MCDM for Road Safety Management Using Fuzzy Analytical Hierarchy Process

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Abstract—**Road accidents are a major concern in this modern city life. The accidents not only affect the sentiments and feelings of the individual and it also plays a major part in the economic development of a country. This paper analyses the cause of the accidents and the analytical study is done through a pair wise comparison using Analytical Hierarchy Process and the results are given for better traffic management in the particular roads and also the type of vehicles.**

Index Terms—**Multi criteria decision making (MCDM), AHP , ranking, triangular fuzzy number**

I. Introduction

The idea of fuzzy set was first proposed by Bellman and Zadeh [1], as a mean of handling uncertainty. Decision making is the process of finding the best alternative from a number of feasible alternatives which is called as Multi Criteria Decision Making. The MCDM problems may be divided into the classical MCDM in which the ratings are measured as crisp numbers and the other is the FMCDM, which is based on the vagueness of the problem and expressed in linguistic terms [6],[7]. In [3], [4],[8]and[10] a fuzzy version of Saaty's AHP method was developed by Triangular Fuzzy Numbers for Linguistic terms**.** In developing countries due to the lack of infrastructure such as roads and bridges, a number of accidents take place and this will consume massive financial resources both the individual and the country apart from the loss of life. In this paper we propose an AHP for traffic study in a particular area. Since the data is not predictable and the decision making is difficult in the process, fuzzy pairwise comparison is used. The fuzzy pair wise comparison between each alternative is defined and an ideal solution is obtained using AHP.

II. Preliminaries

A. Fuzzy Number: 2.1 [8]

A fuzzy set $\tilde{A}$ of the real line R with membership function $\mu_{\tilde{A}}(x) : R \to [0,1]$ is called fuzzy number if i) A must be normal and convex fuzzy set;

   ii) the support of $\tilde{A}$, must be bounded

   iii) α_A must be a closed interval for every

$\alpha \in (0, 1]$;

B. Triangular Fuzzy Number: 2. 2 [5]

A fuzzy number A is defined to be a triangular fuzzy number if its membership functions

$$\mu_{\tilde{A}}(x) : R \to [0,1] \quad \text{is equal to}$$

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} & for\, a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & for\, a_2 \le x \le a_3 \\ 0, elsewhere \end{cases}$$

C. Sum of Two Fuzzy Numbers: 2.3 [5]

Let A $= (l_1, m_1, n_1)$ and B$= (l_2, m_2, n_2)$ be two fuzzy numbers. Then their sum A+B is given by

A+B$= (l_1 + l_2, m_1 + m_2, n_1 + n_2)$ .Similarly

$\alpha A = (\alpha l_1, \alpha m_1, \alpha n_1)$ where α is a real number.

III. Decision Making Using Analytical Hierarchy Process and Evaluation of Alternatives

Coimbatore city is the third largest city in the state of Tamil Nadu. The city has a population of about 1.2 million and is very much industrialized and economically makes a good contribution to the government by revenue generation in Textiles small scale and software industries. The city has vehicular population of both public as well private around 400 thousands. Though there is increase in vehicular traffic the infrastructure such as roads are not developed here. Here we consider four major arterial roads in the city along with a corporation road and five different types of vehicle are taken into consideration and the data is collected and analyzed and is tabulated with numerical rating and linguistic terms for evaluation.

A. Scale of Relative Importance Saaty, (1980)

Verbal Judgment	Numerical rating	Fuzzy rating	Range
Safe	1	(1,1,1)	0-5
Moderate	3	(1,3,5)	5-10
Risky	5	(3,5,7)	10-15
Highly Risky	7	(3,5,9)	15-20
Dangerous	9	(5,7,9)	>20

TABLE I: THE PAIR WISE COMPARISON MATRIX BETWEEN ROADS AND VEHICLES

Roads / Vehicles	Auto	Car	Bus	Truck	Two wheeler	Priority Vector (w)
Trichy	1	3	3	9	9	**0.019**
Pollachi	3	5	9	5	9	**0.279**
Sathy	3	5	7	7	9	**0.279**
Avinashi	1	3	3	3	7	**0.138**
Other corporation	1	1	3	1	9	**0.107**
Total	**9**	**17**	**25**	**25**	**43**	

TABLE II: THE PAIR WISE COMPARISON MATRIX BETWEEN VEHICLES AND ROADS

Vehicles / Roads	Trichy	Pollachi	Sathy	Avinashi	Other corp	Priority Vector(w)
Auto	1	3	3	1	1	**0.071**
Car	3	5	5	3	1	**0.137**
Bus	3	9	7	3	3	**0.205**
Truck	9	5	7	3	1	**0.166**
Two wheeler	9	9	9	7	9	**0.358**
TOTAL	**25**	**31**	**31**	**17**	**15**	

