A DECISION SUPPORT APPROACH FOR THE EVALUATION OF TRANSPORT INVESTMENT ALTERNATIVES

Dr. Nurbanu Caliskan

Technical University of Istanbul, Faculty of Civil Engineering, Dept. of Transportation

tel.:+90 212 2853671 fax.:+90 212 285 3420

e-mail:ncaliskan@srv.ins.itu.edu.tr

1. INTRODUCTION

Arriving at a conclusion in transport investment needs serious attentiveness and attention, because the transport issue is very complicated. First of all, you'll face high costs. These wide-scaled investments have always been carried out causing the state budget to bear big shares. However, it's not only the financial aspect. Transportation has a dynamic build and has multidimensional effects. The social characteristics of society, urbanisation, environmental conditions, energy supply, political balance; are all major factors to be considered and that affect the solution of transport. In other words, there is a mutual influence. As much as the content and importance increase, these mutual influences enlarge more and more. Thus, while deciding on investments, these dynamic mutual influences must be taken into account as much as the capacity that will be gained. It's vital to choose the most suitable and useful investment according to the countries' conditions and economy, in short, deciding to make the best investment.

The decision-making mechanism to invest is generally under control of political office. But this power is emphatically advised to consult with scientific bodies. It is obvious that consulting experts and scientists while making a decision on transport investments will be very positive and contemporary.

2. THE OUTLINE OF THE NEW APPROACH TO THE DECISION EVALUATION OF TRANSPORT INVESTMENTS

A decision supporting criteria or basis must be established based on scientists and scientific experience and foreseeing, in order to be able to evaluate the transport investment. For this purpose, cognitive maps that reflect a person's thoughts network as a mathematical model have been studied to be one of the modern decision-making methods. Taking the fact that cognitive maps enjoy the property to show hierarchy structure of cause-result relations into consideration, another decision-making method named Analytical Hierarchy Process, has been decided to be supported (Caliskan, 1998).

The decision-support method Analytical Hierarchy Process, which has proved that it can be applied to transport problems successfully, that is, it enables the possibility to make data transfer between the decision-making and the model, was thought to take the subjective evaluation of the experts into consideration and to have the capability to judge all the possible findings and thus contribute to the decision process. So, the model was tried to be established.

It is believed that the stage, in which the judgements of experts are determined, which will provide the Analytical Hierarchy Process with data support, will help to put the complex problems of recent years to a certain form. Besides, the use of the Cognitive Map method, which is an excellent tool for understanding the relationships, will be an

appropriate and original approach. So, it was found that experts' points of view that are extensive complicated, can be grouped and some can be eliminated; and thus, that Cognitive Centrality that will form a base Analytical Hierarchy Process can be obtained (Caliskan, 1998).

3. COGNITIVE MAPS

The Cognitive Map is a signed digraph including the way individuals, groups, and experts realise and understand a problem as well as the bilaterally connected elements (Lee et al, 1992). So, the thoughts, values, and tendencies and the relations among them have been modelled to give the opportunity to work on them. The Cognitive Map can present individuals' thoughts and their belief systems in a mathematical model. Concepts, that's, decision choices, call results, effects and purposes are represented with nodes and the causal relationships are indicated with graded and signed arrows (Hwang and Lin, 1987).

There are two kinds of elements as concepts and derived beliefs. Concepts are shown as variables and causal beliefs as the relations among variables. Concepts can be connected to each other by three types of causal relations. The degree of complication varies in connection with the type of the cognitive map. There are three types of Cognitive Maps: the simple form, graded map estimate map.

There are three kinds of expression in the simple form and they are "+", "-", "0". If there is a linear relationship between two concepts, ie. if one's value increases while the other's value is increasing, this relationship is expressed with a "+". If the opposite is valid, the expression is "-"; and if there is no relationship at all, the expression becomes "0". If the relationships are shown with their weights, this forms the weighted map. This weighting is done with definitional terms like "less, a little bit, more" in fuzzy maps.

In general many different beliefs extracted from the same causal variables and going to the same effect variable, come together in a complicated structure (Hwang and Lin, 1987). A graded and signed digraph in connection with energy consumption is given in figure 2.1 (Roberts, 1976).

Figure 1: Cognitive Map

On the map of the example above, the increase in energy capacity causes a decrease in energy price, and this causes an increase in energy consumption. This increase in turn, brings along an increase in energy capacity. These types of feedbacks cause an inconsistency in the system. Whereas, the feedback coming back from the energy consumption via nodes of environmental quality and population is negative; because, the

increase in energy consumption causes a decrease in environmental quality and thus a decrease in energy consumption. Negative feedbacks usually result in consistency. If a cycle has two negative signs, this means that there is a positive feedback. One negative sign brings along negative feedback.

