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Integrated Land Use and Transport Models
State of the Art and New Challenges

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Introduction

In all industrial countries market-driven spatial development has led to dispersed settlement structures connected with extensive motorised mobility, congested road networks, air pollution and high energy consumption. Concern about finite energy resources and the prospect of long-term climate change have created the awareness that the use of fossil energy and the emission of greenhouse gases in the richest countries of the world must be significantly reduced. For urban planning, this implies that in particular distances travelled by car need to be reduced.

Many experts believe that the growth of urban traffic has been largely caused by urban dispersal and recommend a return to higher-density mixed-use settlement patterns. The problem of these recommendations is that their effectiveness has not been ascertained. There is evidence that under current conditions of a large unregulated transport market and low travel costs urban re-concentration would not lead to significant reductions of energy consumption by urban transport. This poses a question of great relevance for urban planning: Is a return to higher densities really necessary? Do we need to rebuild our cities?

To answer this question the effectiveness of alternative policies to reduce car mobility has to be assessed. There are in principle three ways to do this. First, one could ask people how they would change their mobility behaviour under changed conditions ("stated preference"). Second, one could draw conclusions from the observed behaviour of people how they would behave under changed conditions ("revealed preference"). Third, one could simulate their mobility behaviour in mathematical models.

All three approaches have their advantages and disadvantages. Surveys and interviews can reveal subjective factors of mobility decisions but suffer from the fact that the respondents are only able to make conjectures about how they might behave under still unknown circumstances; the validity of such conjectures is unknown. Empirical studies based on observation of behaviour generate detailed and reliable results, but these are valid only for existing situations and not appropriate for predicting the impacts of policies in new situations. Moreover, it is not possible to link observed changes of behaviour unambiguously to individual causation factors because in reality several influencing factors usually change at the same time.

Mathematical models of human behaviour are also based on empirical surveys and observations, but their conclusions are quantified. Strictly speaking, the results of mathematical models just like those of empirical studies are not universally valid but only in situations similar to those in which their parameters were estimated. Nevertheless it is possible to transfer human behaviour modelled also to unknown situations if certain rules of model building are observed. In addition, mathematical models are the only method to assess the effect of individual causation factors by keeping all other factors constant. It is therefore possible to use mathematical models of land-use transport interaction to forecast the spatial development of an urban area and the resulting mobility patterns and to provide information on how to achieve a more equitable and sustainable urban system in the future.

In this paper the history of integrated urban land-use transport models is outlined. It is shown how changing problems of cities and changing planning paradigms have influenced the acceptance and application of urban models in the planning practice. It is argued that to cope with the demographic and ecological challenges cities are facing today substantial changes in model philosophy and method are required.

Land Use and Transport

That land use and transport in urban regions are closely interrelated is common wisdom among urban planners. That the spatial separation of human activities requires the movement of people and goods between them is one of the basic tenets of transport analysis and forecasting. Based on this paradigm it is easy to understand that suburbanisation is connected with increasing spatial division of labour and hence increasing mobility.

The reverse relationship, from transport to land use, is less well known. There is a vague understanding that the evolution from the medieval city in which most movements were on foot to the sprawling agglomeration of today with its massive daily traffic flows would not have been possible without first the railway and later the automobile, which has made almost every location in the urban region nearly equally suited as a place of work or place to live. But exactly how the development of the transport system influences the location decisions of landlords, investors, firms and households is not understood by many planners.

The recognition that mobility and location decisions co-determine each other and that therefore transport and land use planning need to be co-ordinated led to the notion of the "land-use transport feedback cycle" (Wegener and Fürst, 1999). The set of relationships implied by this term can be summarised as follows (see Figure 1):

- The distribution of *land uses*, such as residential, industrial or commercial, over the urban area determines the locations of households and firms and so the locations of human *activities* such as living, working, shopping, education and leisure.

- The distribution of human *activities* in space requires spatial interactions or trips in the *transport system* to overcome the distance between the locations of activities.

- These spatial interactions are based on decisions of travellers about car availability, number of trips, destination, mode and route. They result in *traffic flows* and, in case of congestion, in increased travel times, trip lengths and travel costs.

- Travel times, trip lengths and travel costs create opportunities for spatial interactions that can be measured as *accessibility*.

