
3. Adjustment of demand and supply

The detail of the supply network can differ by study region and the network features are not limited to physical elements. Link types can also be used to represent waiting times, parking times or in the extreme case of the London Underground the individual services. The public transport services and inter-modal terminals are more and more represented in the MEPLAN based models. The MEPLAN models are also commonly used for multi-modal policy studies in the UK.

The modal split and assignment in MEPLAN are carried out individually for passenger flow types and freight flow types in the morning peak. The user has to specify the number of passenger and freight flow types. For each of the flow types the available modes are input and mode specific constants, time and cost parameters are defined. The modal split model has a hierarchical structure and is represented with a two level logit model of discrete choice. The purpose of the traffic assignment procedure is firstly to transfer the flows on a mode into vehicles and secondly assign these vehicles to the link on their modal path.

The assignment procedure (probabilistic multi-path Dial algorithm) is based on the same random utility theory as the modal split procedure and spatial allocation model. An iterative process is used to stabilize the congestion on each link on the network. The method in the model results in a stochastic user equilibrium assignment.

The transport module measures across the modes average money costs, travel times and disutilities for each pair of transport zones for each trip type. This information is fed back through the interface model and coverted into disutilities per unit of trade. The disutilities are input for the land-use model for the next time period. The disutility of travel that is sent to the land-use model is composited across links and then across modes according to the log-sum approach.

B.4.5 Calibration and validation of the model

The calibration and validation of the LASER model is used as example of the calibration and validation of a MEPLAN application.

B.4.5.1 Method

The spatial choice model and transport model are calibrated for the base year and the incremental models are calibrated through time. The main steps in the calibration process were:

- Household income and expenditure; the family expenditure survey has been used to adjust the model parameters until the households spend their budgets in the correct proportions by socio-economic group;
- Rents: observed rent levels have been used to calibrate the parameters controlling the demand for floorspace;
- Travel to work distribution and household location; the 1981 census data on travel to work was used to establish the appropriate spread of commuter trip by SEG.
- Distribution and location of other activities; average travel distances from the NTS were used to estimate the spread of non-residential locations;
- The incremental models were calibrated through time;
- Assignment characteristics and congestion levels: the assignment parameters (e.g. capacity restraint, spread across routes) were calibrated on observed flows, vehicle miles by mode, average trip lengths and speeds by area;
- Mode split: Workplace statistics and a household interview survey were used to calibrate mode specific constants, time/cost modifiers through future years, terminal costs, etc.

B.4.5.2 Validation

The validation of the LASER model has mainly concentrated on checking how well it reproduces 1991 results for which observed data was available. The conclusions of the study were severely limited in scope by difficulties of consistency between the 1981 (base year) data sets used in the model, and the available post 1991 for validation purposes. The main findings of the validation process were (DETR study):

- It predicted the changes in location of households very well between 1981 and 1991
- It was less accurate at predicting changes in employment location
- Trips to central London were underestimated
- The screenline and main road flows validated very well
- The transport model was thought to be under-sensitive to land-use changes

B.4.6 Policy measures

The range of policies that can be tested in the MEPLAN framework can be very diverse, depending on the type of application. The MEPLAN software is mostly used for more strategic level appraisal. In the LASER model the following policies were tested:

Land-use policies:

- Subsidizing certain locations for employment or housing;
- Constraining activity or availability in certain locations;
- Change attractiveness of an zone to represent changes in amenity or environment

Transport policies

- Infrastructure investment;
- Traffic management;
- Parking control;
- Road tolling;
- Congestion charging;
- Public transport fares;
- Fuel prices;
- Park and ride schemes.

B.5 Discussion of the reviewed models and recommendations for the new TIGRIS model

The previous chapters present an overview of the features of the IRPUD, URBANSIM and MEPLAN models. In this chapter the main advantages and disadvantages of the reviewed models are discussed in the context of the TIGRIS modelling purposes and the context with the Dutch situation. The technical documentation of TIGRIS, version 3, has been used as information source for the TIGRIS model. It should be noted that the specifications of the new TIGRIS model are in an initial phase. The result is that some of the recommendations are no more than points of attention for the next steps of the development process. The models will be discussed by topic that will correspond to the order of Part B.

B.5.1 Model structure

IRPUD and URBANSIM have a composite structure and are built up by interactions between the sub-models. An advantage of a composite structure is that the sub-models can be calibrated and validated independently. The land-use model in MEPLAN is an example of unified model, the spatial choices on the labour market, housing market and origin-destination choices of the transport model are interrelated and solved simultaneously. The many intertwined processes in the model make it complex to calibrate the model. Furthermore, it is difficult to develop and explain such a complex model. The strong point of this unified concept is, that the transport disutilities are fully integrated in all the spatial decisions.

For the new version of TIGRIS, a composite structure is preferable for reasons of transparency, flexibility and simplicity of calibration and validation. Crucial for such an approach are the interactions between the various sub-models. The URBANSIM model is a good example of clear interactions and easy to identify sub-models. The IRPUD model is more confusing by handling parts of the housing and labour market in different sub-models.

