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**ORIGINAL ARTICLE**

# Ranking Causes of Road Accident Occurrence Using Extended Interval Type-2 Fuzzy TOPSIS

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## Abstract

Over the past century there has been a dramatic increase in the number of road accidents in Malaysia. Hence, it is necessary to create a decision making method which can consider various preferences and criteria in order to identify the main causes of the accidents. This paper proposes an Interval Type-2 Fuzzy Technique for Order Preference by Similarity to Ideal Solution (IT2FTOPSIS) method which provides a comprehensive valuation from experts. This method is developed based on the aggregation of experts' opinions on preferred causes of road accidents. The extended IT2FTOPSIS employs a linguistic scales of positive and negative Interval Type-2 Trapezoidal Fuzzy Number (IT2TrFN) and hybrid averaging approach (from an ambiguity and type-reduction methods) to formulate a collective decision environment. Three authorised personnel from three Malaysian Government agencies were interviewed where they were asked to rank the causes. The analysis shows that the linguistic scales of positive and negative Interval Type-2 Trapezoidal Fuzzy Number (IT2TrFN) and hybrid averaging approach are effective in measuring the uncertainties in the interviewees' responses. Thus this paper concludes that the extended IT2FTOPSIS is more aligned with the users' decisions compared to the earlier IT2FTOPSIS.

**Keywords:** Multiple criteria decision-making; interval type-2 fuzzy set; IT2FTOPSIS; road accidents

## Introduction

Road accidents have become one of the major problems leading to deaths in Malaysia for many years. The United Nations has ranked Malaysia as the 30th country with the highest number of fatal road accidents with an average of 4.5 deaths per 10,000 registered vehicles (Bernama, 2006). The report from Royal Malaysian Police (2008) reveals that accidents in Malaysia has increased at the average rate of 9.7% per annum over the last three decades. Thus, there is a need to find a method that can consider the subjective factors of road accidents based on the experts' preferences. Multi-Criteria Decision Making (MCDM) method is useful in settling the conflicts in the preferred causes of road accidents by synthesizing various factors.

MCDM is a study of method and procedure which concerns with how multiple conflicting criteria can be formally incorporated not only in the management planning process, but in other areas such as medical decision and intelligent systems (Triantaphyllou et al., 1998). Despite many MCDM techniques, such as the Analytic Hierarchy Process (AHP) (Saaty, 1980), we chose Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) proposed by Hwang and Yoon (1981) as the target for the analysis because of its stability and ease of use with cardinal information. The main advantage of TOPSIS is that it is easy to compute and can be easily understood as it directly gives a definite value to the experts to calculate their final results (Wang et al., 2009). Fuzzy TOPSIS (FTOPSIS) was introduced to handle uncertainty in linguistic judgment. Initial research on FTOPSIS was conducted by Chen (2000) who extends TOPSIS to type-1 fuzzy environments. This extended version uses type-1 fuzzy linguistic value, represented by Type-1 Fuzzy Number (T1FN) as a substitute for the directly given crisp value in grade assessment (Chen, 2013). T1 FTOPSIS problem is to find the most desirable alternative(s) from a set of *n* feasible alternatives according to the decision information by experts about criteria weights and values. However, the existing T1 FTOPSIS is still ineffective in defining the uncertainties (Chen and Lee, 2010; Wang et al., 2012; Hu et al., 2013; Chen and Wang, 2013).

Interval Type-2 Fuzzy TOPSIS (IT2FTOPSIS) has been introduced by Chen and Lee (2010) to overcome the uncertainty problems. IT2FTOPSIS is believed to give a room for more flexibility in IT2FTOPSIS since it uses Interval Type-2 Fuzzy Sets (IT2FSs) rather than Type-1 Fuzzy Sets (T1FSs) to represent the uncertainties. The use of IT2FTOPSIS helps in providing successful results for managing many decision making problems, but there is a need for a new wave of decision system which considers the conflicting problems in experts' decisions. The current IT2FTOPSIS techniques do not effectively deal with the variety of ideas and opinions among the experts and this results in high uncertainty levels.

Hesitation and conflicting decisions, views, and opinions in experts' assessments occur when experts appraise their preferences among the criteria and alternatives (Naim and Hagras, 2013). Conflicts in decision making lead to worries, arguments, confrontations, litigation and separation (Forman, 2007). The hesitancies, conflicts and misperception exist internally and externally. The internal conflicts, such as self-esteem and confidence level affect the experts' judgment during the assessment. The external circumstances, such as political situation, global circumstances prevailing during the time, and the environmental conditions also affect experts' opinions. In a decision making system, these uncertainties cannot be controlled in order for the experts to provide fair, neutral and unbiased decisions. Hesitations and conflicting thoughts and ideas regarding a particular decision making process can also be fruitful and productive (Lopez, 2003). This is because hesitancy and conflicting views and ideas, provoke controversy which generates new insights that can lead to an expansion of knowledge about the role conflict plays in groups and organizations (Mannix, 2003).

This paper aims to solve the problems of high uncertainty encountered in the decision making process in determining the causes of road accidents. The extended IT2FTOPSIS proposed by Zamri et al. (2015) handles the linguistic uncertainties caused by linguistic scales of positive and negative Interval Type-2 Trapezoidal Fuzzy Number (IT2TrFN) and simultaneously computes the aggregation by hybrid averaging approach. The method is able to model the conflicts in decision-making process exhibited in the experts' opinions from the extended fuzzy membership functions. Consequently, these linguistic scales react to the subjective judgments from the experts where the lowest scale and the highest scale are equally strong. While considering the linguistic scales of positive and negative IT2TrFN, the extended IT2FTOPSIS also considers a hybrid averaging approach to include this linguistic scale to formulate a collective decision environment. The positive data is the subset of all correctly classified examples and the remaining data is the negative data. The negative data in this study does not mean that the data is wrong or corrupt. The ambiguity concept by Ban et al. (2011) and the type-reduction method proposed by Wu and Mendel (2002) are used as the hybrid averaging approach. Until now, there is no proper discussion on type-reduction in

MCDM. Previous studies mainly used the type-reduction in IT2 fuzzy logic system (e.g. Wu and Tan, 2005; Nie and Tan, 2008; Wu, 2012; Khosravi et al., 2013; and Lu and Chen, 2013). We chose the type-reduction method proposed by Wu and Mendel (2002) for defuzzification process because it is fast, less time consuming and has low computational volume (Mendel, 2007). It can also skip the T1FS process which means that this method can defuzzify the Interval Type-2 Fuzzy Numbers (IT2FNs) to crisp numbers (John and Coupland, 2012). By applying this method, we offer a brand new generation method of linear orders for the conflicting linguistic scale.