- The spatial distribution of accessibility influences, among other attractiveness indicators, location decisions of investors and results in changes of the *building stock* by demolition, upgrading or new construction.

- These changes in building supply determine location and relocation decisions of households and firms and so the distribution of *activities* in space.

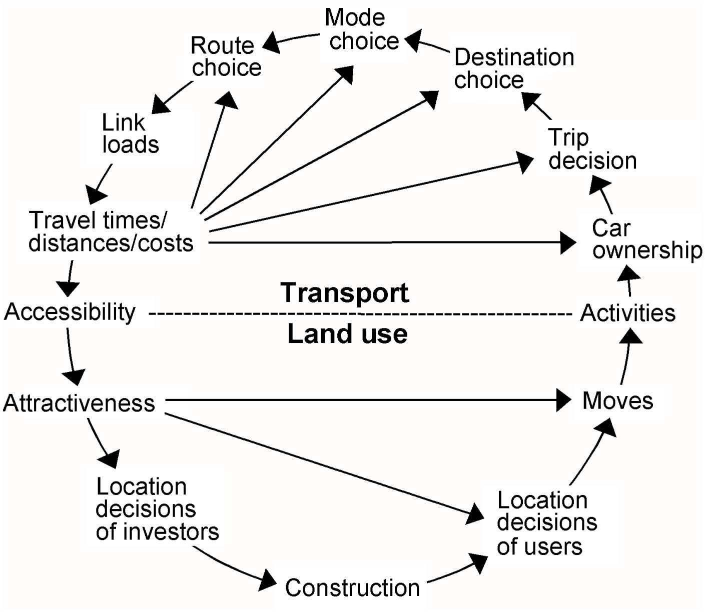


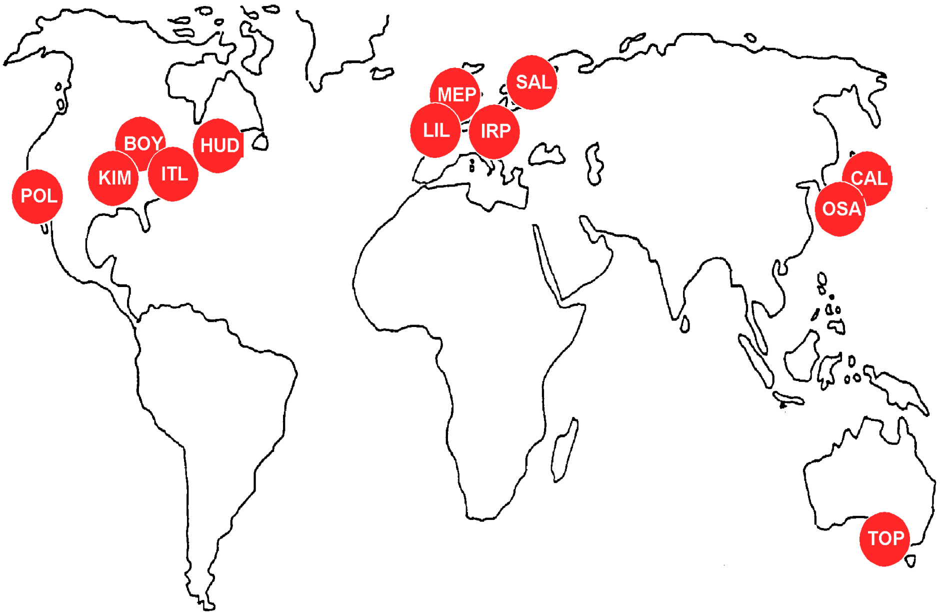
Figure 1. The land-use transport feedback cycle

Models of Spatial Urban Development

The growing knowledge about the relationships between urban land use and transport was behind the development of the first integrated land-use transport models in the USA in the 1960s. The *Model of Metropolis* by Lowry (1964) was the first attempt to quantify the land-use transport feedback cycle in one integrated model. The Lowry model essentially consists of two nested spatial interaction models of work trips and shopping and service trips used to predict the locations of residences and retail and services facilities. The Lowry model stimulated a large number of increasingly complex land-use transport models in the USA, including the models by Goldner (1971) and Putman (1983; 1991), and only little later also in Europe, such as the models by Echenique (Geraldes u.a., 1978), Mackett (1983) and Wegener (1982).

