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TOPIC 1
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EFFICIENT, EQUITABLE AND ECOLOGICAL URBAN STRUCTURES

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Abstract

The paper argues that a combination of microsimulation and geographical information systems (GIS) could provide the basis for a new generation of spatially disaggregate land-use transport environment (LTE) models able to respond to the information needs of efficient, equitable and sustainable urban land-use and transport planning.

INTRODUCTION

Under conditions of growing affluence and low transport costs market-driven land-use development leads to settlement patterns with concentrated work places and dispersed residences. This requires a high level of personal mobility, produces congestion in the transport network, is wasteful in terms of energy and space consumption and reinforces spatial division of labour and the social segregation of the population.

There have been many suggestions to reduce the negative impacts of laissez-faire urban development by more stringent land use control. However, there exists no consensus about the direction land use planning should follow to guide spatial urban development. There seem to be three generally accepted objectives (Masser et al. 1992):

- The urban structure should be *efficient*. Space requirements and mobility needs of firms and households should be satisfied with minimum cost in order to enhance the city's economic attractiveness.
- The urban structure should be *equitable*. Social and spatial disparities should not be aggravated, ie differences between accessibility and quality of life in different parts of the city should minimised.
- The urban structure should be *ecological*, ie as sustainable as possible. The use of resources (energy, materials, open space) and the contamination of the environment (water, air, noise) should be as low as possible.

These requirements are frequently in conflict. Everybody realises that rapid urban growth tends to be associated with social disparities and environmental problems. Most people also understand that the need to save energy and protect the environment may require constraints on unsustainable forms of economic activity. It is less well known that a spatial structure which is environmentally satisfactory is not necessarily equitable. Under these conditions the research question addressed in this paper becomes a complex multi-objective optimisation problem with conflicting goals: Which is the 'ideal' urban structure in terms of efficiency, equity and sustainability?

It is likely that there is more than one answer to this question depending on the country and city investigated, the socioeconomic and political framework and the relative weight given to the three goals. Moreover, even if the 'ideal' urban structure is known, it may not have a chance to be implemented because it is in conflict with powerful economic interests or with established lifestyles and mobility patterns of a large part of the population. Nevertheless it seems worthwhile to ask the question to explore the options available to urban planning today.

The paper starts by rephrasing the question of what is the ideal urban structure in more operational terms. It points to deficiencies of current urban land-use transport models, in particular with respect to modelling the urban environment, and discusses how they would have to be further developed to become land-use transport environment (LTE) models. A combination of microsimulation and geographical information systems (GIS) is proposed as the basis for a new generation of spatially disaggregate LTE models. The paper closes by presenting a current study designed to systematically compare hypothetical configurations of land use and transport systems in the Dortmund metropolitan area with respect to efficiency, equity and sustainability.

MODELLING THE URBAN ENVIRONMENT

Of the three goals efficiency, equity and sustainability the efficiency goal has the longest tradition. Efficiency, ie minimisation of travel or transport and location costs or maximisation of economic benefit, is at the heart of regional and urban economics and was operationalised in various ways as central place theory, location theory or bid-rent theory. Efficiency, ie minimisation of travel time or cost, is also the rationale behind the four-stage urban transport model, either endogenously as user-optimum equilibrium or exogenously as criterion for choosing between transport infrastructure scenarios. There is a long tradition of urban land-use transport (LT) models in which the spatial development of cities is modelled as a process of mutual adjustment of activity location and mobility subject to economic or efficiency objectives. A comprehensive review of the state of the art of urban land-use transport models is given in Wegener (1994a).

Equity considerations have played only a subordinate role in the mainstream urban modelling tradition. Even though most urban land-use transport models use socioeconomic groups of households to model residential location, only few of them have paid attention to issues such as gentrification, displacement of low-income households to less attractive neighbourhoods and the resulting social segregation, or social and spatial disparities in accessibility or quality of life. However, at least in principle, most existing models have the potential of producing indicators expressing the degree to which certain groups of the urban population or certain neighbourhoods are privileged or deprived. Therefore these models can be used to assess the equity or inequity of urban structures. In fact there are models that routinely produce such indicators as part of their economic evaluation submodels, such as MEPLAN (Echenique et al. 1990; Echenique 1994) and TRANUS (de la Barra et al. 1984; de la Barra 1989).