## Background Knowledge

This section briefly reviews some definitions of Type-2 Fuzzy Sets (T2FSs) from Mendel et al. (2006). A T2FS $\tilde{\tilde{A}}$ in the universe of discourse $X$ can be represented by a type-2 membership function $\mu_{\tilde{\tilde{A}}}$, shown as follows;

$$\tilde{\tilde{A}} = \left\{ \left( (x,u), \mu_{\tilde{\tilde{A}}}(x,u) \right) \middle| \ \forall x \in X, \forall u \in J_x \subseteq [0,1], 0 \leq \mu_{\tilde{\tilde{A}}}(x,u) \leq 1 \right\}, \tag{1}$$

where $J_x$ denotes an interval in $[0,1]$. Moreover, the T2FS $\tilde{\tilde{A}}$ also can be represented as follows;

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{\tilde{A}}}(x,u) / (x,u), \tag{2}$$

where $J_x \subseteq [0,1]$ and $\iint$ denotes the union over all admissible $x$ and $u$.

Let $\tilde{\tilde{A}}$ be a T2FS in the universe of discourse $X$ represented by the type-2 membership function $\mu_{\tilde{\tilde{A}}}$. If all $\mu_{\tilde{\tilde{A}}} = 1$, then $A$ is called an IT2FSs. An IT2FS $\tilde{\tilde{A}}$ can be regarded as a special case of a T2FS, represented as follows;

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} 1/(x,u), \tag{3}$$

where $J_x \subseteq [0,1]$.

The extension of IT2FTOPSIS is discussed in detail in the next section.

## The Extended IT2FTOPSIS

The extended IT2FTOPSIS by Zamri et al. (2015) consists of new linguistic scales (positive and negative IT2TrFN and hybrid averaging approach method. Experts provide their relation preference scale of each criterion and alternative in the positive and negative IT2TrFN linguistic scale. Below is the overview of the extended IT2FTOPSIS procedures:

Assume that there is a set $X$ of alternatives, where $X = \{x_1, x_2, \ldots, x_n\}$, a set $F$ criteria, where $F = \{f_1, f_2, \ldots, f_m\}$ and assume that there are $k$ experts of $D_1, D_2, \ldots,$ and $D_k$.

The proposed method is presented in nine steps.

***Step 1: Constructing a Hierarchical Diagram of MCDM Problem.***

This method considers both positive and negative sides in defining conflicting linguistic scale. We utilized seven scales of linguistic variable where the Very Low is defined as the lowest negative scale. The Very High is defined as the highest positive scale. This is shown in Fig. 1 and the linguistic terms are described in Tables 1 and 2.

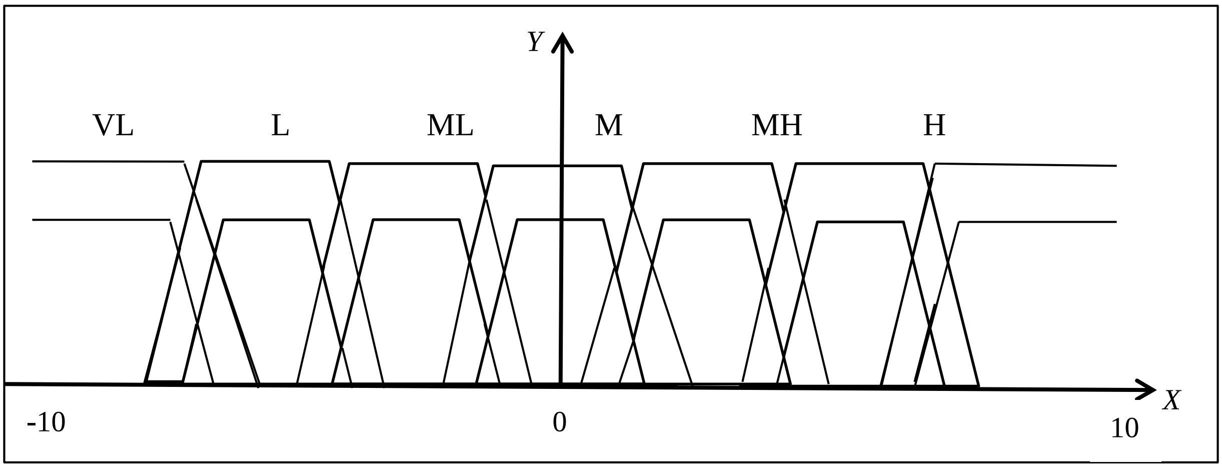


**Figure 1.** The linguistic scale of positive and negative IT2TrFN

**Table 1.** Linguistic scales of weight and their corresponding positive and negative IT2TrFN

| Linguistic Terms | Positive and Negative IT2TrFN |
|---|---|
| Very Low (VL) | ((-1.0, -0.9, -0.8, -0.7; 0.8, 0.8), (-1.0, -1.0, -0.8, -0.6; 1, 1)) |
| Low (L) | ((-0.8, -0.7, -0.5, -0.4; 0.8, 0.8), (-0.9, -0.7, -0.5, -0.3; 1, 1)) |
| Medium Low (ML) | ((-0.5, -0.4, -0.2, -0.1; 0.8, 0.8), (-0.6, -0.4, -0.2, 0; 1, 1)) |
| Medium (M) | ((-0.2, -0.1, 0.1, 0.2; 0.8, 0.8), (-0.3, -0.2, 0.2, 0.3; 1, 1)) |
| Medium High (MH) | ((0.1, 0.2, 0.4, 0.5; 0.8, 0.8), (0, 0.2, 0.4, 0.6; 1, 1)) |
| High (H) | ((0.4, 0.5, 0.7, 0.8; 0.8, 0.8), (0.3, 0.5, 0.7, 0.9; 1, 1)) |
| Very High (VH) | ((0.7, 0.8, 1.0, 1.0; 0.8, 0.8), (0.6, 0.8, 1.0, 1.0; 1, 1)) |

**Table 2.** Linguistic scales for the rating and their corresponding of positive and negative IT2TrFNs

| Linguistic Terms | Positive and Negative IT2TrFNs |
|---|---|
| Very Poor (VP) | ((-10, -9, -8, -7; 0.8, 0.8), (-10, -10, -8, -6; 1, 1)) |
| Poor (P) | ((-8, -7, -5, -4; 0.8, 0.8), (-9, -7, -5, -3; 1, 1)) |
| Medium Poor (MP) | ((-5, -4, -2, -1; 0.8, 0.8), (-6, -4, -2, 0; 1, 1)) |
| Medium (M) | ((-2, -1, 1, 2; 0.8, 0.8), (-3, -2, 2, 3; 1, 1)) |
| Medium Good (MG) | ((1, 2, 4, 5; 0.8, 0.8), (0, 2, 4, 6; 1, 1)) |
| Good (G) | ((4, 5, 7, 8; 0.8, 0.8), (3, 5, 7, 9; 1, 1)) |
| Very Good (VG) | ((7, 8, 10, 10; 0.8, 0.8), (6, 8, 10, 10; 1, 1)) |

Based on the information in Tables 1 and 2, the design matrix $Y_p$ of the *p*th experts and the average decision matrix are constructed as shown below.

