

Prospects of Transportation Modelling

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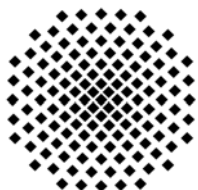
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Veröffentlicht in / Published in:

Friedrich, M. (2004): Prospects of Transportation Modelling, CD-ROM, *Proceedings of 2nd International Symposium Networks for Mobility*, Stuttgart.



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Prospects of Transportation Modelling

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Abstract: The paper looks at the current state of development in transportation modelling and tries to identify future developments which are either likely or desirable. It discusses developments in the fields of data modelling, surveying techniques for supply and demand data, traffic assignment and travel forecasting models, microscopic modelling, and user interface.

Key Words: Transportation Modelling, Data Models, Traffic Assignment

1 Introduction

Over the last forty years a variety of operational models has been developed and applied in the field of transportation.

The first models in transportation focused primarily on forecasting travel demand in transport networks. This type of models has seen significant improvements over the years and has become a principal tool for strategical transportation planning. Travel forecasting and assignment models describe the relationship between supply and demand and support medium- and long-term decisions in transportation planning. Various impact models forecast the consequences of planning scenarios in terms of volumes, journey times, emissions, costs and revenues thus permitting a quantitative comparison.

A second type of widely used models addresses the problem of timetable planning and vehicle and driver scheduling in public transport or freight logistics. Optimisation algorithms minimizing the number of vehicles or labour cost form the core of this model type.

A third type of models applies time discrete simulation techniques to model the travel behaviour of people or the flow of vehicles typically on a microscopic level. With increasing computer performance microscopic simulation models have become very popular during the last 10 to 15 years especially for simulating vehicular traffic flows at intersections and ramps. They allow to evaluate traffic actuated signal control strategies or other measures to dynamically influence vehicle flows.

The paper looks at the current state of development in transportation modelling and tries to identify future developments which are either likely or desirable. It focuses on

- *data models* describing the structure of the data used by transportation models,
- *surveying techniques* to collect travel demand and supply data which are used as input for transportation models,

- *impact models* like traffic assignment or vehicle flow simulation which allow to analyse and evaluate the cause-impact mechanisms within a transport system, and on
- the *user interface* which provides the possible interactions between model-user and transportation model.

The prospects of transportation modelling expressed in the following sections result from the author's personal experience in transportation modelling. Therefore the paper can only present the limited view of a single person.

2 Data Models

Depending on the area of application particular data models are employed. Strategical planning, operational planning, traffic control and traveller information look at the supply and demand data in various levels of detail. At the same time private and public transport show specific characteristics which need to be considered:

- For a simple *static network analysis* in private transport it is sufficient to model nodes, links, turnings, and traffic zones.
- A *multimodal network analysis* requires additional network objects for public transport like stops and public transport lines with their timetable.
- A *dynamic, i.e. time dependent network analysis* needs a time axis to describe that travel demand, travel time, and service frequency may vary over time.
- *Microscopic traffic flow models* simulating the flow of individual vehicles and the control logic of traffic signals require a more detailed description of the road network on the level of individual lanes. At intersections it is necessary to describe the intersection topology (number of incoming and outgoing lanes and lane pockets), the intersection geometry (length of lane pockets, radius), and the control logic.
- *Operational planning* and *automatic vehicle location systems (AVL)* in public transport do not only look at the location of a stop but also require information on the individual stop points (bus bays, platforms) of each stop for each direction.
- *Traveller information system* providing information on routes for private transport and on connections for public transport additionally need address data and Points of Interest (POI), which travellers can specify as origin and destination of a journey or which provide supplementary information on sights, hotels, or other services.

Table 1 gives an overview on the scope of data considered by a variety of program systems applied for transport planning and operation. Current and future developments should aim at providing more compatible and scaleable data models. Planning authorities, public transport operators, and the operators of the traffic management centre should be put into a position where they can derive their data model from a common network model. Using the same network topology as a basis a more seamless process from long-term strategic planning to short-term operational planning seems to be possible. To achieve this

- model-developers need
 - to cooperate and make their data model public,
 - to revise and probably extend their model,
 - to provide systems which are truly multi-user systems.
- model-users from different backgrounds (planning or operation, private or public transport) need
 - to cooperate and define responsibilities for certain data areas,
 - to invest in compatible models,
 - to show the necessary discipline to maintain the common basis of the model, for example unique identifiers of road links.

