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Methods for Highway Network Development Planning in Hungary

– With argumentation for EU Funding –

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TABLE OF CONTEXT

1 INTRODUCTION

The highway network development planning means the solution of at least ***two types of tasks***, which arise on regional and national level: the selection of the best project alternative from a set of different possible solutions in a given moment and the definition of the best way (by projects) to achieve the optimal (national/regional) network in the very long term.

The first means the evaluation of alternatives one by one (ceteris paribus) in a region in different sequential stages by summing up the network effects over the time.

The second means the evaluation of different solutions in different regions with different realisation dates and in different time periods (spatial and temporal interdependencies) and gradual summing up of the network effects over the time.

To solve the different planning tasks TRANSMAN has developed over decades the **TRANSWAY model and program system**, which enables the forecast of transport demand flows and traffic loads in the network, further the calculation of changes in transport time, operation costs, accident losses, air pollution, noise, occupied land and the improved accessibilities between zones as well as the changes of location potentials. The efficiency evaluation and ranking of alternatives by cost-benefit analysis (CBA) and multi-criterial analysis (MCA), should demonstrate the social-economic viability of the projects and the national economy.

In the previous times two national development plans have been carried out. The first in 1985 for the National Road Network [1], the second in 1995 for the National Highway Network [2] under the collaboration of UVATERV and the TRANSMAN team. In both cases in the network model more than 20.000 km's were considered from the total 30.000 km's of the national roads. In these planning processes a gradual development plan had been worked out for very long term (30 years), with long term (15 years) ranking of projects. TRANSMAN has just started the third national planning to define the revised long term optimal network.

In the last two years more motorways (M3-M35, M8, M30, M6-M56) had been investigated by TRANSMAN, where the selection of the best project alternative was the task and the mentioned methodology was applied, in a network approach and by both efficiency evaluations. Recently the Ministry for Economy and Transport prepared guidelines for road network planning, which are in main parts similar to the methods described here.

Beside the efficiency requirements of the infrastructure developments the **financing** of the projects is always a crucial issue. It becomes very important also in the accession countries, which expect **funding from the EU**. Therefore it seems also important to show to which extent the best of the alternative contributes to the cohesion and values on European level, which can be showed – as a proxy – by the **participation of the international traffic** from the benefits of the total traffic. In connection to the CBA and MCA evaluations, calculations have been made about the benefits gained and the burdens caused by the foreign traffic, which can be an argument for EU-funding also as a compensation for "supra-national inequalities". The higher the international participation from the benefits (and from the burdens) is, the higher the proportion of EU-funding should be as a contribution to the national efforts.

2 TRANSPORT RELATED IMPACTS AND MODELLING TOOLS

2.1 The nature of development effects

The transport infrastructure developments determine changes in the transport internally through possible changes in the “regulators” (e.g. time, costs, and other conditions) influencing the transport patterns, what leads to shifts in transport modes and changes in traffic volumes, conditions and “outputs”.

The interventions have impacts on the accessibilities, which influence the involvement of land, capital and labour and change the land-use and the socio-economic framework of an area. In this changed frame, socio-economic phenomena will change, as e.g. life quality, estate values, welfare, economic prosperity, cohesion, regeneration, tax revenues, attracted investments, etc.

It is important how one calculates and considers the effects in the course of evaluation. The different effects caused by transport investments and policies on different bearer groups can be characterised as follows:

- **direct effects on the transport users**, which cause changing transport patterns and result changes in traffic volumes and conditions; e.g.: time spent in traffic (including congestion), fuel consumption, accidents on users etc.

- **semi-direct effects on exposure groups**, outside of transport, which depend also on traffic volumes and conditions: e.g. emitted pollutants and noise as immission at the recipients, which cause damages; or accidents with involvement of non transport users etc.

- **indirect effects on different social-economic actor-groups**, which arise from the improved (new) infrastructure or services on it, as a possibility or potential for territorial and economic developments.

- **rebound effects** from the economy to the transport by the changed land use and activities resulting new transport demands and traffic volumes.

Transport infrastructure and policy measures (interventions) need sensitive tools enabling the measuring/modelling the changes in the transport, in the environment and in the socio-economic life.

The direct transport (network) effects by the changes in **transport supply** lead to changes in transport demand introducing induced traffic, traffic volumes/trips and other circumstances (e.g. **times** and **costs**, expressed in aggregated **“generalised costs”** C_{ij}) which changes can be valued as user benefits (B), as difference between the “do- nothing” (0) and the “do-something”(1) which reflect the changes in **consumer surplus (P)** between trip origin (i) and destination places (j) (see 1. Figure):

$$B_{ij,m} = P^1_{ij,m} - P^0_{ij,m}$$

The changes in consumer surplus can be calculated by the "rule of the half" on the base of the relational (i-j) trip flows (F_{ij}) and generalised costs (C_{ij}) as follows:

$$B_{ij} = \frac{1}{2}(C^0{}_{ij} - C^1{}_{ij}) \cdot (F^0{}_{ij} + F^1{}_{ij})$$

The cost between i an j is the sum of the section costs (C_s) along the route (R_{ij}):

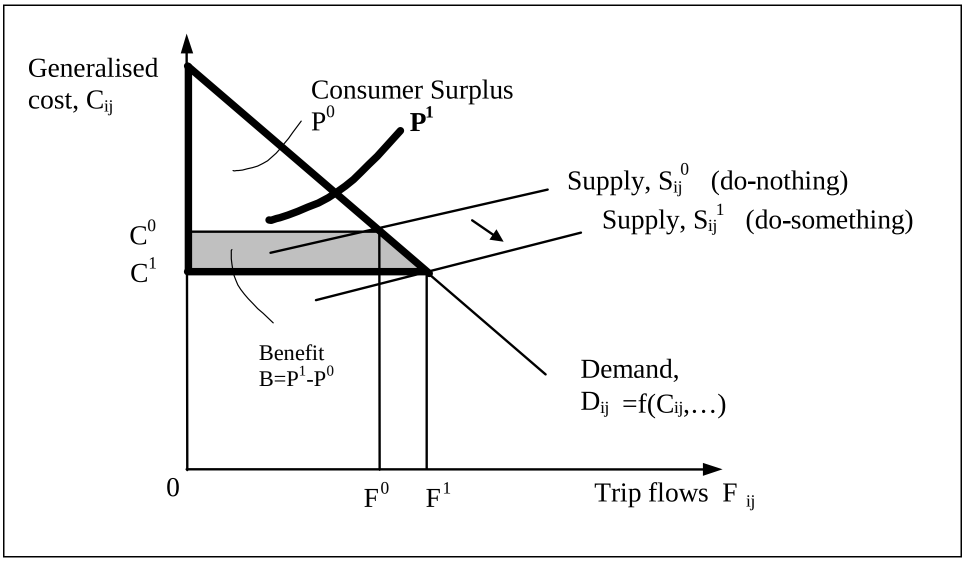
$$C_{ij} = \sum_{s \in R_{ij}} C_s$$

If we assume there is no induced traffic, what means that $P^1_{ij} = P^0_{ij}$ than the user benefit is equal with the cost difference in relation i-j:

$$B_{ij} = (C^0{}_{ij} - C^1{}_{ij}) \cdot F^0{}_{ij}$$

On network level the user benefits (B) are:

$$B = \sum_{ij}(C^0{}_{ij} - C^1{}_{ij}) \cdot F^0{}_{ij} = \sum_{ij}(P^1{}_{ij} - P^0{}_{ij}) \qquad \text{(I)}$$



1. Figure: User benefit (difference of consumer surplus) in the "do-something" case

We get a similar result if we assign the traffic flows (F_{ij}) to the network links/sections (s) along the route (R_{ij}) between each i and j pair to traffic loads (M_s) and calculate the benefits (e.g. as differences of generalised cost (C_s)) by sections (s) in dependency of the traffic volumes (M_s) and speeds (V_s):

$$M_s = \sum_{ij(s \in R_{ij})} F_{ij} \quad \text{and} \qquad C_s = f(M_s; V_s)$$

$$B = \sum_s (C^1{}_s \cdot M^1{}_s - C^0{}_s \cdot M^0{}_s)$$

If we assume that in the network the only flow is $F_{ij}(=M_s)$ and there is again no induced traffic generated ($F^1_{ij} = F^0_{ij}$), than the benefits (II) on network level are:

$$B = \sum_s (C^0{}_s - C^1{}_s) \cdot M_s = \sum_{ij} (C^0_{ij} - C^1_{ij}) \cdot F_{ij} = \sum_{ij} (P^1{}_{ij} - P^0{}_{ij}) \qquad \text{(II)}$$

While the sum of the section costs (C_s)along the route between i and j is $\sum_{s \in R_{ij}} C_s = C_{ij}$, both benefit volumes of the "relational" and the "section wise" calculations are identical.

In the section-related case we loose the information about the relational flows but we know the changes of the loads on the network sections.

Because the section wise approach is more simple it can be used as a proxy for the user benefit calculation. A weak point is, that generated new traffic (ΔF_{ij}) can be considered only as an average of the investigated development alternatives (a) as a function *(f)* of the improved accessibilities (ΔA_{ij}) expressed by the generalised costs ($\Delta C_{ij,a} = C^0_{ij} - C^1_{ij,a}$).

$$\Delta F_{ij,a} = f(\Delta C_{ij,a}) \text{ the average } \Delta \overline{F}_{ij} = \sum_a \frac{\Delta C_{ij,a}}{n}$$

That means that at each alternative the same "fixed" matrix $(F_{ij} + \Delta \overline{F_{ij}})$ will be used, which is to keep simpler the user benefit calculations.

The direct effects are computed (partly) by the traffic models, the semi-direct effects by different consequence models (e.g. accident, pollution, noise models) also on a "section wise" base.

Air pollution and noise emissions as "traffic outputs" can be calculated section wise (s) too. Air pollution is a result of the emission of the different vehicles and can be summed up over the network. Noise level consumption needs the " collective of all vehicles" on a section. Noise needs special considerations, because the low level sections can not cross compensate the sections of high level noise (over standard values). Only the sections over the standards should be captured.

Accidents by seriousity depend also on the sectional traffic volumes and composition as well as the road category. The damages are partly to the transport users, partly to the residents related.

The indirect transport (network) effects will be perceived in the transport demand and economy growth initiated by improved **accessibility** (A_i) for a place (zone) i.

The **changes of accessibility** (ΔA) are responsible for changing location choices and activities, increasing production volumes, incomes and finally for changing social welfare.

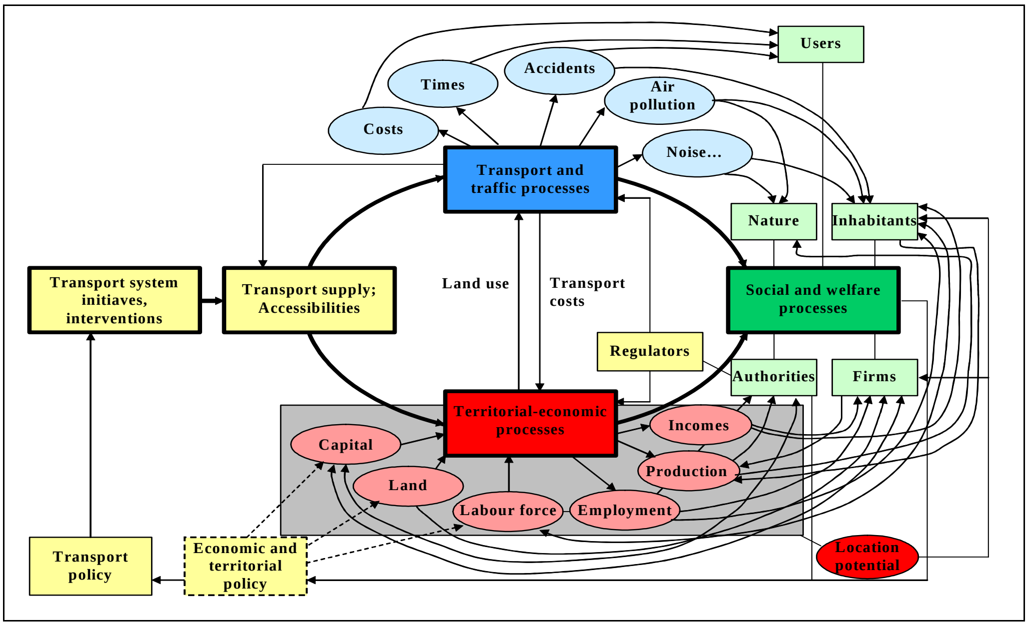
In some cases accessibility can be seen also as a substitute for spatial, economic and social development potentials, which can be evaluated in the frame of MCA-s.