B.5.2 Spatial scale level and unit of analysis

The spatial scale level in MEPLAN is flexible and capable of operating at an interregional level. In URBANSIM, the distributive impacts of housing and transport policies are modelled at a metropolitan scale level. IRPUD also only models the intra-regional distribution of activities. The new TIGRIS model aims to operate at an interregional level and at this scale several housing and labour markets are incorporated. The interregional exchanges can be included exogenously or endogenously in the TIGRIS model. In the case of an endogenous modelling approach a more regional economic based model is needed.

A clear trend can be observed in all the spatial models towards more spatial detail in the modelling. Increasing computing power and spatial databases are the driving forces of this trend. For the new versions of the IRPUD and MEPLAN models (London application), the development results in high increases in the level of spatial detail. The URBANSIM model is an example of a land-use model operating at a very detailed spatial scale level for the supply side. The demand side of the UrbanSim model uses the transport zones as spatial unit.

In the case of TIGRIS, the national set up of the model and computation time restrictions make it difficult to operate at a very detailed spatial level of, for example, 4-digit postcodes. The idea is that the model runs at a minimum detail of the LMS-zones, but preferable at the subzone level of the LMS. For the supply side a more detailed spatial scale level can be used, if the data is available.

B.5.3 Demographic

The demographic modelling in MEPLAN is not covered in great detail. The economic inactive households are exogenous input in most applications and the changes in the economic active households depend on changes in the basic employment of a region. It should be noted that MEPLAN is a flexible system and the user can specify the structure. The URBANSIM model uses regional totals and characteristics of the zones to model the demographic changes of a zone. This approach makes use of existing national and regional projections.

From the three reviewed models, the IRPUD model pays most attention to the demographic changes. The model separates the external migration and demographic changes in the study region. The demographic changes are modelled bottom-up by administrating the demographic changes of the population in the zones. Although it requires extra data management in the model, the model results will benefit of such an administration, for example the move choice of residents depends on the age of the residents and changes in the household size. Besides the housing and labour market also the transport market depends significantly on the demographic changes.

For the new version of TIGRIS it seems to be worthwhile to consider a more detailed modelling of the demographic changes. A better insight in the relations between demographic changes and the transport, labour and housing market is needed.

B.5.4 Housing market

MEPLAN uses a sophisticated utility modelling for the settlement choices of the economic active population. However, the economic inactive households are not included in the spatial choice modelling and are exogenous input to the model. The inadequate modelling of economic inactive groups such as unemployed, students and especially elderly is a weak point in the modelling. The IRPUD and URBANSIM models also use the random utility theory to explain the preferences of the households and the prices as mechanisms to clear the market. An interesting feature of IRPUD, especially for the modelling in the Netherlands, is the option that a household can choose to wait, if the alternatives are not satisfying enough. A problem is how to calibrate this feature and it is unclear how this was done in the IRPUD model.

Recommendations and points of attention for TIGRIS are:

- The TIGRIS model addresses conditions in the Netherlands by setting minimum and maximum growth levels of housing development. It seems interesting to keep this feature, but to change the underlying mechanisms. One overall vacancy rate for housing in a region as explaining factor is discussable in a diverse housing market;
- The modelling of the housing market will further benefit of spatial detail and the segmentation of household in social-economic groups;
- The housing market model in IRPUD and URBANSIM can be divided in a move choice module and a location choice module. Such a structure can be interesting for the TIGRIS model;
- Discrete choice theory can be used to model the location preferences of the households. The explaining variables can be a combination of household characteristics and location characteristics;
- In the location choice module the house-seeking household can be administrated by origin. In this way, the distance can be included in the preference for a new location, the moving behaviour of the residents is strongly distance related;
- The modelling of the housing market will benefit from the inclusion of prices to model the market behaviour. A way has to be found to deal with the parts of the housing market, where prices are not the explaining variable. A possible way is the division of the housing

market into public rent, private rent and ownership. The MEPLAN application of NAPLES is an example of such an approach;
- In the location choice module, it is further advisable to pay attention not only to the quantitative match at the housing market, but also to the qualitative match between demand and supply.

B.5.5 Labour market and social-economic developments

MEPLAN separates basic employment (not producing for the region) for projection and derives the non-basic employment as result of the basic employment and population. The hierarchical structure in MEPLAN is Lowry-based and the basic employment attracts the population and the population attracts the local employment. In URBANSIM and IRPUD, the regional changes in employment are exogenous input for the model. In the IRPUD model, the demand side is also dominant and the population will follow the changes in employment. The URBANSIM model has a less hierarchical structure and the accessibility of the population is a variable in the location choice of the jobs.

In reality, the decisions are made by firms, but it is complicated to use firms as the unit of analysis in the modelling and all three land-use models use jobs as unit of analysis. The supply of available workspace is often expressed in floorspace, for the industrial or agricultural jobs available land is a better indicator. Recommendations and points of attention for the TIGRIS model are:
- A minimum division of the jobs in agriculture, industrial and service jobs can be helpful in addressing key differences in location decision;
- In the case of TIGRIS, the modelling of firms seems to be complicated and modelling jobs as unit of analysis is more practical.
- A point of discussion is the relation between the number of jobs and population are the number of jobs following the people or are the people following the number of jobs. Both casual relations seem to be partially true and a non-hierarchical structure as in URBANSIM can be a good option. A disadvantage is that processes in the model are less structured.
- A very significant factor in the labour market of the Netherlands is the labour participation factor. Changes in employment do not only influence unemployment, migration and commuting but also the participation rates. The question is, if labour participation has to be included endogenously in the modelling.