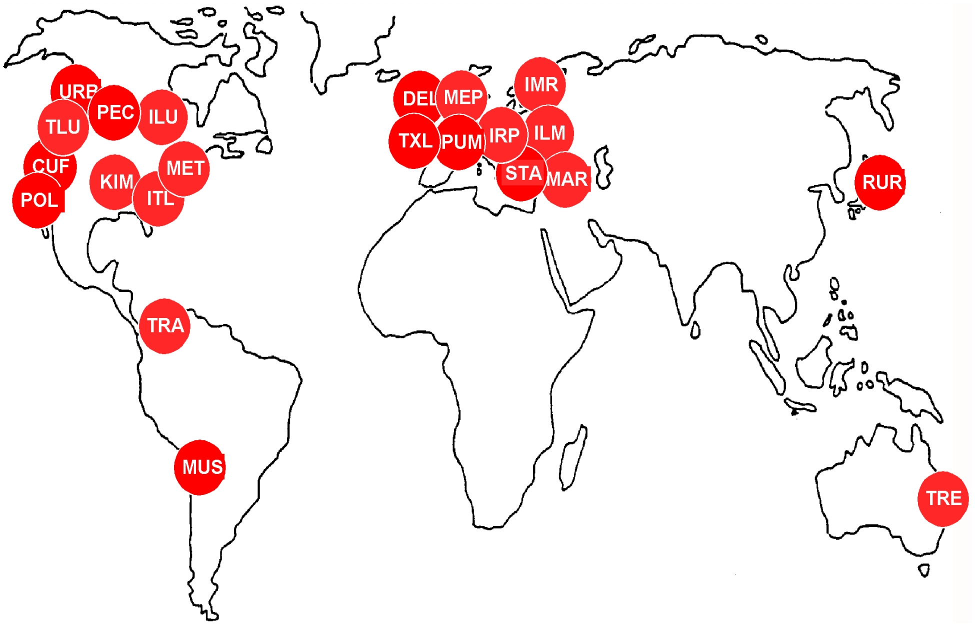
Many of these early models were not successful because of unexpected difficulties of data collection and calibration and the still imperfect computer technology of the time. More important, however, was that the models were mainly oriented towards urban growth and the efficiency of the transport system and had nothing to say about the ethnic and social conflicts arising in US cities at that time. Moreover, the models were committed to the paradigm of synoptic rationalism in planning theory, which was increasingly replaced by incremental, participatory forms of planning. In his "Requiem for large scale models", Lee (1973) accused the models of "seven sins": hypercomprehensiveness, grossness, mechanicalness, expensiveness, hungriness, wrongheadedness and complicatedness. The result of the change in acceptance of the models was that the urban modelling community retreated to the basements of academia.

But the requiem was premature. Many of the technical problems of the early models were solved by better data availability and faster computers. The spatial and substantial resolution of the models was increased and they were based on better theories, such as bid-rent theory, discrete choice theory and user equilibrium in transport networks. In addition better visualisation techniques made the results of the models better understood by citizens and policy makers. A new generation of models paid more attention to aspects of social equity. Figure 2 gives an overview of the major land-use transport models in the world in the 1980s.



BOY	Boyce	IRP	IRPUD	MEP	MEPLAN	POL	POLIS
CAL	CALUTAS	ITL	ITLUP	LIL	LILT	SAL	SALOC
HUD	Kain	KIM	Kim	OSA	Osaka	TOP	TOP

Figure 2. Integrated land-use transport models in the 1980s



CUF	CUFM	DEL	DELTA	ILM	ILUMASS	ILU	ILUTE
IMR	IMREL	IRP	IRPUD	ITL	ITLUP	KIM	Kim
MAR	MARS	MEP	MEPLAN	MET	METROSIM	MUS	MUSSA
PEC	PECAS	POL	POLIS	PUM	PUMA	RUR	RURBAN
STA	STASA	TLU	TLUMIP	TRA	TRANUS	TXL	TIGRIS XL
TRE	TRESIS	URB	UbanSim				

Figure 3. Integrated land-use transport models today

The 1990s brought a revival in the development of urban land-use transport models. New environmental legislation in the US required that cities applying for Federal funds for transport investments demonstrate the likely impacts of their projects on land use. This had the effect that virtually all major metropolitan areas in the US maintained an integrated land-use transport model. In Europe the European Commission initiated a large research programme "The City of Tomorrow", in which in several research projects integrated land-use transport models were applied (Marshall and Banister, 2007). Several integrated land-use transport models (TRANUS, MEPLAN, ITLUP, IMREL, RURBAN, UrbanSim, DELTA and PECAS) were applied in a growing number of metropolitan areas, and the first such models were made available as Open Source on the Internet (TRANUS and UrbanSim).