The last decade has seen successful approaches like the Geographic Data File (GDF) format [7] which has set standards by developing an appropriate model and by marketing the model, i.e. by providing essential data. Other approaches like the German Model for Public Transport (ÖPNV-Datenmodell) [18] or the European TRANSMODEL [17] have been less successful. The paper “Data Management System for Transport Planning, Traveller Information and Traffic Control” [9] presented at this conference suggests a comprehensive data management system which provides some essential prerequisites for more compatible and scalable data models.

	Geographic information systems (GIS)	Strategic transportation models	Microscopic traffic flow models	Timetabling and crew scheduling systems	AVL systems	Timetable information systems	Routing systems
Demand data	□	■	■	□	□	□	□
Network topology	■	■	■	■	■	■	■
Lanes	□	■	■	□	□	□	□
Stops	■	■	■	■	■	■	□
Stop points	□	□	■	■	■	■	□
Depots	□	□	□	■	■	■	□
Zones	■	■	■	□	□	□	□
Line routes	■	■	■	■	■	■	□
Timetables	□	■	■	■	■	■	□
Operating days	□	□	□	■	■	■	□
Line blocks	□	■	□	■	■	□	□
Driver duty plans	□	□	□	■	■	□	□
Beacons	□	□	■	■	■	□	□
Traffic detectors	□	□	■	□	□	□	□
Traffic lights	□	■	■	□	■	□	□
Adresses	□	□	□	□	□	■	■
POI	□	■	□	□	□	■	■
□ not modelled ■ simplified model ■ detailed model							

Table 1: Scope of data in different systems for planning and operation of transport.

3 Surveying of Supply and Demand Data

Until now conventional household surveys, workplace surveys, or passenger surveys remain the dominant source of information on the actual travel behaviour of people. Travellers are asked to name purpose, destination, mode, and other characteristics of their journeys. Because of the high costs such surveys can cover only a sample of the population and may only be repeated occasionally. Combined with land use data and road side measurements the results of the surveys form the main input for transportation models which describe the process of trip generation, destination choice, mode choice, route choice, and the movement along the route. Research has developed new survey methods (e.g. stated preference) and new survey techniques (e.g. computer-aided interviews). Survey methods which apply GPS devices or mobile phones (e.g. TeleTravel-System TTS [12]) still need to recruit the participants of the survey.

Floating Car Data (FCD) and Floating Phone Data (FPD) from mobile phones may provide a new source for a comprehensive and continuous monitoring of travel behaviour and supply quality. If data from mobile phones and extended map matching methods succeed to identify mobile and immobile persons, to recognize the mode of transport, and to reconstruct at least the core elements of the routes from origin to destination it will be possible

- to gain a better understanding of route choice in the context of the current traffic situation,
- to continuously observe travel times in the network as one major indicator for service quality,
- to generate more reliable trip tables by mode, type of day, and time of day,
- to evaluate the impacts of specific traffic control measures on the traffic flow,
- to gain knowledge on the user acceptance of telematic applications.

Travel time measurements from Floating Car Data on the level of road links will provide a better source for calibrating network models with time dependent values for speed of links and intersection delays. Floating taxi data [6] may become an accessible source for such measurements in urban networks.

Additionally existing sources of geo-data like topographic maps, (e.g. ATKIS), land holding maps, aerial photos, and contour points gained from remote sensing can be combined with digital transport networks and exploited to a greater extent. This may provide supplementary information on land use pattern, building density, building volumes and road side characteristics (residential, commercial, green space).

4 Traffic Assignment and Travel Forecasting Models

Traffic assignment for private transport is probably the most frequently used method in transport planning. It models the route choice behaviour of car users in congested networks and produces as main result volumes and travel times on links. Assignment methods for private transport are described and analyzed in a great number of publications. Most prominent assignment methods are the deterministic user equilibrium (Wardrop's first principle [19]) and the stochastic user equilibrium (see for example

CASCETTA [5]). Although traffic assignment is a well known method a variety of issues remain for future research:

- *Quality of routes*: Assignment methods for the deterministic user equilibrium provide a unique solution for link volumes. However, they do not provide unique routes. As shown in Figure 1 several routes and route volumes can fulfil the requirements of the deterministic user equilibrium. Therefore all post-assignment procedures relying on route volumes (matrix estimation, selected link analysis, intersection analysis) are based on assumptions about the actual route volumes. Stochastic user equilibrium explicitly calculates a choice set of routes, but here little is actually known about the number of alternative routes travellers really include in their choice.