Stakeholders	Main Impact Areas	Possible Indicators	Evaluation Method CBA	Evaluation Method MCA
Transport Users	Transport Times	Transport Time Values	+	+
	Operation Costs	Veh. Operation Costs	+	+
	Accident Losses (1)	Accident Losses	+	+
Exposed Environ	Accident Losses (2)			
	Air Pollution	Air Pollution		+
	Noise	Noise		+
	Occupied Land	Land Area		+
Infrastructure Provider	Investment Costs	Investment Costs	+	+
	Operat.+Maint. Costs	Operat.+Maint. Costs	+	+
Other Actors of Economy				
▪ Households	Disposable Income	Accessibilities		+
▪ Firms	Net Income	Location Potentials		+
▪ Governments	Employment			

1. Table: Main impact areas, indicators and evaluation methods at highway network development investigations with the TRANSWAY-System

The calculation of indirect effects of transport initiatives/investments would need macroeconomic models, which allow the consideration also of **rebound effects**, but which are for Hungary at the moment not available. Therefore TRANSMAN uses a model based on the accessibilities, which has been developed before decades. The theoretical structure of the model is shown in 2. Figure, where the changes of “location potentials” are proportional substitutes for economic changes and values.

A substantial improvement would bring the extension of the macroeconomic CGEurope model to Hungary, developed and used in IASON [6].



2. Figure: Main relations of integrated territorial economic and transport network planning

2.2 Modelling tools

For impact studies of transport infrastructure and policy interventions by using calculation methods and considering a network approach it is advised to apply following **models and methods**:

- **transport demand models** to estimate the transport needs reflecting interzonal and intermodal changes in patterns because of different interventions

- **network traffic models** to assign traffic flows to the network elements (links, nodes) along the routes considering the traffic conditions and generalised costs (by time, fuel, comfort, etc. components)

- **traffic impact models** to compute the "outputs" as a consequence of the network traffic (travel time, fuel consumption, air pollution noise, accidents, etc.); the monetarisation of the direct and semi-direct effects of this outputs is a basic condition for cost-benefit-analyses (CBA) of the intervention; otherwise only multicriterial (utility value) analyses (MCA) are possible,

- **socio-economic models** to estimate in one the inputs for the transport demand models and the indirect effects arising from the existence or extension of transport networks and services, improving the connectivity and accessibility as a potential for further socio-economic developments; as we can see that is only possible in a permanent feed back process, because the output of one stage is the input for the next one.

The most important base of a well-done evaluation is the right quantification of the impacts. Different types of measures/interventions into the transport request different model tools. The most evident changes in the transport systems arise by infrastructure development measures in both in direct transport and indirect social impacts because the network and traffic volume changes can have substantial impacts. But also legal regulations can have an influence on transport and traffic volumes.

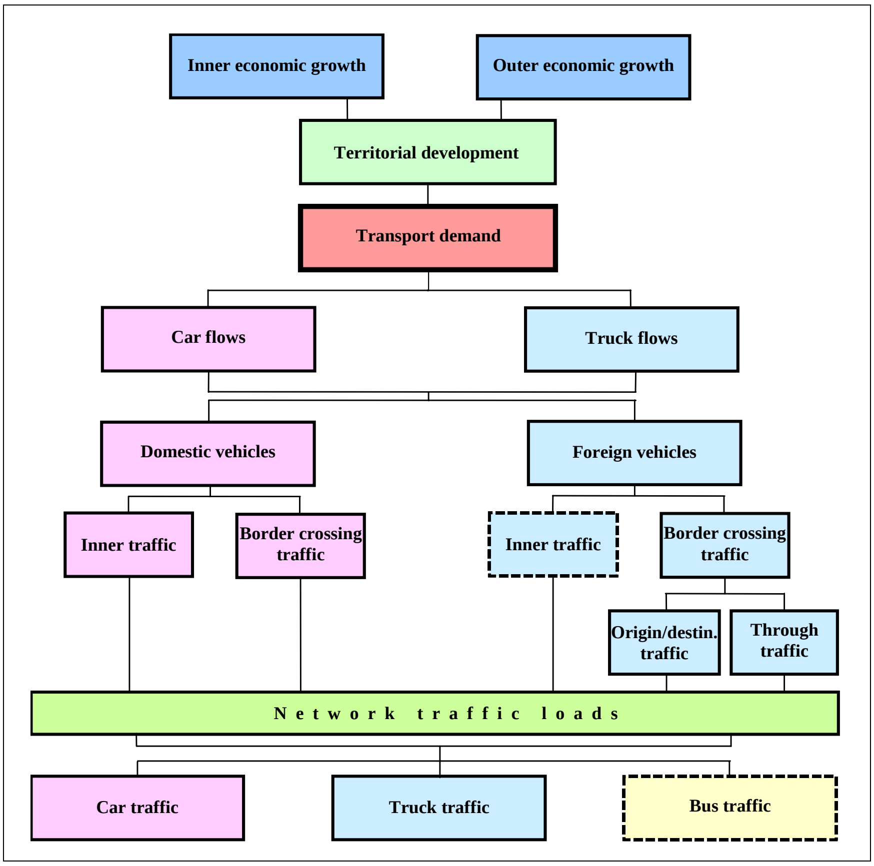
Therefore transport demand and traffic models are at least so important for a good assessment than the evaluation technique itself. Insufficient transport models increase the risk and the uncertainty of the evaluations.

2.3 Traffic forecasting models

The **traffic demand** has been calculated by an **uni-modal traffic model system** (TRANSWAY) based on vehicle (car and truck) O-D-surveys of 1987 and upgraded for 1993 and 2001 concerning the following traffic layers (see 3. Figure):

- **domestic traffic**: for generation daily trip rates by different zone types had been derived for car and truck traffic; for the 317 inner zones (+23 Budapest districts) the generated volumes have been modified by zonal demographic and economic data (population, employment, GDP, car fleet, recreation potential) and by the accessibility potentials of the zones; the motorisation (number of cars) of the traffic zones is shown in 4. Figure; the 5. Figure demonstrates the generated trip origins by zones; the traffic flows have been estimated using gravity type models for different characteristical interregional relations;

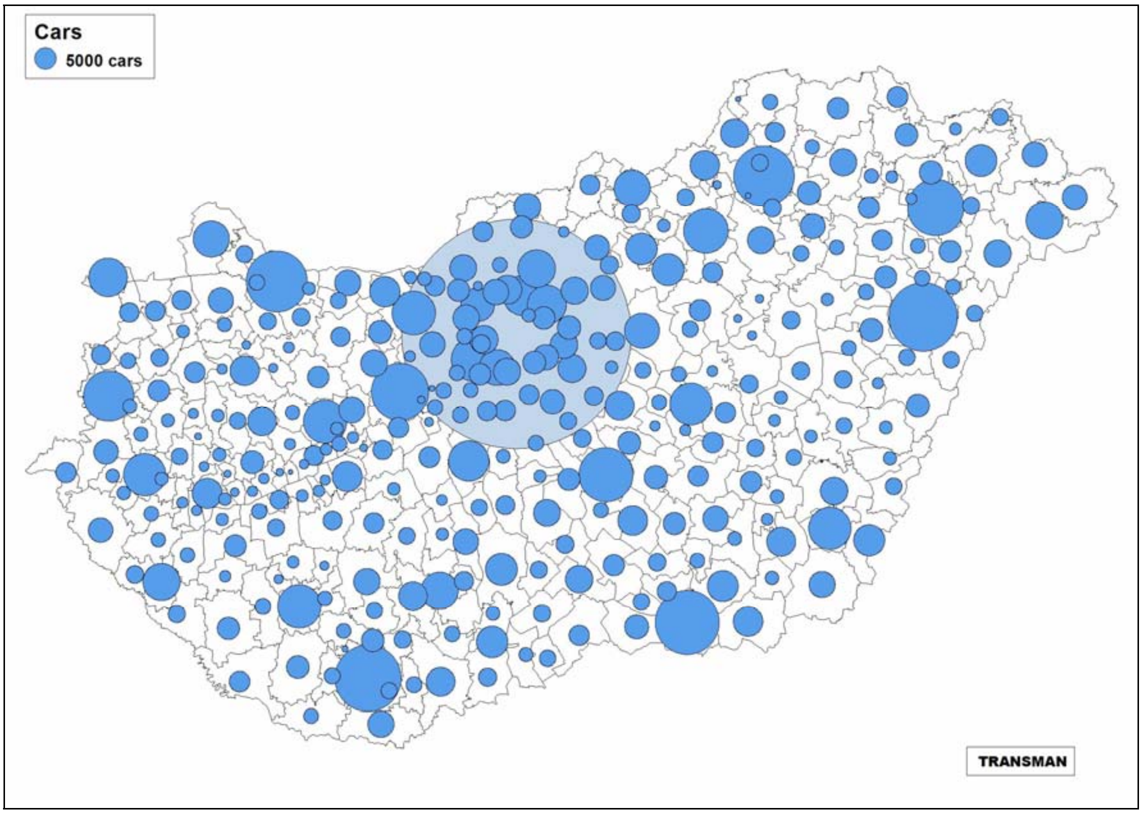
- **international traffic:** the Hungarian and foreign vehicle flows crossing the border have been computed separately in previous years by the international statistics considering 40 border crossings and socio-economic data of 20 European countries (e.g. motorisation, GDP, export, import, tourism potentials).



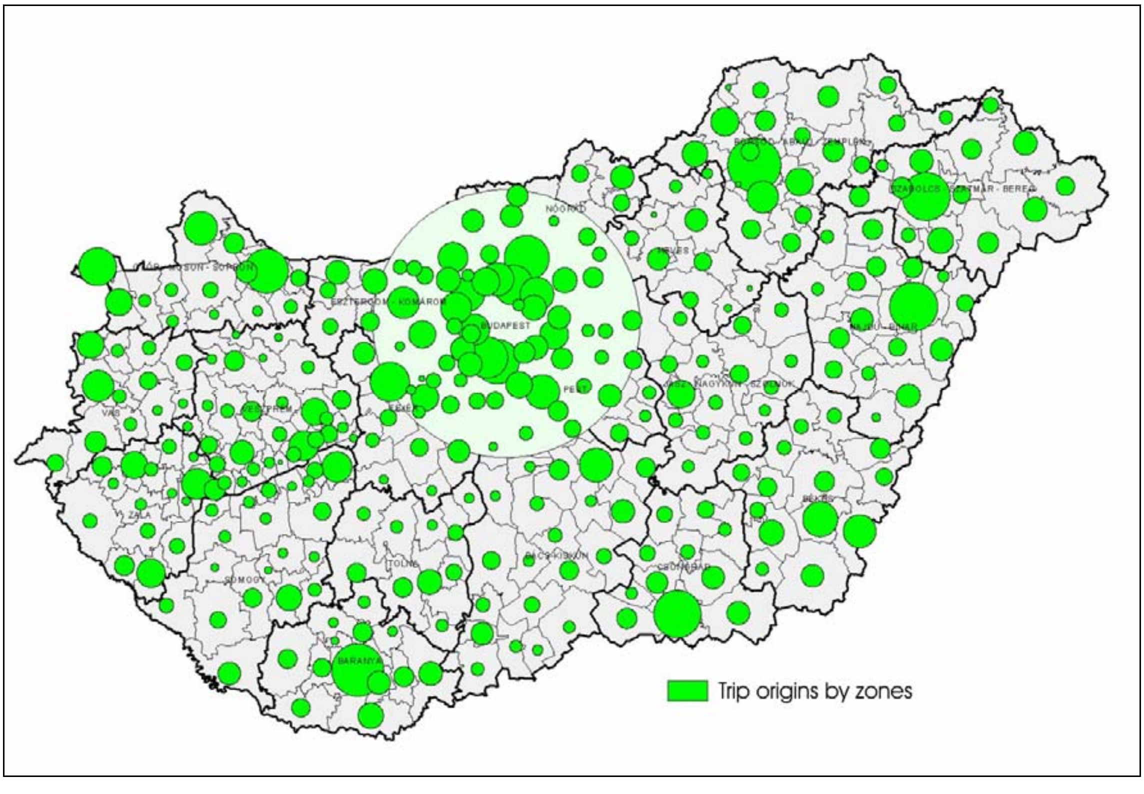
3. Figure: The scheme of the traffic model in the TRANSWAY-System

Because of the appearance of tolled motorways in the network different user groups by income level have been considered. The categorisation in “wealthy” “average”, “needy” groups happened by the distribution of the domestic and foreign road users regarding these categories considering the life standard of Hungary and the foreign, western and eastern countries.

