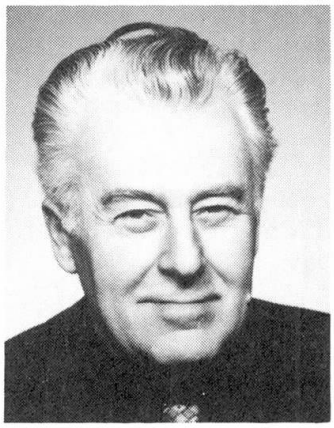
Economic and socioecological aspects of a European motorway

Economic and Socioecological Aspects of a European Motorway

Effets économiques et socio-écologiques d'une autoroute européenne

Ökonomische und sozio-oekologische Beurteilung einer europäischen Autobahn

Lumír BOROVIČKA
Dr. Eng.
Pragoprojekt
Prague, Czechoslovakia



Lumír Borovička, born 1921, received his civil engineering and Ph.D. degree at the University of Prague, and has been responsible for bridge and road research, design and construction supervision in several design and research institutes in Czechoslovakia. He has acted as UNO expert in vocational training in civil engineering field in Asia and Africa.

SUMMARY

The governments of 10 European countries are preparing and gradually implementing a 10000 km long motorway transport system connecting the Polish port Gdansk with the Turkish frontier to Iran. The Czechoslovakian experts have been entrusted with the preparation of «Guidelines for Economic, Aesthetic and Environmental Impact Assessment of the Trans-European North-South Motorway» and for the assessment of alternative projects. This new system enables the assessment of economic and environmental effects as well as the influence on the economic development of the regions through which the motorway passes.

RÉSUMÉ

Les gouvernements de dix pays européens préparent et réalisent un système autoroutier de 10000 km reliant le port polonais de Gdansk avec la frontière turco-iranienne. L'élaboration d'un «Standard d'évaluations des effets économiques et socio-écologiques pour la comparaison des variantes des tronçons étudiés de l'autoroute européenne Nord-Sud» a été confiée aux experts tchécoslovaques. Le système nouveau permet d'évaluer globalement les différents aspects, les effets sur l'environnement et le développement des régions traversées par l'autoroute Nord-Sud.

ZUSAMMENFASSUNG

Im Auftrag von zehn europäischen Regierungen wird die 10000 km lange transeuropäische Nord-Süd Autobahn projektiert und etappenweise ausgeführt. Nach ihrer Vollendung wird sie den polnischen Hafen Gdansk mit der Türkisch-Iranischen Grenze verbinden. Tschechoslowakische Experten wurden mit der Aufgabe betraut, Richtlinien für die Beurteilung von Alternativprojekten zu erarbeiten. Mit diesen lassen sich gleichzeitig ökonomische Aspekte und solche des Umweltschutzes sowie auch die Einflüsse auf die ökonomische Entwicklung der von der Autobahn tangierten Regionen beurteilen.

1. PRINCIPLES OF THE TEM-PROJECT

Since the mid of seventies ten European countries - Austria, Bulgaria, Czechoslovakia, Greece, Hungary, Italy, Poland, Romania, Turkey, Yugoslavia - have made significant efforts to coordinate the planning and successive realisation of the Trans-European North-South Motorway (TEM) connecting them (see Fig.1).

The project started within the framework of the United Nations Development Programme (UNDP) and the Economic Commission for Europe (ECE). Each country is responsible for the construction and financing of the sections of the motorway running through its own territory.

In order to achieve its objectives of the first phase (1978-83) the UNDP project undertook among others:
- the development and promotion of common standards of motorway design, maintenance and management (entrusted to Italian experts);
- an "origin and destination" survey and international traffic flow forecasting (entrusted to Danish experts);
- studies on environmental implications and socio-economic assessment of alternatives (entrusted to Czechoslovak experts);
- studies on synchronization of construction, investment and recommendations on construction technology.

