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Microsimulation of Sustainable Mobility

Michael Wegener*, Ilan Salomon** and Klaus Spiekermann*

*Institute of Spatial Planning, University of Dortmund
D-44221 Dortmund, Germany
**Department of Geography, Hebrew University of Jerusalem
Mount Scopus, Jerusalem 91905, Israel

Abstract

The paper presents current work to develop an experimental disaggregate activity-based transport model and to implement it for the city of Netanya in Israel. The model to be developed is innovative in that it incorporates features that have not yet been implemented in one integrated approach and combines these with new techniques of spatially disaggregate modelling. First, the state of the art in microsimulation and transport modelling is summarised. Second, an outline of the disaggregate transport model under construction is given.

1. Introduction

Activity-based transport modelling based on principles of time-space geography originated in the 1980s but has yet failed to replace the mainstream tradition of aggregate transport modelling represented by the conventional four-step transport model. However, several developments have contributed to a significant revival of activity-based modelling in the 1990s. One is the availability of larger and more powerful computers that has overcome former barriers to handling large disaggregate data bases. A second development is the growing diversification of urban life styles of which mobility behaviour is a specific component. A third issue is the increased attention paid to environmental aspects of transport due to the growing urgency of the environmental debate and associated legislation in many countries.
Life-style based activity patterns and environmental-oriented transport planning attract attention to more complex forms of spatial behaviour such as trip-chains, car sharing and intermodal trips, all of which cannot be represented in traditional trip-based models, and requires the analysis of environmental impacts of transport that cannot be captured by aggregate, zone-based, approaches. Modelling sustainable mobility requires the consideration of multi-purpose and multi-modal trips including 'soft' modes such as walking and cycling. Modelling social indicators requires information on socio-economic and ethnic groups and their spatial distribution at the neighbourhood scale. These requirements call for a new type of an urban transport model that is much more disaggregate than previous models. New developments in spatial information systems make such models today possible.

At the Institute of Spatial Planning (IRPUD) and the Hebrew University of Jerusalem work is under way to develop an experimental disaggregate activity-based transport model and to implement it for the city of Netanya in Israel. The model to be developed is to be innovative in that it incorporates features that have been proposed by several authors but have not yet been implemented in one integrated approach and to combine these with new techniques of spatially disaggregate modelling developed at IRPUD.

In the paper current work towards an activity-based transport model is presented. First, the state of the art in microsimulation and transport modelling is summarised. Second, an outline of the disaggregate transport model under construction is given. Finally, first steps towards the implementation of the model for Netanya by identifying life styles and establishing the disaggregate data base are presented.

The modelling concepts presented in this paper are based on previous work of the two authors. Salomon pioneered the life-style approach in activity-based transport modelling (Salomon, 1983, 1997). Wegener has applied microsimulation techniques to modelling household location choice in a model of the regional housing market of Dortmund, Germany, the IRPUD model (Wegener, 1985, 1998). In the paper these streams of research will be brought together.

2. Microsimulation in Urban Modelling: State of the Art

Microsimulation was first used in social science applications by Orcutt et al (1961), yet applications in a spatial context remained occasional experiments without deeper impact though covering a wide range of phenomena such as spatial diffusion (Hägerstrand, 1968), urban development (Chapin and Weiss, 1968), transport behaviour (Kreibich, 1979), demographic and household dynamics (Clarke *et al*., 1980; Clarke 1981; Clarke and Holm 1987) and housing choice (Kain and Apgar, 1985; Wegener, 1985). Only recently microsimulation has found new interest because of its flexibility to model processes that cannot be modelled in the aggregate (Clarke, 1996). Today there are several microsimulation models of urban land use and transport under development (Hayashi and Tomita 1989; Mackett 1990a; 1990b; Landis, 1994; Landis and Zhang, 1998a; 1998b; Waddell, 1998a; 1998b; Wegener and Spiekermann, 1996).

