Utilisation of Intelligent Systems in the Economical Evaluation of Transportation Projects

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Abstract: Transportation projects are high-cost investments. For this reason in order to perform correct decision making process special approaches and methods have to be used in feasibility analysis. Benefit Cost Analysis (BCA) is a widely used method all over the world and in Turkey for the economical evaluation of the transportation projects. But, the most important disadvantage of this method is the difficulties in predicting the costs, missing and lacking data and the uncertainty in the long-term analysis period risks affecting the results negatively. In order to avoid this risk, protective measures such as sensitivity analysis and probability distributions are used in the traditional benefit – cost analysis. But, in a project where there are high uncertainties and approximate data are present the said methods are becoming insufficient in real-life applications. Especially, the countries with a quickly changing socio-economic structure, for the transportation projects having long-term analysis period there are uncertainties in predicting parameters such as traffic volumes, accident data, time value etc. As a result of all those items the evaluation of the feasibility of the transportation projects is always facing risks of wrong decision-making. Therefore, the need to develop a more sophisticated method eliminating all the uncertainties of the traditional benefit cost analysis becomes evident. This paper, aims to develop a model that will contribute to the traditionally widely used benefit cost analysis in economical evaluation of transport projects by the Turkish State Highway Authority. Through this proposed model it is also aimed to eliminate the missing and uncertain data and wrong estimations in feasibility analyses. As a result the paper is proposing an intelligent system framework, utilising The Fuzzy Cognitive Map for the transportation projects' benefit cost analysis

Keywords: Economic evaluation, Benefit Cost Analysis, Transportation Projects, Fuzzy Cognitive Map, Intelligent Systems

Introduction

There are different methods for analysis of the evaluation of the transportation projects. The main idea of all of those methods is based on calculations by updating the inputs and outputs or revenues and expenses related to the project [Aktan & Sakal, 2006]. The most widely used method in the economical evaluation of the transportation investments is the Benefit Cost Analysis (BCA) method [Bilgiç & Evren, 2002]. Besides this method there are other methods such as, Net Present Worth (NPW), Annual Equivalent Cost (AEC) and Internal Rate of Return (IRR) method [Akbıyıklı, 2014].The choice of the method in the economical evaluation process is depending on the amount and content of the analysis and uncertainties of some parameters in analysis. As an example; in the developing countries, since the interest rates are high and uncertain, the IRR method is selected. On the other hand when the economic life of the project is uncertain the AEC method is applied [FHWA, 2004].

Until now benefit-cost analysis is considered as the primary economic analysis method for the infrastructure Project investments in our country. This method is a technique used in public sector as an economical tool to evaluate the efficiency of the investment projects and to choose the projects having the maximum benefits to the society or determining the priority of the projects [Aktan & Sakal, 2006]. For this reason it is considered to a very important economic analysis for big infrastructure transportation investment projects. With the help of this analysis, benefits and costs in different alternatives are determined and measured systematically and used a decision making tool to decide for the feasibility of the project.

Benefit Cost Analysis method is requiring a lot of data to be analysed. At the same time this method is also including future predictions in its long evaluation period. In order to obtain a correct result from the analysis the mentioned data and estimations also have to be correct and complete. But, it is very difficult to make correct estimations for the future in countries having social and economic indeterminacy and ambiguities. Besides not systematic data collection creates wrong statistical data and in conclusion resulting an economic analysis that is totally based on wrong inputs and as a result fatal wrong decision making becomes unavoidable. Therefore, it is needed to develop a model that will eliminate all of these ambiguities faced in the traditional benefit – cost analysis method.

In this study, it is attempted and aimed to develop a model that will contribute to the existing benefit – cost analysis used by the Turkish Highway Directorate in economic evaluation and feasibility studies of highway investments. In this respect through this proposed model it is aimed to eliminate the missing and uncertain data and wrong estimations in feasibility analyses and propose an intelligent system framework, utilising The Fuzzy Cognitive Map for the transportation projects' benefit – cost analysis.

General Directorate of Highways Traditional Benefit Cost Analysis

The economic analysis of Turkish Highway Directorate is based on two pillars: The first is costs which are composed of expenses starting from the Project Initiation to Project Handover. The second is benefits which consist of revenues expected during the Project evaluation period [KGM, 2013]. The benefit and cost parameters used in economic analysis by the Turkish Highway Directorate is shown in Table 1.