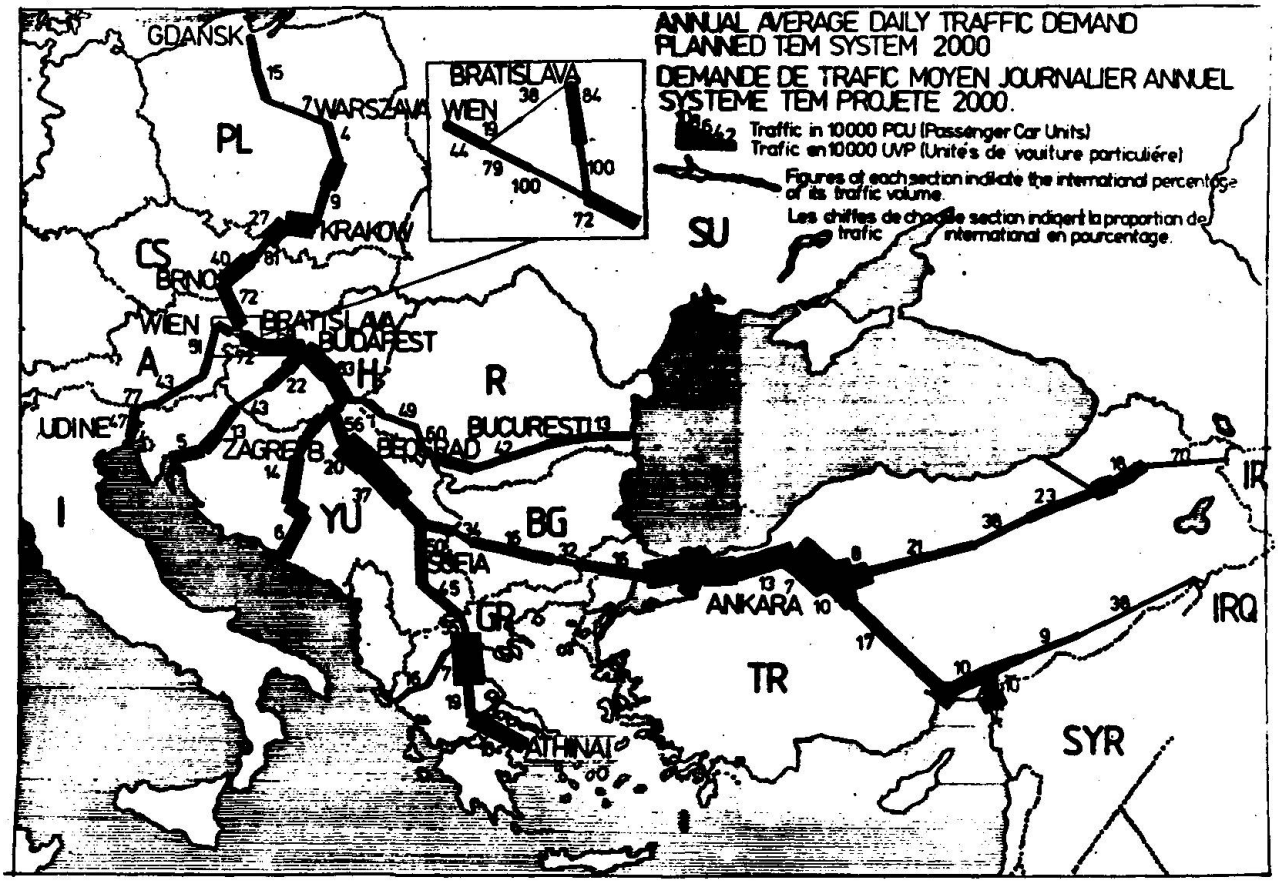


Fig.1 Average daily traffic forecast for the TEM system in 2000.

2. GUIDELINES FOR ECONOMIC, AESTHETIC AND ENVIRONMENTAL IMPACT ASSESSMENT FOR THE TRANS-EUROPEAN NORTH--SOUTH MOTORWAY

The elaboration of "Guidelines for impact assessment for the whole TEM project" - in following AECOTEM - has been entrusted to Czechoslovakia. This task has been completed and aided by useful international contacts - late 1983.

