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Fuzzy Approach for Ranking of Motor Vehicles Involved in Road Accidents

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***Abstract*—**Increasing number of vehicles and lack of awareness among road users may lead to road accidents. However no specific literature was found to rank vehicles involved in accidents based on fuzzy variables of road users. This paper proposes a ranking of four selected motor vehicles involved in road accidents. Human and non-human factors that normally linked with road accidents are considered for ranking. The imprecision or vagueness inherent in the subjective assessment of the experts has led the application of fuzzy sets theory to deal with ranking problems. Data in form of linguistic variables were collected from three authorised personnel of three Malaysian Government agencies. The Multi Criteria Decision Making, fuzzy TOPSIS was applied in computational procedures. From the analysis, it shows that motorcycles vehicles yielded the highest closeness coefficient at 0.6225. A ranking can be drawn using the magnitude of closeness coefficient. It was indicated that the motorcycles recorded the first rank.

***Keywords*—**Road accidents, decision making, closeness coefficient, fuzzy number.

I. Introduction

ONE of the most prevalent discussions about motor vehicles on the road or highways is accidents. In the midst of large volume of traffics on the road, accidents which involve the various types of vehicles inevitably happen. Accidents are generally classified as single vehicle accidents in which the vehicle is either colliding with fixed objects or with pedestrians or the vehicle may fall in a ditch etc. and multiple vehicle accidents in which two or more than two vehicles can either collide head–on, or one vehicle may collide with the front vehicle at the back or may a have side-swipe type collision. There are a collision between car and car, others between car and motorcycle, also between car and bus and so on. Accidents, may causes damages, injuries or even worst is deaths. It was reported that over 43,200 people died due to road accidents in the year 2005 and 42,636 in the year 2004 in United States [1]. In Malaysia, the fatality figures caused by road accident are very much alarming. The United Nations has ranked Malaysia 30th among countries with the highest number of fatal road accidents, registering an average of 4.5 deaths per 10,000 registered vehicles [2]. Royal Malaysian Police [3] reported that traffic accident in Malaysia have been increasing at the average rate of 9.7% per annum over the last three decades. Compared to the earlier days, total number of road accidents had increased from 24,581 cases in 1974 to 341,252 cases in 2005. The number of fatalities also increased but at slower rate compared to total road accident from 2,303 in 1974 to 6,287 in 2006. Thus, road accidents have become a hot topic of discussions among public and definitely a concern for all countries.

In Malaysia, road accidents involving various types of vehicles are reportable to the police, who collect data prior formally published for public. The Royal Malaysian Police pools the data and publish annually the main statistics in road accidents. The Malaysian road accident database details out the accident in series of years based on the severity that caused by accidents [3]. Also, reported the types of vehicles involved in casualties such as pedestrian, motorcycle, car, four wheel drive vehicle and other. There was no separation between traffic compositions or vehicles to enlist frequency of accidents whereby most of traffic involved in accidents is a combination of small, medium or heavy vehicle. The other weakness of the road accident data is the under-reporting of separation of vehicles according to human and non human factors caused of road accident such as road conditions and drug influences. Perhaps it due to the multiple factors attributed to accidents and also multiple vehicles involved in accidents. As a result, it seems very difficult to rank the vehicles involved in accident when multiple factors are taking into account. Some of the previous studies reported other parameters enveloping accidents. For example [4] and [5] report on sites of accident and limited their findings for selecting and ranking hazardous road sites according to their level of hazard. On the other hand [6] review causes of road accidents from the angle of cars condition, traffic rules violation and poor road conditions without proposing a rank for causes of accidents. So far, there have been little discussions about an attempt to consider all possible factors attributed to accidents and to be associated with type of vehicles into a single measurement.

The contributing causes of road accidents are diverse indeed. Most of the accidents are said to be attributed by the fault of the driver. Mechanical causes such as brake failure, tyre burst etc. are also there in lesser number of cases. Therefore, the majority of accident causes are linked with road conditions and driver behaviour. These statements confirm the statistics released by [7]. In most of the accidents, a single factor is not present and an accident is a result of a number of complex factors that jointly responsible for the accident. The alarming figures of accidents rate involving multiple vehicles and multi factors linked to accidents motivate the need to

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further explore these issues. Human and non human factors must be accounted for deriving an indicator to rank vehicles according to its magnitudes. It is noticeable that accidents may be caused by many attributes and some of these attributes are qualitative measures which require subjective assessment by human experts. As to this, the ranking of vehicles involve in accident can be seen as a multi criteria decision making (MCDM) problem. MCDM has proven to be an effective approach for ranking by a finite number of alternatives characterized by multiple criteria. One of the techniques for order preference is called Technique for Order Performance by Similarity to Ideal Solution and abbreviated as TOPSIS. This technique based on fuzzy sets theory has proven to be a powerful modelling tool for coping with subjective and imprecision in human judgements. Modelling using fuzzy sets has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise [8]. Many fuzzy TOPSIS method has been proposed to handle linguistic decision making [9] [10]. [11] sustained that linguistic terms are intuitively easier to use when decision makers express the subjectivity and imprecision of their assessment. In short, the purpose of this paper is to propose a ranking order of vehicles involved in accident based on fuzzy multi-criteria decision making, TOPSIS.

The rest of the paper is organized as follows. In section 2, some basics preliminaries of fuzzy theory are introduced. In Section 3, a simple fuzzy method is proposed to deal with fuzzy MCDM. A real data is illustrated in Section 4 to show the use of the proposed method in ranking the vehicles involved in road accidents. The paper is concluded in Section 5.

II. DEFINITION OF FUZZY NUMBERS

In this section, for the purpose of reference, some basic definitions and formulas that are used in our paper will be covered.

Definition 2.1 [12], [13]. Let X be a Universe of discourse. Where A is a fuzzy subset of X; and for all $x \in X$, there is a number [0, 1] which is assigned to represent the membership degree of x in A, and is called membership function of A.

Definition 2.2 [13] A fuzzy number A is a normal and convex fuzzy subset of X. Here, normality implies that

$$\exists x \in R, \vee_x \mu_A(x) = 1 \quad (1)$$

and convex means that

$$\forall x_1 \in X, \forall \alpha \in [0,1], \quad \mu_A(\alpha x_1 + (1-\alpha) x_2) \geq \min(\mu_A(x_1), \mu_A(x_2)) \quad (2)$$

Definition 2.3. [13]. A triangular fuzzy number A can be defined by a triplet (a,b,c), where the membership can be determined as follows.

$$\mu_A(x) = \begin{cases} 0, & x < a \\ \dfrac{x-a}{b-a}, & a \leq x \leq b \\ \dfrac{c-x}{c-b}, & b \leq x \leq c \\ 0, & x > c \end{cases} \quad (3)$$

Definition 2.4. [14]. Given a triangular fuzzy number $A = (a_1, a_2, a_3)$, the graded mean integration representation of triangular fuzzy number A is defined as

$$P(A) = \frac{1}{6}(a_1 + 4 \times a_2 + a_3) \quad (4)$$

Definition 2.5 [14]. Let $A = (a_1, a_2, a_3)$ and $B = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. The representation of addition operation $\oplus$ on triangular fuzzy numbers A and B can be defined as

$$P(a) \oplus P(b) = P(a) + P(B) = \frac{1}{6}(a_1 + 4 \times a_2 + a_3) + \frac{1}{6}(b_1 + 4 \times b_2 + b_3) \quad (5)$$

Definition 2.7[14]. The canonical representation of multiplication operation on fuzzy numbers A and B defined as

$$P(a) \otimes P(b) = P(a) \times P(B) = \frac{1}{6}(a_1 + 4 \times a_2 + a_3) + \frac{1}{6}(b_1 + 4 \times b_2 + b_3) \quad (6)$$

III. FUZZY TOPSIS

A systematic approach to apply the TOPSIS to the fuzzy environment is presented in this section. This method is very suitable for solving the group decision making problem under fuzzy environment. A decision-making problem is the process of finding the best opinion from all of the feasible alternatives. General process of fuzzy TOPSIS is listed below [15].

Step1. Establish a decision matrix for ranking. A MCDM problem can be concisely expressed in matrix format as

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_M \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (7)$$

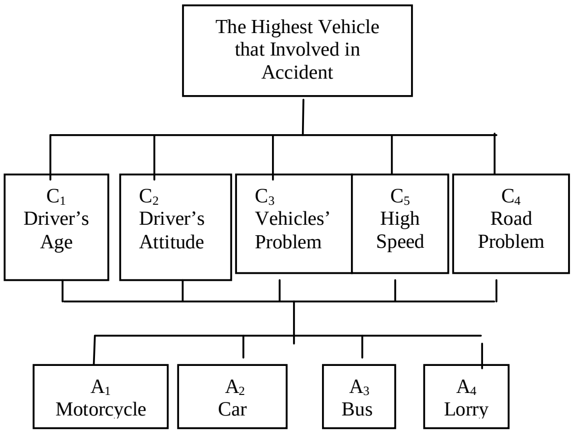

Fig. 1 Hierarchical structure of the decision problem

where $A_1, A_2, \ldots, A_m$ are possible alternatives among which decision makers have to choose, $C_1, C_2, \ldots, C_n$ are criteria with which alternative performance are measured, x_{ij} is the rating of alternative A_i with respect to criterion C_j.