However, urban modellers have for a long time ignored ecological aspects in their models and have only recently been prompted to redirect their attention from economic to environmental impacts of land use and transport policies. The main reason for this is the threat of long-term climate change due to production of greenhouse gases by the burning of fossil fuels for heating and transport. A major additional thrust to include environmental impacts into urban models has come from the United States Intermodal Surface Transportation Efficiency Act (ISTEA) which shifts the criteria for new transportation investment from travel time savings to environmental benefits such as air quality or reduction of single-occupancy vehicle trips.

The urban environment can be classified into three categories that are relevant for urban modelling (see Wegener 1995c):

- *Resources*. Most human activities consume resources. Some of them are global resources which are brought into the region, such as energy, some are local resources such as water. Sustainable development aims at using non-renewable resources as little as possible in the interest of future generations. From the point of view of urban modelling the most important resources are *energy*, *water* and *land*.
- *Emissions*. Most human activities give rise to metabolisms producing obnoxious emissions. Emissions are produced locally but have local, remote or global effects. From the point of view of urban modelling the most important emissions are *gases*, *waste water*, *soil contamination*, *solid waste* and *noise*.
- *Immissions*. Air pollution, noise and water contamination are environmental impacts of which emission and immission points differ. As their effect is felt at immission points, calculation of immissions from emissions is critical for these kinds of impacts. Three types of emission-to-immission models are candidates for being included into urban models: *air dispersion*, *surface/ground water flows* and *noise propagation*.

However, there exists no two-way relationship between land use and transport and the urban environment. Land use and transport affect almost all environmental indicators but the reverse is not the case. Land use changes are strongly affected only by land availability, soil contamination, air pollution and noise; all other feedbacks from the environment are weak. Transport decisions are not affected by environmental indicators at all, except if there is a major change in the policy framework, for instance a substantial change in energy cost.

Only very few of such interactions are modelled by today's land-use transport models. An informal survey (Wegener 1995a) revealed that land consumption, energy use and CO_2 emissions are most frequently modelled; all other indicators, and in particular immissions, are almost never considered. Most models generate environmental indicators as output only and do not consider their feedback on land use. In summary, most present land use transportation models are still far from deserving the name land-use transport environment (LTE) models.

So it is not surprising that there have been only very few studies in which the environmental impacts of different configurations of urban form have been systematically compared. The models included in the ISGLUTI study (Webster et al. 1988) examined relatively small modifications of existing land use and transport systems and contained only a minimum of environmental indicators. Rickaby (1987; 1991; Rickaby, et al. 1992) used the TRANUS model mentioned above to compare spatial configurations of cities with respect to accessibility and energy efficiency, however, the results were inconclusive because of a too limited set of investigated alternatives. Roy (1992) used an analytical model of a circular city to confirm the hypothesis that a polycentric urban structure with subcentres is more energy-efficient than a monocentric city. Wegener (1994b) demonstrated that a *reorganisation* of urban activities (moves or changes of job) is more effective in reducing CO_2 emissions than *reconstructing* the city (increasing its density).

A FRAMEWORK FOR LTE MODELS

No wonder that all above efforts to integrate environmental indicators into urban land-use transport models addressed energy consumption or CO_2 emissions—it does not matter where in the urban area energy is saved or CO_2 emissions are avoided.

Most existing land use models lack the spatial resolution necessary to represent other environmental phenomena. In particular emission-immission algorithms such as air dispersion, noise propagation and surface and ground water flows, but also micro climate analysis, require a much higher spatial resolution than large zones in which the internal distribution of activities and land uses is not known. Air distribution models typically work with raster data of emission sources and topographic features such as elevation and surface characteristics such as green space, built-up area, high-rise buildings and the like. Noise propagation models require spatially disaggregate data on emission sources, topography and sound barriers such as dams, walls or buildings as well as the three-dimensional location of population. Surface and ground water flow models require spatially disaggregate data on river systems and geological information on ground water conditions. Micro climate analysis depends on small-scale mapping of green spaces and built-up areas and their features. In all four cases the information needed is *configurational*. This implies that not only the *attributes* of the components of the modelled system such as quantity or cost are of interest but also their physical *micro location*. This suggests a fundamentally new organisation for urban LTE models based on a microscopic view of urban change processes. Such an organisation will now be proposed.