In this study, the establishment of a Cognitive Map will be explained, without going into its mathematics.

3.1 ESTABLISHMENT OF COGNITIVE MAPS

There are 3 methods to establish a C.M. that allows us to make precise analyses.

1. Documentary Coding Method: Some Cognitive Maps are formed depending on certain coding rules.
2. Questionnaire Method: This method is applied by sending questionnaires to individuals to form especially group Cognitive Maps.
3. Depth Interviews: It can be considered as the synthesis of documentary coding and questionnaire methods.

In transport problems questionnaire method is preferred because it is more suitable to the purpose of the model to be established.

3.1.1. Questionnaire Method

The main principle in this method is to send a questionnaire form to experts, who are in a position to determine the casual relationships (Hwang & Lin, 1987). Its basic advantage is that personal opinions of the experts of the subject are gathered together and thus a rather wide database is obtained. The process needed to establish a cognitive map with the questionnaire method is given below (Roberts, 1976, Ulengin and Topcu, 1998).

1st Stage: The experts are asked to determine all of the concepts, variables and relationships about the subject. The related answers obtained from the experts are then grouped by cluster analysis:

2nd Stage: These grouped variables, which are also collected in a table, are sent back to the experts; and the experts are asked to sort these variables according to their global importance and relative importance. The evaluation scale for global importance is 1-7, while it is 1-100 for relative importance. This means that the least important should be evaluated as 1 in global importance and the most important as 7; while the least important should be evaluated as 1 in the relative importance and the most important as 100. There could be no 7 points at all in a group, but there should be at least one 100 points. One or two variables with the highest global and relative importance from each group are selected.

3rd Stage: An Interaction Matrix is established, which enables the pairwise comparison of variables obtained at the end of this elimination. This matrix is then sent back to the experts and the experts are asked to determine the relationships between the variables in the rows and columns of the matrix. If an increase in a variable in the i. row causes an increase in a variable in the j. column, this relation is expressed with a “+”; while it is expressed with a “-” if it causes a decrease. If there is no relationship between the variables in the i. row and the j. column, it should be expressed with “0”.

Interaction Matrices coming from the experts are then taken into evaluation. The values in each cell of the matrix are summed up in order to determine the resulting values in majority; and thus, the Global Interaction Matrix of Experts is established.

4. ANALYTICAL HIERARCHY

Analytical Hierarchy Method, which is both a quantitative and qualitative approach, is a decision support system that evaluates different alternatives for a purpose by comparing them. This method, which was developed by Thomas Saaty (1989), was successfully applied to many cases that required complex decision analyses. Since many problems come into question in the choice of transportation investments, a multi-criteria model, that considers both quantitative qualitative aspects of the problem with a system approach, should be developed. For this purpose, Analytical Hierarchy Method was preferred because it disaggregates the problem to its parts and reflects it by sub-systems, it examines the problem by considers the opinions of every different socio-economical group that gives different weights to different criteria and it is easy to use. Another advantage of the Analytical Hierarchy Method is that there is no need to openly establish a benefit function (Ülengin, 1992).

Analytical Hierarchy disaggregates a complex multi-purpose problem into a hierarchy, whose levels comprise of certain criteria. These criteria are then divided into sub-elements. The alternatives that are to be evaluated are placed into the last level. In order to establish such a hierarchical structure and to determine the relevant criteria, all of the elements of the system and the relationships between these should be observed.

4.1 Establishing the Hierarchical Structure

This stage corresponds more to the “model establishment” stage when compared to the classical problem solution techniques. The most important issue in the hierarchy is the elements at each level and the relationships between these elements; because with this model, the main purpose is to measure the effect of the relative priority of the elements at each level to the highest level of the model.

After the hierarchical model is established, the next stage is to determine the attributed weights at the same hierarchical level. For this all of the elements at a level and one element at the higher level are taken as data; and the relative effects of all the elements at the lower level on the element at the higher level are determined. Pairwise Comparison Matrices are prepared for this.

A Hierarchical model example is seen in Figure 2. Another example for the pairwise comparison in such a model is given in Figure 3, where a Pairwise Comparison Matrix belonging to the D, E, F, G criteria, is formed. The importance of criterion D to E is scaled with a value from 1 to 9, according to its effect on criterion B. For example, in the matrix in

Figure 2: A Hierarchical Model Example

Figure 3, if D and E are equally important, $X_{DE}=1$; if D is certainly more important than E, $X_{DE}=9$. In this situation, it is apparent that $X_{ii}=1$ and $X_{ij}=1/X_{ji}$.

