BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
FACULTY OF TRANSPORTATION ENGINEERING
DEPARTMENT OF TRANSPORT TECHNOLOGY

DEVELOPMENT OF TRAFFIC MODELS ON THE BASIS OF PASSENGER DEMAND SURVEYS

Thesis of the PhD dissertation

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CURRICULUM VITAE

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Education

Budapest University of Technology, Faculty of Transportation Engineering, 1989-1994, MSc. Transport Engineer

Budapest University of Technology, Faculty of Natural and Social Sciences, 1991-1995, MSc. Technical Teacher

Language and degree of proficiency

Hungarian (mother tongue), English (good), German (good)

Other training

1993. Pan European Joint Project, Germany
1994. Pan European Joint Project, France
1995. Advanced Traffic Forecasting Course, PHARE, Hungary
1997. Operations Research and Decision Aid Methodologies in Traffic and Transportation Management, NATO Advanced Study Institute, Hungary
2002. ESRI Internet Technology, ESRI Hungary
2003. Programming with Microsoft Visual Basic .NET (2373), NetAcademia
2003. "Grundlagen der Verkehrsplanung für Praktiker und Entscheidungsträger", Institute für Verkehrsplanung und Verkehrstechnik der TU WIEN, Österreich
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Membership of professional societies

Member of the Hungarian Scientific Association for Transport
Qualified Member of the Hungarian Chamber of Engineers
KÉ-Sz: Expert in Civil Engineering
KÖ-Sz: Expert in Transportation Engineering
KÖ-T: Category A designer in Transportation Engineering

Professional record

Involvement in EU RTD programmes

I was involved in 12 *EU RTD programmes* of which the followings are the most relevant regarding the topics of the thesis:

- EUROPRICE: Energy Efficiency of Urban Road Pricing Investigation in Capitals of Europe (DG VII, 1997-1999)
- IASON: Integrated Assessment of Spatial Economic and Network Effects of Transport Investments and Policies (DG TREN 2000-2003)
- TREMOVE: EU-wide policy assessment transport model (DG ENV 2002)
- MOTOS Transport Modelling: Towards Operational Standards in Europe (DG TREN 2006-2007)

List of Domestic Reference Works

I was involved in some 100 domestic projects in the field of transportation planning of which the followings have a direct connection to the thesis:

- Concept of the geographic information system for regional transport (with TÉRKÉPTÁR Ltd.), for the Budapest Transport Association, 2007
- Foundation of the traffic surreys of Budapest and the agglomeration, for the Municipality of Budapest, 2006
- Feasibility study of the on-line passenger information system to the area of the Budapest Transport Association (with CData Ltd.), for the Budapest Transport Association, 2006
- Plan for the rationalization of the public transport network in Miskolc, for the Public Transport Company of Miskolc, 2006
- Development concept of the public transport system in Miskolc, for the Public Transport Company of Miskolc, 2006
- Development of a PT-tailored GIS, for Budapest Transport Co., 2005
- Analysis of the survey of travelling habits of households in Budapest and the surrounding settlements, for Budapest Transport Co., 2005
- Development plan of the public transport network of Miskolc, for the Public Transport Company of Miskolc, 2005
- Survey of travelling habits of households in Budapest and the surrounding settlements, Final Report, for the Budapest Transport Co., 2004
- Contribution to the development of the software for the BKV traffic survey, for CData Bt, 2004
- Development possibilities of the urban- and regional transport modelling systems from the point of view of the determination of the travelling-flows of the Budapest Transport Association, for Ministry of Economy and Transport, 2004
- The unification of the urban and regional timetable structures for the forthcoming transport associations, in light of the needs of network planning, managing and information systems, for Ministry of Economy and Transport, 2003
- Investigation of the passenger transport network of Szeged (with Dunabit), for the Municipality of Szeged, 2000
- Investigation of the acceptance and social patronage of different transport modes, for the Municipality of Budapest, 2000
- Travelling habits and views on transport system of the citizens in Budapest, for the Municipality of Budapest, 2000

PRELIMINARIES OF THE RESEARCH

The planning of transport, as a service satisfying the passenger and freight transport needs in connection with the social-economic activities, is the subject of continuous improvement since the goal is that "our transportation systems should meet the economic, social and environment requirements of our society" require more and more efforts and more complex improvement measures than before.