A different approach emerged from the theory of cellular dynamics. Cellular automata (CA) are objects associated with areal units or *cells*. CA follow simple stimulus-response rules to change or not to change their *state* based on the state of adjacent or near-by cells. By adding random noise to the rules, surprisingly complex patterns that closely resemble real cities can be generated (White and Engelen, 1993; Batty and Xie, 1994; Batty, 1997). More complex stimulus-response behaviour is given to CA models in multi-reactive agents models. Multi-reactive agents are complex automata with the ability to control their interaction pattern; they can change their environment but also their own behaviour, i.e. are able to learn (Ferrand, 1999). The distinction between the behaviour of multi-reactive agents and the choice behaviour generated in microsimulation models is becoming smaller.

Probably the most advanced area of application of microsimulation in urban models is travel modelling. As a reaction against the inability of aggregate travel models to reproduce the complex spatial behaviour of individuals and to respond to sophisticated travel demand management measures, disaggregate travel models aim at a one-to-one reproduction of spatial behaviour by which individuals choose between mobility options in their pursuit of activities during a day (Axhausen and Gärling, 1992; Ben Akiva et al., 1996). Activity-based travel models start from interdependent 'activity programmes' of household members and translate these into home-based 'tours' consisting of one or more trips. In this way interdependencies between the mobility behaviour of household members and between the trips of a tour can be modelled as well as intermodal trips that cannot be handled in aggregate multimodal travel models. Activity-based travel models do not model peak-hour or all-day travel but travel behaviour by time of day, which permits to model choice of departure time. There are also disaggregate traffic assignment models based on queueing or CA approaches, e.g. in the TRANSIMS project (Nagel et al., 1998), which reproduce the movement of vehicles in the road network with a level of detail not known before.

2. Life Styles

In the Netanya model the variation in human spatial behaviour is represented by modelling different *life styles*. Life style is an empirical concept which attempts to capture human spatio-temporal behaviour. It can be viewed as the sum of activities, distributed in time, space, inter-personal and intra-personal dimensions. It is a physical expression of the pattern of activities which the individuals aspire to engage in subject to constraints (Salomon, 1983; 1997).

For the purpose of forecasting behaviour, the concept of life style seems to be richer in information than the conventional classification of market segments along socio-demographic and economic (SDE) variables. As life style expresses the aspiration one has with regard to the way of living (i.e. activities in time and space), peoples' revealed behaviour is either consistent with their aspirations or a deviation thereof in the presence of constraints. Thus, identifying a person's life style is expected to be instrumental in predicting her behavioural responses to new situations.

In the social sciences life styles usually are represented in the form of free-form narratives or ‘stories’. The story format, though open and potentially rich in content, is not suitable for mathematical modelling. Therefore life styles need to be translated from the open narrative format to some kind of quantitative representation which, however, should preserve as much of the variation in life styles found in reality. Such a representation is the representation of life styles as fuzzy objects. A ‘life style’ in the Netanya model is a fuzzy object defined by a set of probabilistic membership functions. A probabilistic membership function is a vector of probabilities specifying the likelihood that individuals with a particular life style belong to a particular category of a set of classified attributes.

The probabilities of the membership functions can be found as observed frequencies in empirical investigations, e.g. household surveys. In the absence of such surveys they are determined by expert judgement and calibrated against observed aggregate distributions. The calibration is performed by microsimulation by which a fictitious spatially disaggregated population of individuals and households is generated which as far as possible conforms to the membership functions defining each life style, aggregate observed distributions such as population by age and sex and the observed spatial distribution of land use and activities by zone. Figure 1 contains a tentative suggestion for the membership functions to define a life style in the Netanya model.

3. Travel Behaviour

The travel behaviour microsimulation models for each member of each household the selection of an activity programme and, subject to that selection, for each tour a tour departure time and for each trip a trip departure time, destination, mode and route (see Figure 1):