Table 1: Parameters used by Turkish highway directorate for benefit cost analysis

Agency Costs (Costs)	Road Users' Costs (Benefits)
• Road construction costs • Operation and maintenance costs	• Time costs • Accident costs • Vehicle operating costs

The benefit and costs indicated in Table 1 is discounted to net present values by suitable discount rate. There are two fundamental concepts in dealing with compounding and discounting process in engineering economics. These are:
1. Compounding Process

To solve for the future sum F we use Equation 1;

$$F = P\,(1+)^{n} = P\,(\frac{F}{P}\,, i\,, n) \tag{1}$$

Here, P is the present value, n is the interest periods and i is the interest rate. F is the accumulated sum at the end of the n periods. The factor $(1 + i)^n$ is known as the single - payment compound-amount factor. Given this factor, all other important interest factors can be derived. The (F/P) factor is referred to as compounding factor and the process of finding F is known as compounding process [Akbıyıklı, 2014].

2. Discounting Process

Finding the present worth P of a future sum F is simply the reverse of compounding and is known as the discounting process [1].

$$P=F\left[\frac{1}{(1+i)^{n}}\right]=F\left(\frac{P}{F}\,, i, n\right) \tag{2}$$

Here, the $(1/(1+i)^n$ factor is known as the single-payment present-worth factor and is designated as (P/F) factor. This factor is also referred to as the discounting factor and the process is known as discounting process [Akbıyıklı, 2014].

The economic discounting process and the decision rule for benefit – cost analysis and (B/C) ratio is shown in Equation 3.

$$P_{Benefits} = \sum_{1}^{n} \frac{F_{i\ accident}}{(1+i)^{n}} + \sum_{1}^{n} \frac{F_{i\ time}}{(1+i)^{n}} + \sum_{1}^{n} \frac{F_{i\ vehicle\ operating}}{(1+i)^{n}}$$

$$P_{Costs} = \sum_{1}^{n} \frac{F_{i\,maintenance}}{(1+i)^n} + P_{construction}$$

$$\frac{P_{Benefits}}{P_{Costs}} > 1 \rightarrow \quad accept \qquad (3)$$

In equation 3 all the benefits and costs (including the first capital investment cost) are discounted to the present value and established the ratio (B/C). If we are to accept the project the ratio has to be greater than 1. The most important features of the analysis are that all the data related to time values, vehicle operating costs, accident costs, construction costs and operation and maintenance costs have to be correct and without ambiguities. Otherwise wrong data will create wrong decision making accordingly no value for money for the taxpayers. Ultimately a sensitivity analysis is done as final step of the economic evaluation process for the investment project.

Benefit- Cost Analysis Proposal

It is aimed to remove all the indefinite and imprecise and missing data and wrong estimations in the developed benefit-cost model. It is aimed to evaluate the traditional benefit-cost analysis from a wider perspective of risk analysis framework. The constituent parts of the proposed framework are shown in Figure 1 below.