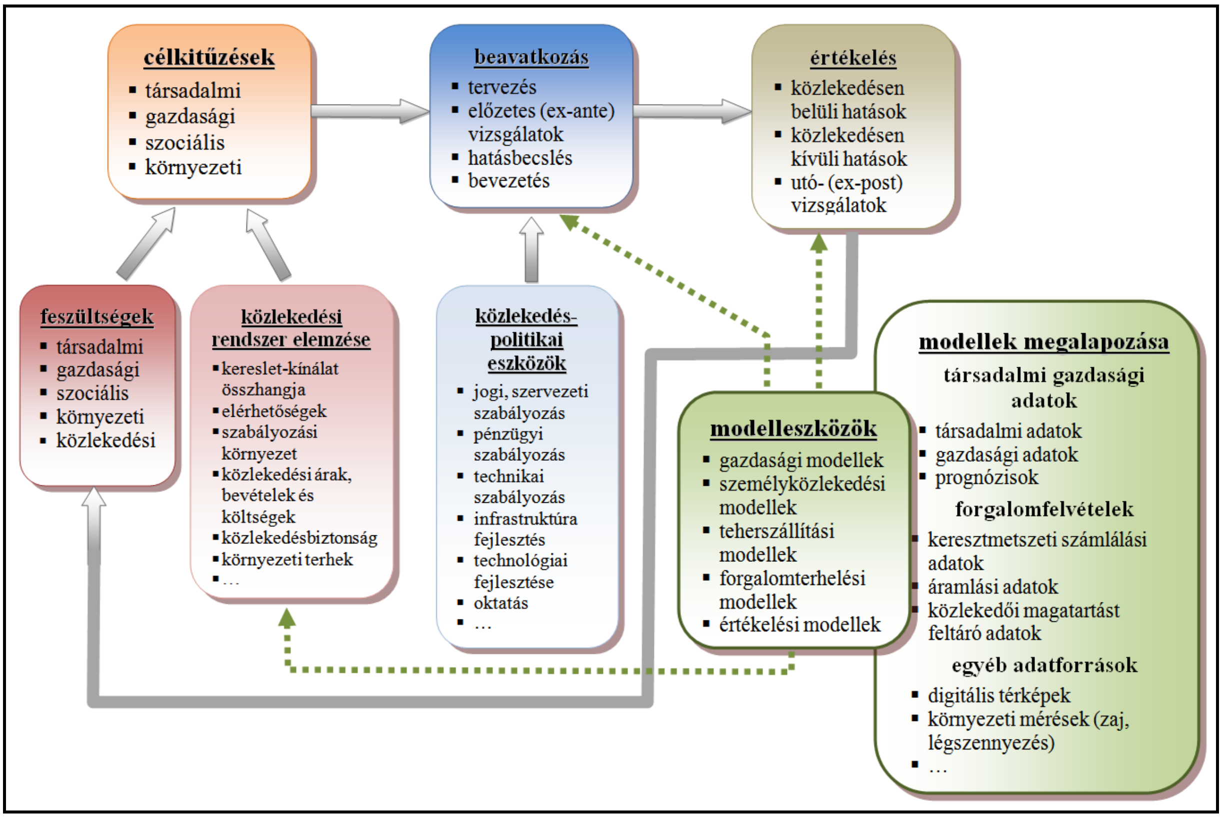

Figure 1: The Position and Role of Transport Models in Policy Making

Figure 1 shows the position and role of transport models in policy making (own figure based on Monigl and MOTOS project). It clarifies that the goals of transport policy are derived from the transport related tensions and the analysis of the transport system.

There are a number of possible transport policy measures to mitigate the harmful impacts of transport problems. The usage of these measures is highly dependent on the policy goals and circumstances. To fulfil the policy requirements a number of measures are available (e.g. infrastructure development – accessibility improvement, changing of user costs) but a package of comparative measures (e.g. a bypass road and traffic calming measures in the central area) could be used as well.

The modelling is qualified to forecast the transport demand and the impacts of measures made to improve the actual situation. Modelling contributes to the preparation of financially supportable (either from EU or domestic funds) successful projects by supplying the input indicators to the cost-benefit and use-value analysis. The former models were not capable of reliably forecasting the impacts of measures of new nature. The new information technology achievements – which enable the collection of large and even more detailed transport data reality – should be utilised in the modelling context. It follows that there is an increasing need for the development and usage of transport models.

The development of a transport model begins with the observations of the environment and data collection. It helps to describe real systems with mathematical equations and models to understand the internal and external impacts of transport. It makes it possible to forecast and evaluate the potential impacts of the proposed measures.

Technological development – to be specific e.g. the satellite based positioning systems, the digital maps, GIS, the computer assisted transport data recording – makes it possible to investigate the causes of the transport demand and the decisions of transport system users and the incorporation of these data in the methodology of transport and impact modelling.