Step 2. Calculate the normalized decision matrix. The normalized value { r_{ij} } is calculated as

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} x_{ij}^{2}}}, \quad j = 1,...,J; i = 1,...,n. \tag{8}$$

Step 3. Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as

$$v_{ij} = w_{ij} \text{ x } r_{ij}, \quad j = 1,...,J; i = 1,...,n, \tag{9}$$

where w_i is the weight if the i th criterion, and $\sum_{i=1}^{n} w_i = 1.$

Step 4. Determine the positive ideal solutions and negative ideal solutions respectively

$$A^* = \{v_1^*,...,v_n^*\} = \{(\max_j v_{ij} \mid i \in I'), (\min_j v_{ij} \mid i \in I'')\},$$

$$A^- = \{v_1^-,...,v_n^-\} = \{(\min_j v_{ij} \mid i \in I'), (\max_j v_{ij} \mid i \in I'')\}, \tag{10}$$

where I' is associated with the positive criteria, and I'' is associated with the negative criteria.

Step 5. Calculate the separation measures using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as

$$D_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^*)^2}, \; j = 1,..., J. \tag{11}$$

Similarly, the separation from the negative-ideal solution is given as

$$D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2}, \; j = 1,..., J. \tag{12}$$

Step 6. Calculate the relative closeness to the ideal solution. The relative closeness of the alternative a_i with respect to A^* is defined as

$$C_j^* = \frac{D_j^-}{D_j^* + D_j^-}, \; j = 1,..., J. \tag{13}$$

Step 7. Rank the preference order. A large value of closeness coefficient C_j^* indicates a good performance of the alternative A_i. The best alternative is the one with the greatest relative closeness to the ideal solution.

IV. An Experiment

In accordance with the purpose and method of this research, criteria and alternatives were identified. The alternatives comprise four vehicles that mostly involved in accidents i.e. motorcycles (A_1), car (A_2), bus (A_3) and lorry (A_4). The five criteria that considered in this study were Driver's Age (C_1), Driver's Attitude (C_2), Vehicles' Problem (C_3), Road Problem (C_4), and High Speed (C_5). Furthermore, a committee of three decision-makers or experts, D_1, D_2 and D_3 has been identified to seek reliable data over the accidents. Data in form of linguistics variables were collected through interviewing of three authorised personnel from three Malaysian Government agencies. The interview was conducted in three separated sessions to elicit information about vehicles that regularly involve in accident and factors linked to accidents. Three decision-makers were an Assistant Enforcement Officer from Road Transport Department of Kuala Terengganu (D_1), a Traffic Police Inspector from Police Traffic Department of Kuala Terengganu (D_2) and the third expert was an Assistant Superintendent of Fire Brigade Department of Kuala Terengganu (D_3). The hierarchical structure of this experiment can be seen in Figure 1.

TABLE I
LINGUISTIC VARIABLES FOR THE RATINGS OF THE VEHICLES

Linguistic Variables for The Ratings of The Vehicles	
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium Good (MP)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

The interviewing process was mainly focused on the opinion of the experts regarding rating of the vehicles prone to accidents based on the identified criteria. The experts were asked to specify rating of association of the criteria for each vehicle with linguistic expression varying from 'very poor' (VP), 'poor' (P), 'medium poor' (MP), 'fair' (F), 'medium good' (MG), 'good' (G), and 'very good' (VG). The weights of importance for each criterion were specified by experts with linguistics expression varying from 'very low' (VL), 'low' (L), 'medium low' (ML), 'medium' (M), 'medium high'(MH), and 'very high'(VH). These score were later aggregated to calculate the rating as a triangular fuzzy number for each criterion.

In this experiment, the rating x_{ij} of alternative A_i and the weights w_j of criteria C_j are assessed in linguistics terms represented by triangular fuzzy numbers as shown in Table I and Table II.