Microsimulation of urban change

On a micro level of explanation, urban development is a subprocess of total societal development which results from thousands or millions of human decisions, many small and some large, occurring over time as a broad stream of concurrent, unrelated or interrelated, individual or collective choices (Wegener 1986). A microanalytic theory of urban development therefore has to decompose the total process into subprocesses and within these identify the main actors and their decision behaviour.

Urban change processes can be classified with respect to causation. Most urban changes are the outcome of a more or less rational decision by some actor. However, some processes are not decision-based but simply the result of time such as ageing and death. Figure 1 decomposes urban change processes into domains and atomistic process modules. Three types of process modules are distinguished:

- *Choices (C)*. A choice module represents a choice process. A typical choice module represents for instance the behaviour of a household looking for a dwelling in the housing market (Wegener 1985; 1995b). Its propensity to move depends on its satisfaction with its present dwelling. It first chooses a neighbourhood in which to look for a dwelling, and this is not independent of its present residence and work place. The household then looks for a dwelling in that neighbourhood guided by the attractiveness and price of vacant dwellings there. Finally the household decides whether to accept an inspected dwelling or not. It accepts the dwelling if it can significantly improve its housing condition. If it declines, it enters another search phase.

- *Transitions (T).* A transition module represents a transition from one state to another. A typical transition for instance is the evolution of a household during a certain time interval during which it is promoted to another household category with respect to nationality, age, income or size conditional on the relevant probabilities for events such as naturalisation, birth of child, ageing/death, marriage, divorce, relative joins or leaves household (Wegener 1985; 1995b). Also choice-based events such as marriage or divorce may be treated as transitions if the causal chain behind them is of no interest for the purpose of the model.
- *Policies (P).* Choice modules in which the decision maker is a public authority represent decisions by which the public authority intervenes in the process of urban development. Only policies resulting in physical change are indicated.

Process	*Domain*	*Process module*
nonresidential construction	public	construction (P)
		demolition (P)
	private	construction (C)
		demolition (C)
residential construction	public	construction (P)
		upgrading (P)
		demolition (P)
	private	construction (C)
		upgrading (C)
		demolition (T)
transport construction	public	construction (P)
		upgrading (P)
		demolition (P)
economic change	jobs	redundancy (C)
		employment (C)
demographic change	labour force	accession (T)
		new job (C)
		unemployment (C)
		retirement (T)
	persons	nationality (T)
		birth (T)
		ageing/death (T)
	households	nationality (T)
		birth (T)
		ageing/death (T)
		marriage (T)
		divorce (T)
		relative joins (T)
		relative leaves (T)
technological change	cars	car ownership (C)
labour mobility	labour market	relocation (C)
		change of job (C)
residential mobility	housing market	immigration (C)
		outmigration (C)
		starter (C)
		move (C)
daily mobility	traffic	work trips (C)
		shopping trips (C)
		service trips (C)
		school trips (C)

Figure 1 Process modules of urban change: choices (C), transitions (T), policies (P)

The *actors* involved in choice processes of urban development may be either public or private:

- *Public actors* of urban development are governments and government agencies from the local to the national level. Public policy decisions relevant for urban development are direct investment or construction decisions of local governments or other public or semi-public bodies as well as indirect government policies implemented through legislation or regulations regarding taxation, land development, construction, transport or the environment. These public interventions constitute the *planning* component of urban development.
- *Private* actors of urban development are firms, households and individuals. Private decisions relevant for urban development are location, migration and travel decisions which cannot, or can only indirectly, be influenced by public planning. The private actors of urban development interact on spatial markets such as the land and construction market or the housing market. Hence the decisions of private actors constitute the *market* component of urban development.