The International and National Researches on the Subject

Household Surveys to Lay the Foundation of Transport Behaviour Researches

Household surveys are of prime importance in the research of transport behaviour factors. They were already carried out in Hungary in the sixties and seventies. The following ones should be mentioned in this context:

- Household surveys in 10 rural cities and in Budapest in 1970's – a brief is given by Monigl in the Handbook of City Transport.
- There are household surveys in Budapest with a 10 year schedule; done in the years 1973/74, 1983/84, 1992/1994 and 2004. The earlier ones were led by Bényei, Monigl, Szegő on behalf of METRÓBER, the later ones were governed by Monigl and his colleagues (Nagy, Berki) and the field work has been directed by Közlekedés Ltd. (Várady, Szegő, Dobrocsi, Dávid).
- A nationwide survey was conducted with the leadership of Institute of Transport Sciences (KTI), namely Vörös and Albert.
- The outskirts of Budapest were surveyed in the years of 1996, 2004 and 2007, typically using a smaller sample.
- Recently there were surveys in other Hungarian cities, above all in Győr, Miskolc, Sopron, Szeged, Debrecen, and Vác.

The surveys of TU Dresden (Böhme) and Socialdata (Brög) should be nominated among the foreign surveys.

Computerised Household Surveys to Record Transport Behaviour Indicators

Computers were launched in the beginning of the nineties to record transport behaviour indicators. The benefits were summarised in the publications of Saris, de Leeuw and Nicholls.

Among the works and publications of researchers, primarily the following present the most important stages of developments:

- Methodological papers of Couper and Burt in 1994,
- Paper on programming issues of Connett in 1996,
- Report on British Household Panel Survey in 1999, by Banks and Laurie,
- Article of Wachs on probable development trends in 1999-ben,
- Publications of Wolf on data collection methods,
- The CHASE programme developed by Doherty and Miller in 2000; this was further developed by Lee, Doherty, Sabetiashraf and McNally.

The following bullet points show the key researches in the roadmap of GIS usage:

- Abdel-Aty–Kitamura–Jovanis in 1995 carried at research on the routing decisions by using GIS.

- Lawton and Pas investigated the impacts of transport management measures by applying GIS based tools and analysis.
- Kreitz investigated the possible solutions to incorporate spatial datasets into the surveys and transport models.

Kövesné-Havas-Debreczeni-Tóth-Mándoki made scientific investigations on computerised surveys in the Department of Transport Technology, Faculty of Transportation Engineering, Budapest University of Technology And Economics (BME). In the field of transport informatics the work of Tóth J. and Csiszár are remarkable. In connection with the large computerised household survey of Budapest Transport Co. Berki published a paper in 2005.

Transport Modelling

Transport modelling has its root in the middle of the 20th century. The classical four-step approach based models were based on the analogies of physical laws (like gravity and Kirchoff model). The discrete choice models were developed in the United States on the basis of econometric theories.

The key scientist working on the development of discrete choice models are Domencich and McFadden but the research of Ben-Akiva, Hensher, Axhausen, Bierlaire, Manski, Spear, Train, Brög, Dagazano, Daly, Mäcke and Mahmassani are also remarkable.

The stated preference based models primarily connected to the works and publications of McFadden, Hensher, Bradley, Train, Wilson, Ben-Akiva, Lerman and Morikawa.

Among the national model developments the most prominents are:

- the self developed assignment method of Nagy at UVATERV;
- the investigations of Bakó-Kálmán-Koren Cs.-Marton-Pusztai in the Széchenyi István University who developed the NETWINFO road traffic model;
- the researches of Monigl, Vásárhelyi, Scherr, Ujhelyi, Koren T. in the Institute of Transport Sciences who developed an analytic traffic forecasting method;
- in the Institute of Transport Sciences Monigl led the work to develop a multi-modal transport modelling system called KOMPLEX on the basis of large scale household surveys, while the development TRANSZKOMPLEX freight model is connected to research of VÖRÖS;
- Monigl, Koren T., Ujhelyi, Nagy and Berki developed a multi-modal demand and assignment model system including private and public motorised transport.

The key researches from the point of view of the thesis in the Budapest University of Technology And Economics:

- in the Department of Transport Technology, Faculty of Transportation Engineering Kövesné, Tóth, Debreczeni and Mándoki investigate the effects of globalisation on transport modelling;
- in the Department of Control and Transport Automation, Faculty of Transportation Engineering the research works of Varga and Bokor should be mentioned on the field of road transport and simulation;
- in the Department of Highway and Railway Engineering, Faculty of Civil Engineering Fi and colleagues are dealing with road transport modelling.

The drivers of discrete choices are investigated by Koren Cs., Pálfalvi, Sándor, Tánczos and Török. However the usage of discrete choice theory in transport modelling is primarily connected to the scientific work of Monigl and his colleagues (Berki-Koren T.-Nagy-Ujhelyi).