In the above Tables 1 and 2 the pair wise comparison matrix between Roads and vehicles and vice versa has been formed and each entry is divided by its column sum. Now, the average of the corresponding row entries is the priority vector with respect to each criterion. On the above priority vector of Tables1 &2 we find that in Table 2, Two-wheeler has highest priority vector, so we conclude that two-wheeler are more prone to accidents

B. AHP Priorities of Criteria:

In Table1 the priority vector (w) is same for Pollachi and Sathy roads, so the pair wise comparison of roads with respect to each criterion is formed using the fuzzy linguistic comparative words as in 3.1.These linguistic terms are converted into fuzzy numbers according to the scale 3.1

Now each entry of the below pair wise fuzzy comparison matrix with respect to each criteria is divided by its column sum .Now the row average of resulting matrix is the fuzzy priority vector with respect to each criteria.

C. Fuzzy Score of Roads

The fuzzy score of each road is the sum of the products of weights of criteria with their corresponding fuzzy numbers in fuzzy priority vectors.

TABLE III: PAIR WISE COMPARISON OF FUZZY MATRIX BASED ON ROADS AND VEHICLES

Roads / Vehicles	Auto	Car	Bus	Truck	Two Wheeler	Fuzzy Score of roads
Trichy	(1,1,1)	(1,3,5)	(1,3,5,)	(3,7,9)	(3,7,9)	**(0.0319, 0.0360, 0.0359)**
Pollachi	(1,3,5)	(3,5,7)	(5,7,9)	(3,5,7)	(5,7,9)	**(0.0837, 0.0757, 0.0761)**
Sathy	(1,3,5)	(3,5,7)	(3,7,9)	(3,7,9)	(5,7,9)	**(0.0736,0.0802 , 0.0797)**
Avinashi	(1,1,1)	(1,3,5)	(1,3,5)	(1,3,5)	(3,7,9)	**(0.0176,0.0175, 0.0218)**
Other corporation	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(5,7,9)	**(0.0158 , 0.015,0.0107)**
Total	(5,9,17)	(9,13,25)	(11,23,33)	(11,23,31)	(21,35,45)	

D. Crisp Score of Road

Let (a,b,c) be a triangular fuzzy number .The Left score L and the right score R and the Total score T of this fuzzy number are given by

$$L = \frac{1-a}{1+b-a}, \quad R = \frac{c}{1+c-b}, \quad T = \frac{1+R-L}{2}, \quad (1)$$

Using the equation (1) we get the total crisp score of Trichy Road =0.5497, Pollachi Road=0.623, Sathy Road=0.6127, Avinashi Road =0.5348, Other Corporation Roads=0.5137.

IV. DISCUSSIONS AND CONCLUSION

From the above study on roads it has been ranked by AHP and the highest value is more risk prone both in the cases of roads as well as the type of vehicles. It was found that Pollachi road is more prone to accidents when compared to other Roads and also in the case of two wheelers which are more dangerous than other type of vehicles. Here in the above study Table 1 gave a result of equal values in case of Sathy road and Pollachi Road .In this paper Fuzzy pair wise comparison was done using triangular fuzzy number and crisp score value and rating was obtained as in Table4.

TABLE IV

Roads	Vehicles	Priorityvector for roads %	crispscore of roads%	Ranking for roads	Priorityvector forvehicles %	Ranking for vehicles
Trichy	Auto	19.5	54.97	III	7.18	V
Pollachi	Car	27.9	62.3	I	13.7	IV
Sathy	Bus	27.9	61.27	II	20.5	II
Avinashi	Truck	13.8	53.48	IV	16.6	III
Other Corpor	Two-wheeler	10.7	51.37	V	35.8	I

The following suggestions were given to the experts for traffic management and the following suggestions were given to them to ensure proper safety and smooth flow of traffic in this region.

i) Provision of dividers and widening of the road will decrease the rate of accidents ii) Identifying Accident Prone spots and cautioning the motorists to be careful on the particular area.iii) Educating the public in safe driving ways iv) The speed limits of the vehicles should be governed and those who over speed the vehicles has to be punished severely. On line cameras has to be installed to monitor the movement for vehicles. vi) On road accident and trauma care systems has to be developed to reduce the fatality in case of emergencies. In case of the vehicles, two wheelers are more prone for accidents and the fatality also is much more in case of two wheelers. Spot fine and action for violations in traffic. Speed limit has to be maintained and any deviation from the above heavy punishment has to be enforced. Educate the two wheeler riders on safety aspects. Wearing of helmets should be made compulsory and the violators should be punished. Proper driveway in the highways has to be created for the two –wheelers.

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