More recent developments seem to herald an unlimited golden future for urban land-use transport models. New developments in data availability brought about by geographical information systems (GIS) and further advances in computer technology (parallel computing) have removed former technical barriers. New developments in model theory and method, such as activity- and agent-based models, have widened the range of issues that can be studied. A world-wide community of urban modellers meets regularly at conferences, such as the World Conference on Transport Research (WCTR), Computers in Urban Planning and Urban Management (CUPUM) and the Annual Meeting of the Transportation Research Board (TRB). Figure 3 shows the most important integrated land-use transport models in the world today (Wegener, 2004).

However, not all modelling projects were successful. Many large modelling projects failed to deliver in the time available or had to reduce their too ambitious targets. Many applications of established models by others than their authors did not become operational. Many projects got lost in data collection and calibration and did not reach the state of policy analysis. Many projects remained in the academic environment and produced only PhD theses. Many applications of microscopic activity- or agent-based models ignored the pitfalls of stochastic variation and published results with illusionary precision. In addition, most present modelling projects have not yet responded to the new challenges urban planning will face in the future.

New Challenges

The world is changing fast, and so are the problems of urban planning. The first land-use transport models were growth-oriented and mainly addressed technical problems, such as the reduction of urban sprawl and traffic congestion. The second generation of models increasingly considered equity aspects, such as social and ethnic segregation, accessibility of public facilities and distributive issues as who gains and who loses if certain policies are implemented (Wegener, 1994). Today the third generation of models tries to take account of the observed individualisation of lifestyles and preferences by ever greater spatial, temporal and substantial disaggregation. A few models are linked to environmental models to show the impacts of planning policies on greenhouse gas emissions, air quality, traffic noise and open space (Lautso et al., 2004).

However, today new challenges come to the fore that cannot be handled by even the most advanced urban land-use transport models.

The first challenge is the transition from growth to decline foreseeable in many European cities. This does not refer to every form of population decline. With small population decline and moderate economic growth the demand for housing still grows because of decreasing household size and increasing floorspace per capita. The same is true for work places due to the growing floorspace demand per worker. However, if the losses of population and employment become larger than the growth in floorspace demand per capita or per worker, the task is no longer the allocation of growth but the management of decline by new types of policies, such as rehabilitation of neighbourhoods, upgrading of rundown housing or conversion or demolition of derelict or vacant buildings. Only few current urban models are able to handle this.

The second and much larger challenge for the models arises from the possibility of future energy crises and the requirements of climate protection. Both causes are likely to make mobility significantly more expensive. For model design it does not matter whether car trips become more expensive through higher prices for fossil fuels on the world market or through government policies to meet greenhouse gas reduction targets. What matters is that these targets cannot be achieved without rigorous changes in the decision environment of mobility and location in urban areas, in particular without significant increases in the price of fossil fuels.

Most current urban models are not prepared for this. Many of them are not able to model transport policies, such as carbon taxes, emissions trading, road pricing or the promotion of alternative vehicles and fuels, or land use policies, such as strict development controls, improvement of the energy efficiency of buildings or decentralised energy generation. Even fewer models are able to identify population groups or neighbourhoods most affected by such policies or possible problems with access to basic services, such as schools or health facilities, or participation in social and cultural life in low-density suburban or rural areas under high transport costs.

Many current transport models cannot correctly predict the impacts of substantial fuel price increases. Many do not consider travel costs in trip generation, trip distribution and modal choice. Many do not forecast induced or suppressed trips. Many use price elasticities estimated in times of cheap energy. Many do not consider household budgets for housing and travel and model car ownership in relation to disposable household income.

