AN EVALUATION METHOD FOR URBAN TRANSPORTATION EFFICIENCY

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1. Introduction

In the context of growing urbanization process, urban transportation plays important role for every cities in the developed as well as developing countries. Among the many global issues of the present world such as, economic growth, sustainable development, world environmental conditions etc. are very much related to the transportation. As the transport sector occupies significant portion in the national economy, it should be analyzed and assessed before formulation of any short term or long term planning goals. In this paper, urban transportation efficiency, factors affecting, evaluation frame-work and mathematical approaches to solve and interpret during decision making process are studied. Relative importance of different criteria and factors under each of criteria can be determined by using very popular approach "Analytic Hierarchy Process (AHP)". In this paper the relative importance-"weight" of factors affecting the urban transportation efficiency under different hierarchal structure is determined by using AHP. After the determination of weight of each weight, Fuzzy Logic method based on MATLAB environment is used for the determination of urban transportation efficiency.

2. Urban Transportation System Hierarchy and Efficiency

A system may be defined as the combination of interdependent and interrelated components that form a complex and unified whole, intended to serve some purpose trough the performance of its interacting parts. System hierarchy provides order and function to the operation of the individual component. Functionally, urban transportation system is just one of many systems that allow urban areas to exist.
The basic definition of efficiency is the relation between input and output or between costs and benefits in a certain system. From an economic standpoint, efficiency is the extent to which a certain amount of productive resources can meet the demand of human beings. The transportation efficiency can be defined as extent to which a certain transportation input can meet travel demand of people. Travel efficiencies benefit the users of the facility in question. The benefits are in the form of travel time saving, vehicle operating cost saving. Transportation system efficiency can be explained in fig. 2.
Generally, the efficiency of the urban transportation can be measured by ratio of the social benefits to the costs. The greater the ratio, the higher the transportation efficiency is. However, social costs and benefits both can not be quantified exactly.

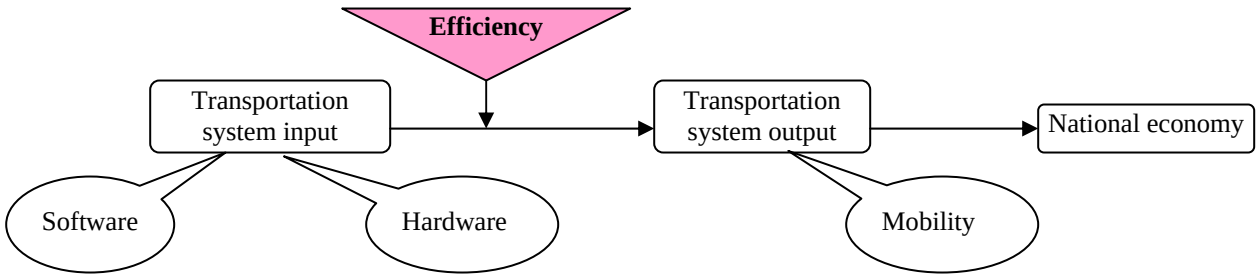

Fig. 2- Transportation system efficiency

3. Factors Influencing Urban Transportation Efficiency

Important factors for the evaluation of transportation efficiency are as: urban land use pattern; modes of transportation; transportation infrastructure and traffic management. Urban transportation pattern: The composition of different modes of urban

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transportation system should be harmonized with the land use pattern of that area, which will help to balance the transportation demand and supply. The promotion of public transportation and development of mass transit system are great factors to improve the urban transportation efficiency. Urban land use pattern: As the transportation demand is derived from economic and social activities of people then, its efficiency greatly depends upon the urban land use pattern, its characteristics and intensity. In order to improve urban transportation efficiency, suitable land use pattern is necessary. Suitable land use policy should consider the decentralization of urban functions, balanced transportation demand, congestion reduction in central business districts etc. Urban transportation infrastructure: it includes roads, parking lot and terminals. Transportation infrastructure is key factor to determine the urban transportation efficiency. Traffic management: it is important component which controls and guides the distribution of traffic flow and it help to improve the environment to some extent. Traffic safety could also be improved by appropriate traffic management system.

4. Evaluation Index Hierarchy in Urban Transportation

Main factors affecting urban transportation efficiency consists of other underlying indices, which are modeled in a hierarchical structure for the purpose of their analysis. A fragment of the index hierarchy is shown in Fig. 3.

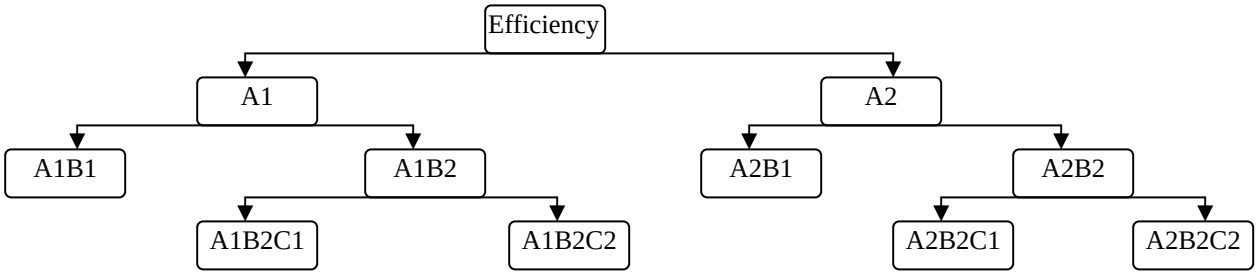

Fig.3- Hierarchy of the evaluation indices

The indices A, B, C represent their hierarchy level from top to bottom respectively, and a combination of a ABC shows the position in the root structure.