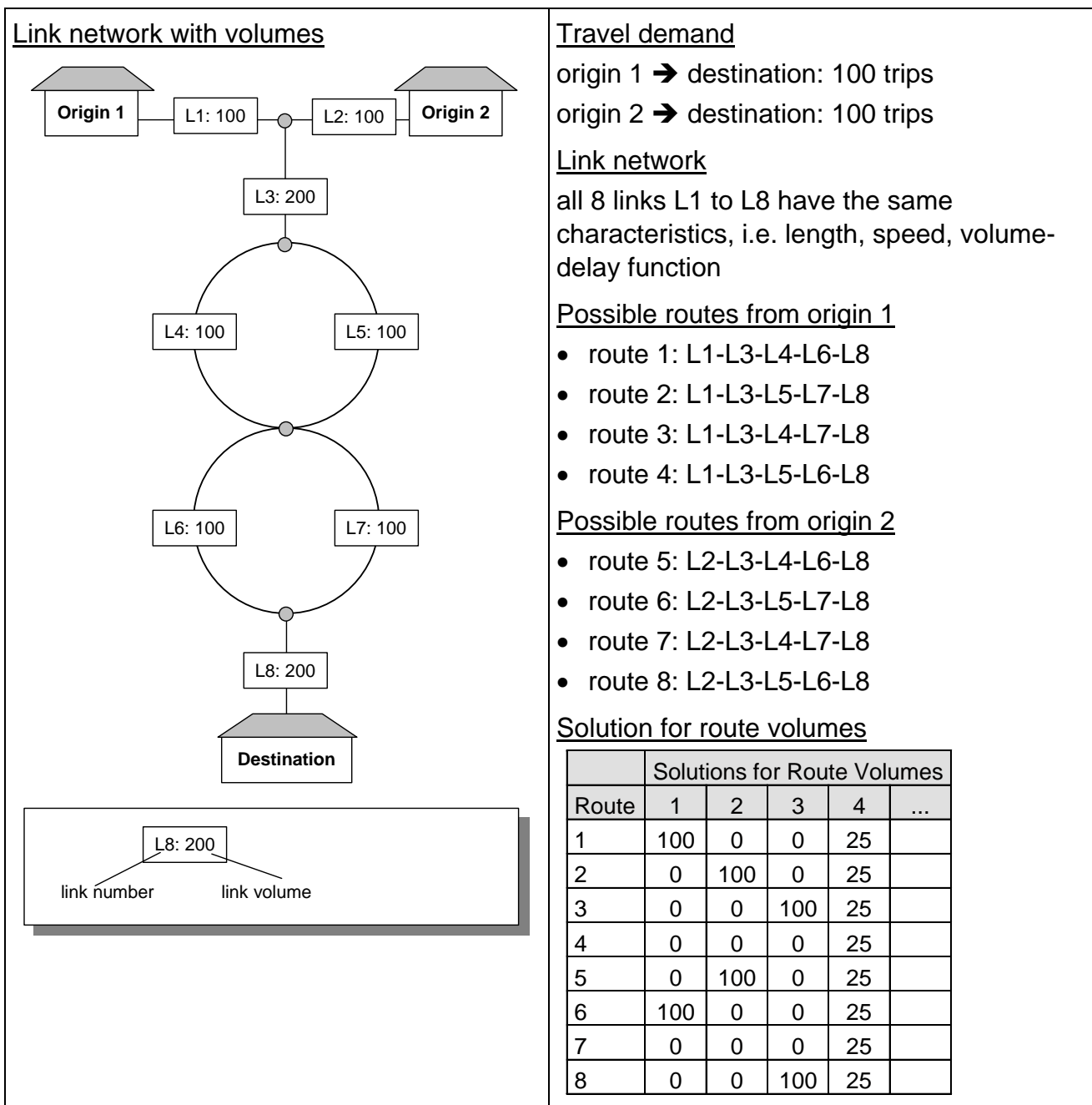


Figure 1: Example network with unique link volumes in user equilibrium (left). For route volumes several solutions fulfil the condition of user equilibrium (right).