TABLE II
LINGUISTIC VARIABLES FOR THE WEIGHT w_j OF CRITERIA C_j

Linguistic Variables for The Importance Weight of Each Criterion	
Very Low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very High (VH)	(0.9, 1.0, 1.0)

The decision-makers use the linguistic rating variables (see Table I) to evaluate the rating of alternatives with respect to each criterion and vehicles in form of decision matrix (Refer to (7)). The weight for each criterion is also translated into fuzzy weight based on definition in Table II. These results are presented in Table III and Table IV.

The equations (8) and (9) are applied respectively to yield the fuzzy normalized decision matrix and fuzzy weighted normalise decision matrix. After considering the equations (10), (11), (12) and (13) the final results of the fuzzy TOPSIS method is presented in Table V. Due to the limited space, the detailed results are not shown in this paper.

It can be easily seen that the final motor vehicles ranking is A_1, A_2, A_4, $A_{3.}$ Motorcycle is ranked first, followed by car and lorry. Bus is ranked last. After taking into account the five criteria and the opinion from three experts, a single measurement for each vehicle is obtained and motorcycle recorded the highest closeness coefficient at 0.6225.

V. CONCLUSION

Amid multiple factors linked to road accidents, it is critical to use suitable methods for ranking vehicles prone to accidents involvement. This paper has given an account of the five criteria to rank the four types of vehicles involved in accidents based on fuzzy TOPSIS. This method can be dealt with qualitative assessment of multiple causes of accident and multiple motor vehicles. The linguistic data from authorised personnel shows that this approach can be easily applied to rank the vehicles involved in accidents. The four selected motor vehicles were ranked according to its closeness coefficients. The first rank went to motorcycles while the last rank went to buses. The evidence from this study suggests that the five factors need to be thoroughly investigated in order to reduce the accidents especially the most prone to accidents involvement vehicles i.e. motorcycles. A decision based on linguistic judgment is successfully made after taking into account the multiple factors.

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REFERENCES

[1] NHTSA. (2008, April 08). [Online]. Available: http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.
[2] Bernama. (2006, April 10). [Online]. Available: http://www.bernama.com.my/bernama/v3/news.php?id=213066.
[3] Royal Malaysia Police., (2008, April 08) [online] . Available: http://www.rmp.gov.my/rmp .
[4] T. Brijs,., D., Karlis,., F. Bossche, , G. Wets, "A Bayesian model for ranking hazardous road sites," Journal of the Royal Statistical Society: Series A (Statistics in Society), vol.170, no.4, pp. 1001–1017, 2007.
[5] P. J. Schlüter, J. J.Deely, and A. J. Nicholson, "Ranking and selecting motor vehicle accident sites by using a hierarchical Bayesian model," Journal of the Royal Statistical Society: Series D (The Statistician), vol. 46, no. 3, pp. 293–316. 1997.
[6] M. A. .Nzegwu, and C. O.Nzegwu, ,. "Review of causes of road traffic accidents in Benin City, Nigeria: A 1-year study, " Emergency Medicine Australasia August 2003- July 2004. Vol.19. no.1, pp 77-78. 2007.
[7] Department for Transport. (March 08). [Online]. Available: http://www.dft.gov.uk/stellent/groups/dft_transstats/documents/page/dfttransstats_032188.pdf.
[8] H.J. .Zimmermann ,. Fuzzy sets theory and its applications. Boston: Kluwer Academic Publishers. 1996.

[9] C.T. Chen,. "Extension of the TOPSIS for group decision making under fuzzy environment," Fuzzy Sets and Systems, Vol. 114, no. 1, pp. 1-9, 2000.
[10] T.C., Chu, "Selecting plant location via a fuzzy TOPSIS approach,"
[11] International Journal of Advance Manufacturing Technology, 20, 859-864. 2002.
[12] F. Herrera,. & Herrera –Viedma, E. "Linguistic decision analysis
[13] steps for solving decision problems under linguistic information," Fuzzy
[14] sets and Systems, Vol.115, no. 1, pp. 67-82. 2000.
[15] L.A Zadeh.. "Fuzzy Sets," Information and Control, 8, 338-353. 1965.
[16] A. Kauffman, and M Gupta,. . Introduction to Fuzzy Arithmetic: Theory and application., NY: Van Nostrand-Reinhold. 1985.
[17] C.C Chou, " The canonical representation of multiplication operation on triangular fuzzy numbers," Computers and mathematics applications, Vol. 45, no. 10-11, pp. 1601-1610. 2003.
[18] D.L Olson, "Comparison of weights in TOPSIS model," Mathematical and Computer Modeling, Vol. 40, no. 7, pp. 721-727. 2004.