2.1 Principles of AECOTEM Guidelines

The planning and design of motorways represents a complex decision-making process. When determining the alignment of future motorways the designer is limited not only by the technical standards, regulations and by-laws but also by economic, aesthetic, ecological and other considerations prevailing in the particular region. As these aspects are very different in their nature - and the well-known existing methods of assessment of route variants based purely on monetary values cannot be satisfying enough to consider all aspects at once - a new method for complex assessment of variants is elaborated in the "AECOTEM Guidelines", which is based on value analysis of all different aspects to be taken into consideration.

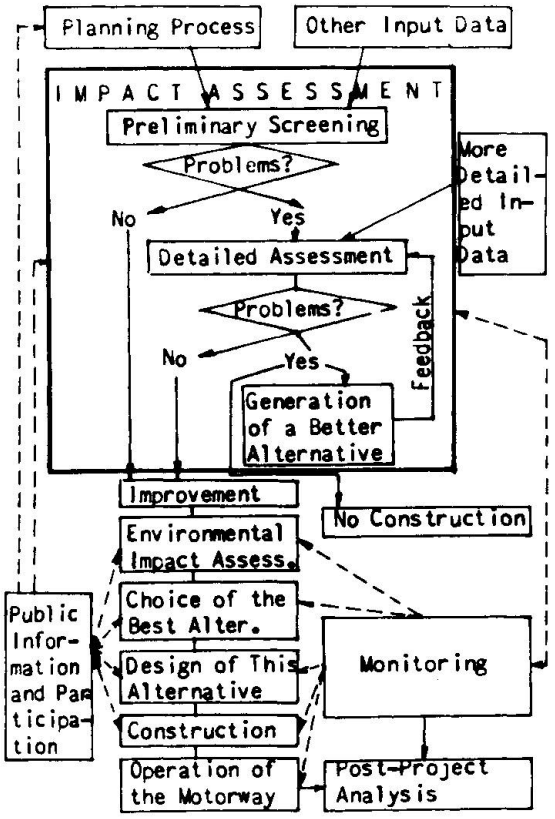


Fig.2 Impact assessment process

The AECOTEM Guidelines enable so - in a more advanced and secureful way than before -

- for the planners, civil engineers and consultants: to gain data - for each variant of rather costly motorway or its section - with increased security and quality and with possibility of differentiation of complexity of aspects; this enables them to recommend the truly most advantageous variant of the respective TEM section for implementation - advantageous for construction, exploitation, with minimum adverse effects for environment and most positive effects for the regional development;
- for the decision-makers: to possess means for appropriate decisions - with feed-back control - in selecting the best variant.

The assessment itself is usually carried out in two steps (preliminary screening and detailed assessment) and is often repeated (generation of new alternatives). It finishes with the final ranking of alternatives as a basis for the final decision which alternative to select for implementation. The scheme of usual approach recommended for TEM is indicated in Fig.2.

2.2 Preliminary Screening

When the first planning sketches, fesibility studies or preliminary alignment drawings - of a number of alternatives - are set up (available), it is necessary to analyze the advantages and disadvantages of different alternatives, taking into consideration (a) different activities emanating from TEM (construction, exploitation, regional development etc.), (b) different effects (e.g. investment costs, maintenance, traffic safety, users´ needs, environmental effects). The "Guidelines" recommend a special "Cause-Effect Matrix Method" -

MATRIX II VARIANT C			A. ACTIVITIES										
			A1				A2						A3
			Access roads	Earthworks	Drilling/blasting	Demolition	Pavements	Cuts and fills	Bridges, tunnels	Pavements	Traffic	Maintenance	Transport in region
E. AREAS OF POTENTIAL EFFECTS	Physical	Ground waters		-3	-2		-1	-2				-2	
		Surface waters						-2	-1	-1			
		Climate								+1	-1		
		Agricult. land								-2	-1		
		Forest land	-1							-1	-2		
		Erosion						-3					
		Noise	-1	-2	-1						-3		
	E	Fauna								-1	-1		
		Flora		-1								-1	
	AE	Blending/landsc.								-3			
		Architecture						-2	-1				
	Transport	Invest. costs				-2							
		Travel time								+2			+3
		Energy demands	-2							+1			+3
		Traffic safety	-1							+3			+1
		Maintenance											
	Social	Labour										+1	
		Housing				-2							+1
		Recreation	-1							-2			+3

Note: A1 - construction, A2 - operation, A3 - regional development, E - ecology, AE - aesthetics

Fig.3 Example of Preliminary Screening

one matrix for each alternative - where their advantages and disadvantages are screened. The number of suitable alternatives for following design steps (e.g. preliminary designs) may be reasonably reduced to some two or three variants.