That with land-use transport models plausible forecasts of the impacts of substantial energy price increases can be made was demonstrated by the results of the EU project "Scenarios for the Transport System and Energy Supply and their Potential Effects" (STEPs). They show that with appropriate combinations of transport and land use policies significant reductions in greenhouse gas emissions without unacceptable loss of quality of life can be achieved (Fiorello et al., 2006).

Summary

During and after the energy transition energy for transport will no longer be abundant and cheap but scarce and expensive. This will have fundamental consequences for mobility and location in cities. Land-use transport models calibrated on behaviour observed in the past and not considering the costs of travel and location in relation to household income cannot adequately forecast these consequences. To deal with significantly rising travel costs, land-use transport models must consider basic needs of households which can be assumed to remain relatively constant over time, such as shelter and security at home, accessibility of work, education, retail and necessary services and the constraints of expenditures for housing and travel by household incomes.

To avoid the danger that the models, as in the 1970s, are again rejected by the planning practice, they must adopt seven new rules: (i) less extrapolation of past trends, more openness to fundamental change, (ii) less belief in equilibrium, more attention to dynamics, (iii) less reliance on observed behaviour, more theory on needs, (iv) less consideration to preferences and choices, more taking account of constraints, (v) less emphasis on calibration, more use of plausibility analysis, (vi) less effort on detail, more focus on basic essentials and (vii) less forecasting, more backcasting – don't ask what could be done but what needs to be done.

References

Fiorello, D., Huismans, G., López, E., Marques, C., Steenberghen, T., Wegener, M., Zografos, G. (2006): *Transport Strategies under the Scarcity of Energy Supply*. Final Report of the EU project "STEPs – Scenarios for the Transport and Energy Supply and their Potential Effects", edited by A. Monzon and A. Nuijten. Den Haag: Bucks Consultants. http://www.steps-eu.com/reports.htm.

Geraldes, P., Echenique, M.H., Williams, I.N. (1978) A spatial economic model for Bilbao. In: *Proceedings of the PTRC Summer Annual Meeting*. London: PTRC, 75-94.

Goldner, W. (1971) The Lowry model heritage *Journal of the American Institute of Planners*, 37, 100-110.

Lee, D.B. (1973): Requiem for large-scale models. *Journal of the American Institute of Planners* 39, 163-178.

Lautso, K., Spiekermann, K., Wegener, M., Sheppard, I., Steadman, P., Martino, A., Domingo, R., Gayda, S. (2004): *PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability*. PROPOLIS Final Report. Helsinki: LT Consultants. http://www1.wspgroup.fi/lt/propolis.

Lowry, I.S. (1964) *A Model of Metropolis*. RM-4035-RC. Santa Monica, CA: Rand Corporation.

Mackett, R.L. (1983) *The Leeds Integrated Land-Use Transport Model (LILT)*. Supplementary Report SR 805. Crowthorne, Berkshire: Transport and Road Research Laboratory.

Marshall, S., Banister, D., Eds. (2007): *Land Use and Transport. European Research towards Integrated Policies*. London: Elsevier.

Putman, S.H. (1983) *Integrated Urban Models: Policy Analysis of Transportation and Land* Use. London: Pion.

Putman, S.H. (1991) *Integrated Urban Models 2. New Research and Applications of Optimization and Dynamics*. London: Pion.

Wegener, M. (1982): A multilevel economic-demographic model for the Dortmund region. *Sistemi Urbani* 3, 371-401.

Wegener, M. (1994): Mobilität und Raumaneignung als Gerechtigkeitsproblem. In: Sturm, P. (Ed.): *Um die Wette leben – Geschwindigkeit, Raum und Zeit*. Schriftenreihe 39. Bochum: SRL, 83-95.

Wegener, M. (2004): Overview of land-use transport models. In: Hensher, D.A., Button, K.J. (Eds.): *Transport Geography and Spatial Systems*. Handbook 5 of Handbook in Transport. Kidlington, UK: Pergamon/Elsevier Science, 127-146.

Wegener, M., Fürst, F. (1999): *Land-Use Transport Interaction: State of the Art*. Berichte aus dem Institut für Raumplanung 46. Dortmund: Institut für Raumplanung, Universität Dortmund. http://www.raumplanung.uni-dortmund.de/irpud/fileadmin/irpud/content/documents/publications/ber46.pdf.