B.5.6 Calibration and validation

The main models in MEPLAN, the spatial choice model and transport model, are calibrated for the base year. The calibration process can be difficult and time consuming, if base year observed data is lacking or inconsistent. In a base year calibration the calibrated behaviour relies on one point in time. The URBANSIM model is an incremental model and the model is calibrated on longitudinal data. The composite structure of the model enables an individual calibration of the sub-models. The calibration of the IRPUD model is not clearly described, it seems that only elements of the model are calibrated. The other parameters in the IRPUD, and also DELTA model, are estimated by expert judgement. The DELTA and IRPUD model are incremental models.

The land-use model of the current version of TIGRIS is incremental. It is likely that a new version of TIGRIS would also be incremental in nature, unless a MEPLAN/TRANUS type of framework is chosen. The time dependency of the changes and the small size of the changes are reasons to choose for an incremental model. Longitudinal data series will be needed to calibrate such an incremental model. The use of longitudinal data for the calibration of preferences can be difficult, if the set of policy constraints in a regulated market can not be reproduced for the past years. Another way to calibrate the preferences is by making use of stated preference data.

C. The transport model for the new TIGRIS

The previous chapters described the international literature review on land-use models and general recommendations were made for the TIGRIS model in the last paragraph. In addition to the literature review RAND has been asked by the AVV to describe in more detail the advantages and disadvantages of different types of transport models and their linkage with the land-use model.

Paragraph C.1 will explore the range of options for a transport model by describing the features of at the one side a strategic transport model and at the other side using the LMS (Dutch National Transport Model) as an example of a detailed and complex transport model. The second paragraph specifies the requirements for the transport model. The model requirements depend on many factors including the types of policy measures that are to be evaluated, availability of data, consistency with detailed planning models, the required accuracy of the results, computation time, interaction with the land-use model and complexity of model usage. It should be kept in mind that many of the requirements are still under consideration, and only some choices at a strategic level have been made.

Paragraph C.3 will address the issue of the type of linkage. Two options are compared here, 1) the integration of the transport model and land-use modules in one unified model package, and 2) the external linkage of a separate transport model and a separate land-use model.
In the final paragraph, C.4, the requirements for the transport model are transformed into a general description of the features of a transport model meeting the specified criteria. The paragraph further describes how such a model could be derived from the LMS. The description is meant to identify the main choices and their consequences.

C.1 Spectrum of transport models

In this paragraph we look at transport models capable of operating at an inter-regional or national level. The number of different types of possible transport models is wide, and the spectrum ranges from strategic transport models at one side to detailed and complex transport planning models at the other side. A strategic model will be described by outlining its features. The LMS will be used as an example of a detailed and complex national model. Other possible transport model options lie somewhere between these two extremes.

A typical strategic transport model is developed to analyze the impact of transport measures at an aggregate level. Key features of a strategic transport model are short calculation time and modest data requirements. The detail level of the data in the modelling is coarse. For example:

- Corop level as transport zones (40 in NL)
- Strategic motorway network, main structure only, where adjustment factors are used to correct for the lack of detail in the network
- Little or no segmentation of the population.

The impact of policy measures on transport demand is typically modelled using demand elasticities “imported” from elsewhere.

The LMS model can be characterized by the use of detailed spatial data and social-economic segmentation of the population. The model has a strong foundation in the behavioral theory. The main features of the model are listed below:

- Detailed data
  - Social-economic segmentation of the population
  - Spatial unit of analysis at sub-zone level, 1308 subzones for the Netherlands
  - Transport networks

- Behavioral modelling representing choices made by individual travellers:
  - Car driver license holding
  - Car ownership
  - Tour generation (including multiple destinations)
  - Mode choice
  - Destination choice
  - Time of day choice
  - Route choice

Other characteristics in the LMS are the multiple iterative procedures to include the impacts of congestion on mode, destination, time-of-day and route choice.

Nowadays, on a 1GHz PC, a full model run of the LMS takes around 23 hours. This includes 6 NSES (mode and destination choice) runs of a total of approximately 11 hours, and 9 hours for 15 Q-block (used to estimate congestion) runs. The time-of-day procedure is not very time consuming.

C.2 Requirements for the transport model

C.2.1 Policy measures

A first selection of transport measures that need to be suitable for simulation in the new TIGRIS model is:

- **Small infrastructure changes (including temporal measures such as specific peak hour lanes)**
  A detailed representation of the transport network is needed to include small infrastructure changes in the transport model. A time-of-day module is needed to model the temporal measures endogenously.
- **Major infrastructure measures**
  Change in route assignment and the need to include route assignment endogenous in the modelling. In the current TIGRIS version the route assignment is external.
- **Parking policy**
  It is difficult to gather detailed local information. Parking policy can be included at a strategic level and the parking policy changes the accessibility of the zones. The accessibility of the zones influences the OD-module of the transport model and the allocation module of the land-use model. The parking policy has to be implemented at a transport zone level and included in the travel disutility between zones for the car mode.
- **Pricing policy**
  Needs to be included in the new TIGRIS. The model should address future policies as price differentiation in space and time. The variation in space means

the need of a detailed road network representation. The variation in time means the need of a time-of-day module in the transport model.