Besides the university research national professionals working for consultancies contributed to the development of modelling practice. The key companies dealing with transport modelling are TRANSMAN, KÖZLEKEDÉS, Bauconsult, COWI, FŐMTERV, KTI, KVANTITÁS, UVATERV, ProUrbe and Terra Studio

The Evaluation Models of Transport Policy Measures

In the field of transport the cost-benefit analysis is commonly used in the comparison of indicators that can be expressed in monetary terms while multicriteria analysis is used for the indicators in natural terms.

In the sixties Berg developed a cost-benefit analysis method to investigate road infrastructure developments.

The methods incorporating the network based approach were developed by UVATERV and KTI. The research has been made by Faludy, Koren Cs., Koren T., Monigl and Scherr primarily.

The developments of evaluation methods using quality indicators are mainly published by Mrs. Köves following the research made by Turanyi. Debreczeni, Mándoki and Tóth J. contribute to these achievements.

The most well-known researches of this field are led by Mrs. Tánczos at the Department of Transport Economics of BME. A key result of these improvements is INNOFINance a financial planning and evaluation model which is used in a number of large national projects.

Prileszky built up an evaluation method for the complex evaluation of public transport developments in the Széchenyi István University.

OBJECTIVES OF THE THESIS

Transport model is of prime importance in transport planning and impact evaluations. Therefore the quality of transport models – the capability of the models to describe the passenger transport sub-processes of real transport actions, and to minimise the gap between the observed and calculated values – is a key factor that determines the investigation of transport policy measures. Therefore the focus of my research was on transport model development and on the utilisation of the achievements (see Figure 2).

Transport models are based on observed data. Thus the key questions are:

- How could we define the type of the survey that fits the goals of the investigation?
- How could we increase the quantity, quality, and the richness in detail of the data?
- How could we minimise the time, and cost resources needed?
- How could we improve the data mining and analyses?
- How could we disseminate the results in an efficient and digestible way?

The former state-of-modelling practice was to build uni-modal traffic models while the mode choice impacts were estimated in an empirical way.