- *Level of convergence:* Experience of transport planners and comprehensive work by BOYCE [4] shows that minor changes in the network (with / without scenario) may lead to changes of link volumes in the entire network. Studies by BOYCE confirm that a better stability of volumes does require better convergence. A convenient level of convergence requires more computing time or improved algorithms, for example the origin-based user equilibrium by BAR-GERA [1].
- *Intersection modelling:* For a more realistic route choice in urban areas it is necessary to appropriately model delays at intersections. Delays for turning movements can be incorporated into the standard assignment procedures, assuming that the delay only depends on the volume and a constant capacity of the turning. However, if the capacity of a turning is influenced by conflicting traffic streams, the convergence of the procedures is not guaranteed. So far little practical experience exists on the performance of traffic assignment including models of intersection control.
- *Dynamic assignment:* Dynamic traffic assignment for private transport has reached a state which would permit a wider application in daily practice to model route choice and congestion within the course of a day. Various formulations have been developed in the literature varying in the type of choice model (stochastic, deterministic, with/without departure time choice) and the traffic flow model (capacity restraint [15], macroscopic [2], microscopic [3]). At the same time at least in Germany there is a lack of practical experience so that no reliable information concerning the quality and the robustness of the models is available.
- *Public transport and intermodal assignment:* Assignment procedures for a public transport network need to reflect the constraints imposed by line routes and timetables. Existing approaches for transit assignment can be divided into two categories: Headway-based assignment (e.g. [16]) is a static assignment which simplifies the search by using average values for the transfer time. Schedule-based assignment (e.g. [10]) is a dynamic assignment as it considers the timetable of each transit line with its exact departure and arrival times. Future developments need to address shortcomings of these approaches with respect to intermodality and capacity restraints. Intermodal assignment should consider constraints imposed by the availability of the private transport vehicle, i.e. a car should only be used for the home-based part of a journey and travellers should pick their vehicle up on the return journey. Modelling capacity restraint in public transport needs to consider that passengers on long distance services may be able to reserve seats and that certain price segments have limited availability. In urban networks crowding can force passengers to wait for the next vehicle of the same line or to consider alternative routes.

Potential developments of travel forecasting models which estimate the future travel demand may result in various improvements:

- *Feedback of assignment and travel demand:* Transportation models including a feedback loop between demand and supply are still rather the exception than the rule. Software packages and good practice examples need to support the practitioner to integrate the feedback loop more easily.
- *Activity chain models:* Models which derive the travel demand from activity chains provide a transparent approach for demand modelling as the idea is easy to

understand. Unfortunately the available implementations (e.g. VISEM [8]) do not consider constraints concerning attraction sums of traffic zones like in doubly constrained trip distribution models. Also the concept of trip chains ends before the assignment, when trip chains are aggregated to trip tables. As these shortcomings result primarily from computational limitations, it should be possible to improve models based on activity chains.

- *Commercial traffic:* Since commercial traffic is responsible for a growing share of the transport volumes and the road delays, travel demand models need to explicitly consider freight transport and work related trips. This is equally important for urban/regional models with a focus on vehicle tours and for national models with a focus on mode choice between unimodal and intermodal routes.

5 Microscopic Simulation

With increasing performance of Personal Computers microscopic simulation has become a regular tool for transportation planners and traffic engineers in the 1990ties. Especially microscopic vehicle flow simulations are by now widely applied to analyse traffic flows at intersections and to develop traffic actuated signal control measures including public transport priority. Larger scale microscopic models like TRANSIMS (TRANSPORTATION ANALYSIS and SIMULATION SYSTEM) developed at the US National Laboratory at Los Alamos (see NAGEL and RICKERT [13]) intend to simulate the entire process of passenger travel in a city or region. TRANSIMS for example applies micro-simulation techniques for the generation of households, persons and person activities, for mode and route choice and finally for the traffic flow.

As progress in computer performance continues microscopic approaches will increase. This leads to fundamental questions as “Will micro-simulation take over?” or “How much micro-simulation do we need?”