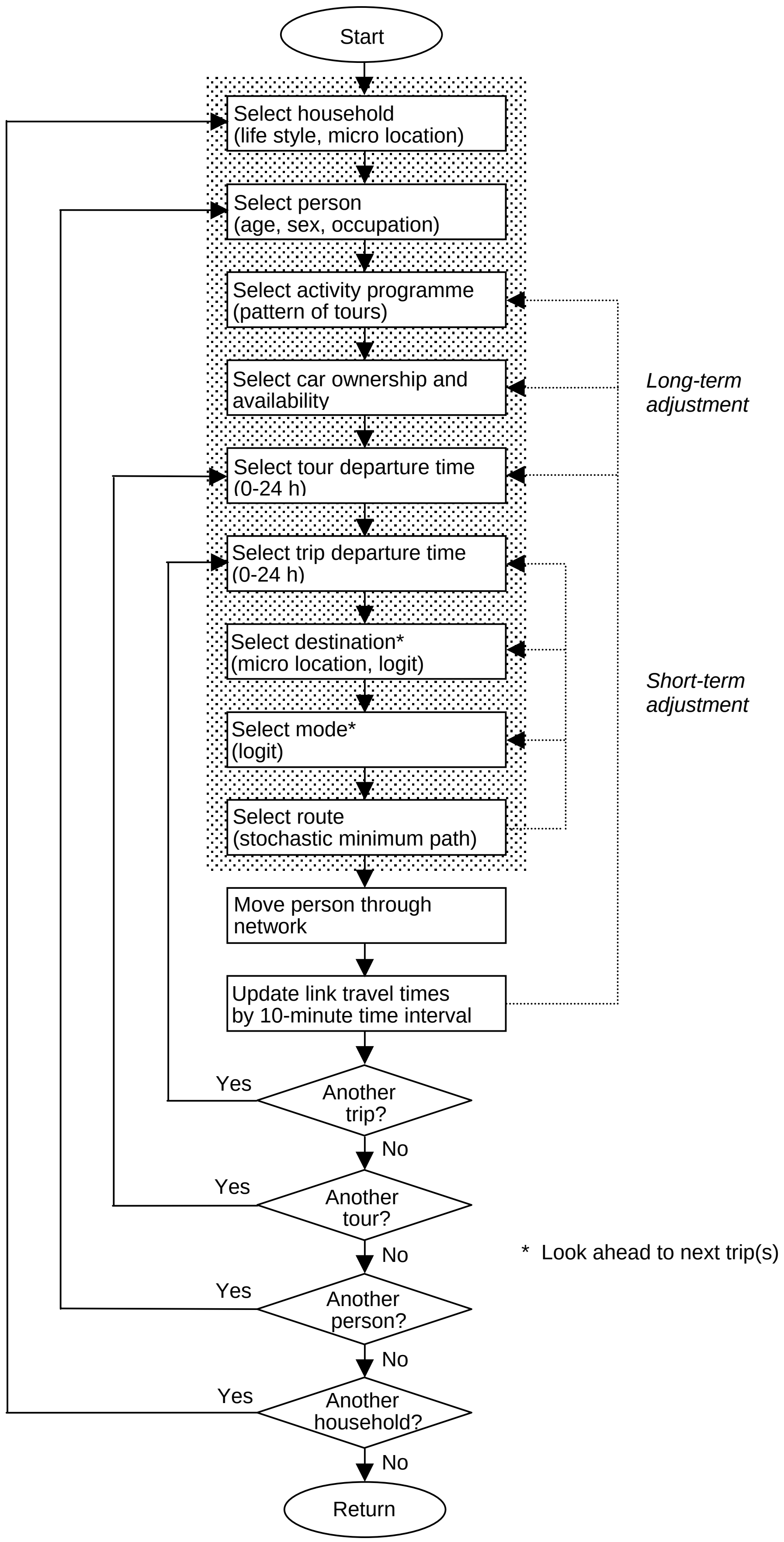

Figure 1. Microsimulation of travel behaviour: one day

- *Select household*. In the first step a household is selected for processing from the list of households. The selection has to be spatially random to ensure a non-biased assignment of the network. Each selected household is defined by its household attributes and its associated life style (see Figure 2) and by the personal attributes of its members. The household attributes include its residential location. A location in the model is a micro location, i.e. street address, geographical coordinates or a raster cell.