5. Research Methodology

Modeling all the factors and indices according to the fig. 3 was the first step of the research. In the second part of the research analysis - "evaluation" is performed. The most important part "analysis" is done by the application of two very popular tools- Analytic Hierarchy Process (AHP) and Fuzzy Logic theory based on MATLAB environment.

5.1. Application of Analytic Hierarchy Process

The evaluation of many engineering system is based on the analysis of a number of factors "criteria". The problem become very complicate one when the criteria are expressed in different units or the pertinent data are difficult to be quantified. The AHP is a multi-criteria decision-making approach and was introduced by Saaty T.L. in 1977 and revised in 1994. For the analysis of the transportation efficiency, following process is performed:

- Determination of hierarchical structure of evaluation indices.
- Perform pair wise comparison.
- Assess consistency of pair wise judgments.
- Computation of the relative weights.

The typical structure of the decision problem consists of a number of 'm' alternatives and 'n' numbers of decision criteria. Each alternative can be evaluated in terms of the decision criteria and the relative importance (weight) of each criterion can be estimated as well. The typical MCDM problem can be represented by the decision matrix given below:
For the pair wise comparison of indices in the same level of hierarchy is performed according to the scale of relative importance according to Saaty. It is performed by discrete choice and then this choice attributed by a certain numerical value from this the set of {9, 8, 7, 6, 5, 4, 3, 2, 1, ½, 1/3, ¼, 1/5, 1/6, 1/7, 1/8, 1/9}. The consistency of the pair wise judgment is done by calculating the Consistency Ration (CR), which should be greater than 10 % to consider the pair wise decisions are acceptable.

	Criteria				
	C_1	C_2	C_3	….	C_n
Alternatives	W_1	W_2	W_3	…..	W_n
A_1	a_{11}	a_{12}	a_{13}	……	a_{1n}
A_2	a_{21}	a_{12}	a_{23}	……	a_{2n}
A_3	a_{31}	a_{32}	a_{33}	…….	a_{3n}
.					
.					
A_m	a_{m1}	a_{m2}	a_{m3}	…..	a_{mn}

After the decision matrix is prepared the individual priority vectors are derived. Given the decision matrix, final priorities (A^i_{AHP}) of the alternatives in terms of all criteria combined are determined according to the formula:

$$A^i{}_{AHP} = \sum_{j=1}^{N} a_{ij} * W_j, \qquad \text{for } i = 1, 2, 3, \ldots\ldots M$$

5.2. Application of Fuzzy Logic to Analyze Urban Transportation Efficiency

After calculating the weights of each evaluating indices, the Fuzzy Logic method is used to evaluate the efficiency of the urban transportation. These days Fuzzy theory is being very popular in solving many engineering problems. Main principle in Fuzzy set theory is that there is no exactly defined boundaries between elements in a set, because of generalization of a characteristic function to a membership function. The concept of Fuzzy inference is a method that interprets the value in input vector and, based of some set of rules, assigns values to the output vector (Fig. 4).

In this study, above described factors are taken as input variables and transportation efficiency is taken as output variable. Each variable are given certain membership function. After the formulation of the membership function of each input and output variables, rules are determined to calculate the efficiency. These steps are performed by using graphical user interface (GUI) provided by Fuzzy Logic Toolbox. There are five primary GUI tools: FIS editor, Membership function editor, Rule editor, Rule viewer and Surface viewer. They are dynamically linked to each other.