As microscopic approaches directly model real world objects with their characteristics (e.g. a car, a driver, a household) and their interaction they generate high resolution results. For example, a queue of vehicles at an intersection is a generic result of a micro-simulator which is rather complicated to describe in similar detail with macroscopic approaches. As a consequence it is relatively easy to extend microscopic simulations to include complex dependencies or behaviour, like

- household interaction (e.g. bringing kids to school),
- trip chains (e.g. picking up the car at the same park&ride terminal on the return journey),
- reliability of timetables in public transport (e.g. delays of a service due to late arrival of the vehicle from the preceding service trip at the terminal),
- traffic control (e.g. reaction of travellers to certain control measures or impacts of car to car ad hoc networks).

Main disadvantages of microscopic approaches concern

- the amount of data required for feeding a model,
- the necessity to repeating the simulations several times for producing average values,

- consideration of constraints which are only known as aggregated values (e.g. number of work places in a zone or link counts),
- the calibration process as the number of model parameters is very high.

Considering the advantages and disadvantages it seems to be desirable to improve and apply microscopic simulation for dynamic systems where a high level of detail is required. Besides household interaction and trips chaining this is the case for analysing control measures in AVL systems, for looking at park search traffic, or for evaluating telematic applications. Whenever large networks are considered and long term impacts of measures are to be estimated the application of microscopic approaches should be considered carefully as aggregated models may deliver more reasonable results.

In all cases it is desirable to develop microscopic and macroscopic approaches so that they build on the same assumptions concerning the decision making of travellers. For example a dynamic assignment should share the methods for route search and for calculating the share of each route, but may apply traffic flow models of different detail.

6 User Interface and e-Planning

Central task of the planning process is the development of new solutions. Although new solutions may be generated through optimisation algorithms, most solutions are still developed using the planner's creativity and experience, since the complex interdependencies within a transport system can often not be described appropriately through an objective function. Therefore practitioners spend a remarkable amount of their time modifying the network data, analysing the results, and identifying deficiencies. On an extreme level one may argue that as long as a planner prefers to take a pen and a sheet of paper in order to develop the first draft of a public transport network or decides to develop his or her own spreadsheet for storing spatial data (e.g. road link counts, passenger counts, or detector locations), the graphical user interface (GUI) of the software needs to be enhanced.

User interfaces have improved dramatically during the 1990ties. Most of the DOS-based software systems providing only text based input and output capabilities or basic network editors are now replaced by more comfortable window-based user interfaces. At the same time the software packages support better transfer of data to standardized formats like spreadsheets, relational databases or geographic information systems.

Future user interfaces should ideally fulfil several requirements:

- *Data handling*: The user interface should provide efficient ways to modify, analyse, and evaluate transport related data. This may include means for multi-select operation, undo functionality, and easy to use graphical views, or tabular reports.
- *Expert mode*: As the data models and impact models will become more complex by including a growing number of specific features for certain user groups the GUI needs to hide irrelevant functionality. Additional functionality could only be visible as option in distinct expert modes. For strategical planning purposes a simple network model

consisting of nodes, links, and public transport line routes with headways may suffice. Operation planning requires additional data describing the transport supply in more detail. Operational planning in public transport for example needs to include the timetable, operating days, depots, and vehicles. Similarly planning of intersection control requires specific information on the intersection topology and the control system.

- *Scenario management:* To support the planner in developing, analysing and comparing various scenarios the GUI and the data model should provide means for an integrated scenario management. Such a scenario management might be based on the idea of a master network, where the attributes of each network object, e.g. link capacity or speed may vary for each scenario.