Both public and private actors pursue their possibly conflicting goals. However, mainly the behaviour of the private actors is of interest. The following basic assumptions about the behaviour of private actors are made: Actors *attempt* to act *rationally*, ie to perceive and accomplish their *preferences*. In doing so they are subject to group-specific economic, institutional and informational *constraints*. In response to these constraints they are content with obtaining suboptimum *aspiration levels*. The degree of optimality of the aspiration levels of actors is determined by their *experience*. In particular actors with low income are likely to be forced to *reduce* their aspiration levels.

The *preferences* of actors are multiattribute. For instance, the attractiveness of a dwelling for a household is a function of its quality and size, the quality of its neighbourhood, its location to work places and to other activities in the region and of its rent or price in relation to the household's income. The attractiveness of a site as a location for a firm is a function of its size and zoning category, the quality of its neighbourhood, its location in the region and its land price. The attractiveness of a given route in the transport network for a traveller is a function of its travel time, travel distance and travel cost in relation to alternative routes and to the traveller's perceived travel time and money budgets. The preferences of different groups of actors are different because of their different needs and financial means such as housing or travel budgets.

Constraints are circumstances narrowing the decision margin of actors (cf. Hägerstrand 1970). Economic constraints are limits to the ability or willingness to pay. Institutional constraints are restrictions of access to services or facilities. Informational constraints are restrictions of the collection of decision information due to lack of time or money. Just as the preferences, the constraints are different for each group of actors because of their different income, social status, education or occupation. Preferences and constraints determine the behaviour of actors in *decision situations* in which they choose between action alternatives. It is assumed that actors in their daily decision making use heuristic choice rules such as 'satisficing' (March and Simon 1958) or 'elimination by aspects' (Tversky 1972), which means that the results of their decisions are not normally optimum in terms of individual utility maximization but represent systematic deviations from optimality the distributions of which can be estimated.

In technical terms, the microanalytic model of urban change is operationalised as a Monte-Carlo or microsimulation. Microsimulation consists of mapping a random number to a cumulative probability distribution representing the likelihood that certain events occur to a certain actor (firm, household or individual):

- In the case of a transition (T) such as ageing/death, for instance, there are only two events, ageing (survival) and death, where the likelihood of death is the age- and sex-specific death rate associated with the subject modelled and the survival rate is the complement to one of the death rate.
- In the case of a choice (C) such as a move, a sequence of choices may be involved, such as decision to search for a new dwelling, choice of new residential location and choice of a new dwelling. The choice of a new dwelling is a choice between alternative dwellings at the selected location. The cumulative probabilities of the microsimulation are proportional to the likelihood that the household (of a certain nationality, age, size and income) will choose a dwelling (of a certain building type, tenure, size and price or rent), ie are a function of the

multiattribute utilities mentioned above. Finally, the household decides whether to accept the inspected dwelling or not. It is assumed that it behaves as a satisficer, ie that it accepts the dwelling if this will improve its housing situation by a certain margin.

- In the case of a policy (P) such as public housing or transport construction, the policy is decomposed into its component measures, and these are unconditionally executed.

After each transaction its consequences are immediately executed. In the case of a move, for instance, the former dwelling of the household is added to the pool of vacant dwellings, whereas its new dwelling is removed from the pool and now registered as occupied. It is not necessary to simulate every transition and every choice occurring in reality. It is sufficient to simulate a large enough sample of transaction to generate the distribution of interest with the degree of detail required for the analysis and aggregate the results accordingly.

Microsimulation was first used in social science applications by Orcutt et al. (1961) and in urban simulation by Chapin and Weiss (1968) and has occasionally reappeared in the literature (eg Kreibich 1979; Clarke et al. 1980), but has not been able to firmly establish itself because of its presumed large data requirements. Only recently microsimulation has found new interest because of its flexibility to model processes that cannot be modelled in the aggregate. Today there are several microsimulation models of urban land use and transport under development (Hayashi and Tomita 1989; Mackett 1990a; 1990b; Landis 1994).