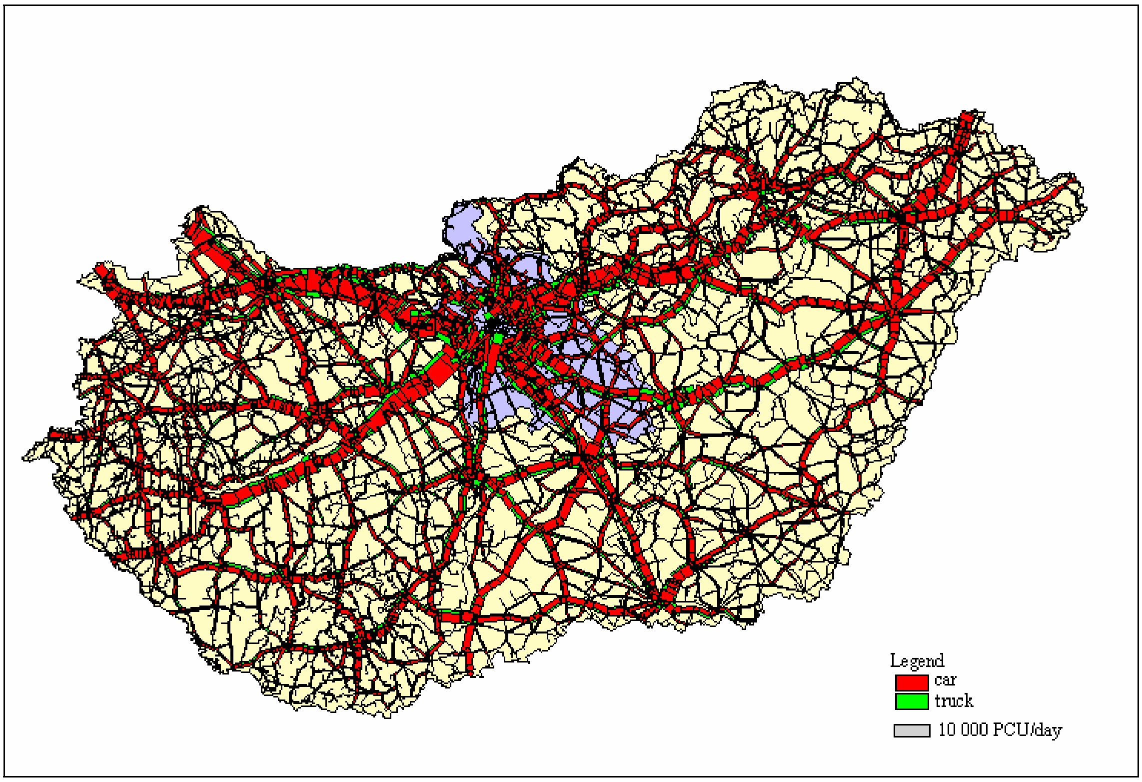
The **traffic assignment** was completed for the different network development alternatives by a multistep successive method using generalised cost functions for the different road categories including time costs, fuel cost, tolls and a “comfort” component depending on the road category. An example of the modelled network traffic loads can be seen in the 6. Figure. The calibration of the assigned traffic flows versus the national traffic counts happened at around 800 cross sections including the main network of Budapest [3] (see 7. Figure).



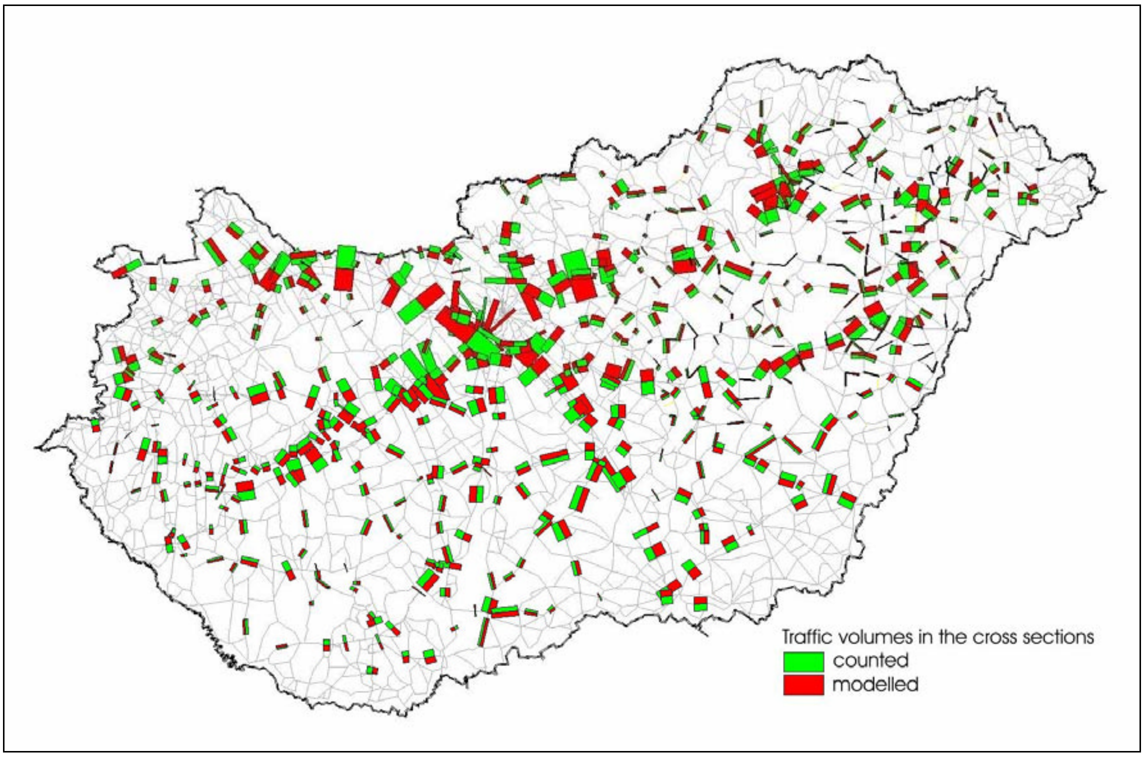
4. Figure: Cars by traffic zones [KSH TSTAR, 1999]



5. Figure: Trip origins by zones



6. Figure: Modelled traffic loads for 1999

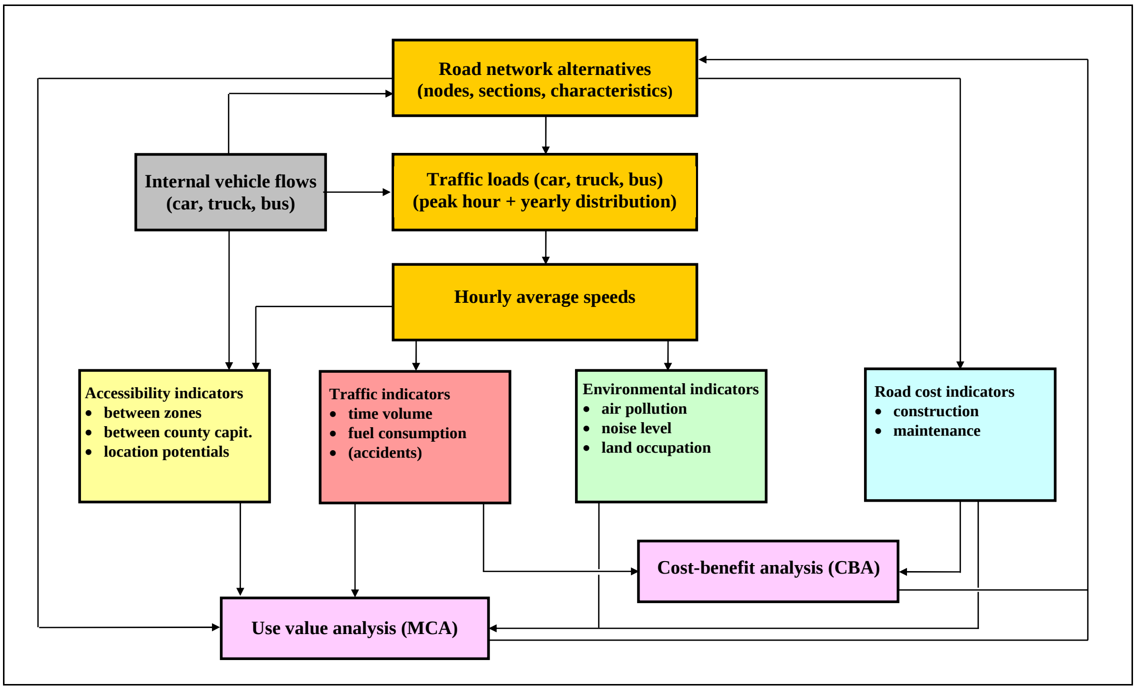


7. Figure: The traffic volumes in the calibration cross sections

2.4 Impact calculation and evaluation methods

In connection to the traffic models different **impact modules** has been elaborated for the quantification of different traffic consequence phenomena [4]. At some of the phenomena hourly traffic volumes, capacity ratios and speeds served as basis for the calculation of the indicators (see 8. Figure):

- **traffic volume-speed dependent indicators:**
  - ***traffic indicators:*** transport time volume, fuel consumption by vehicle type, accidents by road category and traffic composition
  - ***environmental indicators:*** air pollution, noise by vehicle type (the occupied land does not depend directly on traffic volume)
- **accessibility based indicators:** connections (expressed by averaged travel time) between zones, between county capitals, between zones and recreational areas, between border crossings; all these represent some social-regional aspects, and are substitutes for development potentials
- **road cost indicators:** investments and operation/maintenance cost of roads.



8. Figure: Impact modules and evaluation in the TRANSWAY-System

The 9. Figure shows it well that the unit time consumption (T), fuel consumption (F), air pollution (P) etc. depends on the speed (V) defined by the traffic loads (M) on the sections or capacity utilisation ratios (CR) in the different categories (hours) of their yearly distribution.

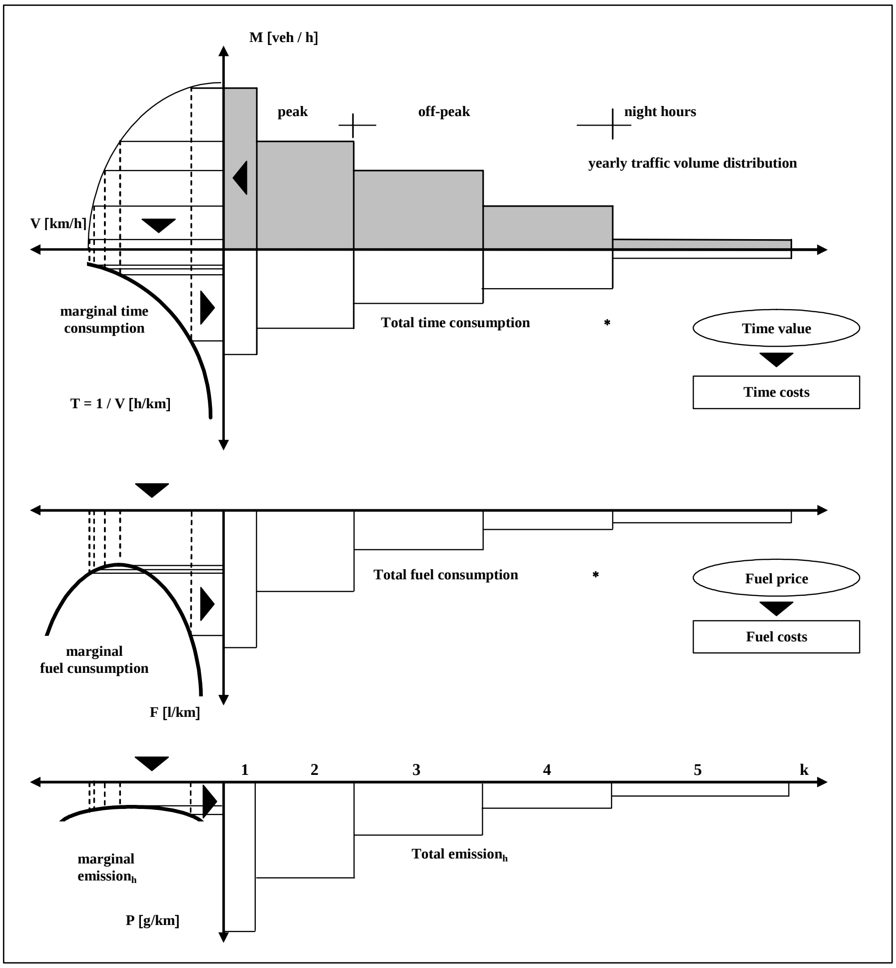
The traffic dependent volumes by nodes/sections are summed up over the network as well as over a year considering the changing traffic volumes, speeds and 'outputs' in the 8760 hours over the target year.

The **time values** of the business- and other purposed trips (included to/from the workplace) are based on the domestic GDP of the year 2000, taking into account the working time basis, the personal consumption and the income level of the car users that is generally higher tan the average. For car travels in the view of the passenger number for the year 2000 one car-hour was 1 612 HUF/hour on the average (see 2. Table).

This value is significantly under the EU average and lover than the Greek and Portugal number, but if we take into consideration that our GDB value is also lover the values are justifiable and acceptable.

The **vehicle operation costs** contain beside the fuel cost mostly the variable segments.

The values of the **accidents and accident losses** were appraised by the expectable numbers in the different seriousity categories (fatal, serious, light) based on specific rates derived by previous investigations for road categories, traffic volumes and composition considering the running-performance on the sections. The considered values of the losses can be seen in 3. Table.