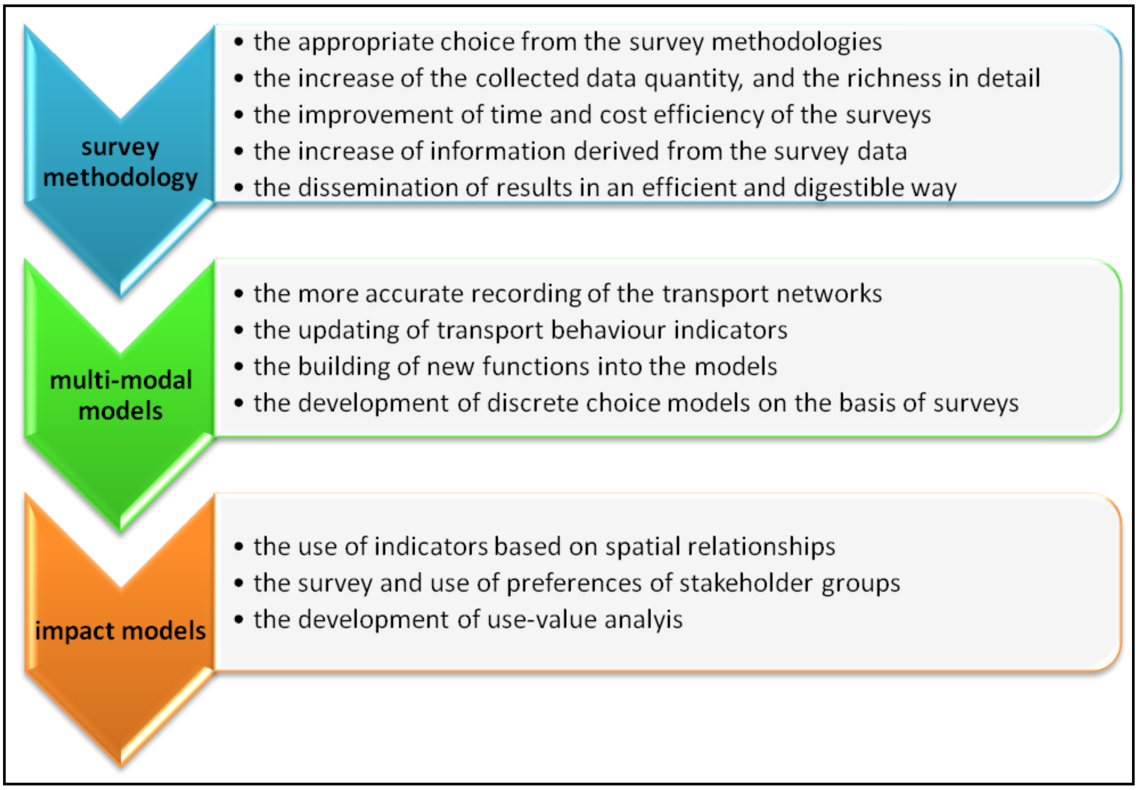

Figure 2: Objectives of the Thesis

The subject of my research is multi-modal models or more precisely the investigation of the mode choice models to improve their capability of following the real decision processes and also to gain more acceptability for them. To reach these objectives I investigated the advantages and benefits of discrete choice models and the usage of discrete choice theory in transport modelling. The goals of these objectives anticipated the need to use the achieved results also in the evaluation models. The improvement of evaluation models could be promoted via traditional indicators but some achievements generate new indicators and a minor development in the evaluation methods.

METHODOLOGICAL BACKGROUND

There is a wide range of scientific methods in the background of my research which were derived from the professional literature and project reports. The used methods are briefly:

- categorization and resource analysis in the development of household survey techniques,
- special quantitative scaling public-opinion poll to record the mode choice preferences of the daily commuters,
- computerised daily activity-travel diary method to collect travel behaviour data,
- geocoded recording of daily activity place, and travel addresses, stops to spatially bind trips with the network,
- a relational database management techniques based on a transport geodatabase for handling large databases,
- graph theory based descriptions, and methods to build a transport supply model,
- thematic maps and spatial relation based analysis to investigate the forms of connection between public transport accessibilities, and the key transport indicators of the household members,
- multi-dimensional category analysis to investigate the complex travelling habits,
- regression model to investigate the relation between monthly income, and daily trip rates (mobility),
- stated and revealed preference survey methods to determine the utility functions of discrete mode choice models,
- multinomial and nested logit model to forecast the transport mode shifts,
- independence (hypothesis-) tests to check the interdependence of the available public transport modes,
- sensitivity tests to forecast the effects of changing the values of the indicators used in the mode choice models in a predefined range,
- derivation the value-of-time of different user groups from the parameters of the utility functions,
- use-value analysis to qualify the effects of transport network developments and measures.

Some of the methods described above were developed by the achievements of my researches (like the computerised household and preference surveys). These developments are part of my thesis work since they contribute to a higher level of observation processes and to the robustness of my findings. They are also essential in the achievements of my other scientific thesis.

NEW SCIENTIFIC RESULTS

1. **I developed a new survey and data management method with a toolset to support individual travel behaviour analysis and setting up mathematical equations describing the travelling and mode choice habits by including the spatial relationship into the databases used. I demonstrated and proved the close relationship of transport demand and accessibility based on the usage of spatially enabled logical connections. With the help of this relationship the effects of transport policy measures influencing transport accessibilities could be calculated more transparently and accountably.**
    a. **I reached an improved quality, accountability level and a more detailed recording of trips by developing a computer assisted household data collection tool that ensures the recording of activity-travel diaries and trip chains including all facets and the geocoding of addresses and stops.**

I analysed the available household survey methods and manual interview capabilities and identified the prime improvement possibilities. In connection with the activity-travel diaries (chains) the key development areas were: recording of more trip details as before, swift and cost effective survey technology, integration with spatial and public transport network description data, capability for transparent analysis in many ways and a development of a new quality management method.

Considering the requirements I made a proposal on a computerised survey method that could fulfil the objectives with higher quality for less costs. I proved the stated advantages in real-life applications and the cost effectiveness was supported with resource accounting and the comparison of manual and computerised surveys. On the basis of my findings I designed and - with the help of professional programmers - developed a computer assisted household data collection tool called TRANSCAPI. It is able to deliver household data that fulfil the requirements in all facets. The software tool is able to filter the faked or spurious trip chains, to minimise the missing activities, to record the location data with sufficient accuracy and map reference and to identify the public transport routes and stops used. The database collected by using TRANSCAPI is able to support disaggregated (individual), spatially enabled analysis that were not possible ever before.

TRANSCAPI was used to collect activity-travel data in fifty thousand households on behalf of Budapest Transport Co. in 2004 covering Budapest and 24 neighbouring settlements and in nine thousand households located in the Central Region of Hungary for the Budapest Transport Association in autumn 2007.

Publications: [1], [3], [9].

b. **I developed a complex GIS based transport data management method. Applying these findings the analyses supporting transport modelling could be expanded in a spatially enabled way and the database could be used in both personal and multi-user environment.**

In the past data collected during the surveys were stored in separate databases and joining the demand and supply data should involve a number of transformations. The analyses were typically made by specialised software tools and sometimes led to inconsistent results too.