Linking microsimulation and GIS

The modules and decision functions of a microsimulation model require disaggregate spatial data. Geographic information systems (GIS) offer data structures which efficiently link coordinate and attribute data. There is an implicit affinity between microanalytic methods of spatial research and the spatial representation of point data in GIS. Even where no micro data are available, GIS can be used to generate a probabilistic disaggregate spatial data base. There are four fields in which GIS can support micro techniques of analysis and modelling (see Figure 2):

- *Storage of spatial data.* There is a strong similarity between the storage of individual data required for microsimulation and the structure of point coverages of GIS. In an integrated system of microsimulation modules a GIS data base may therefore be efficient for analysis and modelling.
- *Generation of new data.* GIS may be used to create new data for microsimulation that were not available before. This data can be derived using analytical tools of GIS such as overlay or buffering.
- *Disaggregation of data.* Most data available for urban planning are aggregate zonal data. Microsimulation requires individual, spatially disaggregate data. If micro data are not available, GIS with appropriate microsimulation algorithms can generate a probabilistic disaggregate spatial data base. A method for generating synthetic micro data is presented in the next section.
- *Visualisation.* Microsimulation and GIS can be combined to graphically display input data and intermediate and final results as well as to visualise through animation the spatial evolution of the urban system over time.

Spatial disaggregation of zonal data

Spatial microsimulation models require the exact spatial location of the modelled activities, ie point addresses as input. However, most available data are spatially aggregate. To overcome this, raster cells or pixels are used as addresses for the microsimulation. To spatially disaggregate spatially aggregate data within a spatial unit such as an urban district or a census tract, the land use distribution within that zone is taken into consideration, ie it is assumed that there are areas of different density within the zone. The spatial disaggregation of zonal data therefore consists of two steps, the generation of a raster representation of land use and the allocation of the data to raster cells. Figure 3 illustrates the steps for a simple example.

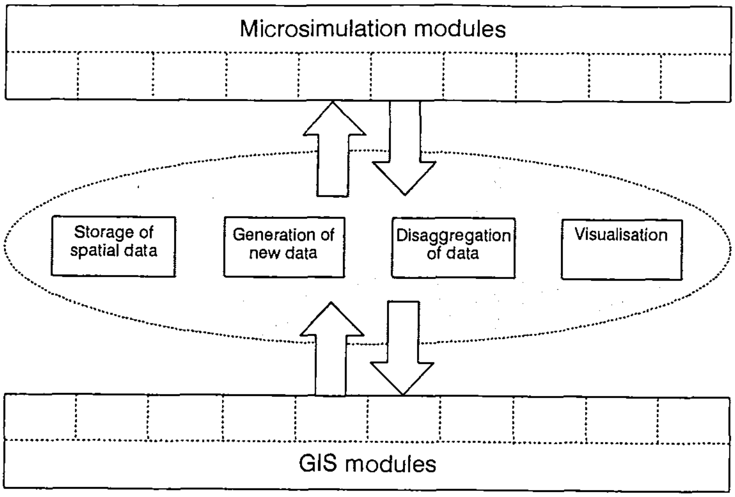


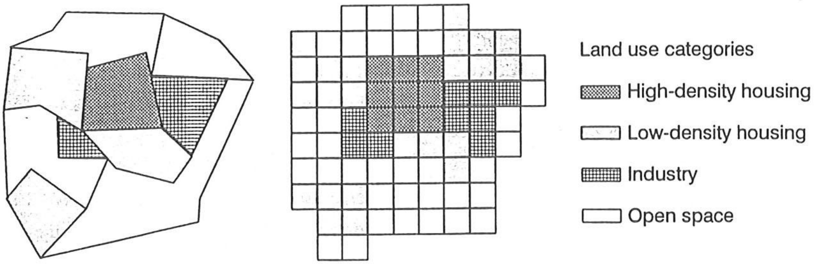
Figure 2 Linking microsimulation and GIS

Vector-based GIS record land use data as attributes of polygons. If the GIS software has no option for converting a polygon coverage into a raster representation, the following steps are performed. First, the land use coverage and the coverage containing the zone borders are overlaid to get land use polygons for each zone. Then the polygons are converted to raster representation by using a point-in-polygon algorithm for the centroids of the raster cells. As a result each cell has two attributes, the land use category and the zone number of its centroid. These cells represent the addresses for the disaggregation of zonal data and the subsequent microsimulation. The cell size to be selected depends on the required spatial resolution of the microsimulation and is limited by the memory and speed of the available computer.