9. Figure: The calculation of the traffic volume and speed related indicators

Year 2000	Based on the EUNET Project (D9)			
Vehicle type	**Hungary**	Portugal	Greece	EU average
	Time value (year 2000) HUF/VehicleHour			
Car business traffic [1)]	**2 501**	2 387	4 850	6 746
Car non business traffic [2)]	**1 019**	1 213	1 175	1 706
Car average	**1 612**	-	-	-
Bus (20pass./veh.)	**28 180**[3)]	27 430	55 500	78 705
HGV	**4 030**[4)]	3 060	7 170	9 000

[1)]1,3 pass./car [2)]1,6 pass./car [3)]15 x avr.car-costs [4)]2,5 x avr.car-costs

2. Table: Time values (HUF/VehicleHour)

Year 2000	Based on the EUNET Project (D9)				
Injured	**Hungary**	Portugal	Greece	EU average	TINA guide
	Accident losses (year 2000) Mill HUF/pers.				
Dead	**50**	104	121	228	43 000 AWH
Sever injuries	**3,5**	13	15	30	5 100 AWH
Slight injuries	**0,8**	1,5	1,8	3,3	400 AWH

AWH – Average Working-Hour value

3. Table: Accident losses (Mill HUF/pers.)

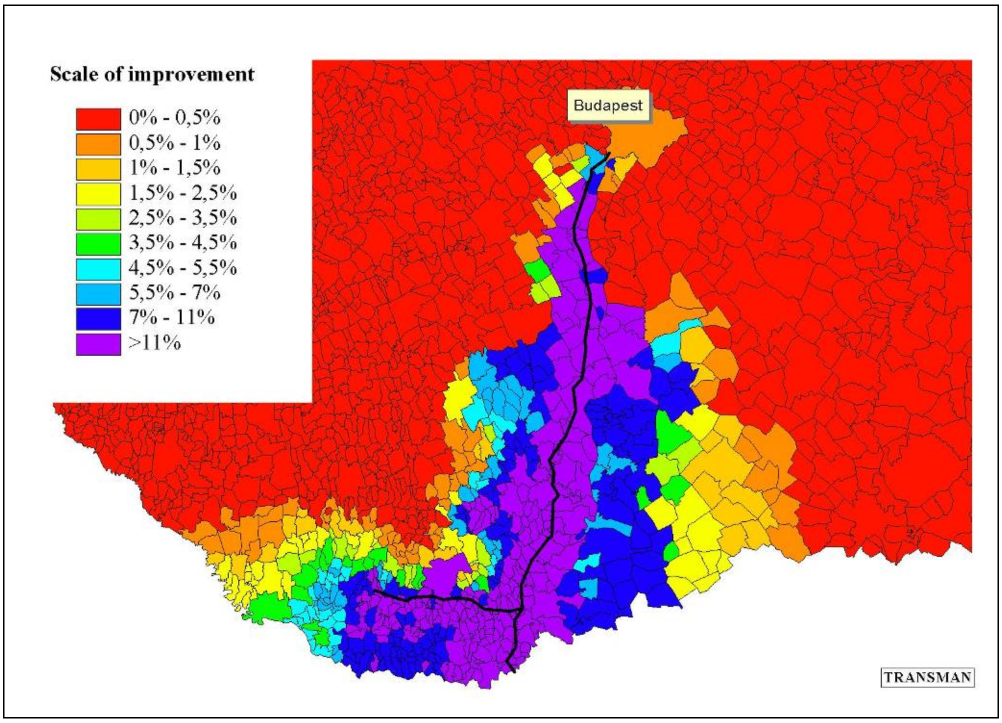
The environmental impacts (air pollution, noise) are calculated as emission values and considered in natural measures, because national investigations are missing for the calculation of monetary losses. It is possible to weight the emitted volumes by the area type (e.g. urban, rural, agricultural, recreational, etc.).

The **"location potential changes"** (ΔP_i) of the settlements (i) along a developed route are calculated on the base of "accessibilities" (generalised costs, C_{ij}) and reachable "economic volumes" (E_j) from each settlement, before and after the construction (ΔP_i).

The main elements for the calculation are: $P_i = \sum E_j / C^a_{ij}$. The economic weights (E) of the settlements *j* can be expressed e.g. by the yearly net company revenues. The higher the generalised costs between *i* and *j* are the smaller the influence on the potential, what is expressed by the exponent *a*, which can be set a=2.

The 10. Figure shoves as an example the potential changes along the M6/M56, south of Budapest in Hungary, which are considerable in the vicinity of the route.

The indicators expressed in monetary terms (time, fuel, accident losses and maintenance costs) are conjoined with the road investment costs and serve as basis for **cost-benefit analysis (CBA).**



10. Figure: Potential changes of the settlements along the M6-M56 motorways

With exception of the investment costs all indicators are included in a **multicriterial use values-analysis (MCA)** scheme, where the "utility scales" are adjusted to the optimal indicator values of the best of the alternatives (100 scores).

The aggregation of the different indicator values (scores) for each network alternative happened by "preferential weights" for different stakeholder groups (communes, ministries, operators, planners/researchers and other groups) results network wide **use-value indicators.** A combination of the monetised and not-monetized values became possible in the form of a **use value-investment cost-ratios,** which show the efficiency of the unit investment cost regarding the improvement of the use value of an alternative.

The efficiency indicators allow the **choice of the relatively best alternative** (network solution) on very long term and the ranking of the different regional projects on medium-term possible. The same evaluation tools provide a base for the calculation of economic losses because of the investment source constrains.

3 TRAFFIC- AND EFFICIENCY ANALYSIS OF HIGHWAY PROJECT ALTERNATIVES

3.1 Task interpretation and investigation process

The investigation and evaluation of highway development alternatives is shown by the example of the M8 motorway.

The M8 highway is an expressway capable for extend to a motorway and the construction of it's Veszprém-Dunaújváros section should be started between 2004 and 2008 according to the governmental decree. For the M8 highway –and the given section – more feasibility investigation and decision-supporting study have been prepared, based on these three investigated route alternatives have been chosen. The task was the traffic modelling of the route- and network alternatives and a CBA and MCA analysis based on this.

The investigation should be prepared to the 2008, 20015 and 2030 years taking into consideration the reorganization of the traffic based on of the economy-intensifying effect and improved accessibility by the new roads. The changes of the direction- and the size of the traffic have to be analysed separately at every possibilities.

The task needs sufficient network and traffic demand-models, assignment methods and the adaptation and use of impact-models with the support of graphical and GIS tools, which help the analysis and assess of the results and gives the representation in a easily understandable form.

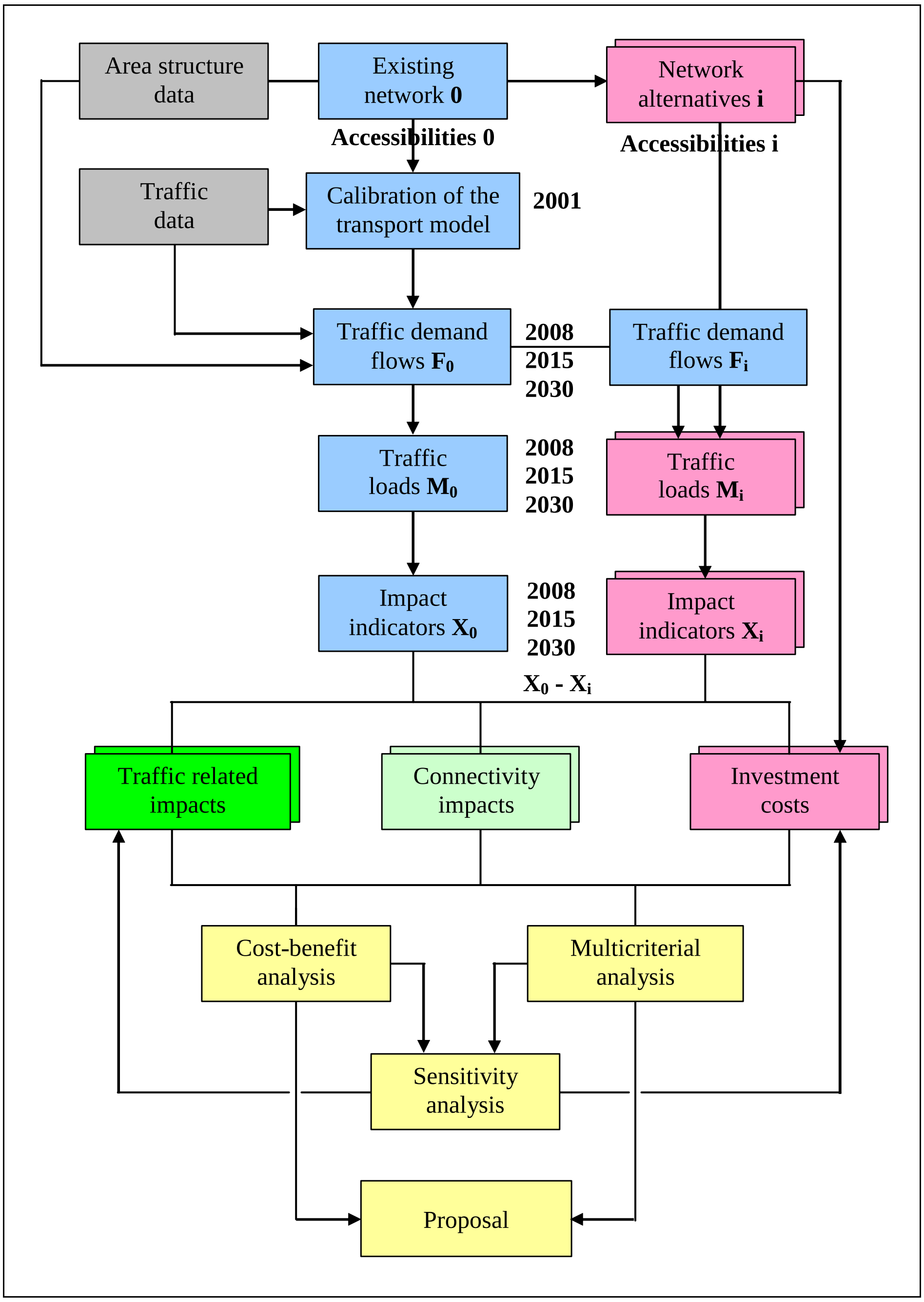
3.2 The course of the investigation process

In this work to find the solution – which is the best version out of the three possible routes – the next investigation process was formed (see 11. Figure), the main phases are the followings:

- **Formation of the network model**; the preparation of the countrywide transport network model, according to the area of the investigation and the timescale of the development.

- **Adaptation of the traffic demand models**; forming and calibrating the models, which are able to define the national and international traffic loads by modes (car, truck, bus) based on traffic counts and area data – that acts a role in generating transport requirements –.

- **Calculation of the indicators regarding the network alternatives**; working out the traffic dependent time, fuel consumption-, accident indicators and costs, moreover the access-potentials that represents the network accessibility and the calculation of the indicators for the different network alternatives and timescales.



11. Figure: Theoretical flow of the investigation procedure

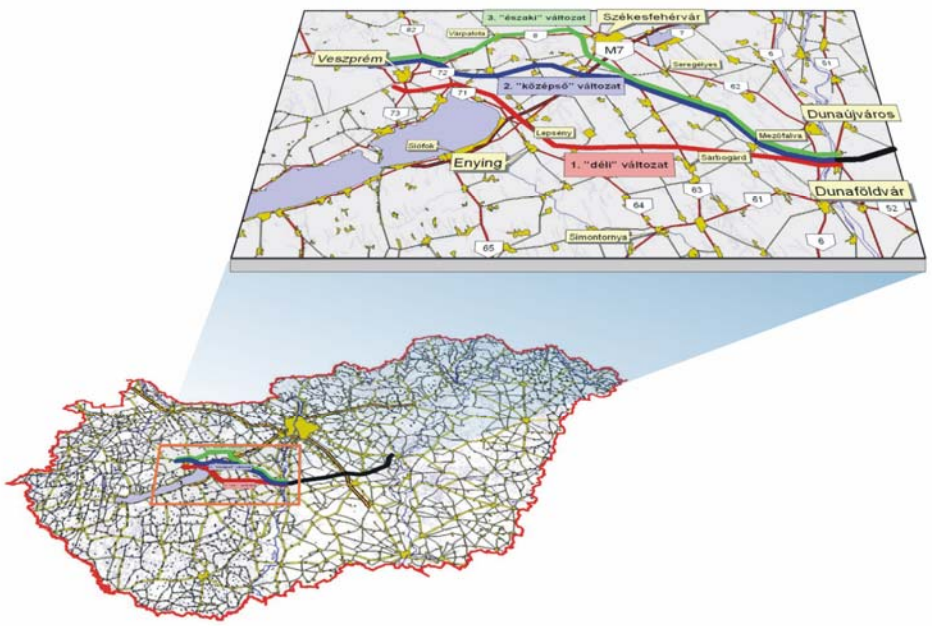
- **Modelling and evaluating of the impacts** in the frame of cost-benefit analysis and multicriterial analysis, pointing out the effectiveness of the alternatives taking into account the investment costs.
- **Sensitivity analysis**, to find the probable most effective version through the changing of the elements, which influence significantly the effectiveness indicators.

3.3 Definition of the investigation's area and timing plan

The solution of the task raises spatial and temporal allocation problems, because of the impact outputs are changing spatially and temporally.