$$Y_p = \left(\tilde{\tilde{f}}_{ij}^{\,p}\right)_{m\times n} = \begin{matrix} \\ f_1 \\ f_2 \\ \vdots \\ f_m \end{matrix} \begin{matrix} x_1 & x_2 & \cdots & x_n \\ \left[\begin{matrix} \tilde{\tilde{f}}_{11}^{\,p} & \tilde{\tilde{f}}_{12}^{\,p} & \cdots & \tilde{\tilde{f}}_{1n}^{\,p} \\ \tilde{\tilde{f}}_{21}^{\,p} & \tilde{\tilde{f}}_{22}^{\,p} & \cdots & \tilde{\tilde{f}}_{2n}^{\,p} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{\tilde{f}}_{m1}^{\,p} & \tilde{\tilde{f}}_{m2}^{\,p} & \cdots & \tilde{\tilde{f}}_{mn}^{\,p} \end{matrix}\right] \end{matrix} \tag{4}$$

$$Y = \left(\tilde{\tilde{f}}_{ij}\right)_{m\times n}, \tag{5}$$

where $\tilde{\tilde{f}}_{ij} = \left(\dfrac{\tilde{\tilde{f}}_{ij}^{\,1} \oplus \tilde{\tilde{f}}_{ij}^{\,2} \oplus \ldots \oplus \tilde{\tilde{f}}_{ij}^{\,k}}{k}\right)$ , $\tilde{\tilde{f}}_{ij}$ is an positive and negative IT2TrFN (Table 2), $1 \le i \le m, 1 \le j \le n, 1 \le p \le k,$ and $k$ denotes the number of experts.

***Step 2: Defining the Values of Weight***

The construction of weighting matrix $W_p$ of the expert criteria and the construction of the *p*th average weighting matrix $\overline{W}$ are shown in (6) and (7) respectively.

$$\overline{W_p} = \left(\tilde{\tilde{w}}_i^{\,p}\right)_{1\times m} = \begin{matrix} f_1 & f_2 & \cdots & f_n \\ \left[\begin{matrix} \tilde{\tilde{w}}_1^{\,p} & \tilde{\tilde{w}}_2^{\,p} & \cdots & \tilde{\tilde{w}}_m^{\,p} \end{matrix}\right] \end{matrix} \tag{6}$$

$$\overline{W} = \left(\tilde{\tilde{w}}\right)_{1\times m} \tag{7}$$

where $\tilde{\tilde{w}}_i^{\,p} = \dfrac{\tilde{\tilde{w}}_i^1 \oplus \tilde{\tilde{w}}_i^2 \oplus \ldots \oplus \tilde{\tilde{w}}_i^k}{k}$, $\tilde{\tilde{w}}_i^{\,p}$ is a positive and negative IT2TrFN (Table 1), $1 \le i \le m$, $1 \le p \le k$ and denotes the number of experts.

***Step 3: Constructing the Weighted Decision Matrices***

The weighted decision matrix $\overline{Y}_w$, is shown below;

$$\overline{Y}_w = \left(\tilde{\tilde{v}}_{ij}\right)_{m\times n} = \begin{matrix} \\ f_1 \\ f_2 \\ \vdots \\ f_m \end{matrix} \begin{matrix} x_1 & x_2 & \cdots & x_n \\ \left[\begin{matrix} \tilde{\tilde{v}}_{11} & \tilde{\tilde{v}}_{12} & \cdots & \tilde{\tilde{v}}_{1n} \\ \tilde{\tilde{v}}_{21} & \tilde{\tilde{v}}_{22} & \cdots & \tilde{\tilde{v}}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{\tilde{v}}_{m1} & \tilde{\tilde{v}}_{m2} & \cdots & \tilde{\tilde{v}}_{mn} \end{matrix}\right] \end{matrix}, \tag{8}$$

where $\tilde{\tilde{v}}_{ij} = \tilde{\tilde{w}}_i \otimes \tilde{\tilde{f}}_{ij}$, $1 \le i \le m,$ and $1 \le j \le n$.

***Step 4: Constructing the Hybrid Averaging Approach Using the Linear Order Method***

The linear order hybrid averaging operation is employed to determine the collective evaluation value of weighted decision matrix $\tilde{\tilde{v}}_{ij}^{hybrid}$ and the collective importance weight $\tilde{\tilde{w}}_{j}^{hybrid}$;

$$y(x)=\frac{1}{2}\left[\left(\left(\frac{-6l+6u-x-y}{12}\right)^{L}\Big/2\right)\left(\frac{H_1\left(\tilde{A}_1^{L}\right)}{H_2\left(\tilde{A}_1^{L}\right)}\right)+\left(\left(\frac{-6l+6u-x-y}{12}\right)^{U}\Big/2\right)\left(\frac{H_1\left(\tilde{A}_1^{U}\right)}{H_2\left(\tilde{A}_1^{U}\right)}\right)\right] \tag{9}$$

where $\left(\frac{-6l+6u-x-y}{12}\right)^{L}$ represented as $\left(\underline{y_l}(x)+\overline{y_l}(x)\right)$ and $\left(\frac{-6l+6u-x-y}{12}\right)^{U}$ represented as $\left(\underline{y_r}(x)+\overline{y_r}(x)\right)$.

***Step 5: Determining the Positive Ideal Solutions (PIS) and Negative Ideal Solutions (NIS)***

The determination of the PIS and NIS are shown in (10) and (11) respectively.

$$f^{+}=\{\tilde{\tilde{Z}}_1^{+},\ldots,\tilde{\tilde{Z}}_n^{+}\}=\{(\max_j \tilde{\tilde{Z}}_{ij}\,|\, i\in I^{'}),(\min_j \tilde{\tilde{Z}}_{ij}\,|\, i\in I^{''})\}, \tag{10}$$

$$f^{-}=\{\tilde{\tilde{Z}}_1^{-},\ldots,\tilde{\tilde{Z}}_n^{-}\}=\{(\min_j \tilde{\tilde{Z}}_{ij}\,|\, i\in I^{'}),\ (\max_j \tilde{\tilde{Z}}_{ij}\,|\, i\in I^{''})\}, \tag{11}$$

where $I^{'}$ is associated with the positive attribute, and $I^{''}$ is associated with the negative attribute.

***Step 6: Calculating the Distance of PIS and NIS.***

The separation measures are calculated using the *n*-dimensional Euclidean distance. The separation of each alternative from the PIS is given as;

$$D_j^{+}=\sqrt{\sum_{i=1}^{n}(\tilde{\tilde{Z}}_{ij}-\tilde{\tilde{Z}}_i^{+})^2},\ j=1,\ldots,J. \tag{12}$$

Similarly, the separation from the NIS is given as;

$$D_j^{-}=\sqrt{\sum_{i=1}^{n}(\tilde{\tilde{Z}}_{ij}-\tilde{\tilde{Z}}_i^{-})^2},\ j=1,\ldots,J. \tag{13}$$

***Step 7: Calculating the Relative Closeness***

The relative closeness is calculated to the ideal solution. The relative closeness of the alternative $x_i$ with respect to *f** is defined as;

$$C_j^{+}=\frac{D_j^{+}+D_j^{-}}{2},\ j=1,\ldots,J. \tag{14}$$

***Step 8: Normalizing the Relative Closeness***

The relative closeness is normalized using the equation below;

$$N_j = \frac{C_j^+}{\sum_{j=1}^{n} C_j^+}, j = 1,...,n. \tag{15}$$

***Step 9: Sorting the Values***

The preference order is ranked in this step. A large value of closeness coefficient $N_j$ indicates a good performance of the alternative $\tilde{\tilde{f}}_i$. The best alternative is the one with the greatest relative closeness to the ideal solution.