I demonstrated how to set up of a transport geodatabase by applying the achievements, the theoretical and practical findings and tools of spatial sciences. Such transport geodatabase directly or indirectly could be related to a database of a computerised household data collection tool or to transport demand and supply data and models. I presented the logical model of a geodatabase developed under my leadership which is capable to store and handle road and public transport supply data.

As a practical example I described the way how one could derive a network model from a stock of digital maps by presenting real application in Szeged, Budapest and Miskolc, and the geodatabase designed to meet the conditions and requirements of Budapest Transport Co. which latter one has a direct link to the household survey data collected by TRANSCAPI. The analyses based on such a geodatabase can be used as an input of new indicators for impact models and contribute to an improved evaluation of development scenarios, and policy measures.

Publications: [2], [7].

c. **I demonstrated and proved the close relationship of transport demand and accessibility based on the usage of spatially enabled logical connections. With the help of this relationship the effects of transport policy measures influencing transport accessibilities could be calculated more transparently and accountably.**

In 2004 the large household survey of Budapest Transport Co. was conducted with the TRANSCAPI software described in thesis 1/a. I build a transport geodatabase incorporating the recorded data and other related (spatial and tabular) databases by applying the theoretical findings of thesis 1/b.

On the basis of this geodatabase I analysed the relationship between public transport service availability and transport demand including mode choice preferences.

I examined the transport demand effect of metro services by comparing the travel behaviour indicators of areas differentiated by metro availability, since metro as a mean of public transport represents the highest standard. I demonstrated that the people living in the service area of the metro lines averagely make some 10% more trips daily and the public transport patronage rate is also higher by some 20% (see Table 1).

The proportions calculated in this way laid the foundation of a trip generation forecast by deriving a household location and trip relation specific generation matrix to model the potential public transport increase impacts of the new metro line 4. Becoming conscious of this relationship I was able to incorporate the multi-modal trip diverting effect in a uni-modal transport model which was used in the traffic forecast works of metro line 4.

Table 1: The Daily Trip Rates and Public Transport Patronage in The Service Area of the Existing Metro Lines and Outside

examined area	zones involved	daily trip rate	daily public transport trip rate	public transport patronage ratio
Vicinity of	0-400 m	2,45	1,28	52,1%
metro line M2	**400-800 m**	**2,34**	**1,20**	**51,1%**
Vicinity of	0-400 m	2,45	1,21	49,4%
metro line M3	**400-800 m**	**2,37**	**1,10**	**46,4%**
Vicinity of	0-400 m	2,43	1,22	50,3%
metro lines	**400-800 m**	**2,35**	**1,13**	**48,3%**
Metro available		2,39	1,16	48,8%
Metro is not available		**2,21**	**0,88**	**39,8%**
Budapest (total)		2,29	1,05	45,9%
The whole service area of BKV		2,25	0,94	41,8%

Publication: [9].

2. **I composed a questionnaire to study the mode choice preferences that wre used in professional practice as well. After processing the survey data I set up an econometric theory based mode choice model for the workers commuting to Budapest.**

To reliably estimate and forecast the probable mode choice changes caused by the planned infrastructure developments and other circumstances (like introduction a congestion charging regime) is one of the most important tasks of examinations based on transport modelling. The former studies include expert estimates on the basis of recorded trips and rarely used mathematical models for the calculations.

I composed a new type of questionnaire as a part of this thesis to study the mode choice preferences and built an econometric theory based mode choice model on the data recorded. The questionnaire is based on the stated preference technique and comments of involved colleagues and was used to make interviews among people commuting to Budapest. I proposed a card-set to conduct the preference survey which was prepared with partial factoral design. The following indicators' values were subject to change in the questions: journey time, travel costs, the frequency (schedule) of the available PT service, the number of transfers, parking conditions at the destination and the availability of P+R.

I set up a logit based mode choice model and determined the parameters of the independent variables for the area of the Budapest Transport Association using the categorisation of the people by living place and personal capabilities. The data were taken from a stated preference survey made in 2007.

The general definition of the logit function:

$$P_{k,i} = \frac{e^{U_{k,i}}}{\sum_j e^{U_{n,j}}} \text{, where}$$

$P_{k,i}$: the probability that decision maker k chooses alternative i,
$U_{k,i}$: the observed utility of decision maker k relating to alternative i.

I used the following explanatory variables in the utility function:

- journey time (T) (minute),
- travel costs (K) (HUF),
- service level (S) (without dimension).

The linear equation of U utility function can be defined as follows:

$$U_{k,i}(0/1) = a \cdot T_{k,i} + b \cdot K_{k,i} + c \cdot S_{k,i} + d_m \text{, where}$$

a, ,b, c: parameters of the independent variables,
d_m: mode specific constant.