The task is complex, because the investigated development alternatives are parts of the national network and thus the impacts of the sections will be built, depends on the trends of the future impacts of other network parts, therefore difficult to allocate the impacts and benefits, which are directly connected to the investment costs of the questionable M8 section. So the main question is what kind of area or network had to be involved in the investigations, considering other developments in the future, the impacts which of them will appear additionally to the "base" impacts.

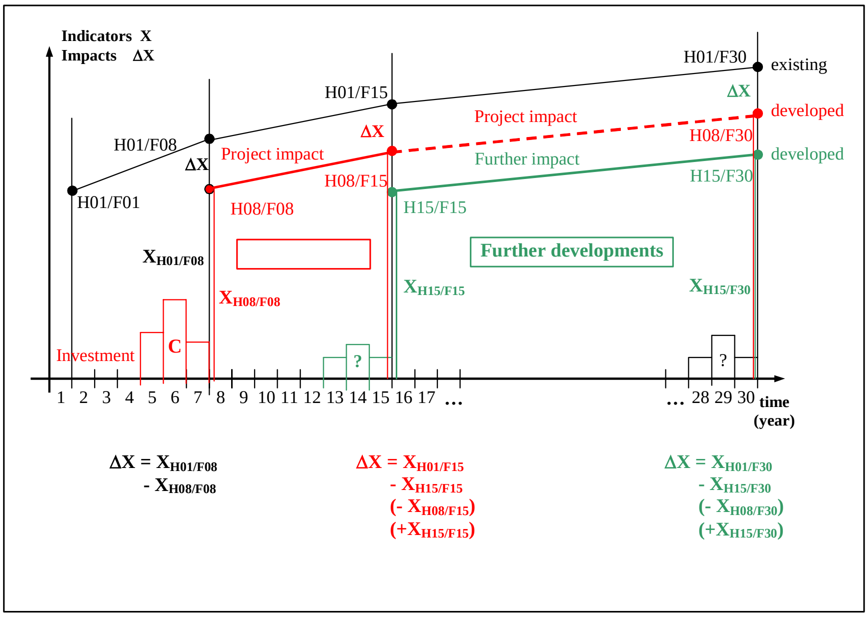
The marked window in the 12. Figure was chosen for the assessment after investigation using traffic load difference maps.



12. Figure: Definition of the investigation area in the frame of the national network

Beside the definition of the investigation area also a "timing plan" has to be considered with the main dates of the development in the future (beside 2001 at least 2008, 2015 to 2003), which are crucial for the proper calculation of the impacts, as a difference of the indicators of the "without" (0.) and "with" (1.) case ($\Delta x_{1,t} = x_{0,t} - x_{i,t}$) (see. 13. Figure).

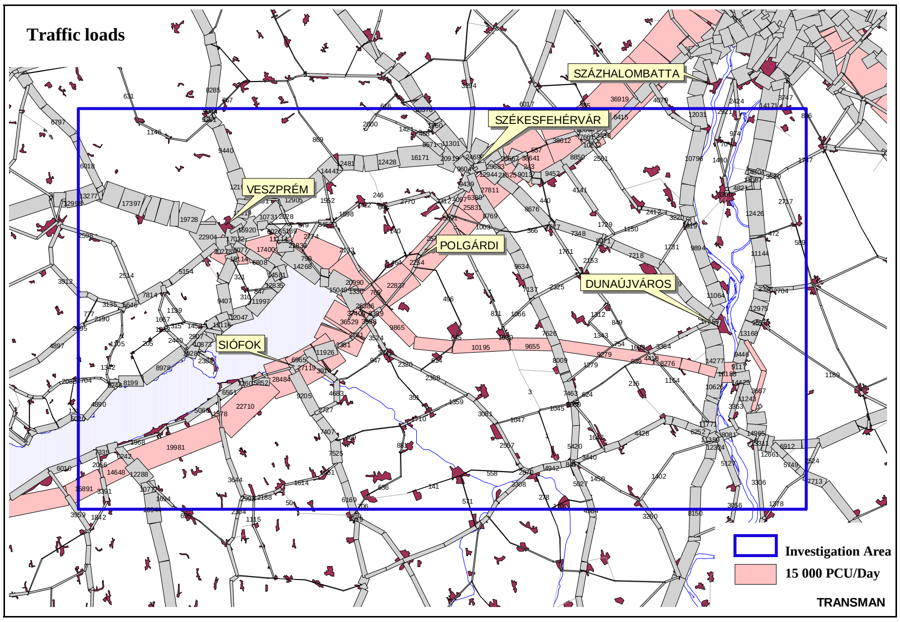
Between the "dedicated" years of the development a linear interpolation can be used later in the CBA calculations.



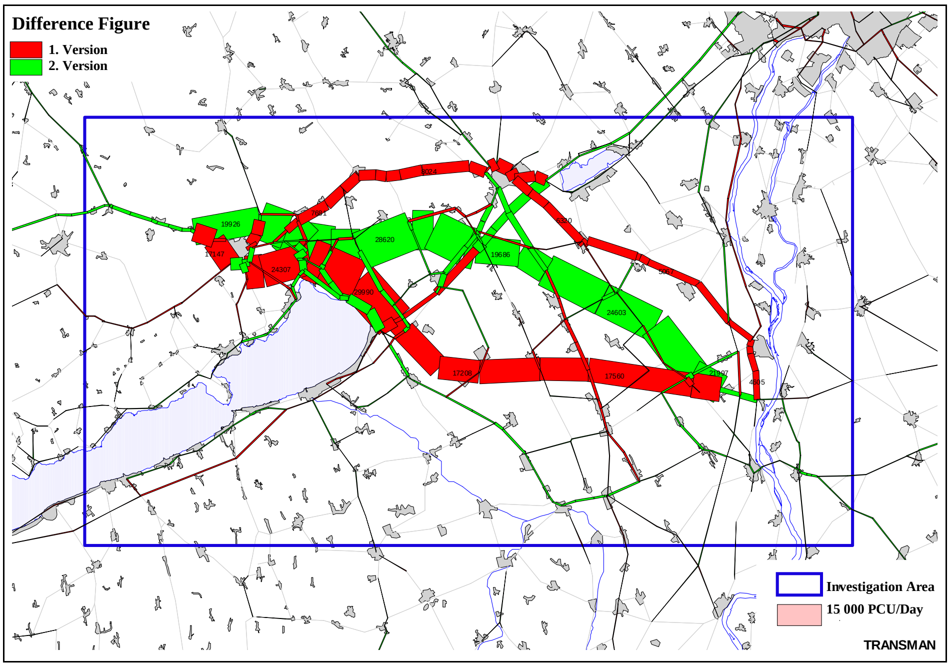
13. Figure: Theoretical formation of the project impacts in case of gradual developments

3.4 Investigations of the traffic development

The most important base volumes are the network traffic loads by versions of the development alternatives in the requested years, which moreover the traffic-technical and measuring aspects, forms the basis of the most important traffic indicators. (see. 14. Figure and 15. Figure). The traffic assignment is done by a multi-step equilibrium method.

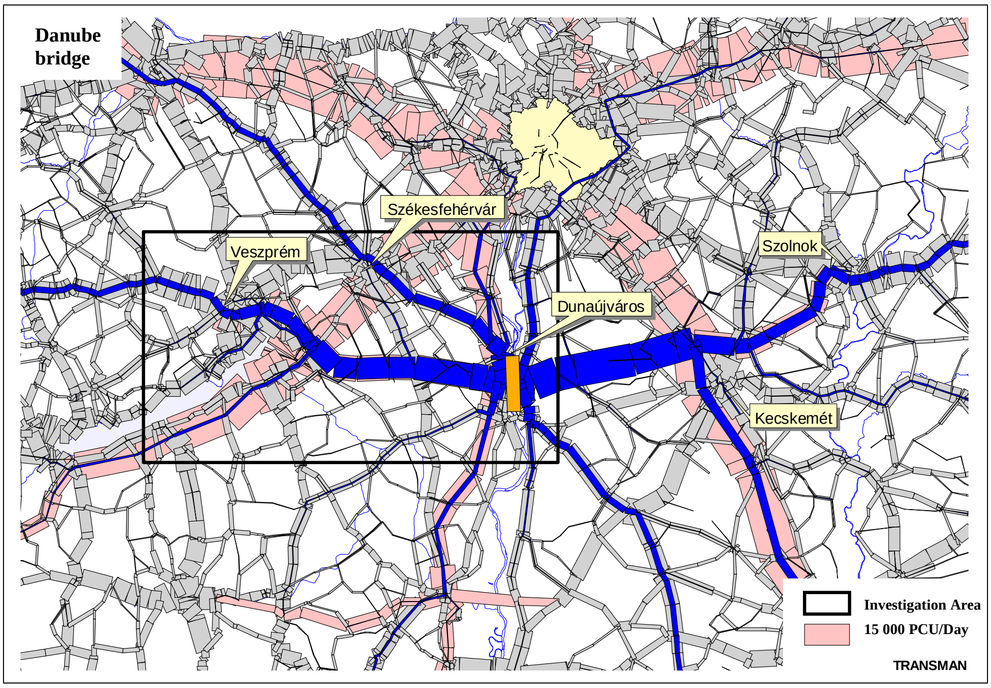


14. Figure: Future traffic loads of alternative 1. in 2008 (as example)



15. Figure: Traffic load differences of the alternatives 1. and 2. in 2015

The TRANSWAY-model allows the analysis of traffic flows passing key cross-sections, as it is shown for the Danube bridge at Dunaújváros .



16. Figure: The direction of the traffic crossing the Danube-bridge at Dunaújváros in 2015

3.5 Calculation of impact indicators and assessment

The quantifying and assessing of the impact changes – in consequence of the network development – is one of the key elements of the planning work from the viewpoint of the decision-support.

Evaluation Indicators

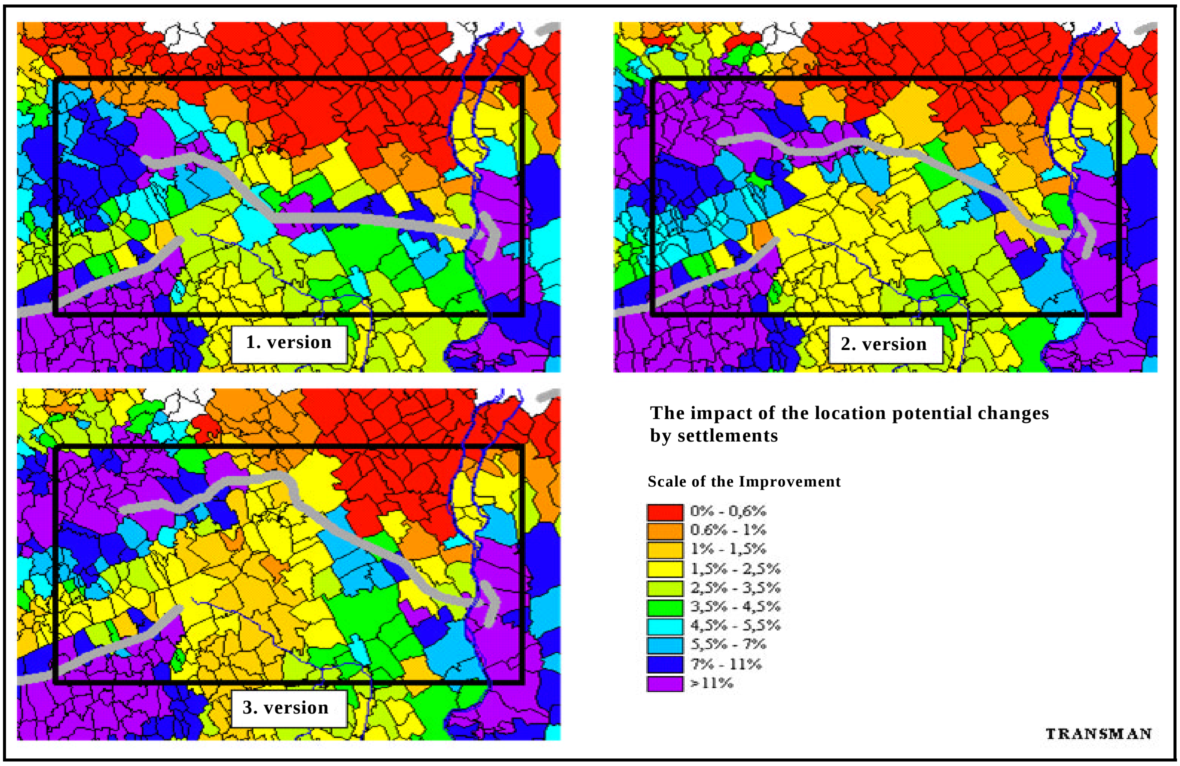
Traffic and environmental indicators:

- Time-expenditure, cost of time
- Fuel consumption, fuel costs
- Accidents, accident losses
- Air pollution
- Noise
- Occupied land

Connectivity indicators

- Connections of the broader area
- Connections of the nearer area
- The **location potential indicators** provide a possibility to a more complex evaluation of the connections and the chances of area development for any involved settlements.