The system may be illustrated in Fig.3 on practical example of assessment of one of three alternatives of proposed motorway near Žilina, Czechoslovakia.

2.3 Detailed Assessment

It is carried out on the principle of value analysis of impacts of different types (not only monetary aspects) using the following four basic steps:

- selection of a system of indicators, by means of which the value of impacts in every alternative may be measured;
- evaluation of acceptability of each impact (partial evaluation);
- aggregation of partial evaluations into an overall assessment of every alternative (general evaluation);
- comparison of alternatives on the basis of their overall assessment (final ranking).

2.3.1 Description of impacts

The value of different impacts in all assessed alternatives should be compared (a) within the limits of one impact itself - considered for the assessment as "subgoal" as well as (b) within a group - considered as "goal" - of impacts of the similar character, (c) higher big group of grouped impacts - considered as "targets" - up to (d) total value of each alternative. The grouping of impacts "subgoals" (the number of which suggested in the Guidelines is 60) - into goals (10) and targets (3) is indicated in the "Decision Tree" - see Fig.4.

By this philosophy the Draft AECOTEM Guidelines significantly differ from and enlarge the well-known cost-benefit analysis systems previously used for the highway feasibility studies. This cost-benefit analysis was based on assessment of only those impacts which may be reasonably expressed on monetary terms.

Each impact considered for the assessment is "measured" by means of "indicator". This refers to a "subgoal I" or further detailed "subgoal II".

The proposed number of indicators (impacts) is not strictly binding and may be reasonably adapted to answer the needs. It is only stressed that the same selected system of indicators must be applied to all assessed alternatives of the same sector of the motorway.

2.3.2 Partial Evaluation

A uniform structure of indicator sheets is proposed. It always incorporates the following data (see examples of indicator sheets 4.1, 6.2):

Description - contains the definition of assessed impacts with technical unit by means of which the indicator value is expressed (min/trip, % of induced traffic, monetary value, number of exposed persons, cost/trip, points of satis-

faction, etc.).
Presentation of results - summary of results, partial evaluation of the individual assessed alternatives (variants) in the target year.
Method of indicator value calculation - see indicators 4.1,6.2.
Data sources - dtto
Calculation of indicator value - dtto.
Determination of value function - definition of value function which enables the transformation of "indicator value into the partial utility value (see vertical coordinates) of respective impact to express the degree of satisfaction (in points, within the limits from 0 - not advantageous - to 100 - the most advantageous alternative).
Possibility of application of cost-benefit analysis - see 4.1, 6.2.
Notes - dtto.
Examples of assessment of two typical subgoals I "cost of motorway construction" (indicator sheet 4.1) and "noise" (6.2) are given as follows on next page