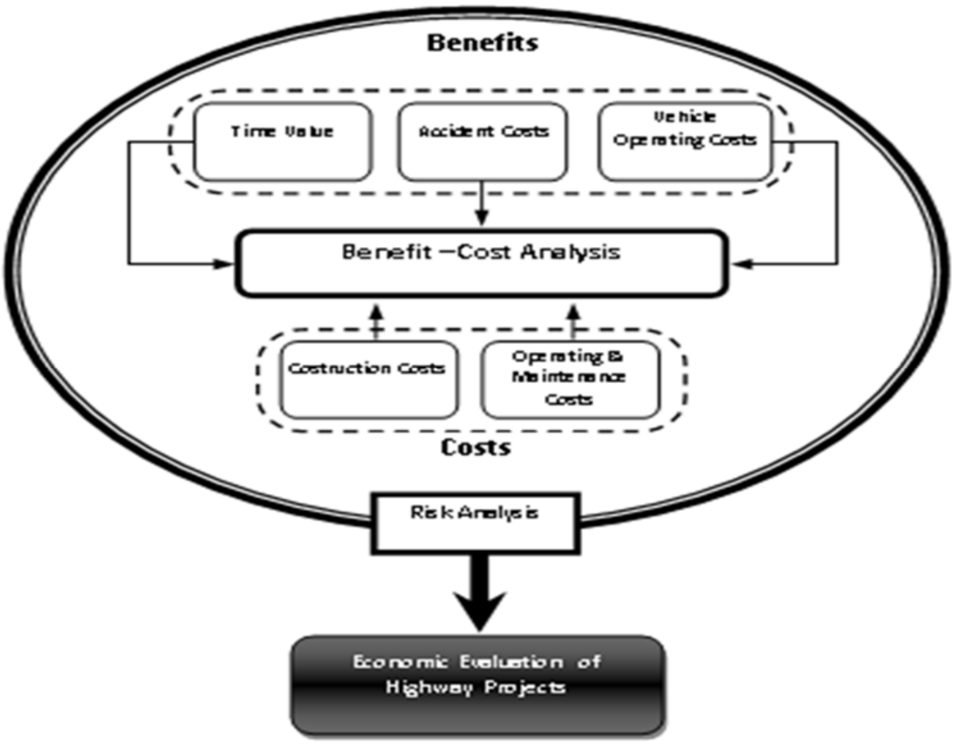

Figure 1: The constituent parts of the developed model

As it is shown in Figure 1 the parameters of traditional benefit-cost analysis it is evaluated within the domain of risk analysis framework. It is needed an intelligent system in order to realise this new analysis process. The intelligent system to be used in the proposed model is expected to have a structure that minimise the negative effects of non-linear, missing and doubtful data. It is assumed that the Fuzzy Cognitive Map method has the ability to fulfil the necessities for the development of the model.

The Fuzzy Cognitive Map plays an important role in defining and modeling complex systems. The Fuzzy Cognitive Map is sheltering solutions depending on the human experience and knowledge in the direction of the dynamics of the system and against different conditions. With this structure the method is widely and effectively applied in decision making analyses.

The Fuzzy Cognitive Map, as shown in Figure 2, is consisted of the conceptual variables of the nodes or the elements composing the system and the lines between the nodes having both directions and weights showing the relations between the conceptual variables [Yaman & Polat, 2009].

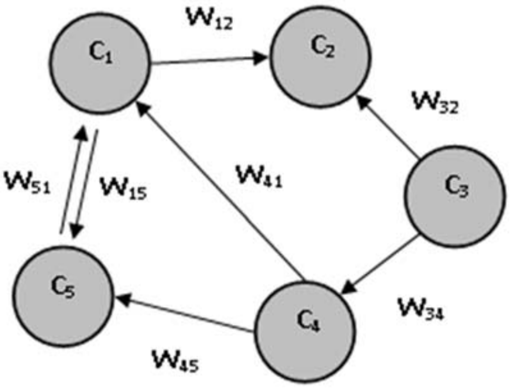

Figure 2: A simplified fuzzy cognitive map [Kosko, 1986]

Conceptual variables or concepts; can indicate mode, variable, event, activity, aim, etc. every conceptual variable, takes variable values by time as result of interaction with other In the Classical Fuzzy Cognitive Map conceptual variable values can within the range of (0,1).. The relations between conceptual variables are defined as fuzzy and have a value in [-1,1] range [Groumpos, 2010]. The conceptual variable value (A_i) for each conceptual variable is calculated with equation 4:

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} A_j^{t-1} W_{ji}\right) \qquad (4)$$

A_i^t, gives the value of C_i conceptual variable at time t; A_i^{t-1}, gives the values of C_j influencing the conceptual variable C_i at time (t-1); W_{ji}, is the influence value to C_i from C_j conceptual variable; and f is the threshold function [Xirogiannis et. al, 2004]. The most used threshold function for the fuzzy cognitive map is given in Equation 5:

$$f(x) = \frac{1}{1+e^{-\lambda x}} \qquad (5)$$

The most important matter in fuzzy cognitive map is establishing the skeleton of the model to be improved and the prediction of the concepts in the system influencing each other. In a later step the determination of the weights between the concepts are realised. The fuzzy cognitive map structure for the developed benefit cost model is shown in Figure 3.