- **Flexible working hours**
  A time of the day module is needed to model the impacts of flexible working hours on the transport system.
- **Public transport**
  Exogenous Level-Of-Service matrix, public transport measures are transformed in new Level-Of-Service matrices.
- **Freight transport**
  Pre-load matrix. The freight transport is not modelled, but a better estimation of the freight transport is needed. The development of main industrial sites can be included in different scenarios (pre-load matrices).

C.2.2 Evaluation purposes, required quality of the results

The evaluation purpose of the new TIGRIS model has not been clearly defined by AVV, and will also depend on the options that are available. In general, it has been stated that the quality and detail of the transport results have to be in line with the results of the land-use model. The model will be primarily used for strategic evaluations rather than for a local impact analyses. But the quality of the results at a strategic level has to be improved compared to the old version of TIGRIS. In practice it would be beneficial, if the transport results of the new TIGRIS model would be consistent with the LMS results.

C.2.3 Interaction between transport model and land-use model

A dynamic two-way interaction between the land-use and transport model has to be created. The land-use to transport link is that the land-use model calculates the social-economic projections of the zones which are input to the transport model. The specification of the data items has to be the same and the output of the land-use modules and social-economic input for the transport model have to be in the same format. The socio-economic data , which will be input for the transport model, can for example be represented by the number of inhabitants and the number of workplaces per zone.

The transport to land-use link is that the transport model delivers accessibility measures that can be input to the land-use model. The logsum can be used as a standard communication measure between the transport and land use model. The logsum is a measure representing the composite utilities of the different alternatives including modes, destinations, times of day, etc. The logsum measures can also be defined at a more disaggregated level representing the accessibility of a zone for a type of household. This measure is based on the activity pattern of the households as well (Ben-Akiva 1998). The use of the logsum is also convenient for evaluation purposes, as this is a theoretically correct measure of changes in accessibility, that can be converted into money equivalents for cost-benefit analysis.

C.2.4 Computation time

The maximum computation time of the integrated model is specified as one day (24 hours). This maximum is based on a forecast horizon of 20 years and dynamic steps within the landuse model of one year. For the transport model the dynamic steps don't have to be the same as for the land-use model, and a less frequent use of the transport model is an option (e.g. new iteration of the transport model once in every five years, or more frequently only when major infrastructural changes have occurred).

C.2.5 Transferability and complexity of model use

The requirement is that the total model system should be transferable to different users. The complexity of the model usage still has to be defined, but the system should be understandable and explainable, no 'black box'. A user profile has to be specified and more concrete requirements have to be formulated. For instance, this could be a computer platform, of which the use is widely accepted, and the hardware and software is generally available. The model system should have a generic structure, that is applicable in different (Dutch) contexts.

C.3 Implementation, interaction between transport and land-use model

The types of alternative linkage between the land-use and transport model can be described as:

A: Unified land-use and transport model (one comprehensive or unified system, see Fig. 12)

B: External Linkage of land-use model and transport model (two separate systems with connection, see Fig. 13)

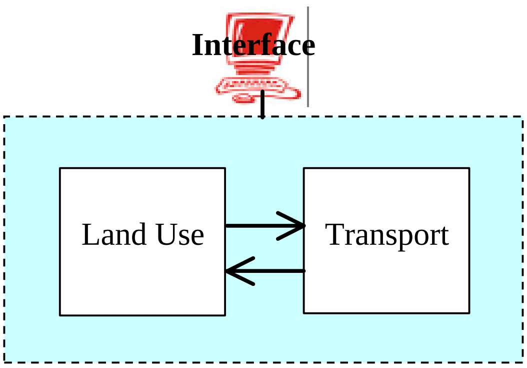


Figure 12: one unified system

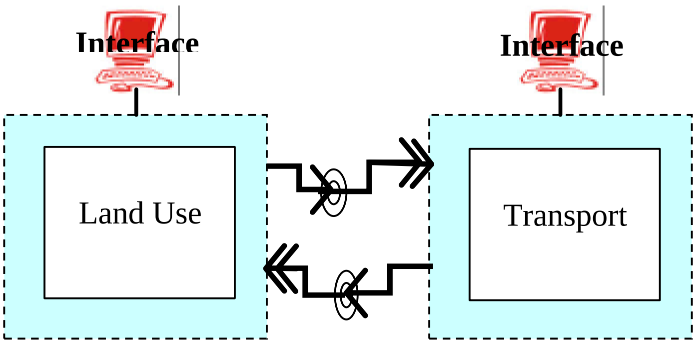


Figure 13: two separate systems

The first integrated land-use and transport models typically had a unified structure. Nowadays the external linkage concept is often used, and the land-use model is linked to an existing and already available transport model in the study region.

The computation time of the integrated LUTI model does not primarily depend on the type of linkage, but on the detail level of data and the complexity of the calculations within the model.