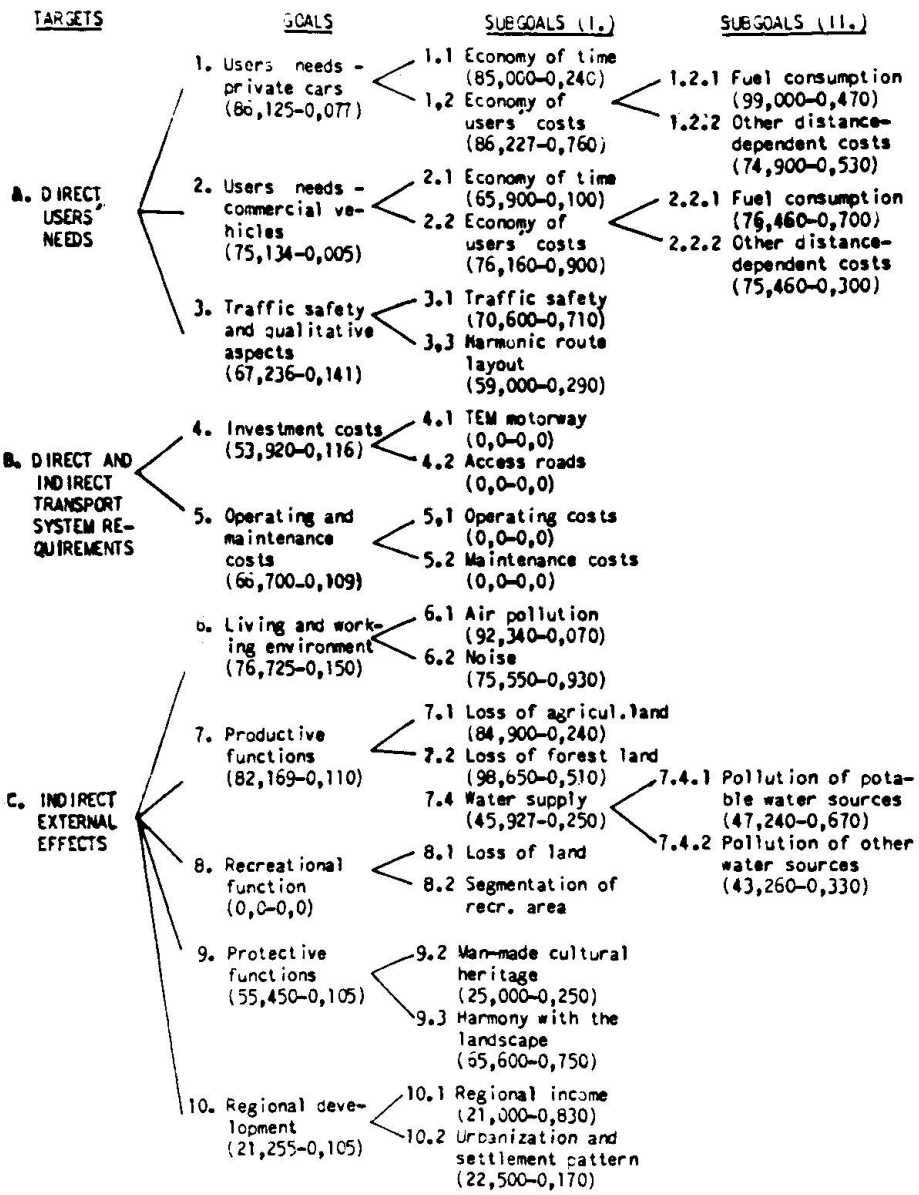


Fig.4 Decision Tree

2.3.3 General Evaluation of Every Alternative

Weighting of impacts

In the third step of assessment it is necessary to sum up the partial evaluations into an overall assessment of every alternative. Therefore partial utility values of individual impacts (subgoals) established in the preceding phases must be aggregated into relevant utility values of goals and further into total utility value of every alternative.

Since individual subgoals and goals are not of equal importance, their utility values cannot be aggregated directly (e.g. on the basis of arithmentic average). Their relative importance must be expressed by means of weighting. The weights determine the contribution of individual subgoals and goals to the overall value, i.e. the extent of their influence on the final result of assessment. The sum of weights considered in all relative groups (goals, subgoals) is always 1.000. The weighting is carried out as technical and preferential weighting.

Technical weighting concerns aggregation of impacts of an analogous type.

A. Indicator sheet for subgoal 4.1 (cost of construction)

Goal: Investment costs of infrastructure

Subgoal I: TEM motorway proper

Indicator: Investment costs of the TEM motorway

1. Description - overall investment costs of the planning and construction of the TEM section, incl. the costs of the right-of-way acquisition and design but without access roads of the motorway. The unit is represented in monetary value (Czechoslovak crowns-Kčs = 0,09 USD).

2. Presentation of results

Target year	Variant	Indicator value overall cost (mil.Kčs)	Partial utility value
1987	V_0	0	100
1987	V_1	4 833,1	48
1987	V_2	5 300,1	43

3. Method of indicator value calculation - individual alternatives are compared using the overall calculated investment costs obtained from on-going projects of the similar motorway sections.