The 17. Figure shows the "location potential changes" of the settlements (i) along the investigated section of the M8 motorway.



17. Figure: The changes of the location potentials by the alignment versions

The results and also the figure should represent the "ability" of the utilization of the improved locational potentials and stand for possible economic and territorial developments (at the moment it is a "proportional substitute" for more complicated economic modelling results, without the danger of double counting).

3.6 Cost-benefit analysis

Based on the calculated indicators by the impact models two assessing methods were used: **cost-benefit analysis (CBA)** for the impacts, which are available in monetary terms and **multicriterial analysis (MCA)** involving all impacts from the model.

The 4. Table shows the evaluation table where the benefits/losses are shown of alternative 1 ("with" case) in comparison to the "without" case (X_0-X_1).

Following efficiency indicators had been calculated:

- Cost-benefit ratio (CBR)
- Net present value (NPV)
- Time of return (TR)
- Rate of return for the first year (RRF)
- Internal rate of return (IRR)

The applied rate d=0,08 seams now days rather low (see 4. Table).

Version: 1. Impacts compared to the 'do nothing' scenario (0): X_0-X_1 traffic: 1,0 time: 1,0 investment: 1,0 2002. year price level

Years	t	$(1+d)^{-t}$	Invesatment cost		Oper.+maint. Cost		Time cost-impact				Operation cost-impact			Accident-impact				Total impacts	
			Nominal	Discounted	Nominal	Discounted	Mill Hours			Nominal	Mill HUF		Nominal	Injuries			Nominal	Nominal	Discounted
		d= 0,080	Bill.. HUF	Bill HUF	Bill. HUF	Bill. HUF	Car	Truck	Bus	Bill. HUF	Light veh. (Car)	Heavy veh. (Truck+bus)	Mrd Ft	Deads	Severe	Light	Bill. HUF	Bill. HUF	Bill. HUF
2001	-7	1,714	0,00	0,00	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2002	-6	1,587	0,00	0,00	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2003	-5	1,469	0,00	0,00	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2004	-4	1,360	0,00	0,00	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2005	-3	1,260	0,00	0,00	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2006	-2	1,166	35,80	41,76	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2007	-1	1,080	64,44	69,60	0,000	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0	0	0,0	0,0	0,0
2008	0	1,000	42,96	42,96	-1,290	-1,29	2,7	0,4	0,1	8,8	-9,7	-6,7	-3,5	10	64	127	0,9	4,9	4,9
2009	1	0,926	0,00	0,00	-1,290	-1,19	2,6	0,3	0,1	8,5	-11,9	-7,6	-4,2	10	61	122	0,8	3,9	3,6
2010	2	0,857	0,00	0,00	-1,290	-1,11	2,5	0,3	0,1	8,2	-14,0	-8,4	-4,8	9	58	116	0,8	2,9	2,4
2011	3	0,794	0,00	0,00	-1,290	-1,02	2,4	0,3	0,1	7,9	-16,2	-9,2	-5,5	9	55	111	0,7	1,9	1,5
2012	4	0,735	0,00	0,00	-1,290	-0,95	2,4	0,3	0,1	7,6	-18,3	-10,0	-6,1	8	52	105	0,7	0,9	0,6
2013	5	0,681	0,00	0,00	-1,290	-0,88	2,3	0,3	0,1	7,3	-20,5	-10,9	-6,8	8	49	100	0,7	-0,1	-0,1
2014	6	0,630	0,00	0,00	-1,290	-0,81	2,2	0,2	0,1	7,0	-22,7	-11,7	-7,4	7	47	95	0,6	-1,1	-0,7
2015	7	0,583	0,00	0,00	-1,290	-0,75	2,1	0,2	0,1	6,6	-24,8	-12,5	-8,1	7	44	89	0,6	-2,1	-1,3
2016	8	0,540	0,00	0,00	-1,290	-0,70	2,8	0,4	0,1	9,1	-33,3	-15,4	-10,6	12	73	146	1,0	-1,8	-0,9
2017	9	0,500	0,00	0,00	-1,290	-0,65	3,3	0,4	0,1	10,9	-32,4	-15,0	-10,3	13	78	156	1,0	0,4	0,2
2018	10	0,463	0,00	0,00	-1,290	-0,60	3,9	0,5	0,1	12,7	-31,5	-14,5	-10,0	14	84	166	1,1	2,6	1,2
2019	11	0,429	0,00	0,00	-1,290	-0,55	4,4	0,6	0,1	14,6	-30,6	-14,1	-9,7	15	89	176	1,2	4,7	2,0
2020	12	0,397	0,00	0,00	-1,290	-0,51	5,0	0,7	0,1	16,4	-29,7	-13,7	-9,4	15	95	186	1,3	6,9	2,7
2021	13	0,368	0,00	0,00	-1,290	-0,47	5,5	0,7	0,2	18,2	-28,8	-13,3	-9,1	16	100	196	1,3	9,1	3,3
2022	14	0,340	0,00	0,00	-1,290	-0,44	6,1	0,8	0,2	20,0	-27,9	-12,8	-8,8	17	106	206	1,4	11,2	3,8
2023	15	0,315	0,00	0,00	-1,290	-0,41	6,6	0,9	0,2	21,8	-26,9	-12,4	-8,5	18	111	216	1,5	13,4	4,2
2024	16	0,292	0,00	0,00	-1,290	-0,38	7,2	0,9	0,2	23,6	-26,0	-12,0	-8,3	19	117	226	1,5	15,6	4,5
2025	17	0,270	0,00	0,00	-1,290	-0,35	7,7	1,0	0,2	25,4	-25,1	-11,6	-8,0	20	122	236	1,6	17,7	4,8
2026	18	0,250	0,00	0,00	-1,290	-0,32	8,3	1,1	0,2	27,2	-24,2	-11,1	-7,7	21	128	245	1,7	19,9	5,0
2027	19	0,232	0,00	0,00	-1,290	-0,30	8,9	1,2	0,3	29,0	-23,3	-10,7	-7,4	22	133	255	1,7	22,1	5,1
2028	20	0,215	0,00	0,00	-1,290	-0,28	9,4	1,2	0,3	30,8	-22,4	-10,3	-7,1	22	139	265	1,8	24,2	5,2
2029	21	0,199	0,00	0,00	-1,290	-0,26	10,0	1,3	0,3	32,6	-21,5	-9,9	-6,8	23	144	275	1,9	26,4	5,2
2030	22	0,184	0,00	0,00	-1,290	-0,24	10,5	1,4	0,3	34,4	-20,6	-9,5	-6,5	24	150	285	2,0	28,6	5,3
Sum:			143,20	154,31	-29,670	-14,45	118,7	15,3	3,5	388,5	-542,2	-263,3	-174,7	339	2099	4099	27,8	212,0	62,7

Indicators:

Cost-benefit ratio (CBR): 0,406 Net present value (NPV): -91,645 Time of return (TR): 54,173

Internal rate of return (IRR): 0,084 Rate of return for the first year (RRF): 0,031

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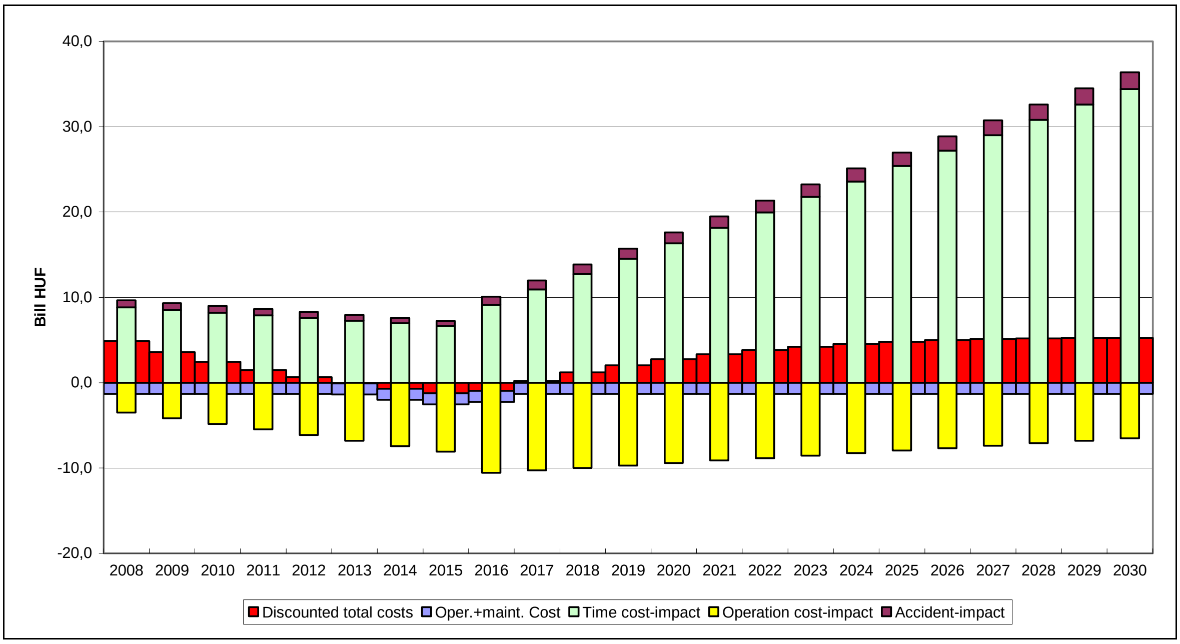
4. Table: Spreadsheet for Cost-benefit analysis (Alternative 1.)

The 18. Figure shoves a diagram coming from this for the CBA:



18. Figure: The tendencies of the savings of the 1. version

We take the modelled accessibility and potential indicators together with time consumption, fuel costs, accident cost air pollution, noise, land occupation into the MCA, which is done parallelly to the conventional CBA involving the monetary values of time, fuel and accident cost savings, against the investment costs.

We would need also the "economic benefits" in the CBA, because the efficiency rates from the conventional CBA are modest, but at the moment we are not able to model them in a fair economic way. These should be substituted by the changes of the location potentials, which are shown for the three alternatives in the 17. Figure.

3.7 Multicriterial analysis

The multicriterial analysis gives the possibility to evaluate also those indicators, which are not monetarizable (e.g. air pollution, noise, accessibility, location potential) but have very important impacts from the viewpoint of transport.

During the multicriterial analysis the indicators are used in natural units, thus the monetarized indicators can be taking into account in money. In the MCA involved indicators ca be seen in the 5. Table.

The definition of the values of the different dimensional indicators (monetariazable and non monetarizable) (XP) is possible with "utility scales" where the value of the best case is

100 of the given indicator (m) and the worse is the minimum. The other alternatives (v) get a score between the two end values (XP_v) as follows:

$$XP_{v,m} = \left\{1 - \left[\frac{X_{v,m} - \min X_m}{\max X_m - \min X_m} \cdot (1 - \frac{\min X_m}{\max X_m})\right]\right\} \cdot 100$$

It is good to show the impacts of the different alternatives by indicators for the decision makers, but usually the representation of the impact in a general frame is required for the decision support.

In the view of that the importance of the different impact values are not the same therefore the aggregation of the use-value (HXP) is possible with importance (preference) weights (S):

$$HXP_{v,c} = \sum_m XP_{v,m} \cdot S_{c,m}$$

The preference weights that represents a scale of values (substituting the monetarization) could be different at a community or a concern (c) while the internal sum of the indicators is1,00 within a group.

The aggregated values can be seen as a relative "use-value" of the given version and that alternative is the best one, which summarized point-value is the highest.

The 5. Table shows an example for the MCA evaluation for the "traffic" scenario, where the traffic related indicators are more preferred as the environmental and connectivity indicators. Calculations for "environmental" and "area development" scenarios have been made too.

Scenario: Traffic

Indicators (X_m)	Unit of measure	Weight (S)	0. Version			1. Version			2. Version			3. Version		
			Value (X)	Score (XP)	Score·Weight	Value (X)	Score (XP)	Score·Weight	Value (X)	Score (XP)	Score·Weight	Value (X)	Score (XP)	Score·Weight
Time costs	Bill. HUF	0,240	100,9	91,3	21,9	92,1	100,0	24,0	93,7	98,4	23,6	94,9	97,3	23,3
Fuel costs	Bill. HUF	0,180	63,2	100,0	18,0	65,5	96,5	17,4	66,6	94,9	17,1	67,2	94,1	16,9
Accident losses	Bill. HUF	0,180	7,8	100,0	18,0	9,2	85,3	15,4	9,0	87,5	15,8	9,2	84,6	15,2
Air pollution (CO eqv.)	t/year	0,053	277240	96,3	5,1	266928	100,0	5,3	272673	98,0	5,1	282267	94,6	5,0
Noise	km · dBA	0,030	50,2	99,9	3,0	50,2	100,0	3,0	50,2	100,0	3,0	50,2	99,9	3,0
Area occupation	Km^2	0,068	6000,0	100,0	6,8	6436,0	93,3	6,3	6451,5	93,0	6,3	6496,5	92,4	6,2
Connections of the wider area	Min.	0,088	68,32	95,872	8,389	65,50	100,000	8,750	65,72	99,678	8,722	65,98	99,297	8,689
Connections of the nearer area	Min.	0,063	44,61	90,944	5,684	40,57	100,000	6,250	41,21	98,565	6,160	41,33	98,296	6,144
Location potential*	Mill HUF/min^2	0,100	1042,213	94,894	9,489	1086,054	98,886	9,889	1098,286	100,000	10,000	1082,323	98,547	9,855
		Use-value (HXP):			96,27			96,17			95,77			94,38
		Investment costs (K):						154,31			161,10			187,50
		Aggregált költséghatékonyság (FKH):						0,6232			0,5945			0,5034

* indicator with opposite scale (100 score= max X)

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5. Table: Multicriterial use-value analysis by the "traffic" scenario

3.8 Summarizing of the efficiency evaluation

The 6. Table shows the results of the cost-benefit analysis and the municriterial analysis in the frame of the investigations of the M8 motorway alternatives.