Considering both the negative and positive sides, and the hybrid averaging approach, it is anticipated that the extended IT2FTOPSIS method makes a more comprehensive view in solving the road accident problems.

**An Application of Road Accidents**

In recent years, there has been a rapid increase in the number of road accidents. Statistic from Royal Malaysian Police (2008) shows that the number of deaths for motorcycles involved in road accidents is 3,197 in year 2007 compared to 3,034 in year 2002. The number of deaths for cars involved in road accidents is 697 in year 2007 compared to 558 in year 2002. The total number of deaths caused by accidents involving lorry is 130 in year 2007 compared to 128 in year 2002.

The seven basic schemes of alternatives for road accident structures commonly used are Driver's Age ($A_1$), Speeding Behaviour ($A_2$), Driver's Gender ($A_3$), Reckless Driving ($A_4$), Driver's Health ($A_5$), Road Condition ($A_6$), Road Environment ($A_7$), Road Environment ($A_8$), Road Environment ($A_9$), and Road Environment ($A_{10}$). The criteria are selected based on the alternatives. The four criteria considered in this study are Motorcycle ($C_1$), Car ($C_2$), Bus ($C_3$) and Lorry ($C_4$).

The face-to-face interviews conducted in this study are based on the questionnaires designed according to the extended IT2FTOPSIS requirement to obtain the equilibrium closeness coefficients for various criteria, and different causes leading to road accidents from three different experts. Data in the form of linguistics variables were collected through interviews with four authorised personnel (stated as $D_1$, $D_2$, and $D_3$) from Malaysian Government agencies. The interviews were conducted in three separated sessions to elicit the information about the highest cause that regularly leads to road accidents. Detailed discussions on alternatives and criteria are presented in the next Subsection.

***Selecting the Best Alternative for Road Accident Causes***

Ten subjective alternatives have been highlighted based on the literature. Driver's age ($A_1$) is one of the main causes that need to be taken into account. Sarkis (2004) describes that individuals of various ages face road accidents but the main victims are those in the age group of 20 to 29 years old. Hassan and Mohamed (2002) and Sabariah (2007) point out that driver's age is also one of the main causes that contributes to the increasing number of road accidents.

Speeding Behaviour ($A_2$) is perceived as socially acceptable, with many think that their peers approve their behaviour and that there is little chance of either being apprehended by the police or causing a collision (Holland and Conner, 1996). Speeding is perceived as normal and there is a widespread belief that it is acceptable to break speed limits, particularly on motorways (Lex Service, 1997). Indeed, there is evidence that many drivers regard speeding as one of the least serious traffic offences (Rothengatter, 1991).

Sarkis (2004) puts forth that the number of male victims involved in road crashes is higher than the female victims. Hassan and Mohamed (2002), Hejar et al. (2005) and Sabariah (2007) also considered gender as one of the main causes that lead to road accidents. Young drivers are likely to perform risky manoeuvres or neglect the precautions (Arnett et al., 1997; Jonah, 1986), hold strong beliefs about their own immunity while driving, and make dangerous errors in recognizing driving-related risks (Elkind, 1978; Finn and Bragg, 1986). Though reckless behaviour might cause injury or death, experimenting with risk-taking behaviour has been seen as a method of developing optimal social and psychological competence, autonomy, independence, and self-regulation (Baumrind, 1987; Shedler and Block, 1990), as well as an essential imperative for the experience of optimal growth and health (Deci and Ryan, 1985).

Driver's health ($A_5$) is also one of the main causes that need to be considered. Hejar et al. (2005) point out that road traffic accidents and injuries are public health problems worldwide. In 2002, 1.2 million people died as a result of road traffic accidents and 50 million were injured and disabled. It is the eleventh cause of death in the world and accounts for 2.1% of all deaths globally (World Health Organization, 2004). Road traffic accidents are estimated to cause between 5% and 15% of facial injuries in developed countries. Comparison may be made with developing nations with a more chaotic system of road use where road traffic accident (RTA) predominate the cause of facial injury leading to greater than 50% of injuries (Martin et al., 2007).

Based on Sarkis (2004), road condition ($A_6$) can be divided into three parts:

a. Road type – Road accidents can happen in different types of road. It can happen in one-way road, divided and undivided two-ways. Road accidents can also occur in wet, muddy, dry, loose sands, and gravel roads. Because this study was carried out in Malaysia, snow roads and icy roads are not taken into account.
b. Location of Accidents – There are two types of locations: rural road and urban road.
c. Road Light Condition – There are five conditions of road light condition: day, dusk, dark light condition, dark unit and dawn condition.

Road environment ($A_7$) refers to the weather at time of accidents. Lots of accidents happen in clear weather. The rest of them happen in rainy weather, foggy and sleet freezing rain.

Based on Sarkis (2004), vehicle condition ($A_8$) can be divided into two parts:

a. Vehicle Type – There are several types of vehicle, such as motorcycle, truck and car.
b. Problems in Vehicle – Few defects or problems are reported for vehicles involved in road accidents. Some reported defective brakes, others reported tire blow outs, and steering problems.

Generally, drivers' experience ($A_9$) refers to whether the drivers are qualified drivers or unqualified drivers. Hejar et al. (2005) put forth that unqualified drivers are commonly involved in road accidents. Another main cause that lead to road accidents is driver's psychology ($A_{10}$). Driver's psychology relates to the psychology factors, such as seeking thrills and being over-confident. All the alternatives and their description are summarized in Table 3.