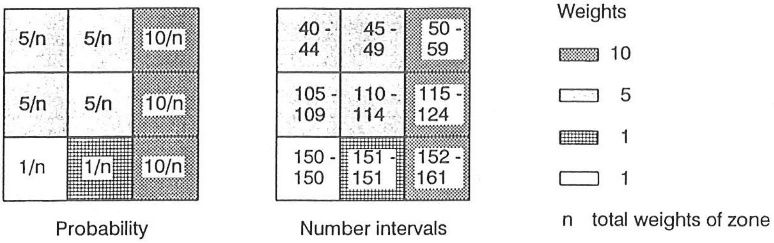
The next step merges the land use data and zonal activity data such as employment or population. First for each activity to be disaggregated specific weights are assigned to each land use category. Then all cells are attributed with the weights of their land use category. Dividing the weight of a cell by the total of the weights of all cells of the zone gives the probability for that cell to be the address of one element of the zonal activity. Cumulating the weights over the cells of a zone one gets a range of numbers associated with each cell. Using a random number generator for each element of the zonal activity one cell is selected as its address. The result of this is a raster representation of the distribution of the activity within the zone.

Figures 4 and 5 demonstrate how this method was used to disaggregate population in Dortmund. Land use and population data were available for 170 statistical districts. Figure 4 shows the digitised land use map consisting of 2,600 parcels classified by twelve land use categories (collapsed to three categories for better reproduction here). Figure 5 (top) shows the spatial disaggregation of population after the disaggregation. The width of the cells used was 50 m, ie every pixel on the map represents a square of 50x50 m. The distribution of the different activities visualises the urban structure of Dortmund and is consistent with the land use pattern of Figure 4. Figures 5 (bottom) visualises the disaggregate population data base in three-dimensional form. One can see the high-density neighbourhoods of the inner city and the low-density neighbourhoods of the inner suburbs in which there are only few high-rise housing areas.

Land use polygons to raster cells



Probabilities by raster cell (detail)



5/n	5/n	10/n
5/n	5/n	10/n
1/n	1/n	10/n

Probability

40 - 44	45 - 49	50 - 59
105 - 109	110 - 114	115 - 124
150 - 150	151 - 151	152 - 161