Attribute	18-29	30-45	45-60	60+	Total
Age of adults					100

Attribute	None	High school	Training	University	Total
Education of adults					100

Attribute	Unemployed	Work	Household	Retired	Total
Labour participation of adults					100

Attribute	None	Blue-collar	White-collar	Manager	Self	Total
Occupation of adults						100

Attribute	1	2	3	4	5	6+	Total
Household size							100

Attribute	1	2	3	4+	Total
Number of workers in household					100

Attribute	Secular	Orthodox	Ultraorthodox	Total
Religious orientation				100

Attribute	<5K	5-10K	10-15K	>15K	Total
Net household income (NIS)					100

Attribute	Central area	Inner suburbs	Outer suburbs	...	...	Total
Residential location						100

Attribute	Central area	Inner suburbs	Outer suburbs	Total
Workplace location(s)				100

Attribute	Housing	Transport	Other	Total
Use of income				100

Attribute	Work	Education	Leisure	Total
Use of time				100

Attribute	Fixed	Flexible	Irregular	Total
Flexibility of time				100

Attribute	High-rise	Apartment	Terrace	Detached	Total
Housing type					100

Attribute	0	1	2	3+	Total
Number of cars in household					100

Attribute	Culture	Social	Sports	Outdoor	Total
Type of leisure					100

Attribute	City	Mall	Local	Total
Type of shopping				100

Figure 2. Definition of life styles in the Netanya model

- *Select person*. Next the first household member is selected. For each working person in the household the location of the workplace is known. For school children and university students the location of the school or university is known.

- *Select activity programme*. Depending on the personal attributes of the household member, i.e. age, sex and occupation and workplace, a daily activity pattern is selected from a catalogue of activity patterns. A daily activity pattern is defined as a schedule of tours.

- *Select car ownership and availability*. Depending on household and personal attributes it is determined whether the person has a car at her disposal.

- *Select tour departure time*. The first tour of the activity programme is selected. The departure time is determined as a random variation of the scheduled departure time.

- *Selection of trip departure time*. The first trip of the tour is selected. The departure time is determined as a random variation of the scheduled departure time.

- *Select destination*. The destination of the trip is selected by logit choice. The locations of destinations are micro locations as above. Generalised costs of travel to the destinations are calculated as the logsum of the travel costs of stochastic minimum paths (see below) of relevant modes. Relevant modes are walk, cycling, public transport and car (if available, see above). For work, school and university trips the destinations are already known.

- *Select mode*. For the selected destination, mode choice is performed by logit choice based on the generalised costs of stochastic minimum paths (see below).

- *Select route*. For the selected mode the stochastic minimum path is selected as route. The stochastic minimum path is the minimum path with a random disturbance term added to each link impedance and each waiting/transfer time in the public transport network.

- *Move person through network*. Each person travelling through the network is recorded on each transversed link by 10-minute time interval.

- *Update link travel times*. After each trip, the travel times of all transversed road links are updated to account for congestion.

If during a trip a significant amount of congestion occurs, a certain amount of short-term adjustment resulting in a postponement of the trip or a change of mode or route may occur. After each trip the next trip of the route, if any, is selected. After each route, the next route, if any, is selected. After each person, the next person, if any, is selected. After each household, the next household, if any, is selected.

In order to facilitate long-term learning, information on the generalised costs of the congested network by time of day of the current simulation period may be used in the next period.

4. First Steps towards Implementation

The model is presently being tested in the city of Netanya in Israel. Netanya (population 150,000) is situated at the northern side of the outer ring of the Metropolitan area of Tel Aviv. It was founded in 1928 as an independent resort town, which over the years, with the sprawl of the metro region, has become part of it. Given this biography, Netanya is clearly not the typical suburban community. It consists of a mix of life styles, which to a great extent represents the Israeli urban scene.

For the purpose of microsimulation of population behaviour it is necessary to generate synthetic households which represent the population of the study area. In the absence of readily available data on life styles it was necessary to identify life style groups which exist in Netanya. The underlying assumption is that for the purpose of generating synthetic households for a microsimulation model, a classification on the basis of life styles seems to be the most pertinent and relevant. However, the operationalisation of the life style concept raises a number of problems. First, if revealed behaviour is indicative of a life style group, the classification can only be done on the basis of prior observation. Alternatively, one can search for indicative attributes which allow the identification and classification of individuals to life style segments.

In order to identify the life-style based market segments in Netanya and the proxy variables which indicate membership, a small survey was conducted in which individuals had to identify four life style groups in Netanya, and to provide a short narrative description of the group. Then they were requested to provide a quantitative assessment, on the basis of the attributes shown in Figure 1 above, for one of the life style groups.