**Table 3.** Alternatives and their description

| Alternatives | Description |
|---|---|
| **Driver's Age ($A_1$)**<br>(Sarkis, 2004; Hassan and Mohamed, 2002; Sabariah, 2007) | All types of ages involved in road accidents. |
| **Speeding Behaviour ($A_2$)**<br>(Blincoe et al., 2006) | Socially acceptable, with many think that their peers approve their behaviour and that there is little chance of either being apprehended by the police or causing a collision (Holland and Conner, 1996). |
| **Driver's Gender ($A_3$)**<br>(Hejar et al., 2005; Hassan and Mohamed, 2002; Sabariah, 2007) | Male or female involved in road accidents. |
| **Reckless Driving ($A_4$)**<br>(Orit et al., 2000) | A threat appeal may lead people who are high in sensation seeking to perceive driving as a source of thrill and consequently engage in risky driving. |
| **Driver's Health ($A_5$)**<br>(Hejar et al., 2005; Hassan and Mohamed, 2002; Sabariah, 2007) | Driver's health including drivers suffering from stroke and heart attack. |
| **Road Condition ($A_6$)**<br>(Sarkis, 2004) | Road type – One-way road, divided and undivided two-ways. Also, wet, muddy, dry, loose sands and gravel roads.<br>Location of accidents – rural and urban road.<br>Road light condition – day, dusk, dark light condition, dark unit and dawn condition. |
| **Road Environment ($A_7$)**<br>(Sarkis, 2004) | Rainy weather, foggy and sleet freezing rain. |
| **Vehicle Condition ($A_8$)**<br>(Sarkis, 2004) | Vehicle type – motorcycle, bus, lorry and car.<br>Problems in vehicles – breaks, tire blow outs, steering problems and so on. |
| **Driver's Experience ($A_9$)**<br>(Hejar et al., 2005) | Unqualified and qualified drivers. |
| **Driver's Psychology ($A_{10}$)**<br>(Hejar et al., 2005; Hassan and Mohamed, 2002; Sabariah, 2007) | Psychology factors such as seeking thrills and being over-confident. |

**Table 4.** Personal profile of experts

| No. | Gender | Position | Sector | Experience | Education |
|---|---|---|---|---|---|
| 1 | Male | Vice Director (Operation) | Fire and Safety Department | 5 – 9 years | Bachelor |
| 2 | Male | Sergeant of Administration | Police Department | 15 years and above | SPM |
| 3 | Male | Officer of Road Transport | Road Transport Department | 5 – 9 years | Diploma |

### *Selecting the Best Criteria*

To formulate the model, the criteria were selected based on the alternatives. These main criteria were selected based on the statistics from Royal Malaysian Police (2008). There are four vehicles that are usually involved in road accidents:

1. Motorcycle ($C_1$)
2. Car ($C_2$)
3. Bus ($C_3$)
4. Lorry ($C_4$)

The decision to choose the four vehicles above was based on the highest number of vehicles involved in road accidents. Based on the Royal Malaysian Police's statistics (2008), the most frequent vehicle involved in road accidents is motorcycle where by 3,197 motorcyclist died in 2007. This is followed by car with 697 car drivers died in 2007, 130 death involving lorry drivers in 2007 and bus with 8 bus drivers died in 2007.

### *Data Gathering*

Data in the form of linguistics variables were collected by interviewing three authorised personnel from three Malaysian Government agencies. The interviews were conducted in three separate sessions to elicit the information about causes of accident. The three experts were:

1. Vice Director of Fire Brigade Department of Kuala Terengganu ($D_1$)
2. Sergeant of Administration from Police Traffic Department of Kuala Terengganu ($D_2$)
3. Officer of Road Transport from Road Transport Department of Kuala Terengganu ($D_3$).

Table 4 shows the personal profile of the three experts. The three authorised personnel were chosen based on their experience of handling road accidents for many years.

All the relative important criteria are described using positive and negative IT2TrFNs linguistic scales which are defined in Table 2. The experts used the linguistic rating scales (see Table 2) to evaluate the rating of alternatives with respect to each criterion in form of decision matrix (Eq. 4). The whole process is shown in eleven steps as follows;

### *Step 1: Constructing the Hierarchy Structure for Evaluating the Highest Cause of Road Accidents.*

The hierarchical structure of evaluating the highest cause of road accidents is given in Fig. 2, where all the criteria and alternatives are drawn horizontally. The hierarchical structure of this experiment can be seen in Fig. 2.

Below is an example of $\tilde{\tilde{A}}_{11}$ calculation to find the IT2 fuzzy judgement matrix criteria.

$\tilde{\tilde{A}}_{11}$ = G = ((4, 5, 7, 8; 0.8, 0.8), (3, 5, 7, 9; 1, 1))
F = ((-2, -1, 1, 2; 0.8, 0.8), (-3, -2, 2, 3; 1, 1))
MP = ((-5, -4, -2, -1; 0.8, 0.8), (-6, -4, -2, 0; 1, 1))

Then, the average for G, F, MP is
((-0.1, 0, 0.2, 0.3; 0.8, 0.8), (-0.7, -0.533, -0.267, -0.1; 1, 1))

The remaining can be stated as shown in Table 5.

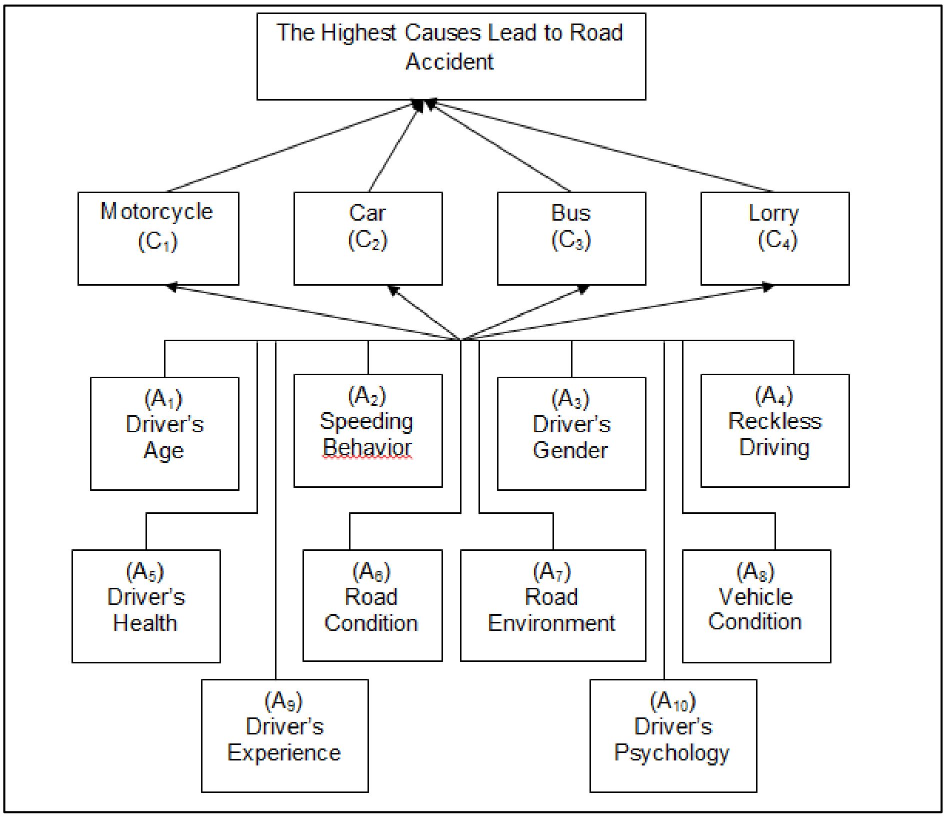


**Figure 2**. Hierarchical structure of the decision problem

***Step 2: Defining the Values of Weight***

The average weights for each criterion $C = \left[ \tilde{\tilde{C}}_{11} \quad \tilde{\tilde{C}}_{12} \quad \tilde{\tilde{C}}_{13} \quad \tilde{\tilde{C}}_{14} \right]$ can be obtained using Eq. 6.