There are examples of unified systems with sophisticated transport models (Tranus, Meplan), and of models with external linkages using strategic transport models (e.g. DELTA). For Tranus and Meplan we refer here to the mode and route choice module. In the concept of Tranus and Meplan an integration of the trips generation and distribution in the land-use model is necessary. In all the other LUTI models different sub-models are connected with each other. In these cases there is a little difference between one comprehensive framework or an external linkage of the sub-models.

Most of the possible transport models can be linked internally as well as externally to the land-use model. A practical reason for using the external linkage concept is sometimes a difference in ownership of the different models. A new transport model for TIGRIS, for example, like outlined in this chapter, can be linked internally or externally to the land-use modules.

Some important considerations to choose for option A or B are:

Advantages of unified system:
- A single user interface can be created for the land-use and transport model;
- The communication between the land-use and transport model, type of data and format, is standardized with the framework.

Advantage of separate systems with linkage:
- The data can be analyzed seperately;
- Land-use model can take easier advantage of existing transport models,
- The structure of the framework is more flexible (can be used with different types if transport model, depending on requirements).

C.4 Type of transport model

Both extremes (strategic model versus complex and detailed model) are insufficient to meet the different modelling requirements. A strategic transport model, as described in C.1, lacks the necessary features to model the impacts of the transport policies in space and time. For example, for the pricing policy these types of models are capable of modelling changes in fuel price, but a strategic model is not capable to model a pricing policy at peak hours and certain locations only. A lack of detail in the spatial transport zones has also implications for the land-use model. The changes in the accessibility of zones as a result of transport measures are estimated less accurately. Also, consistency with the detailed planning models will be difficult to achieve.

A detailed transport model like the LMS, on the other hand, is capable of modelling the policy measures, but it does not meet the criteria of the computation time and complexity of usage. The computation time of a transport model depends basically on the detail level of the spatial data (zone, network), the segmentation (also detail in data) and the complexity of the calculation framework, and in particular the extent of iterative feedback procedures.

C.4.1 Features of the transport model

The set of requirements is still in an indicative stage and far from the definite set of requirements. The model features of course are related to the requirements and a change in the requirements results in different features.

Based on the current set of requirement, the features of the transport model can be described as follows:

- Endogenous route assignment;
- Time-Of-Day endogenously in the modelling;
- Detail in road transport network, required for route searching and to measure the impacts of network measures most of the transport has to be assigned to the network;
- Spatial detail, minimal at the LMS zone level of 345 zones, but preferable at the subzone level of 1308 subzones;
- Road congestion is modelled, but possibly less detailed in the congestion calculation in comparison to NRM or LMS applications;
- Two way interaction land-use – transport model;
  - Adjust social-economic output land-use model and input transport model, the social-economic output of the land-use model is not yet defined;
  - Logsum as accessibility measure;
- Minimum of 4 times transport model run in an integrated 20-year forecast run. Total computation time of the total LUTI-model less than one day;
- The transport model has to be transferable to different users;
- User-friendly interface and usage of the model.

C.4.2 A transport model for TIGRIS derived from the LMS

Given the requirements, the current LMS can not be the transport model for TIGRIS. The running time would be too long to meet the 24 hours constraint, although a 7 day constraint could be met. But given the need to obtain results that are as much as possible consistent with the LMS, and the advantages of using the same databases and the established position of LMS, we would suggest that the most practical transport model would be one derived from the LMS.

The current LMS does not meet the computation time requirements, and therefore, it is not an option to incorporate it fully in TIGRIS. However, the main elements of the LMS modelling can be used to develop a transport model meeting the TIGRIS requirements while retaining the important benefits .

C.4.2.1 Land-use – transport, social-economic data

The land-use model calculates the social-economic projections of the zones. In the LMS population and employment figures are input as target into the modelling. The population targets are disaggregated by gender and age and the employment targets are disaggregated by type of employment. The targets by zone are applied to the prototypical sample. In a LMS based transport model the targets can be adjusted to the housing market and labour market model. This is a relatively simple change in the model.

C.4.2.2 Transport – land-use, accessibility measures

The “logsum” can be used as standard communication measure between the transport and land use model. In the LMS the logs are calculated, but currently not summed as logsum and saved as output. The logsum can be generated in the LMS and saved as output data. In the MEPLAN – LMS project a similar connection was made between the transport and land-use model (HCG 1991). The disaggregated structure of the LMS can be used to calculated accessibility measures for different types of households based on the activity pattern of the households.

C.4.2.3 Driver license holding and car ownership

The car driver license holding and car ownership module of the LMS could be replaced in the case the car ownership is a variable in the residential allocation model. In other cases the current modules could be used to calculate the car driver license and ownership levels per zone, constrained to externally provided targets if necessary.