Number intervals

Zonal data to micro data

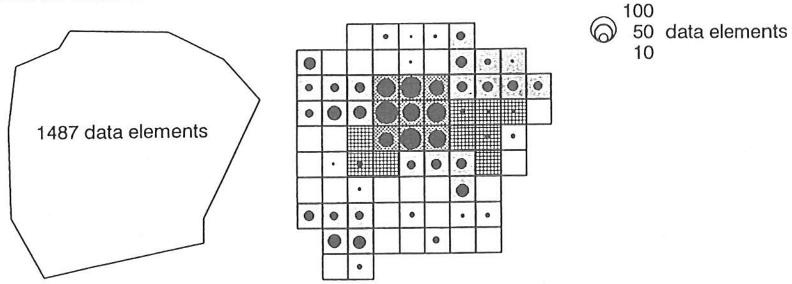


Figure 3 Raster disaggregation of zonal data

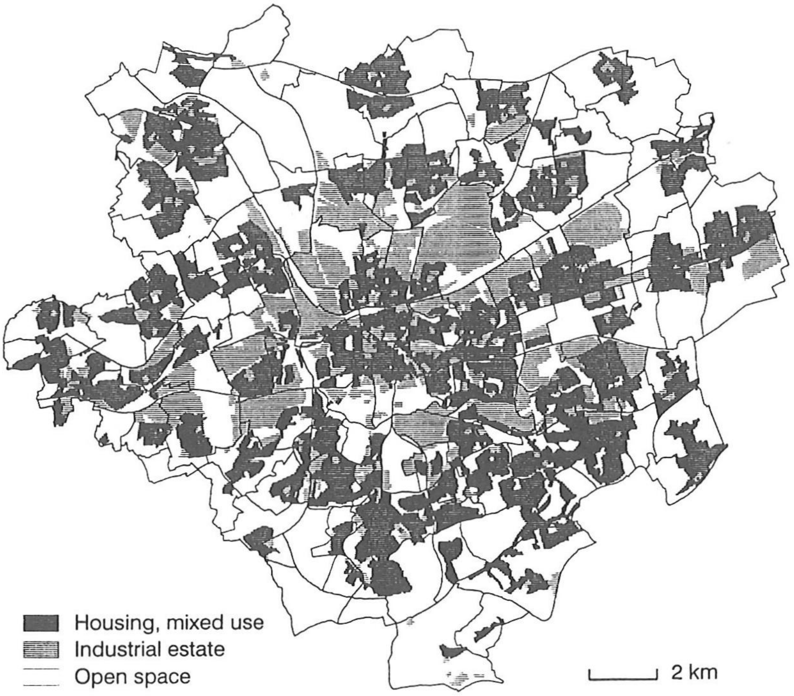


Figure 4 Land use in Dortmund

To correspond to the disaggregate representation of activities, the transport network was coded with great detail. There are about 6,200 road links and about 5,900 public transport links and about 3,900 public transport stops. Public transport lines were coded as a sequence of stops with travel times between them. The cycling and walking networks are synthetically derived from the above networks with similar detail.

The combination of the raster representation of activities and the vector representation of the transport network provides a powerful data organisation for the microsimulation of land use, transport and environment in urban regions:

- The raster representation of activities allows the calculation of microscale equity and sustainability indicators such as accessibility, air pollution, water quality, noise, micro climate and natural habitats, both for exogenous evaluation and for endogenous feedback into the residential construction and housing market submodels.
- The vector representation of the network allows to apply efficient network algorithms known from aggregate transport models such as minimum path search, mode and route choice and equilibrium assignment. The link between the micro locations of activities in space and the transport network is established by automatic search routines finding the nearest access point to the network or nearest public transport stop.
- The combination of raster and vector representation in one model allows to apply the activity-based modelling philosophy to modelling both location and mobility in an integrated and consistent way. This vastly expands the range of policies that can be examined. It is possible to study the impacts of public-transport oriented land-use policies promoting low-rise, high-density mixed-use areas with short distances and a large proportions of cycling and walking trips as well as new forms of collective travel such as bike-and-ride, park-and-ride or various forms of vehicle-sharing (Spiekermann and Wegener 1995).

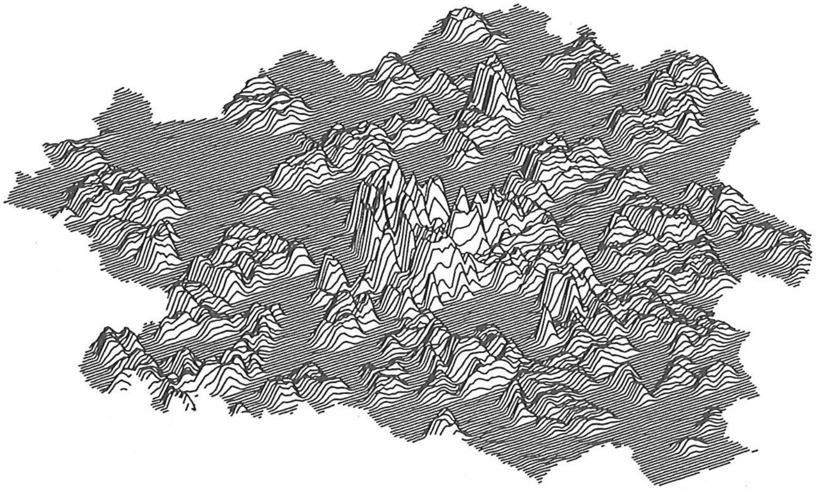


Figure 5 Residences in Dortmund: raster representation (top) and 3D plot (bottom)

CURRENT RESEARCH

In an ongoing research project the microsimulation method described above is being applied to model hypothetical *urban structures* subject to new demographic developments, new lifestyles and new transport and information technologies and to systematically evaluate them using criteria such as accessibility, total passenger-km, energy use, land requirement, other environmental indicators and indicators describing the impacts for different social groups, with respect to the three objectives of equity, sustainability and efficiency.