This pilot study was performed with the cooperation of Israeli students of geography at the Hebrew University. The limitations of this are that the students do not represent the population and second that they differ in their acquaintance with the city of Netanya. Nevertheless as a first tentative approach to generating synthetic households for the microsimulation the exercise brought interesting results.

Some 24 students filled out the questionnaire. In total they provided 58 responses to the question requesting four life-style labels, but these referred to 41 different life styles. This large number indicates that either the respondents had not internalised the concept of life style and actually provided simple SDE variables as the relevant classification basis, or that there are many diverse life style segments in the Israeli (or Netanya) population.

An analysis of the responses suggests, based on an acquaintance with the Israeli society, that in some cases, a single variable is sufficiently powerful to discriminate a group out of the population as a life style segment. For example, being labelled as an ultra-orthodox person provides sufficient information to reveal the life style of that person. This group was mentioned in eight out of 58 responses. However, being labelled as a member of the middle class conveys very little information about the person's or household's life style.
The second element of the questionnaire provided the respondents' assessment of the various parameters noted in Figure 1, for one of the life style groups they mentioned. Once certain life style groups are selected, the quantitative analysis of these parameters will assist in producing the probabilities of attributes of households selected for the microsimulation.

The micro locations of residences and trip destinations used in the microsimulation are implemented by raster cells, where a micro location is a pair of coordinates indicating the row and column in a matrix of 50 by 50 m raster cells. As no household and workplace data at this level of spatial disaggregation are available for Netanya, aggregate zonal data are disaggregated using Monte Carlo simulation with GIS-based land use polygon data as ancillary information. The method is described in Wegener and Spiekermann (1996). Figure 3 shows population density in Netanya based on the disaggregation of population using this method.

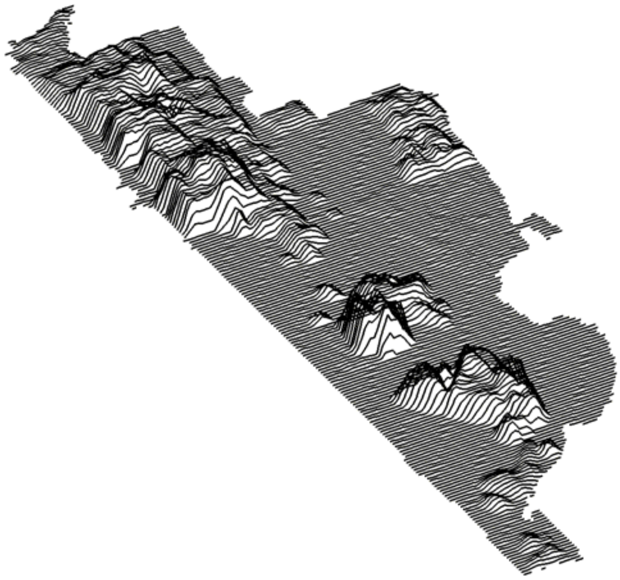

Figure 3. Population density in Netanya

Next work steps will be to identify daily activity patterns for the generated life-style groups of households and individuals, to complete the specification, programming and testing of the microsimulation model and then to use the model to generate daily journey and trip patterns by mode and time of day and to assign car trips to the road links to generate flows that can be compared with existing traffic counts.

5 . Conclusions

This paper outlined a modelling framework in which daily mobility is modelled as sequences of activities, tours and trips by microsimulation using a synthetic disaggregate spatial database. The framework is innovative in that it incorporates features that have not yet been implemented in one integrated approach and combines these with new techniques of spatially disaggregate modelling. The model is currently being tested in the city of Netanya in Israel.

In future work it is planned to extend the principle of microscopic activity-based transport modelling to changes in the life cycle of households and individuals and to decisions on residential location (Salomon et al., 1999). This would open the way for modelling the links between long-term life style decisions and medium- and short-term residential and daily mobility. The implementation of such a modelling framework would make urban models richer in behavioural content and more responsive to land use and travel demand management policies. The higher spatial and temporal resolution of such models would make them also suitable to model micro-scale environmental phenomena such as traffic noise and air pollution. This would be an important prerequisite for using the models for the identification of more sustainable life styles.

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