Evaluation indicator		Dimension	1.version		2.version		3.version	
			Value	Rank	Value	Rank	Value	Rank
Cost-benefit ratio	(CBR)	%	106,1	1	52,9	2	1,1	3
Net present value	(NPV)	Bill HUF	4,2	1	-33,4	2	-81,6	3
Internal rate of return	(IRR)	%	8,4	1	4,6	2	-0,4	3
Time of return	(TR)	Year	20,7	1	41,6	2	2064,9	3
Rate of return for the first year	(RRF)	%	5,7	1	1,9	2	-1,0	3
Use value (transport scenario)	(FKH)	Score/HUF	0,623	1	0,594	2	0,503	3
Use value (Environmental scenario)	(KKH)	Score/HUF	0,627	1	0,597	2	0,506	3
Use value (Area development scenari)	(TKH)	Score/HUF	0,633	1	0,605	2	0,513	3
Discounted investment costs	(C)	Bill HUF	154,31	-	70,88	-	82,50	-

6. Table: Efficiency indexes by versions

At the investigated three project alternatives both the CBA and the MCA have brought the same results (ranks), but it can happen, that the results are different then additional expert evaluation will be necessary.

3.9 Sensitivity analysis

In this case the **sensitivity analysis** was done by the changing of the time values only. The effect of the increase of the time value by 25% to the efficiency indices was investigated. The 7. Table shoves these results, where with the “base” values the “changed” results are also represented. As it can be seen the changing of the time value is influencing the efficiency indexes differently.

Evaluation indicator		Unit	1.version		2.version		3.version	
			Base	Changed	Base	Changed	Base	Changed
Cost-benefit ratio	(CBR)	%	106,1	159,3	52,9	96,7	1,1	31,0
Net present value	(NPV)	Bill HUF	4,16	40,281	-33,389	-2,306	-81,622	-56,924
Internal rate of return	(IRR)	%	8,4	11,9	4,6	7,8	-0,4	2,7
Time of return	(TR)	Year	20,7	13,8	41,6	22,7	2064,9	71,0
Rate of return for the first year	(RRF)	%	5,7	8,9	1,9	4,4	-1,0	0,8
Discounted investment costs	(C)	Bill HUF	154,31		161,0		187,5	
Without residual value		Bill HUF	67,9		70,88		82,5	

7. Table: Efficiency indexes by versions (Sensitivity analysis)

In this case – to show the impact of the results – it is obvious that in the planning procedure all the important factors have to be investigated, which can have an impact on the efficiency results and can mean a risk in the course of the realisation. One of the most important base are the modelled traffic volumes and also the monetary volumes for time, accident demands etc. are essential, as well as the discount rates used. There are further external factors, which are carefully to investigate (e.g. taxes, regulations) they may influence the assumptions and enhance the risk of the viability of the development.

4 THE INVESTIGATION OF THE IMPACTS OF THE FOREIGN TRAFFIC

Taking into consideration that the infrastructure developments occurs from national resources, but the benefits (and the excess burdens) concerns not only the domestic transport users and economy therefore the national developments are worth to international (EU) subsidies.

The aim is to improve the network-planning methods (traffic-estimation, impact-quantification and assessment) that the benefits and burdens caused by the national and foreign users will be possible to demonstrate and hereby **to give the reason for European subsidies**.

The rate of the subsidisation – in line with the EU's efforts – can be determined by the followings:

- Time savings of the foreigners
- Accidents caused by the foreigners
- Air pollution caused by the foreigners
- Economic development in the home countries of the infrastructure users

So the extent of the subsidies should be defined by the advantages of – and burdens caused by – the foreign users and the economic surpluses of their home countries.

For this, appropriate traffic models, different impact-modules as well as macroeconomical models would be requested.

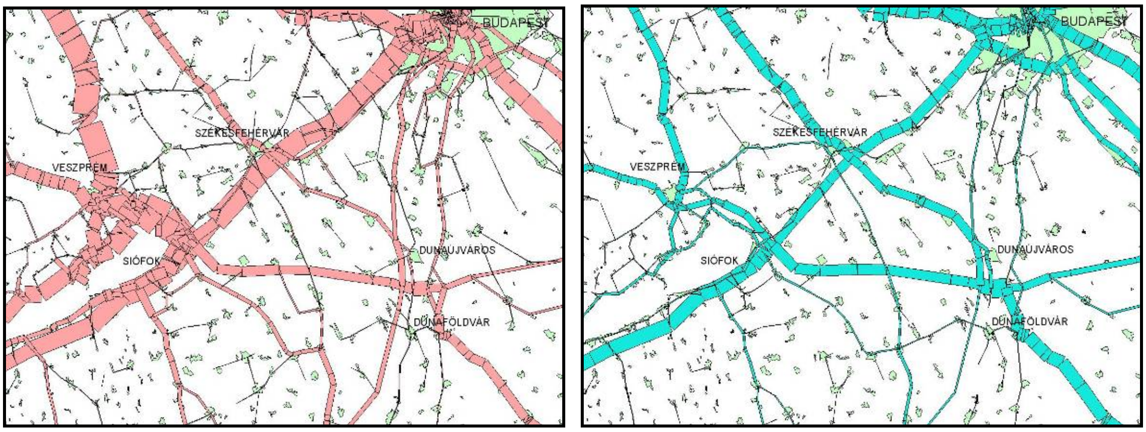
In the previous section, the assessing process of the three alternative routes of the M8 highway – in line with the EU requirements – was introduced and in the followings with the elaboration and fine-tuning of the models in addition to the whole-, the impacts of the foreign traffic will be also represented. The share of the foreigner traffic from the causing of benefits and disadvantages can be the basis of the explanation of the EU support.

4.1 Computation of the foreign traffic loads

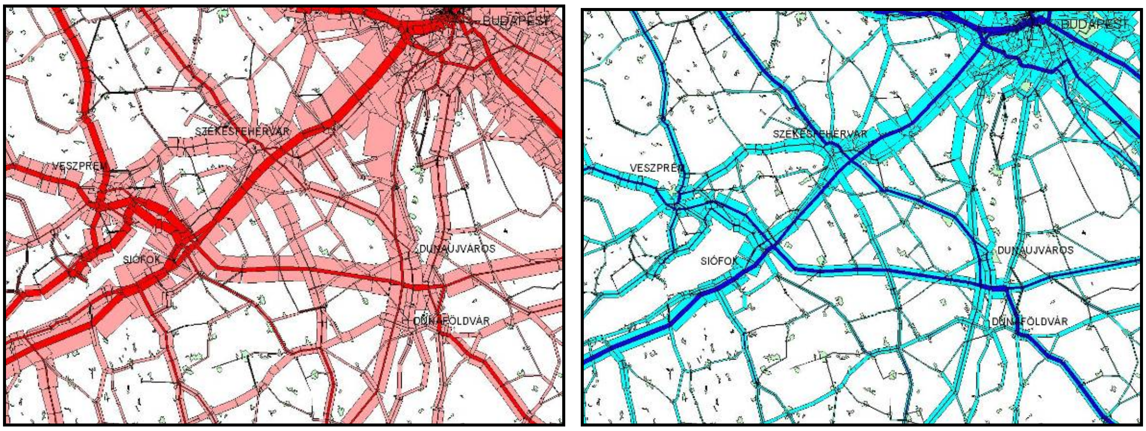
In the TRANSWAY model the following layers of the international traffic is considered (see 3. Figure):

- domestic vehicles (car, truck) border-crossing originating- and destination traffic;
- foreign vehicles (car, truck) border-crossing originating- and destination traffic;
- foreign vehicles (car, truck) border-crossing transit traffic;
- (additional domestic traffic of foreign vehicles (car, truck); approximated).

The bus traffic is defined by an additional procedure based on the car- and freight traffic. The development of the international traffic is estimated by the development of the Hungarian economy and the possible development potentials of the neighbouring areas. The traffic matrixes of the future years (2008, 2015 and 2030) are based on these (see. 19. Figure and 20. Figure).



19. Figure: M8 foreign car and truck traffic loads (2015)



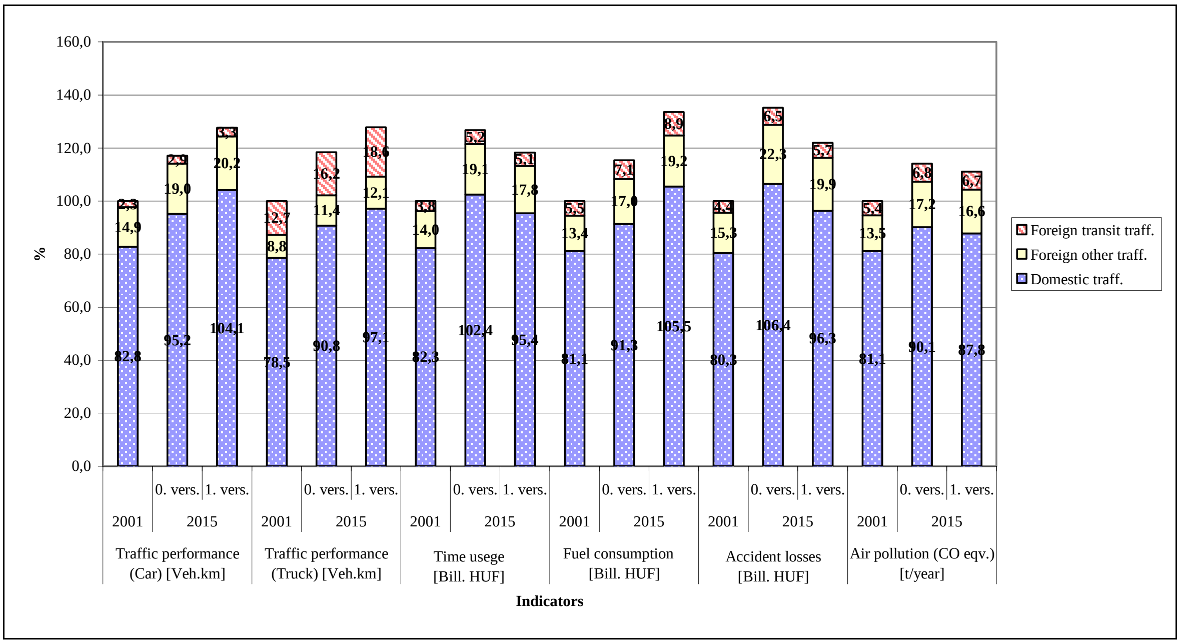
20. Figure: Proportions of the foreign car and truck traffic (2015)

4.2 Calculation of the impact-parts of the foreigners

With the knowledge of the traffic loads are the calculation of the impacts possible (see 8. Figure). The following table (8. Table) shows the indicators of the 1. version of M8 highway development in year 2015, the table also contains the values of the ‘without development’ case. The 21. Figure represents these indicators in graphical form, where the existing case (year 2001) represents 100 %.

