The Assessment of Environmental Impacts of Transport Using ANP

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Abstract: Assessment of environmental impact preferences of transport using ANP is presented in this paper. Authors suggest using ANP method within 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. They are not just environmental impacts that influence acceptance of decision-making but also main factors as time (term), space (territory radius) and way of transport (mode). Finally many expectations of benefits obtained from transport implementation must be included into decision-making process as well. It shows complicating structure of these processes. This research is part of project COST 356, which main objective is to design harmonized methods to build better environmental indicators system by using existing European indices, and to build methods to be applied to the decision-making process in the transport sector.

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

1 Introduction

The environmental impacts caused by implementation of transport policies, plans, programmes and realisation of transport projects increase requirements for complexity and relevance of decisions to be taken. As well as the sustainable mobility calls for really multidisciplinary approach to decision-making process. Most of the current EIA/SEA does not take into account properly the wide range of varieties of the environmental impacts linked with varieties of the tactical and strategic characteristic 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 so important to suggest an evaluation procedure with the use of sophisticated methods excluding subjective access of evaluators. The Analytic Network Process [6], [7] was chosen for this purpose. The ANP applied to the decision-making in the transport sector involves a systemic approach to environmental and transportation issues. Evaluation of environmental impact weights of transport using ANP is presented in this paper with the aim to verify possibilities of ANP method 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. A correct representation of the whole range of impacts is necessary to ensure sustainability that takes into account all environmental issues with a satisfactory qualitative degree of knowledge. This is especially important for the transport sector where the concerns and the stakes are important [3]. In many cases is also necessary to take into account other characteristics of transport policies, plans, programmes and projects as their influence from the point of decision-making time (terms), space (area) and transport mode.

Results of COST 350 concluded 15 main impacts (types of impact) of transport including aims and targets that must be taken into account as far as the environment protection is concerned were elaborated. Results of action included the following: tackling climate change; protecting nature and bio-diversity; environment and health (water protection, soils protection, air quality protection, protection against noise); sustainable use of natural resources and management of wastes [2]. Within the framework of these impact types is 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 distinguished indicators into four main groups according their relative influence on environment (See Table 1). What 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 evident that the importance of nationwide strategy of transport has different relevance to potential production of green-house gases in comparison with e.g. a local rail transport project or even local project of traffic control. These discrepancies of assessment must be solved in way that takes into account both aspects of assessment as these environmental impacts of transport as the type and purpose of transport project or strategy (See Figure 1). According to legislative rules of the Czech Republic 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 nationwide, regional or municipal scale.

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

Table 1: Groups of impacts

3 Multiple Criteria Evaluation of Transport Environmental Impacts

Assessment method for environmental impact indicator preferences or importance uses the Analytic Network Process (ANP) method. This method was chosen because decision structure can consist of all factors and indicators evaluating transport project or policy which are mentioned earlier. The ANP is a method used to derive global preferences from partial preferences that represent relative measurements of the dependence of decision elements [6], [7]. It generalizes the Analytic Hierarchical process (ANP) method [4], [5].

The first step of ANP is based on a creation of a control hierarchy or a control network which describes dependency among decisions 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 in the real world.

The third step consists of the supermatrix construction. The priorities derived from the pairwise comparisons are entering in 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.

3.1 Method for the Assessment of Environmental Impacts of Transport

The basic presumption of this preferences assessment method is existence of dependency between “Type and purpose of transport project/strategy” and “Impacts of transport project/strategy” (See Figure 1), and was influenced and determined by awareness that any transport project causes specific measure of environmental impacts. All these specific impacts must be balanced with transport potential benefits (not building company’s profit!) and in case when eventual benefits are not adequate to public expectation the transport project should be modified or even cancelled.

The right branch “Impacts of transport project/strategy” of proposed control network (See Figure 1) was already created and used for impact priorities assessment within the framework of action COST 356 and published as the case study. Results of pairwise comparisons were obtained from cooperation with transport experts and public by the form of survey and processed by AHP methodology [1].

Other pairwise comparisons between left and right branches and elements of 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. Control network, dependencies of decision elements and their clusters was developed and preferences were calculated using SuperDecision Software [8].
Using Superdecision Software the pairwise comparisons were provided for dependencies among the clusters and decision elements. Preferences were calculated and ANP Supermatrix was made up (See Table 2).

Because proposed control hierarchy contains sinks, identity at sinks computation methods was chosen before ANP Limit Supermatrix was calculated (See Table 3).

![Figure 1: The Control Network for the Assessment of Environmental Impacts of Transport](image)

### Figure 1: The Control Network for the Assessment of Environmental Impacts of Transport

Table 2: The Super matrix for the Assessment of Environmental Impacts of Transport

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</thead>
<tbody>
<tr>
<td>Noise and vibration</td>
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<td>0.411</td>
<td>0.225</td>
<td>0.411</td>
<td>0.225</td>
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<tr>
<td>Static pollution</td>
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<td>0.225</td>
<td>0.411</td>
<td>0.225</td>
<td>0.411</td>
</tr>
<tr>
<td>Dynamic pollution</td>
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<td>0.411</td>
<td>0.225</td>
<td>0.411</td>
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</tr>
<tr>
<td>Chemical pollution</td>
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<td>0.411</td>
<td>0.225</td>
<td>0.411</td>
<td>0.225</td>
</tr>
<tr>
<td>Other pollution</td>
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<td>0.411</td>
<td>0.225</td>
<td>0.411</td>
<td>0.225</td>
</tr>
</tbody>
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ANP Weighting Supermatrix was received using weights derived from ANP Cluster Matrix.
Table 3: The Limit Supermatrix for the Assessment of Environmental Impacts of Transport

In the first column of the ANP Limit Supermatrix consists of final preferences or weights of environmental impacts of 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 according to the environmental impacts.

In our previous work we use the AHP method, so transport strategy/project context was not accounted in environmental impact preferences assessment [1]. Following Table 4 and Figure 2 shows differences between preferences values AHP and ANP.

Table 4: Impact Preferences Calculated by AHP and ANP

Impact preferences presented in chart (See Figure 2) are result of survey and expert discussion. The weights calculated by ANP are more complex because they include also effect of transport strategy/project context.

Figure 2: Graphical Comparison of Impact Preferences Calculated by AHP and ANP

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

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

We suggest multiple attributes approach based on ANP method for the environmental impacts weights assessment having regard also 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 ANP method and Saaty’s pairwise comparison for determination of impacts preferences proved the following conclusions:
The AHP method uses hierarchical structure of decision elements and their experts’ preference estimation. The advantage of the ANP method is network structure of decision elements and possibility to use more complex system of relations among them. This allows accounting into decision-making also other characteristics of transport strategy/project, for instance transport strategy/project context.

The proposed access of evaluation of transport impacts does not include other aspects 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 usage of all these methods to find out the best variant of transport.

Results of case study of impact preferences assessment proved possibilities to use criteria weights and ANP method for EIA/SEA instead of contemporary ways of assessment based mainly on experience and subjective view of evaluators.

Acknowledgment:

This paper is supported by Ministry of Education, Youth and Sports Czech Republic, Project OC193 “Metody hodnocení a multidisciplinární ocenění vlivů dopravy na trvale udržitelné životní prostředí” (“Methods for evaluation and multidisciplinary assessment of transport impacts on sustainable environment”), in frame EU project COST 356: “EST - Towards the definition of a measurable environmentally sustainable transport”

References: