The AHP and ANP Models for Transport Environmental Impacts Assessment

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Abstract: This paper presents an assessment of environmental impact preferences of transport using the Analytical Hierarchical Process (AHP) and the Analytical Network Process (ANP). The authors suggest using these methods within the decision-making process and assessment of transport strategies or projects and their impacts on the environment. There are many various dependencies and links among factors influencing the decision-making process of transport implementation. It is not just environmental impact~~s~~ that influences acceptance of decision-making, but also other major factors such as time (term), space (territory radius) and means of transport (mode). Finally many expectations of benefits obtained from transport implementation must be included in the decision-making process as well. The paper shows the complicated structure of these processes. The AHP model is used for preference evaluation of environmental impacts without any of the other factors or characteristics of transport projects, plans or strategies. The ANP model is more complex and is used for the evaluation including other characteristics of transports projects. The results of both models are compared.

Key-Words: Transport policies, transport strategies and projects, decision making, environmental indicators, ANP method

1 Introduction

Decision-making on different management levels and in various fields needs proper quantitative and/or qualitative tools which help to select the best decision alternative. This work represents the partial results of three projects. One of them is the project MSM6046070904 – "Information and knowledge support of strategic management" by the Ministry of Education, Youth and Sports of Czech Republic, which deals with methods and tools for information and knowledge support of strategy management for various decision-making subjects for solving well-structured or semi-structured or fuzzy problems. The others are project OC193 – "Methods for evaluation and multidisciplinary assessment of transport impacts on sustainable environment" by the Ministry of Education, Youth and Sports of Czech Republic and EU project in frame COST 356 – "EST - Towards the definition of a measurable environmentally sustainable transport", which determine what and how environmental indicators can be used in transport projects assessment and which suggest methods for environmental decision-making.

The environmental impacts caused by implementation of transport policies, plans, programmes and carrying out of transport strategies, plans, programmes or projects increase requirements for complexity and relevance of decisions to be taken. Sustainable mobility calls for a multidisciplinary approach to decision-making processes in the public interest. Most of the current EIA/SEA does not take properly into account the wide range of environmental impact~~s~~ linked with varieties of the tactical and strategic characteristics of transport policies, plans, programmes and projects. A correct representation of the whole range of these factors is necessary to ensure sustainability of transport policies, plans, programmes and projects. Therefore it is essential to suggest evaluation procedures with the use of sophisticated methods excluding subjective access of evaluators.

The Analytical Hierarchical Process (AHP) [7], [8] and the Analytical Network Process (ANP) [9], [10] were chosen for this purpose. These methods applied to decision-making in the transport sector involve a systemic approach to environmental and transportation issues. Evaluation of environmental impact weights of transport using AHP and ANP is presented in this paper with the aim of verifying possibilities of these methods used for transport EIA/SEA decision-making.

2 Assessment of transport strategies, plans, programmes or projects

Most of the present strategic environmental assessments (SEA) or environmental impact assessments (EIA) of transport do not aggregate properly the whole range of impact varieties and their relative importance. Results from the EIA/SEA survey carried out by the authors of this paper in 2009 can be used to back up this statement. Survey data were logged from 101 road projects and 52 car parking projects of “EIAs” carried out during the last two years in the Czech Republic.

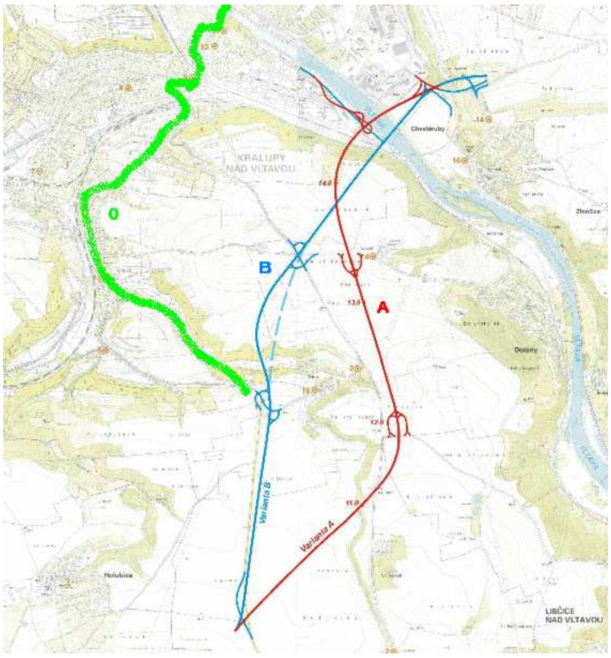

Figure 1: EIA of road construction (0 - contemporary situation, A, B – proposed variants)

As an example we might take the environmental impact assessment that was carried out near to Prague with the aim of selecting the best variant for a new road around the city of Kralupy nad Vltavou (Figure 1). The impacts assessment of this example includes criteria that are listed in Table 1. The EIA used different indicators to determine criteria but their values are modified by a vague interpretation into the criteria value. Finally values of criteria are summarized without any comparison, determination of weights, comparing etc. and the one with the maximum total value is taken as the best variant. In this case variant B was recommended to be built (Table 1).