C.4.2.4 Mode, destination, TOD and route choice

The tour generation modules in the LMS take only a fraction of the calculation time. The most time consuming elements in the module are the mode choice, the destination choice and the route assignment module. In a full calculation these modules interact in an iterative process. In order to meet the computation time requirements, this feedback process needs to be simplified. Options to save computation time are, in order of importance:

1. Interactions in time of the land-use and transport module. Instead of a yearly interaction the transport modulecould be run only once in every five years (or earlier when major transport measures are implemented) with the land-use model. The land-use model itself can keep the time steps of one year.
2. Simplification of the feedback procedures, in particular the reduction of the number of iterations. One possibility would be to investigate the use of travel times from previous years simulations (t-1 or t-5). Another possibility would be to reduce the number of iterations necessary within the assignment loop. A simplified congestion module could be developed, based upon tests and simplification of the current procedure. These tests can for example be corridor based and (non-linear) relationships (or elasticities) can be related to different OD volumes. Of course, the congestion estimation would be less accurate as in the LMS model. The Q-block and runs and iterations are excluded in this option.
3. The spatial unit of analysis can be aggregated. In the current mode and OD –module the spatial unit is at the sub-zone level (1308). Change in matrix of 1308 by 1308 in matrix of 345 by 345. Or limit the study area, although this is in conflict with the original requirements.
4. Aggregate travel purposes in the model, currently there are eight purposes. Although this would increase speed, it would reduce accuracy and is seen by us as undesirable. The number of different modes can be diminished. Although this would increase speed, it would reduce accuracy and is seen by us as undesirable.

Point 1 and 2 might be enough to meet the limit of one integrated model run of the land-use and transport model within one day. Of course, this also depends on the computation time of the land-use model. The spatial level of detail is important to model the land-use impacts of the transport policies and if possible it seems worthwhile to keep the spatial level of detail (3).
The number of travel purposes (4) could be diminished in a transport model for TIGRIS. Not all of the travel purposes are dominant in the location choice of residents and firms, but they are seen as potentially very important for other land-use effects. The above recommendations basically come down to keeping the existing detail in spatial units, network, travel purposes and time of the day, but simplifying the congestion calculation.

The distinction between the standard LMS, and the proposed derived model can be illustrated in Fig. 14 and 15. In Fig. 14 the standard LMS is sketched, complete with full feedback loop mechanisms and leading to a single target-year equilibrium result. Fig 15 gives the proposed simplified structure. Although much remains to be investigated, a possible simplification could be the iterative feedback from route choice back to Time of Day and Destination/Mode Choice. The fact that LMS would be run in 5-year (or n-year) increments could enable a more dynamic type of operation, without the ambition to aim at full equilibrium for each year. This is indicated by the use of the dotted feedback lines, and the t-1 input. In the example also the License holding and Car ownership models have been assumed to be replaced by modules from the Land-use model. This is not necessary and brings only small time gains, but indicates the sorts of adaptations that may be useful or necessary in the design of a well integrated system.

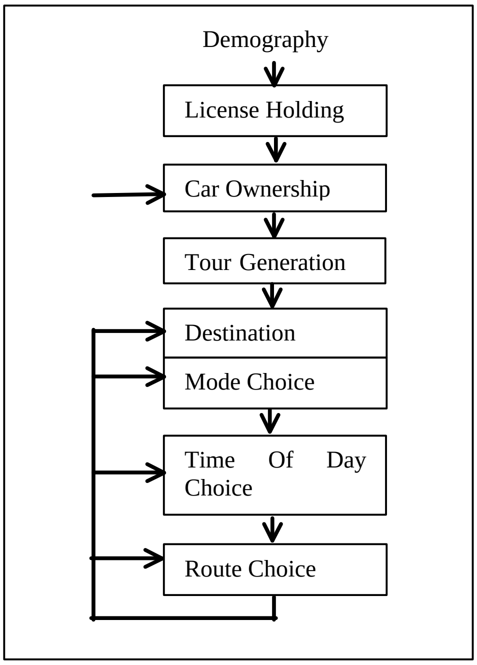


Figure 15: standard LMS

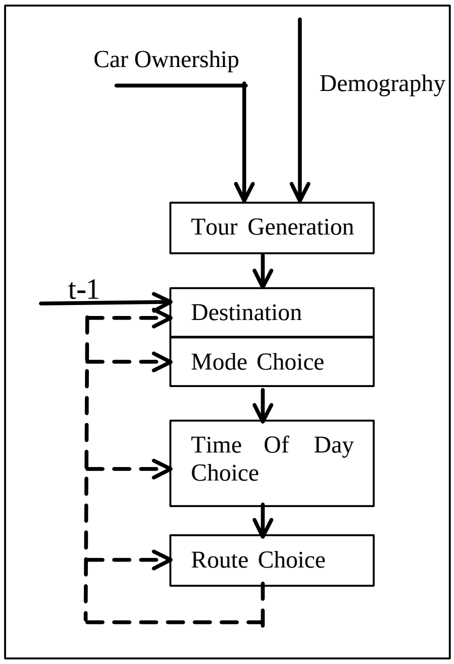


Figure 14: simplified structure

C.4.2.5 Software and use of the model

The ongoing discussion about implementing the LMS in a standard software package can also be useful for this project. The model software can use a com-interface. This is simplified described as an unified datastructure, where different modules uses the same data formats. The use of standard software and datastructures increases the transferability of the model and the number of possible users. Another probably relevant development is the linkage of the model interface to the Internet. Currently it is technically possible to present model results on the Internet and the expectation is that more and more user – model interaction can be done through the Internet in the near future.