An urban structure is defined in the project as a combination of a *land use system* and a *transport system*:

- A *land use system* is a spatial configuration of dwellings, work places and public facilities within an urban area, ie of land use categories such as high-density inner-city residential areas, large high-rise housing estates, low-density suburbs with detached houses, medium-density mixed-use areas, office parks, industrial estates or greenfield shopping centres. Land use scenarios considered for investigation are:

  'Compact City': intensified urban density in the inner city,

  'Polycentric City': decentralised concentration in subcentres,

  'Garden City': dispersed concentration around former village cores,

  'Auto City': the abandonment of urban centres.

  Within one land use system different patterns of activities and spatial interaction are possible. An infinite number of associations of workers and jobs via commuting is possible with the same spatial distribution of dwellings and work places. Also with a given distribution of shopping and service facilities an infinite number of spatial interaction patterns for shopping and service trips is possible. Which activity and interaction patterns emerge depends on the transport system connecting the locations of activities.

- A *transport system* is defined by the transport infrastructure, ie the road network and the public transport network, including the level of service of public transport, as well as cycling and walking. The transport system is also defined by policies that influence mobility by technical standards, legal or institutional regulations, taxes and fees. Transport scenarios considered for investigation are:

  'Star Network': radial public transport and highway network,

  'Grid Network': rectangular public transport and highway network,

  'Mixed Network': radial public transport and rectangular highway network,

  'Local Networks': loosely coupled local transport networks.

Each of these transport scenarios may be combined with different levels of service and fares of public transport and different levels of car ownership and car travel costs and speed limits for the road network.

Theoretically, each land use scenario might be combined with each transport scenario. For practical reasons only combinations that are likely to work in the same direction will be selected. Another possibility would be to keep the land use scenario constant and vary only the transport scenario (or vice versa) in order to isolate the impact of a single policy or group of policies.

The model used in the analysis will be a microsimulation model of residential choice, job choice and daily mobility. The model will build on a previous urban model which is aggregate but contains a microsimulation housing market submodel (Wegener 1994; 1995b). In the new model, decisions affecting the construction of buildings are exogenous, but decisions affecting the location of activities as well as travel decisions are endogenous subject to constraints such as job availability, housing supply, transport costs and traffic constraints.

An important element of the new model will be its combination with a geographical information system (Spiekermann and Wegener 1993). The GIS will be used also to generate artificial urban structures from a spatial database of the Dortmund metropolitan area. Each land use system so created will be characterised by empirical data describing the socio-economic composition of the population, the supply of jobs and the locations of public and private shopping, education, health and leisure facilities based on actual conditions in the Dortmund region.

The combination of microsimulation and GIS is presently under development. Data collection and network coding have been completed for the Dortmund metropolitan area (see above). Current work concentrates on the conversion of the aggregate transport submodel into a microsimulation and on the development of environmental submodels for air dispersion, noise propagation and open spaces as well as on the design of an efficient interface between the model system and a GIS.

SUMMARY

The paper addressed the question how an 'ideal' urban structure that is at the same time efficient, equitable and sustainable would have to look today. It was shown that existing urban land-use transport models do not have the spatial resolution necessary to model new neighbourhood-scale land-use and transport policies and the social and environmental indicators needed to assess their equity and sustainability effects. It was argued that a combination of microsimulation and geographical information systems (GIS) could provide the basis for a new generation of spatially disaggregate land-use transport environment (LTE) models able to respond to the information needs of equitable and sustainable urban land-use and transport planning. The paper closed with an outlook on an ongoing research project in which the proposed methodology is being applied.

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