Criteria	Variant 0	Variant A	Variant B
Impacts on residential households	-2	1	2
Impacts on surface water	0	-1	-1
Noise impacts on residential housing	0	-1	-1
Impacts linked with waste	-2	1	2
Impacts on flora and fauna	0	-1	-2
Impacts on landscape view	0	-1	-2
Impacts on residents	-2	1	2
Impacts on archaeology findings	0	-1	-1
Impacts of remaining ecological impacts	0	-1	0
Other impacts	0	-1	-1
Total	**-6**	**-4**	**-2**

Table 1: Comparison of EIA variants – city Kralupy n/V. 2004 (company VPÚ DECO PRAHA a.s)

The importance of the transport sector is determined on the basis of society’s interests and its role as stakeholder [5]. But in every case it is also necessary to take into account other characteristics of transport from the point of view of decision-making time (terms), space (area) and transport mode.
The complexity of assessment can be shown by different attempts presented in [12]. Authors have been proposed the creation of database system for monitoring the environmental quality of urban road network and for supporting the decision making process of local authorities. The factors that determine and affect the environmental quality of

urban roads were researched and indices were designed to quantify these factors. These factors were categorized into 20 sub-categories and grouped into 8 main categories such as urban planning and architectural factors, traffic patterns, recorded roadside land uses, recorded road equipment, or even financial ones - in total, 124 indices were designed, and examined!

Tsouchlaraki and Zlaji [13] have presented their attempt to determine and affect the environmental quality of urban roads. The proposed evaluating parameters were grouped into five categories: bio-climatic (insulation, sun protection, ventilation – wind protection, air pollution, noise visual disturbance), urban planning (building permit limits - building heights, building density, and system road orientation – profiles building forms border spaces etc.), traffic parameters (traffic load, traffic make-up, average movement speed, parking locations and patterns), artificial elements (road pavement materials, road surface condition, roadside construction materials etc.), and other parameters (population density, inward and outward movements, means of transport, user safety, cleanliness and hygiene, preservation etc.). After theoretically analysing all the parameters of the above categories, this approach was tested in practice for 16 representative roads of the urban complex.

The processing of different indicators or factors, and their aggregation can also prove problematic. Bata et al. [1] says that: “There are dozens of sets of indicators that try to solve the problem of sustainable environmental development at local, regional, national and global levels. Currently, there are two approaches under development: policy-based and capital approach”. They propose to solve the problem by Petri nets. The results of [1] show an example of aggregation for a group of indicators that provides useful information, which support decision-making for regional development management.”

The above mentioned list of references proves and shows difficulties in the complexity of transport assessment.

COST (European Cooperation in Science and Technology), action 356 completed ways of transport impacts assessment. The aim of this action was to design harmonised methods to build better environmental indicators by using existing European indices, and to build methods to apply to the decision making process of the transport sector in the different European countries, in order to contribute to a systemic approach to environmental and transportation issues. Results of action 356 were presented in a conference in Paris in the spring of 2010 and have not been published yet. Part of this paper will be published as a case study of the final report with other details. Results of a former action COST 350 concluded that there were 15 main impacts (types of impacts) of transport including aims and targets that must be taken into account as far as the environment protection is concerned. Results of the action taken included the following: tackling climate change; protecting nature and biodiversity; environment and health (water protection, soils protection, air quality protection, protection against noise); sustainable use of natural resources and management of waste [4].

Within the framework of these impact types proposed system of indicators that can use any chosen representative quantity (formula, quantitative result of software simulation or even verbal declaration etc.). This proposed system groups indicators into four main groups according their relative influence on environment (Table 2). It is important to realize that environmental impact indicators and their evaluating abilities depend on the transport context i.e. spatial scale, transport mode and time (terms of implementation). It is clear that the importance of a nationwide strategy for transport has different relevance to the potential production of green-house gases in comparison with e.g. a local rail transport project or even a local traffic control project. These discrepancies of assessment must be solved in a way that takes into account both aspects of assessment - these environmental impacts of transport and the type and purpose of transport project or strategy (Figure 4). According to the Czech Republic legislation, the environmental assessments are combined with spatial planning processes. They are a prerequisite for spatial plans to be approved. Spatial plans (spatial decisions) are designed (approved) on a nationwide, regional or municipal scale.