Service level is a composite term including the number of boardings and the schedule time of services at public transport and the parking costs and parking lot searching time at individual car transport.

Based on the logit model I calculated the value of travellers' travel time commuting to Budapest and I made a sensitivity analysis regarding the mode choice.

The differentiated travel time calculation by user groups led to the consequence that people having a car among available modes time is a 6.5 times more important factor compared to travellers without car availability.

The mode choice models I developed serve as a basis of calculating the modal shift effects of S-Bahn type infrastructure developments in a professionally sound way. These shifts can be assigned to the new lines/services to calculate the loads including modal shifts.

Publications: [5], [6], [10].

3. **I investigated the capabilities of multinomial and nested logit models based on revealed preference surveys to describe the mode choice attitudes among commuters living in the service area of Budapest Transport Co. outside Budapest. I proved that in this case the nested logit model fits better the nature of the observed decisions because of the similarities in public transport mode indicators.**

By using the household survey data of Budapest Transport Co. recorded in the suburbs I compared the results and statistics of a multinomial and a nested logit mode choice model. I demonstrated that in the case of commuter traffic towards Budapest from these settlements the conditions to build and apply a multinomial mode choice model are not fulfilled (the choice of alternative modes are not independent from each other) therefore a nested logit model could be used.

In the estimation of the parameters of the multinomial logit models in many cases the parameter values of journey time and travel costs turned out to be zero. It was far from the observed preferences of the other kind but showed that these values have a low variance in the sample. As known in a revealed preference survey decision data are collected for one situation thus the sample size and taste variation is much less than in a stated preference survey.

The nested logit model is a generalization of the multinomial logit model in such way that the set of alternatives faced by a decision maker are partitioned into subsets. The probability that a decision maker chooses a given alternative equals the product of the probability of choosing the nest of the given alternative and the probability of choosing the alternative in the nest. My proposal is to make two nests. First I set up the top level nests labelled individual and public transport and estimated the parameters. In the second step I calculated the parameters of public transport mode choice model. The nested logit parameters showed better statistical reliability therefore the usage of nested model is preferred.

Publications: [5], [9], [12].

4. I determined a functional relationship between household income and travel demand and between household income and mode choice rates.

I demonstrated that there is a close relationship between household income and travel demand and between household income and mode choice rates. I proved by building and testing regression models that considering the valid range of the explanation variable there is a linear function in respect to the dependent variables (see Figure 3):

for the daily trip rates:

$$f_i = 0{,}003x_i + 2{,}015 \ (R^2=0{,}83), \text{ where}$$

f_i: is the daily trip rate in zone i
x_i: the net household income per capita in zone i

for the public transport patronage:

$$m_i = -0{,}001x_i + 0{,}557 \ (R^2=0{,}89), \text{ where}$$

m_i: the share of public transport trips in departure of all trips in zone i
x_i: the net household income per capita in zone i

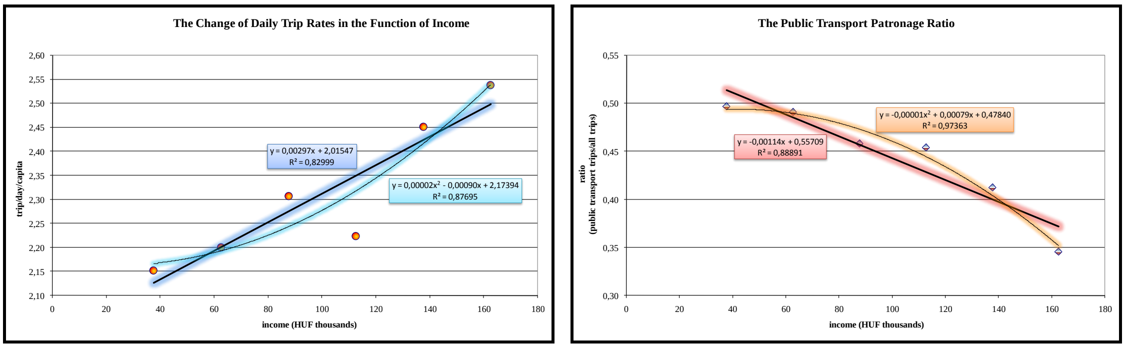

Figure 3: The Functional Relationship between Household Income and Travel Demand and Mode Choice Rates

Speaking in numbers the increase of (per capita) household income by HUF 10,000 causes an increase of 0.03trip/day – which is some 1.3% increase compared to the average 2.29trip/day, while causes a decrease of 0.01 in PT trips – which is some 2.2% decrease compared to the average PT share, 0.46.

Publication: [9].

5. I described and used new indicators to show the spatial relationships and potentials and to improve the evaluation of transport policy measures. These indicators extend the capabilities and the accuracy of use-value analysis.