C.5 Conclusions and recommendations

In C.4.1, we have listed nine necessary attributes of the transport model that should be developed for TIGRIS. In practice these can be grouped into four clusters:

Overall Compatibility with LMS

Here we have listed zone definitions, networks, population land-use data. The network and zone system for TIGRIS may be coarser than LMS if this is needed for other reasons, but a direct *correspondence* should be maintained. Land-use data should also be compatible, and here we note LMS uses many more aspects than population and employment; numbers of student places and other zonal characteristics are needed. These should also be compatible with the land-use module.

In discussing endogenous assignments and time-of-day routines, it is also clear that these must be able to reproduce LMS network response characteristics at a satisfactory level of correspondence.

We note also that coarsening the basic zone system will require the adjustment of the LMS mode-destination models themselves, since the addition of extra (measurement) error into the utility functions otherwise will result in different response characteristics. A process of re-calibration, possibly judged against key elasticities and forecasts, must be undertaken.

Speed

Speed is one of the key requirements of the system, and it is for reasons of achieving acceptable speeds that coarsening of the LMS system is considered. A tactic to bear in mind here will be moving away from the purpose-written system towards commercial systems which have been specifically developed for speed of network processing.

Multi-User Operability

Speed and user-friendly operation are clearly needed to ensure multi-user operability. Of vital importance will be the GUI, typically a hugely expensive part of developing a tool like TIGRIS+LMS. This is yet another persuasive argument for adopting an existing software package, supposing that the agreement of the developers can be obtained for customising the basic code. A deciding factor here may be the capability to operate the system via the Web.

Reliability of Results.

The TIGRIS+LMS system must come with a proper professional ‘pedigree’, which nowadays requires a convincing series of backcasts, preferably some validated forecasts also, and ,general elasticity properties consistent with accepted published results.

It will be seen that the scoping of the workpackages outlined above is no small job. There remains the possibility that a coarsened LMS which retains the existing LMS properties may not be achievable to the required level; this could turn us towards smaller geographic systems, an option to be considered as a workpackage in its own right.

Recent developments of the PTV VISUM/VISSIM software seem to offer one option for the platform we require; another workpackage should be targetted to a comparison of the software with rivals, and the selection of the most suitable. The qualities of speed, GUI, Web operations and willingness of the developers to co-operate will be deciding factors, along with price.

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Appendix A

IRPUD

(from: *The IRPUD Model: Overview & Transport Submodel*)

Model Data

Model Parameters

- Demographic parameters
- Household parameters
- Housing parameters
- Technical parameters
- Monetary parameters
- Preference parameters

Regional Data

- Employment
- Immigration
- Outmigration

Zonal Data

- Population:
  - nationality (2)
  - sex (2)
  - age (20)
- Labour force/unemployed:
  - nationality (2)
  - sex (2)
  - skill/income (4)
- Households:
  - nationality (2)
  - age of head (3)
  - income (4)
  - size (5)
- Dwellings:
  - type of building (2)
  - tenure (3)
  - quality (4)
  - size (5)
- Households/housing:
  - households (30)
  - dwellings (30)
  - housing occupation (30x30)
- Employment/workplaces:
  - industries (40)
- Public facilities:
  - facility type (40)
- Land use:
  - land use/zoning type (30)

- Rents/prices:
  - dwelling types (30),
  - land use/zoning types (10)

Network Data
(per link)
- Link type
- From-node
- To-node
- Link length
- Link travel
- Link travel time (public transport)
- Base speed (road)

(per public transport line)
- List of nodes
- Peak-hour headway

Model Output

- Population
  - Percent foreign population
  - Percent population 0-5, 6-14, 15-29, 30-59, 60+ years
  - Households
- Employment
  - Total employment
  - Non-service, service, retail employment
  - Unemployment rate
  - Job-labour ratio
- Dwellings
  - Total dwellings
  - Percent single family dwellings
  - Housing floor space per capita (qm)
  - Mean housing rent per sqm (DM)
- Transport
  - Trips by trip purpose (work, shopping, education, other)
  - Trips by mode (walking/bicycle, public transport, car)
  - Percent walking/bicycle, public transport, car trips
  - Mean trip length (km)
  - Mean travel time (min)
  - Mean travel cost (DM)
  - Car-km per capita per day
  - CO_2 emissions by car per capita per day (g)
  - CO_2 emissions by transport per capita per day (g)
  - Transport expenses per household per month (DM)
  - Public transport expenses per household per month (DM)
  - Car ownership (cars per 1,000 population)

Specific data for the Transport Submodel

Zonal data
- Origin activities
  - workers by skill level (4 skill levels)

- households by income group (4 income groups)
- students by income group of household (4 income groups)

- Destination activities
  - jobs by skill level (4 skill levels)
  - retail employment
  - service employment
  - population
  - secondary schools (size)

Network data
(per link)

- Link type
- Time label (year of completion)
- Direction (one-way, two-way)
- From-node
- To-node
- Link length
- Link travel time (public transport)
- Base speed (road)

(per public transport line)

- List of nodes called
- Peak-hour headway (by section if different)