The results of assessment should serve as a tool for decision making i.e. policy. Policy makers are required to assess the impact of their policies in terms of sustainable development [2]. In policy making for sustainable development, the objectives are part of the decision-making problem. In other words, the formulation of the decision-making problem is the problem [6]. Because of risks and uncertainties involving future events and risks and uncertainties associated with the costs, benefits or effectiveness of a given policy, modelling and assessment methods alone are not enough to provide adequate decision making support – in other words, policy making involves the existence of “wicked problems". An approach to supporting the solution of wicked problems in policy making for sustainable development was presented in [6].

Water & air	Senses &waste/energy
I1 - Local air quality I2 - Regional air quality I3 - Quality of water I4 - Ozone depletion I5 – Climate changes	I6 - Noise and vibration I7 - Waste I8 - Light pollution I9 - Non-renewable resource use
Countryside	**Technology & Safety**
I10 - Preserved nature areas I11 - Losses of biodiversity I12 - Cultural and technical heritage I13 – Landtake	I14 - Technological hazards I15 - Safety of transport users and pedestrians

Table 2: Groups of impacts

3 Multiple Criteria Evaluation of Transport Environmental Impacts

The transport environmental impacts should be considered in their complexity and relevance by adopting and modifying proper methods for cumulative environmental effect assessment. All these indicators should be aggregated to obtain tools for decision-making processes. These problems represent a large group of specific multiple criteria problems. Therefore multiple criteria decision-making methods will be used for solving these problems. We choose in particular the Analytical Hierarchical Process (AHP) and the Analytical Network Process (ANP).

These methods were chosen because decision structure has to consist of all the factors and indicators involved in evaluating transport project or policy which are mentioned earlier.

The AHP is a method used to derive global preferences from partial preferences that represent relative measurements of the hierarchical dependences of decision elements [7], [8]. It is generalized by the ANP method [9], [10] which does not require independence among decision elements and therefore incorporates more complex relations.

3.1 Analytical Hierarchical Process

- Problem hierarchy construction is the first step of the AHP. The hierarchical structure used for multiple criteria decision problems is typically defined as a decision tree.
  - Typically the first level represents the goal, e.g. the best alternative selection,
  - the second level includes groups of criteria,
  - the third level includes criteria, and
  - the fourth level includes all decision alternatives.
- The level with experts can be also included.
- Local priorities or preferences developed in the second step of the AHP are calculated using pairwise comparisons. The consistency of these judgements has to be controlled.
- Expressing priorities as weights of decision alternatives is the third step. The best alternative selection is then based on synthesis of the weights throughout the hierarchy. According to the hierarchy structure and AHP software support, the decision-maker can also analyse different results depending on priorities of states of nature or on the criteria.

3.2 Analytical Network Process

- The first step of ANP is based on the creation of a control network which describes dependency among decision elements. The ANP allows
  - inner dependence within a set (clusters) of elements, and
  - outer dependence among different sets (clusters).
- In the second step pairwise comparisons of the elements within the clusters and among the clusters are performed according to their influence on each element in another cluster or elements in their own cluster. So the ANP prioritizes not only decision elements but also their groups or clusters as is often the case in the real world. The consistency of these comparisons has to be controlled.
- The third step consists of the supermatrix construction. The priorities derived from the pairwise comparisons are entered into the appropriate position in this supermatrix. This supermatrix has to be normalized using clusters weights.
- In the fourth step the limiting supermatrix is computed and global preferences of decision elements are obtained. These preferences serve as the best decision selection or for the purpose

of analysis of preferences of decision-making elements.

3.3 Two models for the Assessment of Environmental Impacts of Transport

The AHP model is used for preference evaluation of environmental impacts of transport projects, plans or strategies without considering any of their other factors or characteristics. On the contrary the ANP model is more complex and is therefore used for this evaluation of environmental impacts including other characteristics of transports projects, plans or strategies.

3.3.1 AHP model

The first model is of the AHP type [3]. This model has five levels of complete hierarchy (Figure 2) and includes only environmental project characteristics. So in this AHP model transport strategy/project, context was not accounted for in environmental impact preferences assessment [3].