The example of average weight of $\tilde{\tilde{C}}_{11}$ calculation is shown below.

$C_{11}$= VL = ((-1, -0.9, -0.8, -0.7; 0.8, 0.8), (-1, -1, -0.8, -0.6; 1, 1))
L = ((-0.8, -0.7, -0.5, -0.4; 0.8, 0.8), (-0.9, -0.7, -0.5, -0.3; 1, 1))
L = ((-0.8, -0.7, -0.5, -0.4; 0.8, 0.8), (-0.9, -0.7, -0.5, -0.3; 1, 1))

The average for VL, L, L, is
((-0.867, -0.767, -0.6, -0.5; 0.8, 0.8), (-0.9333, -0.8, -0.6, -0.4; 1, 1))

Thus, we can state that the weight $\tilde{\tilde{w}}_1$ of the criteria $\tilde{\tilde{C}}_{11}$ is ((-0.867, -0.767, -0.6, -0.5; 0.8, 0.8), (-0.9333, -0.8, -0.6, -0.4; 1, 1)).
Using the same calculation as $\tilde{\tilde{C}}_{11}$, the weight values for other criteria can be defined as;

$\tilde{\tilde{w}}_2$ = ((-0.4, -0.3, -0.1; 0.8, 0.8), (-0.5, -0.333, -0.067, -0.0333; 1, 1))
$\tilde{\tilde{w}}_3$ = ((-0.1, 0, 0.2, 0.3; 0.8, 0.8), (-0.2, -0.067, 0.2667, 0.4; 1, 1))
$\tilde{\tilde{w}}_4$ = ((0.3, 0.4, 0.6, 0.7; 0.8, 0.8), (0.2, 0.4, 0.6, 0.8; 1, 1))

**Table 5.** IT2 fuzzy judgment matrix

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
|---|---|---|---|---|
| $A_1$ | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,-0.033,0.2333,0.4;1,1)) | ((-0.6,-0.5,-0.3,-0.2;0.8,0.8), (-0.7,-0.533,-0.267,-0.1;1,1)) | ((-0.5,0.4,0.2,-0.1;0.8,0.8), (-0.6,-0.4,-0.2,0;1,1)) | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,-0.033,0.2333,0.4;1,1)) |
| $A_2$ | ((0.5,0.6,0.8,0.8667;0.8,0.8), (0.4,0.6,0.8,0.9333;1,1)) | ((0.5,0.6,0.8,0.8667;0.8,0.8), (0.4,0.6,0.8,0.9333;1,1)) | ((0.5,0.6,0.8,0.8667;0.8,0.8), (0.4,0.6,0.8,0.9333;1,1)) | ((0.5,0.6,0.8,0.8667;0.8,0.8), (0.4,0.6,0.8,0.9333;1,1)) |
| $A_3$ | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,0,0.2,0.4;1,1)) | ((-0.5,-0.4,-0.2,-0.1;0.8,0.8), (-0.6,-0.433,-0.167,0;1,1)) | ((-0.3,-0.2,0,0.1;0.8,0.8), (-0.4,-0.233,0.0333,0.2;1,1)) | ((-0.367,-0.267,-0.1,0.0333;0.8,0.8), (-0.433,-0.333,-0.067,0.1;1,1)) |
| $A_4$ | ((0.1,0.2,0.4,0.4667;0.8,0.8), (0,0.2,0.4,0.5333;1,1)) | ((0.6,0.7,0.9,0.9333;0.8,0.8), (0.5,0.7,0.9,0.9667;1,1)) | ((0.6,0.7,0.9,0.9333;0.8,0.8), (0.5,0.7,0.9,0.9667;1,1)) | ((0.6,0.7,0.9,0.9333;0.8,0.8), (0.5,0.7,0.9,0.9667;1,1)) |
| $A_5$ | ((-0.2,-0.1,0.1,0.2;0.8,0.8), (-0.3,-0.133,0.1333,0.3;1,1)) | ((0,0.1,0.3,0.4;0.8,0.8), (-0.1,0.1,0.3,0.5;1,1)) | ((0.2,0.3,0.5,0.5667;0.8,0.8), (0.1,0.3,0.5,0.6333;1,1)) | ((-0.1.,0,0.2,0.2667;0.8,0.8), (-0.2,0,0.2,0.3333;1,1)) |
| $A_6$ | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,0,0.2,0.4;1,1)) | ((0,0.1,0.3,0.4;0.8,0.8), (-0.1,0.1,0.3,0.5;1,1)) | ((0.2,0.3,0.5,0.5667;0.8,0.8), (0.1,0.3,0.5,0.6333;1,1)) | ((0.1,0.2,0.4,0.5;0.8,0.8), (0,0.1667,0.4333,0.6;1,1)) |
| $A_7$ | ((0.3,0.4,0.6,0.6667;0.8,0.8), (0.2,0.4,0.6,0.7333;1,1)) | ((0.2,0.3,0.5,0.5667;0.8,0.8), (0.1,0.3,0.5,0.6333;1,1)) | ((0,0.1,0.3,0.4;0.8,0.8), (-0.1,0.3,0.5,0.6333;1,1)) | ((0.6,0.7,0.9,0.9333;0.8,0.8), (0.5,0.7,0.9,0.9667;1,1)) |
| $A_8$ | ((-0.367,-0.267,-0.1,0;0.8,0.8), (-0.433,-0.3,-0.1,0.1;1,1)) | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,-0.033,-0.2333,0.4;1,1)) | ((0.2,0.3,0.5,0.5667;0.8,0.8), (0.1,0.3,0.5,0.6333;1,1)) | ((0.2,0.3,0.5,0.6;0.8,0.8), (0.1,0.2667,0.5333,0.7;1,1)) |
| $A_9$ | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,-0.033,0.2333,0.4;1,1)) | ((-0.4,-0.3,-0.1,0;0.8,0.8), (-0.5,-0.033,-0.067,0.1;1,1)) | ((-0.2,-0.1,0.1,0.2;0.8,0.8), (-0.3,-0.133,0.1333,0.3;1,1)) | ((-0.1,0,0.2,0.3;0.8,0.8), (-0.2,0,0.2,0.4;1,1)) |
| $A_{10}$ | ((-0.167,-0.067,0.1,0.2;0.8,0.8), (-0.233,-0.1,0.1,0.675;1,1)) | ((-0.2,-0.1,0.1,0.2;0.8,0.8), (-0.3,-0.133,0.1333,0.3;1,1)) | ((0,0.1,0.3,0.3667;0.8,0.8), (-0.1,0.1,0.3,0.4333;1,1)) | ((-0.1,0,0.2,0.2667;0.8,0.8), (-0.2,-0.033,0.2333,0.3333;1,1)) |