4. Data sources - designs of alternatives and their calculated investment costs. "Average standard costs" per 1 km of motorway in different landscape types according to "Instruction of the Federal Ministry of Transport, CSSR".

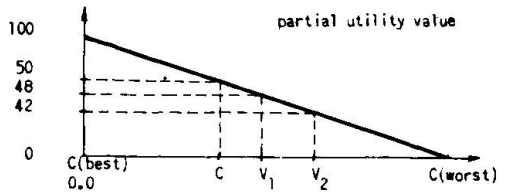
5. Calculation of indicator value - two alternatives of new TEM section V_1, V_2 are compared (with V_0 variant without motorway). Direct (bee-line) distance of their beginnings and ends is 73,5 km. The route of motorway sections-according to variants- is divided into smaller partial sections with regard to the landscape types through which the variants pass. The following table contains the necessary data.

Alternative	Partial section	Calculated costs (mil. Kčs)	Landscape type	Length of par. section (m)
V_1	a_1	1 732,4	B_2	28,4
	b_1	1 256,1	B_3	15,9
	c_1	1 844,6	B_1	40,1
	total	4 833,1		84,4
V_2	a_2	2 745,6	A_2	52,8
	b_2	2 554,5	B_2	39,3
	total	5 300,1		92,1

6. Determination of value function - partial utility value "50" of a value function is given to the "comparative standard cost value" (C) of a motorway connecting by bee-line D=73,5 km long the beginning and the end of all alternatives (increased by 15 % for the sinusoidal alignment) taking into consideration % share of landscape types, average standard investment costs per 1 km (see para 8).

$$C = 1{,}15 \cdot 73{,}5 \cdot \frac{58{,}2 \cdot 28{,}4 + 75{,}2 \cdot 15{,}9 + 45{,}5 \cdot 40{,}1}{84{,}4 + 92{,}1} + \frac{50{,}3 \cdot 52{,}8 + 58{,}2 \cdot 39{,}3}{84{,}4 + 92{,}1} = 4\,605{,}3 \text{ mil. Kčs}$$

Partial utility value 100 corresponds to the state when no investment occurs, i.e. no TEM alternative is constructed and no existing network is reconstructed. Partial utility value for variants V_1, V_2 (with calculated costs 4 833 and 5 300 mil. Kčs) are taken from the diagram:



Costs of alternatives of TEM proper in mil Kčs

7. Possibility of application of cost-benefit analysis - the indicator is expressed directly in monetary terms.

8. Notes - Instructions of the Federal Ministry of Transport, CSSR, stipulates the following average standard costs per 1 km of motorway:

Landscape type	Standard costs in mil. Kčs per 1 km max.	average	min.
A_2	61,3	50,3	40,0
B_1	58,6	45,3	35,9
B_2	73,9	58,2	47,3
B_3	83,4	75,2	57,2

B. Indicator sheet for subgoal 6.2 (Impacts of traffic noise)

Goal: Living and working environment

Subgoal I: Noise

Indicator: Number of persons exposed to more than the maximum-permitted level of traffic noise

1. Description - the number of persons exposed to more than maximum-permitted level of traffic noise produced by traffic in the assessed TEM sector (in Czechoslovakia) and the part of the road network influenced by the motorway.

2. Presentation of results

Target year	Variant	Indicator value No. of persons	Partial utility value
2000	V_0	12 500	50
2000	V_1	4 500	82
2000	V_2	3 200	87,2

3. Method of indicator value calculation - the relevant area where the TEM passes is subdivided into minor zones related to their function to which maximum permissible value of traffic noise L_{Aeq} is attributed (in Czechoslovakia) - quiet zones (hospitals, schools etc.) 50 dB(A), housing zone 55dB(A), industrial zone 65dB(A). The total number of affected persons is calculated according to

$$N = N_1 + N_2 + \dots N_i \quad (1)$$

where N_1, N_2 ... N_i are numbers of persons in different zones.