- The goal is the indicators' preference setting.
- The second level consists of three groups of respondents. The three groups of respondents consist of 22 transport experts (people employed in the transport sector), 59 students of "Logistic Systems" (so called "informed public") and 24 students of "Decision Models" (so called "public") who were interviewed.
- The third level represents the judgement of those experts and students who were asked.
- The fourth level consists of four groups of environmental impact factors (Table 2).
- On the fifth level are 15 indicators that are selected as a preliminary result of COST350 (Table 2).

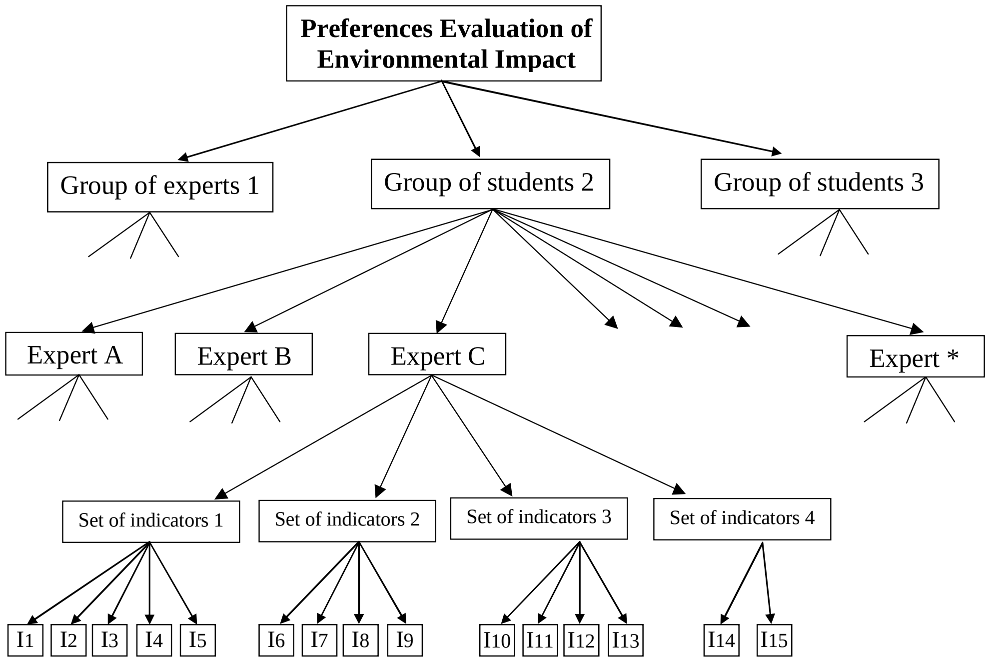

Figure 2: AHP model - The Hierarchy for the Assessment of Environmental Impacts of Transport

An electronic questionnaire in MS Excel was used to obtain data from different groups of respondents and for the calculation of weights on all levels, as well as for their synthesis (Figure 3). The structure of this questionnaire was prepared in a way that requires minimal work of the respondents.

Preferences on the second and third levels are set out as follows:

- Equal preferences for the three groups of respondents - (1/3);
- Equal preferences for the respondents within each group - (1/n), where n is the number of group members;
- Preferences for the groups of indicators are set out according to the number of indicators in these four groups - (5/15, 4/15, 4/15, 2/15).