The evaluation of the transport network development measures is possible by using an objective set of indicators for each scenario as an input for a use-value analysis. This kind of analysis allows joint comparative evaluation of the indicators of different nature (e.g.

indicators in monetary unit and in natural unit), of which all are important to describe a transport network situation.

In connection with the public transport network projects I suggest the usage of the following indicators that could express the change in accessibilities as well:

- Ratio of direct trips by PT line routes: Based on surveys or traffic modelling assignments (assuming a proper model) the ratio of direct trips, which do not require additional feeding and/or draining trips, can be evaluated on route basis.
- Accessibility of the city centre: This indicator serves as a qualifying indicator for spatial and network connections and can be calculated with the average, peek hour headways weighted by traffic flows in a specific spatial context (like towards the city centre).
- Weighted coverage: The catchment area of the stops multiplied by the number of serving vehicles per hour.

The accessibility indicators could be differentiated depending on the type of the study. At road transport studies it is important to differentiate the connections in both administrative and spatial context and therefore to calculate long distance and regional accessibilities separately. The qualification of long distance accessibilities can be expressed by calculating the accessibilities between zones of the examination area and the county capitals (excluding the own one) by using the average travel times weighted by traffic flows. The improvement of regional accessibilities contributes to reaching distant industrial, commercial and tourist regions and border crossing points. The qualification of regional accessibilities can be expressed by calculating cross-accessibilities among zones in the same county/region also by using the average travel times weighted by traffic flows. The subject of the evaluation is the change of accessibilities caused by the developments compared to the "current" network.

The spatial economic development is better explained by the change of transport potentials. By definition, transport potential is the quotient of the sum of the indicators expressing the attractiveness of zones divided by the transport cost increasing by the distance.

I proved - on the basis of preference surveys I made in Szeged and Miskolc (see Figure 4) - that the transport relation based indicators are of prime importance at all stakeholder groups – like travellers/customers, city representatives and professionals working at the operators; however the level of importance is slightly changing. It means that the usage of such indicators is reasonable and well founded.

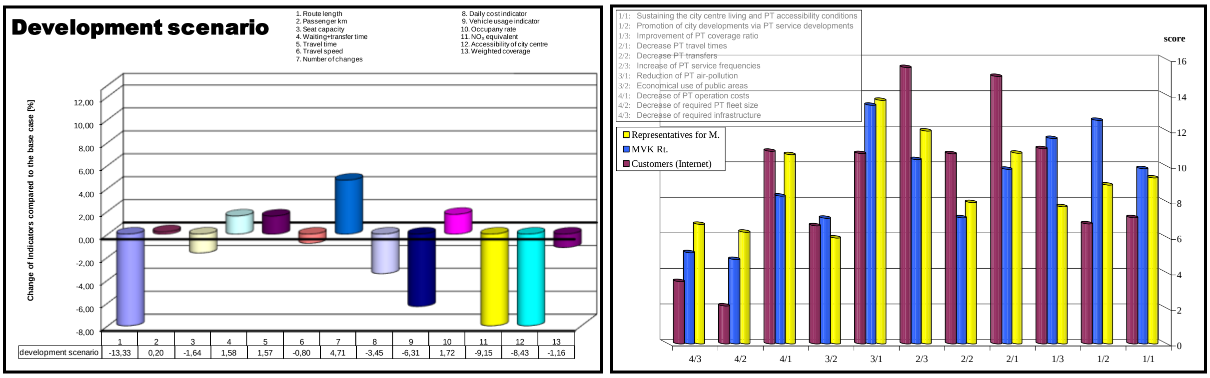

Figure 4: Indicators and preference rates in the use value analysis

This use-value analysis method was used in testing public transport network scenarios in both Szeged and Miskolc.

Publications: [4], [8], [11].

FURTHER RESEARCH AREA

My further research plans are in a direct connection to the scope of the thesis and in some way they make use of these results and findings.

The Budapest Transport Association ordered a survey in 9000 households among people living in the service area of the association but outside Budapest. The surveys were done in autumn 2007 by a modified TRANSCAPI tool, which is a result of my research.

On the basis of the former household surveys, the survey of travelling habits of households in Budapest and the surrounding settlements and the survey in the central region, I plan to extend my scientific research to the following areas:

- develop the explanation power and statistical indicators of mode choice models based on the surveys mad in autumn 2007,
- use the mode choice models and functions in the modelling and forecasting works of the suburban rail system of Budapest (by estimating the modal shift effects at the scenario tests),
- set up trip distribution models based on the discrete choice theory and
- build an activity chain based transport model for Budapest and the Central Region.

SCIENTIFIC PUBLICATIONS IN CONNECTION WITH THE THESIS

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