B	D	E	F	G	
D	1	X_{DE}	X_{DF}	X_{DG}	X_D
E	X_{ED}	1	X_{EF}	X_{EG}	X_E
F	X_{FD}	X_{FE}	1	X_{FG}	X_F
G	X_{GD}	X_{GE}	X_{GF}	1	X_G

X_{ij} = importance of factor i to factor j

X_i = relative weight of factor i

Figure 3: Pairwise Comparison Matrix

After the Pairwise Comparison Matrix is established, the eigen vectors of this matrix are found by using the computer program that is called Expert Choice. These eigen vectors are used for determining the priority orders. Thus, alternatives are determined according to their weights.

5. SYNTHESIS OF SUB-MODELS: MAIN Model

The most important characteristic of this study is the utilisation of the data base formed according to the Cognitive Map (directional schema) formed before and the variables in the forefront of this map, ie. the Cognitive Centrality, in the establishment of the Analytical Hierarchy Model.

When deciding on a transportation investment, the purpose is to select the most effective transport mode or style. This purpose forms the purpose or the aim of the model to be established. After this, important variables or concepts that becomes clear in the map as the result of the Cognitive Centrality Analysis form the criteria of the model, while the other variables that are concentrated around the Cognitive Centrality in the map form the sub-criteria of the model. The alternatives that are to be evaluated for investment are placed at the lowest level.

After the Analytical Hierarchy Model is established by this process, the Pairwise Comparison Matrices, that were mentioned before, are formed by using the model. These matrices are then sent to the experts who were contacted at the Cognitive Map formation stage. The experts are asked to make pairwise comparisons of the criteria at each level with the criteria at a higher level, by using the 1-9 scale.

By utilising the Pairwise Comparison Matrices that come back from the experts, Global Pairwise Comparison Matrices are found. Expert Choice program is used for this purpose and the priorities of the criteria in the model are calculated. Thus, the importance or weights of the alternatives according to the target are found. These weights are then summed up separately for each alternative and the general weights of the alternatives are obtained. After the weights of the alternatives are found, Overall Inconsistency Indexes are calculated. If inconsistency is observed, it means that the expert opinions should be reviewed and the their inconsistencies should be improved.

6. CONCLUSION

The effects of transportation improvements in the economies of countries are far from negligible. Apart from the transportation service they provide, they have certain exogenous effects. These effects are sometimes quite positive, while at other times they can cause irreversible damages. Wrong decisions might cause cities to attract excessive population and thus pave the way for unplanned growth, environmental pollution and deforestation would occur and limited resources could be wasted. The best decision should be made for the investment by foreseeing such negative effects. Thus, many researches have been going on for the evaluation of transportation investments by academically and other relevant public institutions over the years and newer and better methods are sought. Many methods have been used up to date for deciding on transportation investments. However, it can be said that they have been insufficient for certain decisions. For instance, in some cases where cost-benefit analysis is applied, the assumptions made in the beginning, the economical costs and the evaluation of benefits to be obtained are quite controversial. In fact, it is not uncommon to see that different feasibility studies made for the same case have given conflicting results. Multi-criteria evaluation methods that are developed considering the multi-purpose characteristics of transportation investments are big improvements in this context. Many researches have been made lately on this subject. The aim of this study is to propose a new approach, which systemises the evaluations for the subjective aspects of the case, without disregarding the previous methods. The most important characteristic of this approach is to establish a model based on the experts' knowledge, experiences and intuitions instead of applying the concrete data for a given subject to certain algorithms. Besides this, another originality is that the data for the model established with the Analytical Hierarchy Method, which is a decision support approach for the solution of multi-criteria problems at certain conditions, is formed by the Cognitive Map, drawn by another decision support method.

REFERENCES

- Axelrod, R. (1976) *Cognitive Mapping. Structure of Decision: The Cognitive Maps of Political Elites*, Princeton University Press, New Jersey.
- Caliskan, N. (1998) *A Decision-Support Tool for the Third Bosphorus Crossing Selection Problem*. PhD. Thesis, Istanbul Technical University
- Hwang, C.L., Lin M.J. (1987) *Group Decision Making Under Multiple Criteria*, Springer Verlag, Berlin.
- Lee, S., Courtney, J.F., O'Keefe. (1992) A System for Organisational Learning Using Cognitive Maps. *Omega* 20(1): 23-36 pp.
- Roberts, S. (1976) Strategy for the Energy Crisis: The Care of Commuter Transportation Policy. *Structure of Decision: The Cognitive Maps of Political Elites*, Princeton University Press, New Jersey.
- Saaty, T. (1989) *Multicriteria Decision Making: the Analytic Hierarchy Process*, RWS Publications, 4922 Ellsworth ave. Pittsburg, PA 15213.
- Ülengin, F. (1992), "Analytical Hierarchy in Transportation Problems: An Application for Istanbul, 2nd Urban Transportation Congress of Istanbul, December 16-18, Istanbul.