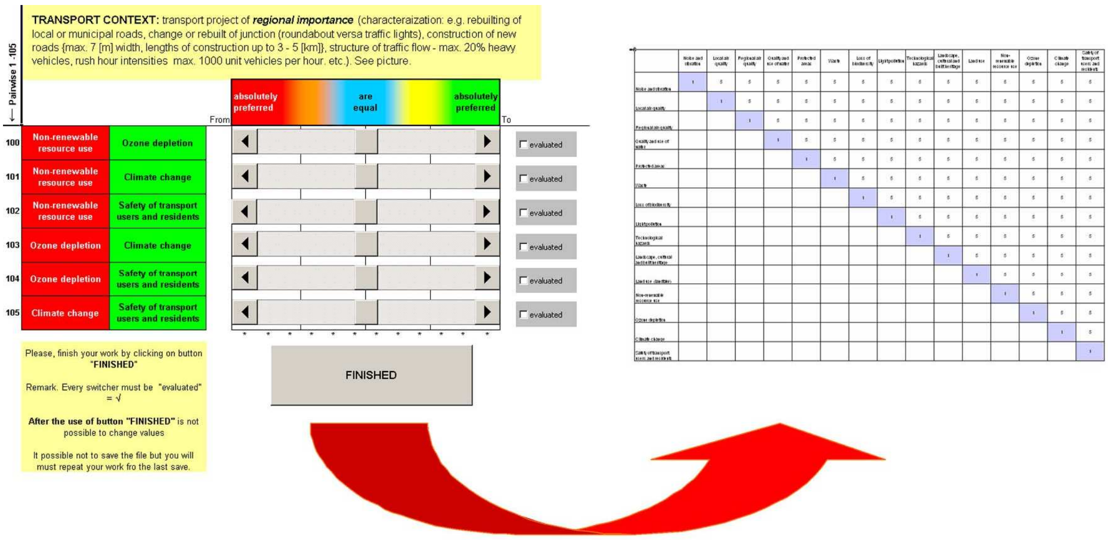

Figure 3: Electronic questionnaire and hidden sheet with table for calculation

3.3.2 ANP model

The second model has the ANP form. It includes environmental and non environmental project characteristics. The basic assumption of the second model for preferences assessment is the existence of a dependency between "Type and purpose of transport project/strategy" and "Impacts of transport project/strategy" (Figure 4). Model was influenced and determined by awareness that any transport project causes specific measure of environmental impacts. All these specific types of impacts must be balanced with transport potential benefits (not the building company's profit!) and, in cases where eventual benefits are not adequate to meet public expectations, the transport project should be modified or even cancelled.

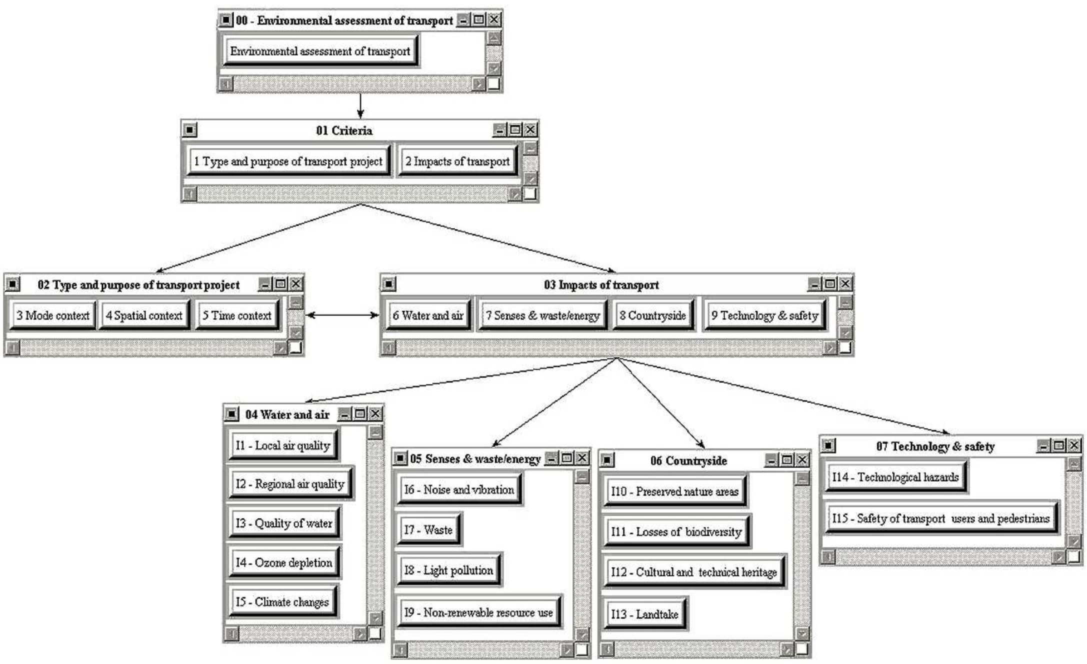

Figure 4: ANP model - The Control Network for the Assessment of Environmental Impacts of Transport

- The model consists of eight clusters and dependencies among them and their elements.
- The right branch “Impacts of transport project/strategy” of the proposed control network (Figure 4) responds to the first AHP model for impact priorities assessment.
- Other pairwise comparisons between left and right branches and elements of the control network were discussed with transport experts.

According to the control network and dependences of decision elements, pairwise preferences were evaluated and decision elements priorities were calculated. These priorities were used to construct the supermatrix. After their normalization, the limited supermatrix was calculated.