4. Data sources - design (study) of the TEM sections, incl. population in the area in the zone of TEM influence, morphological characteristics of the ground

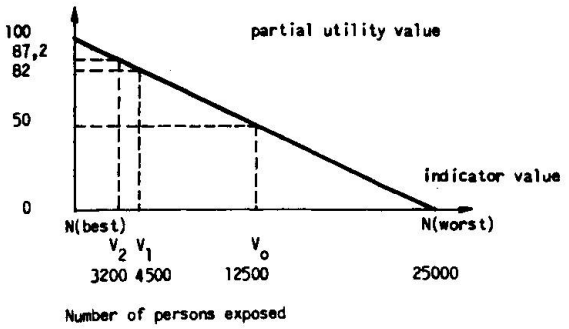
in the zone of TEM influence.

5. Calculation of indicator value - isophones L_{Aeq} (50,55,65 dB/A/) are drawn on the map along the TEM alignment and numbers of affected persons are calculated.

6. Determination of value function - if no person is affected by unacceptably high traffic noise level, the partial utility value equals to 100, the number of persons affected (in target year) with noise in the alternative without TEM gives p.u.v. 50.

7. Principle of monetarization - not required in the method of value analysis.

8. Notes



The weights are determined by calculation using quantificable relations between compared impacts. This weighting is usually used for the aggregation of elements on lower levels of the decision tree.

Preferential weightig concerns aggregation of principally different impacts (on higher levels of the decision tree). The weights are determined either directly, i.e. by inquiries among selected groups of people (representatives, population), or directly by analyses of preceding assessment, decisions or reactions and behaviour of certain groups of population.

Having accepted the values for weighting (w) the different impacts (subgoals I, II) in assessed TEM alteratives are aggregated successively on all levels of the decision tree (Fig.4). In this figure the "values" and "weights" for each assessed indicator and for the whole assessed variant are indicated in brackets (e.g. for goal 1: 86,125 - 0,077); for the whole variant the total value is 64,755. This example is taken from assessment of a section Kaplice-Freistadt (see later) and indicates the variant with the highest "total value".

2.3.4 Final Ranking of Alternatives

The total utility values of the individual alternatives obtained by the procedure described above serve as a basis for their mutual comparison and final decision or the generation of new alternatives. The higher this value the better the ranking of the particular alternative.

In the case when "final values" of alternatives do not differ too much, it is advisable to examine their stability by sensitivity tests. This may be done by reversing the ranking by changing values of individual impacts or changing value functions or changing weights or detailed disaggregation of goals with the highest influence and calculating the total utility value again.

3. TESTING THE NEW ASSESSMENT METHOD

The varification of utility of the "AECOTEM Guidelines" has been carried out - under the sponsorship of UNO and ECE - on selected test examples on (a) two sections (already in operation) of the Czechoslovak motorway system (Fig.3: sections near Žilina, 35-45 km long, mountaneous landscape; indicator sheets 4.1 and 6.2: section near Meziříčí, 73 km, hilly landscape) and (b) European E 14 route, section Kaplice (Czechoslovakia)-Freistadt (Austria), together with Austrian experts (Fig.4). The results were satisfactory and supported strongly the selection of the most advantageous alternative.

4. CONCLUSION AND ACKNOWLEDGEMENT

The value anylysis method for assessment of economic, aesthetic and sociological effects for the planning, construction and operation of all TEM sections -

as prepared in the "Guidelines" - is a new and complex way how to prepare or recommend selection of the best alternative to the decision-makers.

Elaboration of these "Guidelines" was entrusted to PRAGOPROJEKT, Consulting and Engineering Inc. for Highways and Bridges in Prague, Czechoslovakia (telex No. 123 560). Owing to a good team-work of all experts engaged (some 20 experts from Pragoprojekt, other professional institutes, ministries, Technical University - headed by Messrs. Nesvadba and Trčka) and thanks to a good collaboration with the board of representatives from governmental bodies of all TEM countries as well as from the U.N. Agencies (UNDP/UNEP/ECE) the "AECOTEM Guidelines" were elaborated (in 1983) and verified in "Applications" (1984). Both publications are considered the official U.N. materials.

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