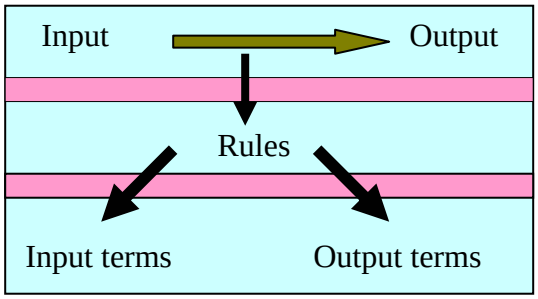

Fig. 4- Principle of Fuzzy Logic model

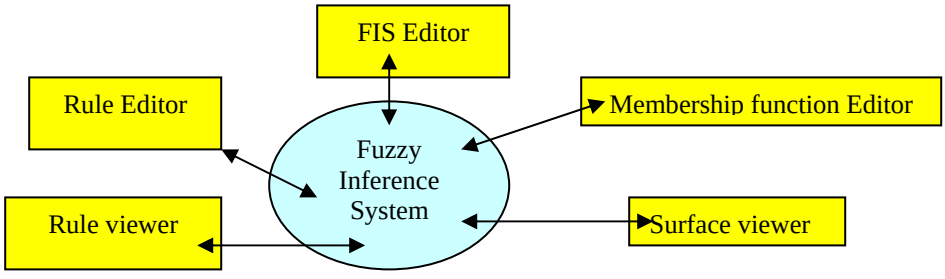

Fig. 5- GUI components in Fuzzy Logic Toolbox

In building the model in GUI, all the input variables with their value rage are given to the Fuzzy Inference System (FIS). In the membership function editor, membership function shape is selected within the built-up different mathematical function. Rule editor is for editing the list of rules that defines the behavior of the system. Rule viewer and surface viewer are for the graphical interpretation of the defined system. A fragment of the model to analyze the urban transportation efficiency is shown in fig. 6.

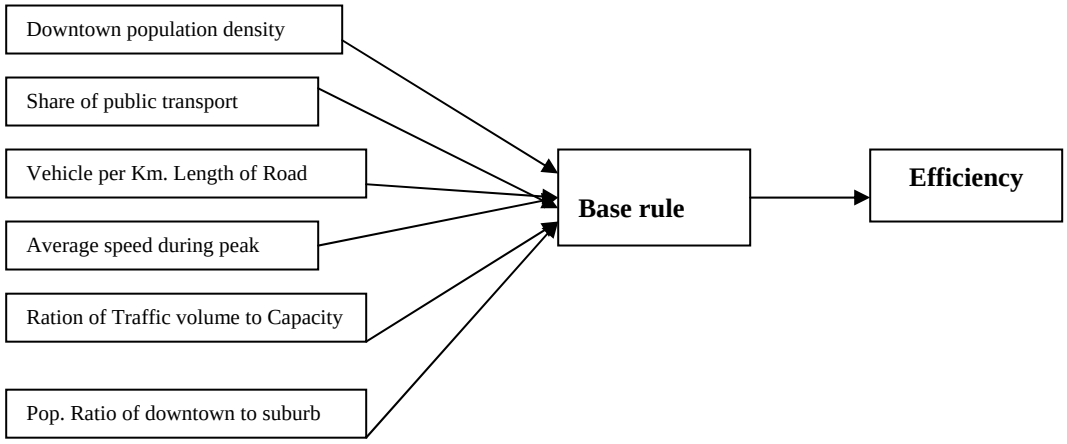

Fig. 6- Model structure to determine transportation efficiency

6. Result and Conclusion

As mentioned above, urban transportation efficiency is only the relative concept; we can evaluate it only for the cities with same level of development. In this study, the cities of the developing countries are considered and the transportation efficiency of Kathmandu city is calculated, and was found 0.457. But this value could be improved by increasing the data.

Urban transportation efficiency is most important indicator which determines the capacity of urban transportation system and the balance between demand and supply. Our efforts to increase the transportation facility always less than ever growing transportation demand. Therefore to improve efficiency of urban transportation is the best way to utilize them effectively. Most important factors affecting transportation efficiency are: Urban transportation structure (modes), land use pattern, infrastructure and traffic management. To analyze the transportation efficiency many indices under the hierarchical structure are evaluated. By using established Fuzzy Logic GUI toolbox, we can evaluate the urban transportation efficiency. During this particular study the urban transportation efficiency of Kathmandu city is calculated. The Fuzzy logic methods are more accurate to analyze and assess many uncertain and complex variables in transportation planning.

7. Acknowledgement

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Reference

1. Michael and Eric J. Miller. Urban Transportation planning. Mc Graw Hill2001.
2. C.S. Papacostas and P.D. Prevedouros, Transportation Engineering and Planning, Printice Hall of India, New Delhi, 2002.
3. The study on Kathmandu Valley Urban Road Development, Final Repart, His Majesty's Government of Nepal, Ministry of Works and Transport, Department of Roads, 1993.
4. Dusan Teodorovic, Fuzzy Logic systems for transportation engineering: the state of the art, Transportation Research Part A 33 (1999) 337-364.
5. Evangelos, Triantaphylou, Stuart H. Mann, Using the analytic hierarchy process for decision making in engineering applications: some challenges, International journal of industrial engineering: application and practice, vol. 2, No. 1, pp. 35-44, 1995.
6. Serdal Terzi, Yasar Topkara, Mahmat Albayrak, A fuzzy logic model for prevention of vehicle pursuit distance as automatically, XII International Turkish Symposium on Artificial Intelligence and Neural Networks- Tainn, 2003.
7. 10th National plan, His Majesty's Government of Nepal, Planning Commission, Chapter 18, Road Transportation 2001.
8. Alecxander S. Belinsky, Operations Research in Transportation Systems, Ideas and Schemes of Optimization Methods for Strategic Planning and Operation Management, Kluwar Academic Publishers, 1998.
9. Saaty T.L, Fundamentals of Decision Making and Priority Theory with AHP. RWS Publications, Pittsburgh, PA USA, 1994.