		00 - Environmental asse	01 Criteria		02 Type and purpose of t			03 Impacts of transport				04 Water and air					05 Senses & waste/ener				06 Countryside				07 Technology & safety	
		Environmental assessme	1 Type and purpose of tr	2 Impacts of transport	3 Mode context	4 Spatial context	5 Time context	6 Water and air	7 Senses & waste/energ	8 Countryside	9 Technology & safety	I1 - Local air quality	I2 - Regional air quality	I3 - Quality of water	I4 - Ozone depletion	I5 - Climate changes	I6 - Noise and vibration	I7 - Waste	I8 - Light pollution	I9 - Non-renewable resou	I10 - Preserved nature ar	I11 - Losses of biodivers	I12 - Cultural and techni	I13 - Landtake	I14 - Technological haza	I15 - Safety of transport
00 - Environmental asses	Environmental assessme																									
01 Criteria	1 Type and purpose of tra	0,667																								
	2 Impacts of transport	0,333																								
02 Type and purpose of tr	3 Mode context		0,2					0,692	0,331	0,21	0,649															
	4 Spatial context		0,4					0,231	0,379	0,55	0,072															
	5 Time context		0,4					0,077	0,289	0,24	0,279															
03 Impacts of transport	6 Water and air			0,308	0,309	0,495	0,392																			
	7 Senses & waste/energy			0,308	0,221	0,125	0,144																			
	8 Countryside			0,308	0,098	0,327	0,32																			
	9 Technology & safety			0,077	0,372	0,054	0,144																			
04 Water and air	I1 - Local air quality							0,22																		
	I2 - Regional air quality							0,218																		
	I3 - Quality of water							0,24																		
	I4 - Ozone depletion							0,168																		
	I5 - Climate changes							0,155																		
05 Senses & waste/energ	I6 - Noise and vibration								0,259																	
	I7 - Waste								0,241																	
	I8 - Light pollution								0,217																	
	I9 - Non-renewable resour								0,283																	
06 Countryside	I10 - Preserved nature are									0,27																
	I11 - Losses of biodiversi									0,229																
	I12 - Cultural and technic									0,254																
	I13 - Landtake									0,246																
07 Technology & safety	I14 - Technological hazar										0,345															
	I15 - Safety of transport										0,655															

Table 3: ANP model - The Super matrix for the Assessment of Environmental Impacts of Transport

		00 - Environmental asse	01 Criteria		02 Type and purpose of t			03 Impacts of transport				04 Water and air					05 Senses & waste/ener				06 Countryside				07 Technology & safety	
		Environmental assessme	1 Type and purpose of tr	2 Impacts of transport	3 Mode context	4 Spatial context	5 Time context	6 Water and air	7 Senses & waste/energ	8 Countryside	9 Technology & safety	I1 - Local air quality	I2 - Regional air quality	I3 - Quality of water	I4 - Ozone depletion	I5 - Climate changes	I6 - Noise and vibration	I7 - Waste	I8 - Light pollution	I9 - Non-renewable resou	I10 - Preserved nature ar	I11 - Losses of biodivers	I12 - Cultural and techni	I13 - Landtake	I14 - Technological haza	I15 - Safety of transport
00 - Environmental asses	Environmental assessme																									
01 Criteria	1 Type and purpose of tra																									
	2 Impacts of transport																									
02 Type and purpose of tr	3 Mode context																									
	4 Spatial context																									
	5 Time context																									
03 Impacts of transport	6 Water and air																									
	7 Senses & waste/energy																									
	8 Countryside																									
	9 Technology & safety																									
04 Water and air	I1 - Local air quality	**0,093**	0,096	0,086	0,091	0,101	0,094	0,142	0,059	0,06	0,075	1														
	I2 - Regional air quality	**0,092**	0,096	0,085	0,09	0,1	0,093	0,141	0,058	0,059	0,075		1													
	I3 - Quality of water	**0,101**	0,105	0,094	0,099	0,111	0,103	0,155	0,064	0,065	0,082			1												
	I4 - Ozone depletion	**0,071**	0,074	0,066	0,069	0,077	0,072	0,109	0,045	0,046	0,057				1											
	I5 - Climate changes	**0,065**	0,068	0,061	0,064	0,071	0,066	0,1	0,041	0,042	0,053					1										
05 Senses & waste/energ	I6 - Noise and vibration	**0,054**	0,049	0,063	0,059	0,045	0,048	0,034	0,131	0,03	0,045						1									
	I7 - Waste	**0,05**	0,046	0,059	0,055	0,042	0,045	0,031	0,122	0,028	0,042							1								
	I8 - Light pollution	**0,045**	0,041	0,053	0,049	0,038	0,04	0,028	0,11	0,025	0,037								1							
	I9 - Non-renewable resour	**0,059**	0,054	0,069	0,064	0,049	0,053	0,037	0,143	0,033	0,049									1						
06 Countryside	I10 - Preserved nature are	**0,071**	0,07	0,073	0,053	0,074	0,075	0,037	0,041	0,147	0,049										1					
	I11 - Losses of biodiversi	**0,06**	0,059	0,062	0,045	0,063	0,063	0,031	0,035	0,125	0,042											1				
	I12 - Cultural and technic	**0,067**	0,066	0,069	0,05	0,07	0,07	0,034	0,039	0,139	0,046												1			
	I13 - Landtake	**0,065**	0,064	0,067	0,048	0,067	0,068	0,033	0,038	0,134	0,045													1		
07 Technology & safety	I14 - Technological hazar	**0,037**	0,039	0,032	0,056	0,031	0,038	0,03	0,025	0,023	0,104														1	
	I15 - Safety of transport	**0,069**	0,074	0,061	0,106	0,059	0,072	0,057	0,048	0,044	0,198															1