**Table 6.** Weighted of Decision Matrix

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
|---|---|---|---|---|
| $A_1$ | ((0.0867,0.0767,-0.12,-0.15;0.8,0.8), (0.1867,-0.0267,-0.14,-0.16;1,1)) | ((0.24,0.15,0.03,0;0.8,0.8), (0.35,0.1778,0.0178,-0.003;1,1)) | ((0.05,0,-0.04,-0.03;0.8,0.8), (0.12,0.0267,-0.053,0;1,1)) | ((-0.03,0,0.12,0.21;0.8,0.8), (-0.04,-0.013,0.14,0.32;1,1)) |
| $A_2$ | ((-0.433,-0.46,-0.48,-0.433;0.8,0.8), (-0.373,-0.48,-0.48,-0.373;1,1)) | ((-0.2,-0.18,-0.08,0;0.8,0.8), (-0.2,-0.2,-0.053,0.0311;1,1)) | ((-0.05,0,0.16,0.26;0.8,0.8), (-0.08,-.04,0.2133,0.3733;1,1)) | ((0.15,0.24,0.48,0.6067;0.8,0.8), (0.08,0.24,0.48,0.7467;1,1)) |
| $A_3$ | ((0.0867,0,-0.12,-0.15;0.8,0.8), (0.1867,0,-0.12,-0.16;1,1)) | ((0.2,0.12,0.02,0;0.8,0.8), (0.3,0.1444,0.0111,0;1,1)) | ((0.03,0,0,0.03;0.8,0.8), (0.08,0.0156,0.0089,0.08;1,1)) | ((-0.11,-0.107,-0.06,0.0233;0.8,0.8), (-0.087,-0.133,-0.04,0.08;1,1)) |
| $A_4$ | ((-0.087,-0.153,-0.24,0.2333;0.8,0.8), (0,-0.16,-0.24,-0.213;1,1)) | ((-0.24,-0.21,-0.09,0;0.8,0.8), (-0.25,-0.233,-0.06,0.0322;1,1)) | ((-0.06,0,0.18,0.28;0.8,0.8), (-0.1,-0.047,0.24,0.3867;1,1)) | ((0.18.,0.28,0.54,0.6533;0.8,0.8), (0.1,0.28,0.54,0.7733;1,1)) |
| $A_5$ | ((0.1733,0.0767,-0.06,-0.1;0.8,0.8), (0.28,0.1067,-0.08,-0.12;1,1)) | ((0,-0.03,-0.03,0;0.8,0.8), (0.05,-0.033,-0.02,0.0167;1,1)) | ((-0.02,0,0.1,0.17;0.8,0.8), (-0.02,-.02,0.1333,0.2533;1,1)) | ((-0.03.,0,0.12,0.1867;0.8,0.8), (-0.04,0,0.12,0.2667;1,1)) |
| $A_6$ | ((0.0867,0,-0.12,-0.15;0.8,0.8), (0.1867,0,-0.12,-0.16;1,1)) | ((0,-0.03,-0.03,0;0.8,0.8), (0.05,-0.033,-0.02,0.0167;1,1)) | ((-0.02,0,0.1,0.17;0.8,0.8), (-0.02,-.02,0.1333,0.2533;1,1)) | ((0.03,0.08,0.24,0.35;0.8,0.8), (0,0.0667,0.26,0.48;1,1)) |
| $A_7$ | ((-0.26,-0.307,-0.36,-0.333;0.8,0.8), (-0.187,-0.32,-0.36,-0.293;1,1)) | ((-0.08,-0.09,-0.05,0;0.8,0.8), (-0.05,-0.1,-0.033,0.211;1,1)) | ((0,0,0.06,0.12;0.8,0.8), (0.02,-0.007,0.08,0.2;1,1)) | ((0.18,0.28,0.54,0.6533;0.8,0.8), (0.1,0.28,0.54,0.7733;1,1)) |
| $A_8$ | ((0.3178,0.2044,0.06,0;0.8,0.8), (0.4044,0.24,0.06,-0.04;1,1)) | ((0.04,0,-0.02,0;0.8,0.8), (0.1,0.0111,-0.016,0.0133;1,1)) | ((-0.02,0,0.1,0.17;0.8,0.8), (-0.02,-.02,0.1333,0.2533;1,1)) | ((0.06,0.12,0.3,0.42;0.8,0.8), (0.02,0.1067,0.32,0.56;1,1)) |
| $A_9$ | ((0.0867,0,-0.12,-0.15;0.8,0.8), (0.1867,0.0267,-0.14,-0.16;1,1)) | ((0.16,0.09,0.01,0;0.8,0.8), (0.25,0.0111,-0.016,0.0133;1,1)) | ((0.02,0,0.02,0.06;0.8,0.8), (0.06,0.0089,0.0356,0.12;1,1)) | ((-0.03,0,0.12,0.21;0.8,0.8), (-0.04,0,0.12,0.32;1,1)) |
| $A_{10}$ | ((0.1444,0.0511,-0.06,-0.1;0.8,0.8), (0.2178,0.08,-0.06,-0.12;1,1)) | ((0.08,0.03,-0.01,0;0.8,0.8), (0.15,0.0444,-0.009,0.01;1,1)) | ((0,0,0.06,0.11;0.8,0.8), (0.02,-0.007,0.08,0.1733;1,1)) | ((-0.03,0,0.12,0.1867;0.8,0.8), (-0.04,-0.013,0.14,0.2667;1,1)) |

***Step 3: Constructing the Weighted Decision Matrix***

The weighted decision matrix with respect to aggregated matrix comparison of each criterion and alternative can be obtained using (8).

Then, we get the value of weighted decision matrix for $\tilde{\tilde{v}}_{11}$ is:

$$\tilde{\tilde{v}}_{11} = \tilde{\tilde{w}}_1 \otimes \tilde{\tilde{f}}_{11}$$

$$\tilde{\tilde{v}}_{11} = \left(\left(-0.1,-0.1,0.2,0.3;0.8,0.8\right),\left(-0.2,-0.033,0.2333,0.4;1,1\right)\right)\otimes$$
$$\left(\left(-0.867,-0.767,0.6,-0.5;0.8,0.8\right),\left(-0.933,-0.8,-0.6,-0.4;1,1\right)\right)=$$
$$\left(\left(0.0867,0.0767,-0.12,-0.15;0.8,0.8\right),\left(0.1867,0.0267,-0.14,-0.16;1,1\right)\right)$$

The remaining values of weighted decision matrix is shown in Table 6.

***Step 4: Hybridizing the Linear Orders***

The linear orders of matrices of positive and negative IT2TrFN are calculated using (9). The full results for each linear order for each value of weighted decision matrix is shown in Table 7.