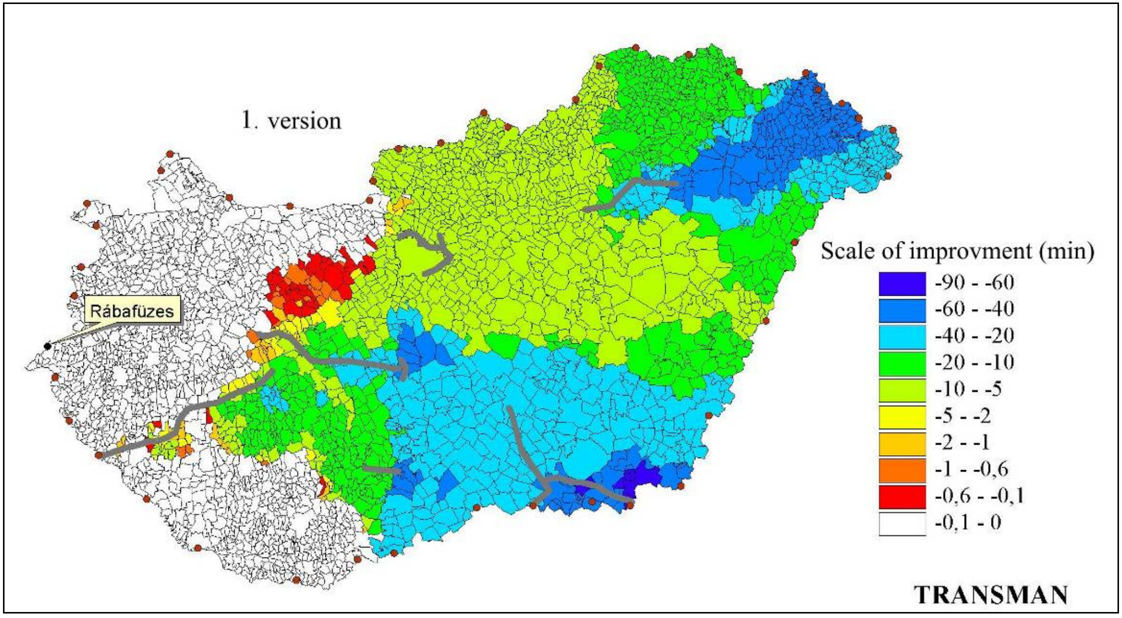
Indicator	Unit of measure	0. Version (2001)			0. Version (2015)			Absolut change year 2015 (2015-2001)		Relativ change year 2015 ((2015-2001)/2001)	
		All traff.	Foreign traff.	%	All traff.	Foreign traff.	%	All traff.	Foreign traff.	All traff. %	Foreign traff. %
Traffic performance (Car)	Veh.km	2725	469	17,2	3190	597	18,7	465	128	0,171	0,273
Traffic performance (Truck)	Veh.km	456	98	21,5	540	126	23,3	84	28	0,184	0,286
Time usage	Bill. HUF	81,117	14,394	17,7	102,784	19,711	19,2	21,667	5,317	0,267	0,369
Fuel consumption	Bill. HUF	58,127	10,982	18,9	67,081	13,995	20,9	8,954	3,013	0,154	0,274
Accident losses	Bill. HUF	16,466	3,241	19,7	22,271	4,752	21,3	5,805	1,511	0,353	0,466
Air pollution (CO eqv.)	t/year	300431	56675	18,9	342990	72160	21,0	42559	15485	0,142	0,273
Indicator	Unit of measure				0. Version (2015)			Absolut change year 2015 (2015-2001)		Relativ change year 2015 ((2015-2001)/2001)	
					All traff.	Foreign traff.	%	All traff.	Foreign traff.	All traff. %	Foreign traff. %
Traffic performance (Car)	Veh.km				3480	642	18,4	755	173	0,277	0,369
Traffic performance (Truck)	Veh.km				583	140	24,0	127	42	0,279	0,429
Time usage	Bill. HUF				95,953	18,539	19,3	14,836	4,145	0,183	0,288
Fuel consumption	Bill. HUF				77,652	16,319	21,0	19,525	5,337	0,336	0,486
Accident losses	Bill. HUF				20,084	4,222	21,0	3,618	0,981	0,220	0,303
Air pollution (CO eqv.)	t/year				333829	70104	21,0	33398	13429	0,111	0,237

8. Table: Impact changes for the total- and foreign traffic (M8, 2015, 1. version)



21. Figure: Impact changes (“without” case (alt. 0) and “with” case (alt. 1) in 2001 and 2015 years)

Because of the development of the M8 highway for the economy of the neighbouring countries Hungary is “getting closer”, which can be represented by the access times measured at the Austrian border-crossing points. As an example this change is showed for the Rábafüzes border-crossing point for the best alternative 1 in the 22. Figure.



22. Figure: Changes of accessibilities from Rábefüzes due the M8 development

As we have mentioned in the introduction it is important to show to which extent the best of the alternatives contributes to the cohesion and values on European level, which can be showed by the involvement of the international traffic in the benefits of the total traffic. In connection to the cost-benefit and multicriterial analysis calculations have been made about the benefits gained and burdens caused by the foreign traffic, which can be a help at arguing for EU-funding. The higher the international participation is the higher the part of EU-funding can be.

In view of the foreign impact-ratios (p) the following EU funding ratios (EUF) looks reasonable for an accession country as Hungary, supposed that a project is efficient (see 9. Table), even if the ratios can be seen as arbitrary.

Foreign impact ratios (p)	**EU funding ratios (EUF)**	**Remarks**
$p > 25$	75	Sections close to the border
$20 < p \leq 25$	70	
$16 < p \leq 20$	65	
$12 < p \leq 16$	60	
$8 < p \leq 12$	55	
$5 < p \leq 8$	50	Average foreign ratio
$2 < p \leq 5$	45	
$< p \leq 2$	40	Small foreign ratio

9. Table: The proposed connection between the foreign impact ratios and EU funding ratios

5 GRADUAL LONG-TERM DEVELOPMENT OF THE NATIONAL HIGHWAY NETWORK

5.1 Definition of the long-term optimal network

At the working out of network connections and highway network alternatives for investigation the following main **principles of network design** had been followed:

- Highways should provide connection with the capital cities and bigger cities of the neighbouring countries mainly in the directions of the European corridors. Building of high capacity highways for the service of the transit demands of other countries, which do not interfere with the domestic long-distance connections is not proposed by the plan due to environmental and efficiency reasons.

- Motorways are planned only on those routes where the main domestic and international routes coincide and the demands are planned to be satisfied jointly.

- The centres of the counties, other important centres, industrial and holiday resorts are also directly connected to the highway network.

- One of the main elements of the highway network is the M0 motorway around Budapest. Beside satisfying the domestic long-distance and international connections the interdistrict and regional traffic has to be served too. As a distributor ring road this route would also distribute the traffic arriving in or leaving Budapest.

- The public road structure of the country improves through the realisation of objectives and principles, the current radial system will be transformed into a radial-ring structure.

Considering these principles long-term network alternatives had been worked out.

The development of the optimal long-term network is planned to be completed in 2029-2030 in several steps on the basis of the expected traffic demands resulting from a motorisation level of approximately 430 cars/1000 inhabitants.

The long-term network structure is the most advantageous form of the Hungarian highway network according to our current knowledge. It is necessary to conduct the planning phase of the development even if we are aware that its realisation will be the responsibility of the future generations.

It means the definition of such a framework, within which the more specific medium term improvement tasks can be determined.

Beyond the technological aspects of planning (e.g.: the data of area planning has to be tied to dates) the harmonisation with the scheduling of the concession motorway has also become possible as a result of the determination of the year of the completion of the long-term plan.

The traffic demands and the distribution of traffic on the network were analysed as a toll-free case, since it is considered inevitable that a future network structure is determined that is the most advantageous in respect of the national economy regardless to the method of financing and the influencing effect of toll.

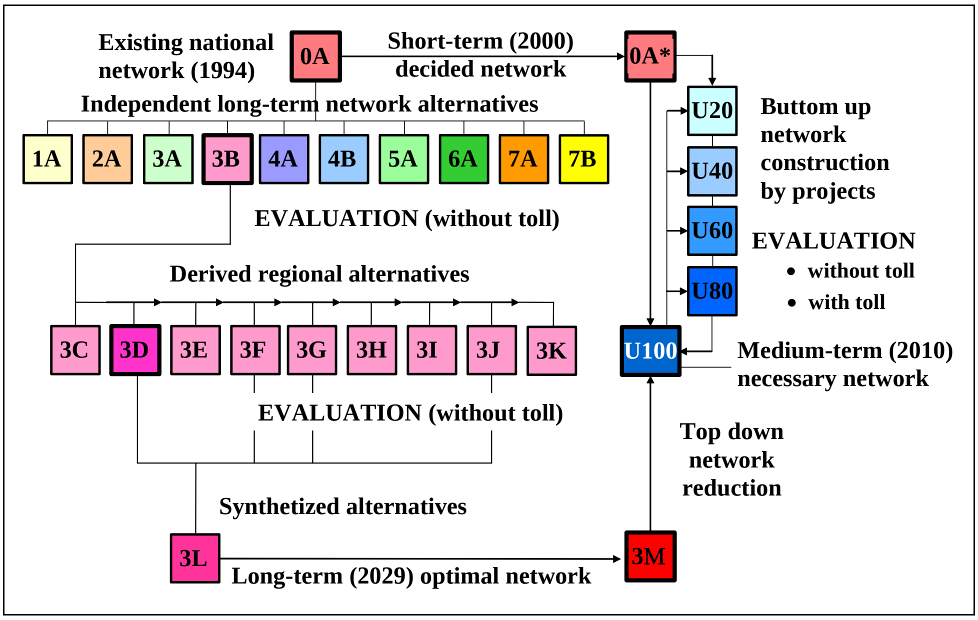
The analysis was conducted in several steps (see 23. Figure):

Step 1: development and examination of independent alternatives (1A, 2A, 3A, 3B, 4A, 5A, 6A, 7A, 7B) (see the evaluation indicators for these long-term alternatives in Table4)

Step 2: analysis of further, regional versions generated from the most advantageous alternative, 3B (3C, 3D, 3E, 3F,3G, 3H, 3I, 3J)

Step 3: selection of the most advantageous one (3M) of the synthesised country-wide alternative (3L) (3M) derived from the regional versions

The 9 alternatives of the highway around Budapest (M0) were analysed separately, where the development objectives were modified according to the characteristics of the region and the evaluation was executed according to five “preference scenarios”.



23. Figure: The planning process of national network optimisation

5.2 Investigation of the medium-term highway network

Within the long-term network – which is regarded a framework concept, rather – an analysis was necessary where more specific as well as financial possibilities were also considered. For determining the demands of the developments (projects) that can be realised on the medium-term (2010) the probable network structure in 2000 (OA*) was taken as a basis (this includes the developments that are realisable or approved of) (23. Figure).

On the medium-term (until 2010) the necessary developments were defined on and other the basis of the traffic demands in 2010 with the consideration of capacity utilisation aspects. 39 projects were defined and examined all in all at various points of the network in order to estimate the impact of each one (ceteris paribus). Since the realisation of given projects is based on the completion of other, earlier projects in these cases the analyses could be conducted according to a set order.

The aim of the analyses is to estimate the impact of the given projects, to **define their order of efficiency** and to present the different savings and losses that can be achieved by the different alternatives of network development according to the different volumes of the investment budget.

For ranking the projects according to their urgency the benefit-cost ratio was applied, which is suitable for the definition of the relative order of the projects even in its form of considering the savings of just the ‘target year’.

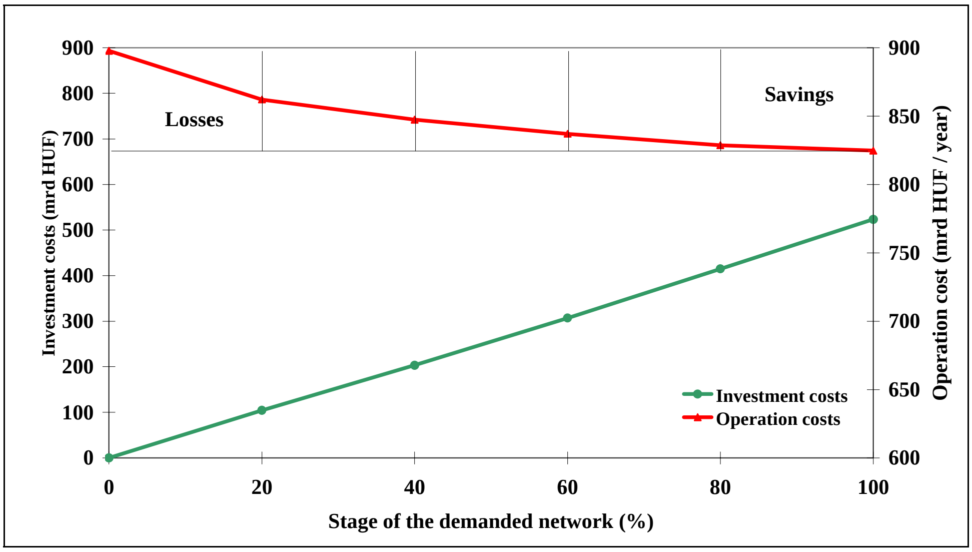
This is usually a monotonously decreasing order (except for the case when in spite of its better efficiency figures the project cannot step ahead because the preceding project where on it is built up is less efficient.

In the course of the analyses the investment cost demand of the given projects were also defined, as a result of which the total cost of the 39 projects that were considered as worth realising between 2000 and 2010 were set at HUF 525 billion (at 1994 price levels). It was feared that this amount will exceed the available budget, which was difficult to estimate.

Thus we took a reverse route: we examined what network structures could be realised if only 20%, 40%, 60% or 80% of the necessary amounts were available.

The joint analysis have proved that the efficiency of the first 20% of the investment amount is much higher than that of the last 20% would be [2].

The financial calculations also enable to present figures on the **savings** to be achieved through the investments (compared to the 0% “do-nothing”network) and **losses** that are generated compared to the 100% (complete realisation) scenario (see 24. Figure).



24. Figure: Impacts of phased developments

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