Table 4: ANP model - The Limit Supermatrix for the Assessment of Environmental Impacts of Transport

The control network, dependencies of decision elements and their clusters was developed and preferences were calculated using SuperDecision Software [11].
Using Superdecision Software the pairwise comparisons were provided for dependencies among the clusters and decision elements.
Preferences were calculated and the ANP Supermatrix was established (Table 3).
Because proposed control hierarchy contains sinks, identity at sinks computation methods was chosen before the ANP Limit Supermatrix was calculated (Table 4).
The ANP Weighting Supermatrix was received using weights derived from the ANP Cluster Matrix. The first column of the ANP Limit Supermatrix consists of the final preferences or weights of the environmental impacts of the transport strategy/project. These values take into account all dependencies among decision elements including transport strategy/project context, therefore all types of transport strategy/project supposed for specific problem solution can be compared only according to the environmental impacts.

3.3.3 Results comparison

The following, Table 5 and Figure 5, shows differences between preferences values calculated by the AHP and ANP models.

Generally these results do not show substantial deviations. It is evident that resulting preferences tend to be similar. This tendency can be explained as the common point of view of transport as a whole and its influence on the environment. On the other hand, it can be expected that a consensus of this type will not be obtained in specific cases of transport strategies or projects. These cases must be the topic of further research and public discourse.

	AHP preferences	ANP preferences
I1	0,073	0,092949
I2	0,073	0,092103
I3	0,08	0,101398
I4	0,056	0,070979
I5	0,052	0,065486
I6	0,069	0,053915
I7	0,064	0,050168
I8	0,058	0,045172
I9	0,075	0,058911
I10	0,072	0,071054
I11	0,061	0,060265
I12	0,068	0,066844
I13	0,066	0,064738
I14	0,046	0,036576
I15	0,087	0,069443

Table 5: Impact Preferences Calculated by AHP and ANP

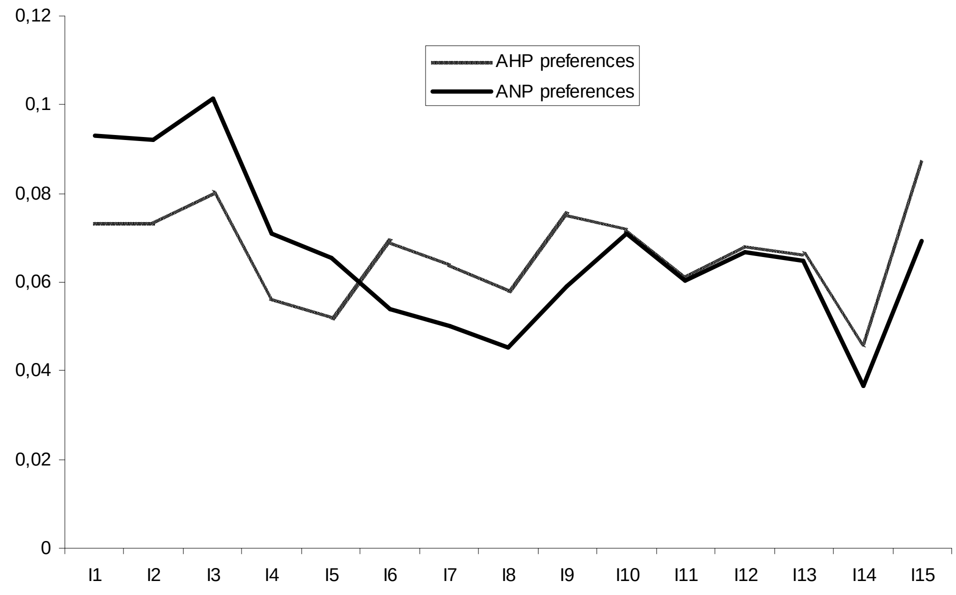

Figure 5: Graphical Comparison of Impact Preferences Calculated by AHP and ANP

The impact preferences presented are the result of a survey and expert discussion. The weights calculated by the ANP are more complex than those calculated by the AHP because they also include the effect of transport strategy/project context.