Model parameters

- Monetary parameters
  - mean travel expenditures per household by income group (time series)
  - consumer price index (time series)
  - function to estimate public transport fare from trip distance
  - function to estimate parking cost from parking demand/supply ratio
  - price of petrol (time series)
  - cost of owning a car (time series)
  - price elasticity of travel budgets
- Technical parameters
  - function to estimate travel time of connector links by mode
  - function to estimate travel distance of walk trips
  - function to estimate transfer time from headway of connecting line
  - initial wait time as proportion of transfer time
  - funtion to estimate parking search time from parking demand/supply
  - link capacity by link type (road)
  - parameters of capacity restraint function
  - average petrol consumption of cars (litres per 100 km)
- Behavioural parameters
  - initial trip rates by trip purpose (time series)
  - car occupancy by trip purpose (time series)
  - average parking time by trip purpose
  - proportion of travelers with driving license (adults, students)
  - function to estimate trips per household from car ownership
  - share of morning peak hour of daily traffic by trip purpose
  - value function of travel time by income group
  - value function of travel cost by income group
  - value weight of travel time versus travel cost by income group
  - parameter of destination (and mode) choice by trip purpose

- parameter of mode choice by trip purpose (optional)
- size exponent of shopping facilities

Output

- 3 matrices of equilibrium travel times (3 modes)
- 3 matrices of equilibrium travel distances (3 modes)
- 3 matrices of equilibrium travel costs (3 modes)
- 12 matrices of equilibrium trip utilities (4 income groups, 3 modes)
- 48 matrices of equilibrium trips (4 trip purposes, 4 income groups, 3 modes)

UrbanSim

(from: *UrbanSim: Modelling Urban Development for Land Use, Transportation and Environmental Planning*)

Data Inputs and Outputs from UrbanSim

UrbanSim Inputs

- Employment data, in the form of geocoded business establishments
- Household data, merged from multiple census sources
- Parcel database, with acreage, land use, housing units, nonresidential square footage,year built, land value, improvement value, city and county
- Land Use Plan
- GIS Overlays for environmental features such as wetlands, floodways, steep slopes, or other sensitive or regulated lands
- Traffic Analysis Zones
- GIS Overlays for any other planning boundaries
- Travel Model outputs
- Development Costs

UrbanSim Outputs (by Traffic Analysis Zone)

- Households by income, age, size, and presence of children
- Businesses and employment by industry
- Acreage by land use
- Dwelling units by type
- Square feet of nonresidential space by type
- Land values per acre by land use
- Improvement values per unit or sqft by land use

Travel Model Outputs (Zone-to-Zone)

- Travel time by mode
- Composite utility of travel using all modes

Factors Considered in Location Demand Components

Household Demand for Housing Types and Locations

- Housing Type: Single Family, Residential with 2-4 units, or Multi-Family
- Accessibility to total employment
- Accessibility to retail employment
- Net density in units per acre of a particular housing type in a zone
- Number of housing units of a particular type in the zone
- Average age of the buildings of a type in a zone
- Percent of households in a zone in the lowest income group
- Percent of households in a zone in the second lowest income group
- Percent of households in a zone in the highest income group
- Percent of the households in a zone that have one or more children
- Percent of the developed land in the zone that is in industrial use
- Percent of the developed land in a zone that is in residential use
- Travel time to the Central Business District, in minutes

Business Demand for Building Types and Locations

- Building Type: Industrial, Warehouse, Retail, Office, or Special Purpose
- Accessibility to total population, total employment, and high income households
- Basic employment in a zone per square mile
- Retail employment in a zone per square mile

- Service employment in a zone per square mile
- Accessibility to Basic, Retail and Service employment
- Total square feet of commercial space of a particular type
- Building age
- Net density of the building type in a zone
- Percent of developed land in a zone in industrial use
- Percent of developed land in a zone in retail use
- Travel time to the CBD, in minutes
- Presence of a highway in a zone

Factors Considered in Land Development and Redevelopment Component

Expected Revenue
- Current market price for type of development at zonal location
- Quantity and type of development feasible under development rules

Expected Costs for New Development
- Land Cost
- Hard Construction Costs (replacement cost of structure)
- Soft Construction Costs (development impact fees, infrastructure costs, taxes or subsidies)

Density of Development
- Regulatory Constraints (land use plan, urban growth boundary, environmental constraints)
- Land Value
- Land Use

Filter for Considering Developed Parcels for Redevelopment
- Improvement to Land Value Ratio of Parcel

Additional Costs for Redevelopment
- Current Building Improvements
- Demolition Costs

Policy Instruments Incorporated in UrbanSim Scenarios

Transportation (From Travel Model)
- Transportation Capacity: Highway, Arterial, Bus, Rail, and HOV
- Transit Level of Service
- Pricing: tolls, gasoline tax, etc.

Land Use
- Land Use Plan: restrictions on conversion of land to alternative urban land uses
- Density Constraints: minimum as well as maximum density by land use
- Soft Construction Costs: development impact fees, infrastructure costs, taxes or subsidies

Policy Overlays *(can affect land uses allowed, density, soft development costs)*
- Urban Growth Boundary
- Environmental Restrictions
- Other Policy Overlays (special planning areas designated for exceptional policies)