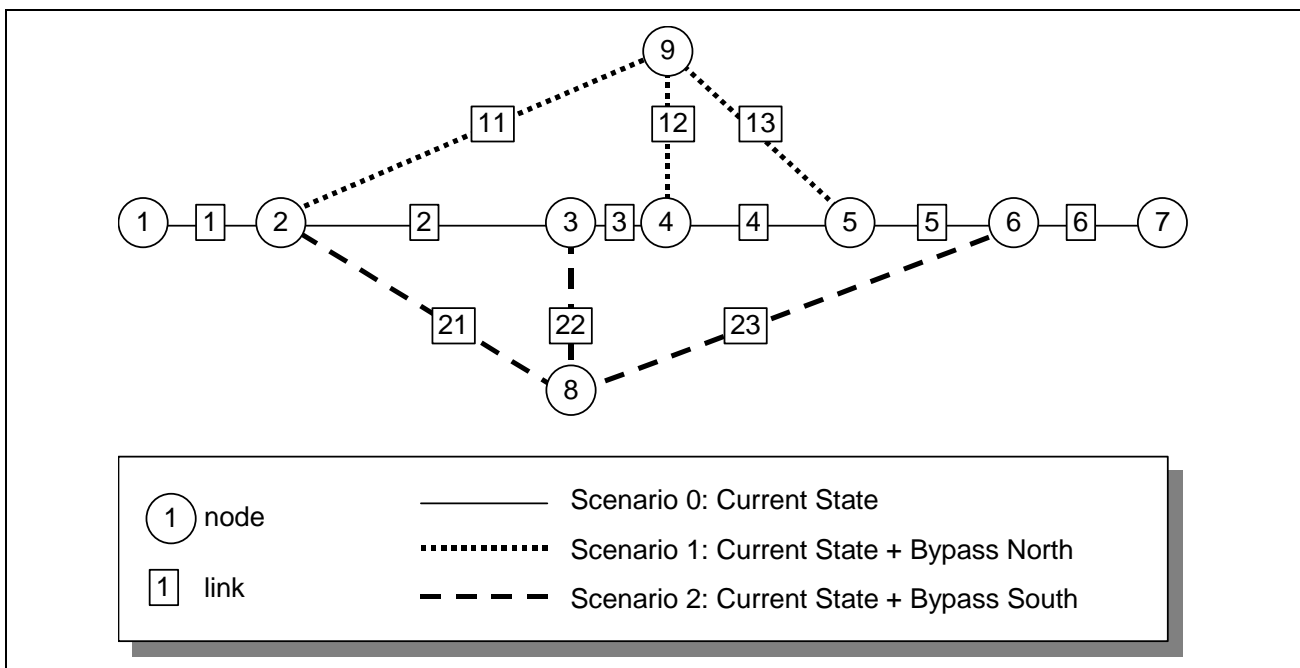


Figure 2: Example of a master network with 2 scenarios.

- *Integration of GIS:* Geographic Information Systems provide a general tool for visualising spatial data. They are employed in various areas ranging from environmental planning to planning of the electricity supply. The author believes that GIS will not replace transportation models in the next decade. Planning and controlling transport networks requires very specific data objects which are difficult to include into a GIS framework. While node and link objects might be described easily in a GIS, objects like turnings, public transport timetables, or trip tables are hard to integrate to a GIS. To guarantee a high quality data transfer between neighbouring disciplines (land-use planning, environmental planning, transportation planning) integration of GIS tools should be improved, for example by using a common data base for certain objects like traffic zones.

As transportation models tend to be rather complex, only experts can build, calibrate, and operate these models. To integrate less experienced users in the planning process specific views or reports could be provided through the Internet. Such an approach for e-Planning would give users on the management or political level access to certain types of results. Without knowledge of the actual transportation planning software they could

retrieve information concerning for example traffic counts or impacts of infrastructure measures. Figure 3 shows a first approach to e-Planning by connecting a transportation model to the Internet (see HAUPT [11]).