4 Conclusion

The environmental impacts caused by different transport strategies or projects are often the topic of the competing interests of various decision-making subjects, stakeholders, land owners and the public as whole. There is also a problem in the quantification of the available information and their aggregation. According to the actions COST 350 and COST 356, the transport environmental impacts should be considered in complexity and relevance by using adopting and modifying methods for cumulative environmental effect assessment.

We suggest a multiple attributes approach based on ANP method for the environmental impacts weights assessment with regard also to transport strategy/project context. The aim of this approach is the evaluation of impact preferences.

We also compare the possibilities and results obtained using ANP and AHP methods.

The experience with the use of AHP and ANP methods and Saaty's pairwise comparison for determination of impacts preferences led to the following conclusions:

It possible to recommend electronic questionnaires from the point of view of easy data processing (in practice, pairwise comparison value could be obtained from internet database with adequate interface and non/restricted access);

The AHP method uses only the hierarchical structure of decision elements and their experts' preference estimation. The advantage of the ANP method is the network structure of decision elements and the possibility to use more complex system of relations among them. This allows for the decision-making also to take into account other characteristics of transport strategy/project, for instance transport strategy/project context.

The proposed approach to the evaluation of transport impacts does not include other aspects, such as, for example, expected social and economic development. These aspects should be evaluated by other methods e.g. cost benefit analysis etc. The decision-making process should be finalised by using all these methods to find out the best variant of transport project, strategy or plan.

The results of impact preferences assessment proved opportunity to use criteria weights and the ANP method for EIA/SEA instead of contemporary ways of assessment based mainly on experience and the subjective view of evaluators.

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References

[1] Baťa R., Obršálová I., Costa-Jordao, T: Comparison of sustainable environment indicators aggregation possibilities by means of chosen Petri nets species, *WSEAS Transaction on Environment and Development*, Issue 3, Volume 6, March 2010, ISSN: 1790-5079, pp 166 – 175.

[2] Boulanger, P. M., Bréchet, T.: Models for policy-making in sustainable development: The state of the art and perspectives for research, *Ecological Economics*, Vol. 55, 2005, pp. 337–350.

[3] Brožová, H., Růžička, M.: Quantitative Analysis of Environmental Impact of Transport Project, *Scientia Agriculturae Bohemica*, Vol.. 40, No. 4, ISSN 0582 – 2343, 2009, pp. 236 – 248.

[4] Calderón, J.E., Pronello, C., Goger, T.: *Integrated Assessment of Environmental Impact of Traffic and Transport Infrastructure*, COST Office 2009, Universidad Politécnica de Madrid, ISBN 978-84-7493-401-4, 362 p.

[5] Joumard, R.: "EST - Towards the definition of a measurable environmentally sustainable transport", *Memorandum of understanding for the implementation of a European Concerted Research Action*, COST356, Brussels, 2005.

[6] Nasser Ayoub-Batres, R., Naka, Y.: An approach to wicked problems in environmental policy making, *WSEAS Transaction on Environment and Development*, Issue 3, Volume 5, 2009, ISSN: 1790-5079, pp.229-239.

[7] Saaty, T., L.: The seven pillars of the analytic hierarchy process, In: *Proceedings of the AHPIC*, Kobe, 1999.

[8] Saaty, T.L.: *The Analytic Hierarchy Process*, McGraw-Hill, New York, 1980.

[9] Saaty, T.L.: *Decision Making with Dependence and Feedback: The Analytic Network Process*, The Analytic Hierarchy Process Series, Pittsburgh: IX, RWS Publications, 2001.

[10] Saaty, T.L.: *The Analytic Hierarchy Process (AHP) for Decision Making and the Analytic Network Process (ANP) for Decision Making with Dependence and Feedback*, Creative Decisions Foundation, 2003.

[11] SuperDecision - Software for decision-making, http://www.superdecisions.com/, 20. 12. 2009

[12] Tsouchlaraki, A., Achilleos, G., Nasioula, Z., Nikolidakis A.: A System for Monitoring Environmental Quality of Urban Road Network and for Supporting Decision Makers. *WSEAS Transaction on Environment and Development*, Issue 3, Volume 6, 2010, ISSN: 1790-5079.

[13] Tsouchlaraki, A., Zlaji, E.: Investigation of Environmental Quality of Roads in Heraklion, Crete, *WSEAS Transaction on Environment and Development*, Issue 12, Volume 4, December 2008, ISSN: 1790-5079, pp. 1120-1140.