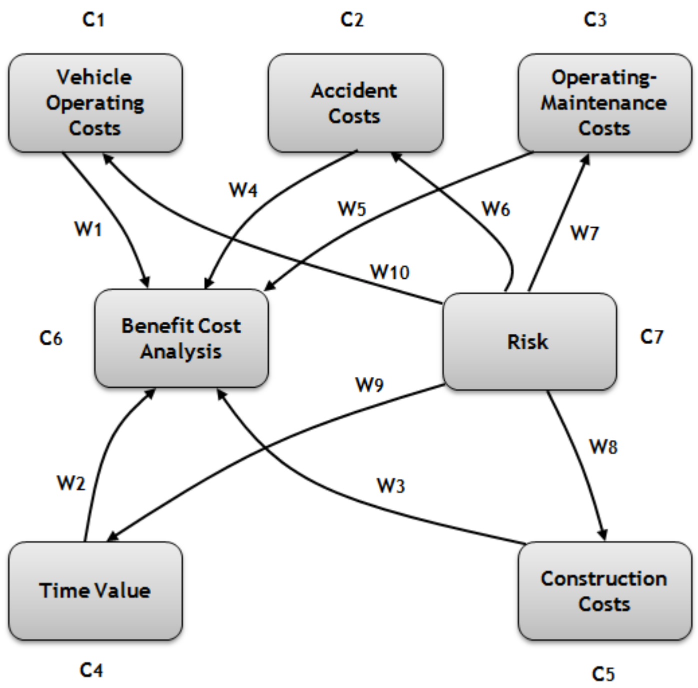

Figure 3: The fuzzy cognitive map of the developed model

As shown in Figure 3, the traditional benefit-cost analysis is put forward in fuzzy cognitive map method. The Model, contains the fundamental parameters of traditional benefit – cost analysis namely, accident costs, time value, vehicle operating costs, construction costs and maintenance costs. In the developed model it is included the risk parameter in the traditional benefit-cost analysis and the effect of this parameter on the other parameters is considered. The system is considered in two ways: The first, predicting the relations and effect levels between the results of basic parameters of the benefit-cost analysis and fuzzy cognitive maps method. The second, fuzzy risk analysing of these basic parameters and predicting the risk value effects on the system. As a result of the analysis and by predicting the weights between the concepts an adjacency matrix will be determined. In Figure 4 is shown such an adjacency matrix for the developed model.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0	0	0	W_1	0
C_2	0	0	0	0	0	W_4	0
C_3	0	0	0	0	0	W_5	0
C_4	0	0	0	0	0	W_2	0
C_5	0	0	0	0	0	W_3	0
C_6	0	0	0	0	0	0	0
C_7	W_{10}	W_6	W_7	W_9	W_8	0	0

Figure 4: Adjacency matrix

In Figure 4 it is shown the adjacency matrix expressing the effectiveness weight levels between the concepts in the system. The W_1, W_4, W_5, W_2, W_3 in the matrix show the effect values related to the result of the parameters in the traditional benefit – cost analysis; the W_{10}, W6, W_7, W_9, W_8 weights show the effect of the risk parameters on the other concepts. As a result of the creation of this matrix and with the help of the Equation 5 the system will be ready to be operated.

The most important matter here is how the calculation of the effect of other concepts will be done after the inclusion of the risk parameter in the developed model.

The risk parameter included in the model will affect the concepts in the system in different levels. Therefore this parameter with a special evaluation method must effect each of the concepts in the system. At this stage the techniques used to determine the weights used in the fuzzy cognitive map method will not be sufficient for this parameter. Now, a new approach is necessary for the prediction of the effects of the risk parameter on other concepts. The steps of the new proposed approach are as follows:

Traditional risk analysis steps have to be used in finding the effect of risk parameter on the other concepts in the system. In this respect the main steps of the traditional risk analysis have to be followed in order to the prediction of the risks, identification of the risks, estimation of the risks and evaluation of the risks.

The prediction and definition of the risks have to be obtained from a deep literature review of benefit-cost analysis of the General Directorate of Highways in Turkey.

1- At the stage of the estimation of risk done have to get help from the specialists of feasibility studies in the General Directorate of Highways in Turkey.
2- The evaluation of the risks has to be done using fuzzy risk analysis method in order to obtain the weight values.

The developed method is aiming to reach the result by risk analysis of each concept in the traditional benefit cost analysis. In this respect each concept will be included in the result as specified risk coefficients. These coefficients are not dynamic and will be obtained after some analysis. These, as shown in Figure 4, will be included in the matrix as static coefficients. The evaluation of these coefficients is in progress.

Conclusion

The highway investments' economic evaluations is depending mainly on future predictions and estimations and obtaining of correct information and data. On the contrary, the wrong decision making by the decision makers will choose Project that are no feasible and no benefits to the society, As a result of this view many economically and socially unpredictable countries with insufficient data for economic analysis are preparing analysis that barely are numbers without applicability in real-life projects. The sensitivity analysis, made at the end of the economic analysis, remains as a general risk analysis on the determined parameters depending on the foresight of the analyst foresight of the analyst. But, since the benefit-cost analysis is the project's "feasibility" evaluation, it has to be put forward as a complete risk evaluation analysis since it will affect the project for many years in future. In this paper risk parameter is included in the proposed benefit-cost analysis model and all the system is evaluated with this parameter aiming to get the most correct result. The final result will be obtained by the inclusion of risk parameter together with the traditional benefit-cost analysis concepts (time value, vehicle operating costs, accident costs, operation and maintenance costs) a final risk analysis will be done. Such an approach will give more reliable conclusions.

The calculation of weights for the model proposed using fuzzy cognitive maps method is continuing. When the model is final the economic evaluation of transportation projects will be closer to the real result.

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