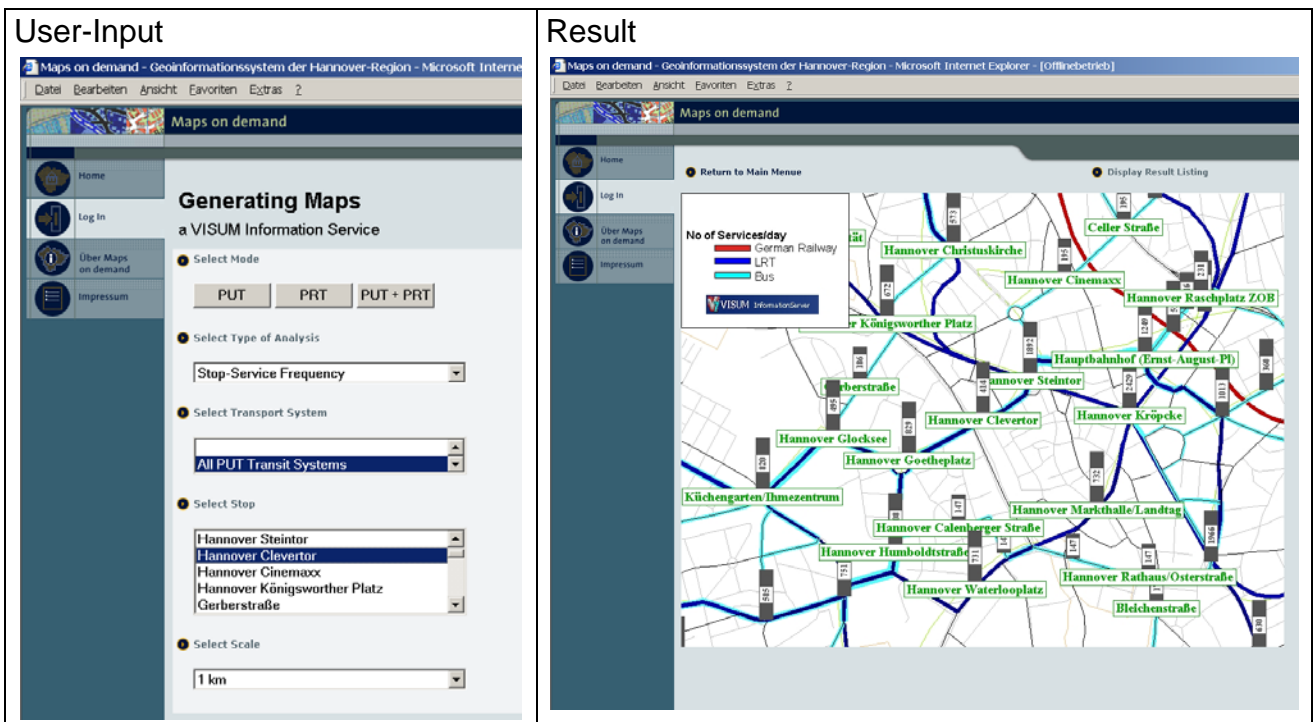


Figure 3: Screenshot of an interactive network analysis provided on the Internet.

7 Outlook

The paper intended to give a fairly personal view of future developments in transportation modelling. From the author's experience the following major shortcomings should be primarily addressed in the future:

- *Feedback between planning and operation:* Offline transportation planning and online operation of the transport infrastructure are separated processes with little feedback. Measurements collected in the daily operation provide valuable information on travel time, vehicle speed, and traffic volumes. The effort for continuously transferring the measured values back to the planning level is high as the data models are not compatible. As a consequence planning is not a continuous process but remains a distinct event triggered by observed or assumed deficiencies.
- *Survey quality and costs:* Collecting transport related data on travel behaviour, travel demand, and the transport infrastructure is an expensive task. As a consequence travel surveys are only affordable for certain points in time. If new sources like floating car data, floating phone data, or data from electronic ticketing can be exploited for planning purposes, this would significantly improve the quality of transport related data in terms of actuality and completeness.

- *Impacts of measures:* Impact models form the core of all transportation models as they forecast the impacts of proposed measures thus providing the basis for decision making. Nevertheless little is known about the quality of the results, if a infrastructure or control measure is actually implemented. Parameters required by the models often come from experience of the model-user or are simply default values of a software package. Post implementation surveys or better a continuous monitoring of travel demand and service quality could help to verify and improve impact models and model parameters.
- *Optimisation methods:* Until now transportation models primarily focused on a detailed description of travel behaviour and the impacts on the transport network or the environment. Consequently impact models (travel demand calculation, traffic assignment, vehicle flow simulation, emission of pollutants, etc.) are the central part of most transportation models. With some exceptions in the field of timetable-building, driver and vehicle scheduling, traffic signal setting or parameter estimation, methods from Operation Research are not yet applied comprehensively to transport related problems.

Besides these technical issues the matter of education should be considered equally. Complex models require well educated and experienced users. Software can only assist the transportation planner or traffic engineer. The development of solutions and the final evaluation remains in the responsibility of man. To achieve a transparent planning process and an efficient operation of transport networks we need reliable models properly implemented in software and modellers who can not just operate the software but also convey the results to non-engineers.

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