**Table 7.** Linear order of weighted decision matrix

| | **$C_1$** | **$C_2$** | **$C_3$** | **$C_4$** |
|---|---|---|---|---|
| **$A_1$** | -0.031 | -0.031 | -0.012 | 0.0306 |
| **$A_2$** | -0.001 | 0.0247 | 0.0424 | 0.0556 |
| **$A_3$** | -0.028 | -0.026 | -0.0004 | 0.0155 |
| **$A_4$** | -0.017 | 0.0256 | 0.0373 | 0.053 |
| **$A_5$** | -0.029 | -0.9E-19 | 0.0208 | 0.0244 |
| **$A_6$** | -0.028 | -0.0002 | 0.0259 | 0.0402 |
| **$A_7$** | -0.01 | 0.0097 | 0.0158 | 0.0583 |
| **$A_8$** | -0.038 | -0.006 | 0.0259 | 0.045 |
| **$A_9$** | -0.031 | -0.021 | 0.0052 | 0.0288 |
| **$A_{10}$** | -0.029 | -0.011 | 0.0148 | 0.0285 |

***Step 5: Determining the PIS and NIS***

The PIS $f^*$ and the NIS $f^-$ are determined using the two concepts as follows;

$$f^* = (1, 1, 1)$$
$$f^- = (0, 0, 0)$$

***Step 6: Calculating the Distance of PIS and NIS***

The separation measures are calculated using the *n*-dimensional Euclidean distance. The distance for PIS and NIS for $A_1$ ($C_1$) can be stated as;

$$D^*_{A_1} = \sqrt{(1-(0.031))^2 + (1-(-0.031))^2 + (1-(-0.012))^2 + (1-(0.0306))^2} = 2.022$$
$$D^-_{A_1} = \sqrt{(0-(-0.031))^2 + (0-(0.031))^2 + (0-(0.012))^2 + (0-(0.0306))^2} = 0.0545$$

The whole results for the distance for PIS and NIS are shown in Table 8.

**Table 8.** The distance

| | **D*** | **D-** |
|---|---|---|
| **A1** | 2.022 | 0.0545 |
| **A2** | 1.9397 | 0.0741 |
| **A3** | 2.0198 | 0.0413 |
| **A4** | 1.9513 | 0.0717 |
| **A5** | 1.9925 | 0.0433 |
| **A6** | 1.9819 | 0.0556 |
| **A7** | 1.9636 | 0.062 |
| **A8** | 1.9873 | 0.0644 |
| **A9** | 2.0094 | 0.0473 |
| **A10** | 1.9987 | 0.0446 |

***Step 7: Calculating the Relative Closeness***

The relative closeness is calculated with respect to the ideal solution. The relative closeness of the alternative $x_i$ with respect to *f** for $A_1$ is defined as;

$$C^*_j = \frac{0.0545}{2.022 + 0.0545} = 0.0262$$

The whole results for the relative closeness coefficients are shown in Table 9.

**Table 9.** The relative closeness coefficients

| | **Closeness Coefficient,** $C^*_j$ |
|---|---|
| **A1** | 0.0262 |
| **A2** | 0.0368 |
| **A3** | 0.0201 |
| **A4** | 0.0355 |
| **A5** | 0.0213 |
| **A6** | 0.0273 |
| **A7** | 0.0306 |
| **A8** | 0.0314 |
| **A9** | 0.023 |
| **A10** | 0.0218 |

**Step 8: Normalizing the Relative Closeness**

The normalization of the relative closeness for $A_1$ is as follows;

$$N_{A_1} = \frac{0.0262}{(0.0262)+(0.0368)+(0.0201)+(0.0355)+(0.0213)+(0.0273)+(0.0306)+(0.0314)+(0.023)+(0.0218)}.$$

The results for the relative closeness coefficients are shown in Table 10.

**Table 10.** Normalized relative closeness coefficients

| | **Normalized Relative Closeness Coefficient** |
|---|---|
| **$A_1$** | 0.095816 |
| **$A_2$** | 0.134364 |
| **$A_3$** | 0.0732 |
| **$A_4$** | 0.129472 |
| **$A_5$** | 0.077673 |
| **$A_6$** | 0.099562 |
| **$A_7$** | 0.111698 |
| **$A_8$** | 0.114529 |
| **$A_9$** | 0.084013 |
| **$A_{10}$** | 0.079674 |

In conclusion, the best alternative selection is $A_2$ and the ranking order of the alternative of selecting the highest cause of road accidents is given by $A_2 \succ A_4 \succ A_8 \succ A_7 \succ A_6 \succ A_1 \succ A_9 \succ A_{10} \succ A_5 \succ A_3$. Speeding Behaviour is ranked first, followed by Reckless Driving, Road Environment, Road Condition, Drivers' Age, and Drivers' Health. Drivers' Gender is ranked last. Speeding Behaviour records the highest closeness coefficient at 0.1344.

Since the extended model introduces a new equilibrium standardized approach in the evaluation process, it is important to compare it with the existing approach. The IT2FTOPSIS method (Chen and Lee, 2010) was used for the comparison. The results of the comparative analysis for the causes of road accidents selections are shown in Table 11.

**Table 11.** Comparative analysis for causes of road accidents selections using the proposed method and IT2FTOPSIS method

| **Methods** | **Ranking order according to closeness coefficient** |
|---|---|
| Ranking causes of road accidents selections using the extension method | $A_2 \succ A_4 \succ A_5 \succ A_7 \succ A_6 \succ A_3 \succ A_1$ |
| Ranking causes of road accidents selections using the IT2FTOPSIS | $A_1 \succ A_5 \succ A_4 \succ A_6 \succ A_2 \succ A_3 \succ A_7$ |

Based on the results shown in Table 11, it can be concluded that the extended IT2FTOPSIS method gives different ranking for different output values. The slightly different outcomes occur, perhaps due to the effect of the linguistic scales.

## Analysis and Comparisons

Prior to the experiments, questionnaires were distributed randomly to the experts to identify their opinions and judgments of the road accident causes. The experts involved in the trials were representatives from three Malaysian Government Agencies. Their opinions were constructed in the proposed decision system as a rule-base in a preference relations decision matrix as explained in the previous section. The ranking to determine output values for different input values have been defined from three sets of input values.

In order to visualize the agreement, we used Spearman Correlation values to investigate the diagnosis agreement and correlation between real output data of causes leading to road accident selections with IT2FTOPSIS and extended IT2FTOPSIS. The Spearman Correlation was used to find the correlation between the users' decisions and the output decisions. Table 12 shows the ranking from the three experts.

**Table 12.** Ranking of alternatives from the three experts

| **Alternatives** $A_n$ $(n = 1,2,\ldots,5)$ | **Scale/Level** | | |
|---|---|---|---|
| | **$D_1$** | **$D_2$** | **$D_3$** |
| Dam/ Reservoir ($A_1$) | 7 | 5 | 7 |
| Dikes (levees/ embankment)/ Channel Improvement/ Diversion schemes ($A_2$) | 1 | 3 | 1 |
| Pumping Station ($A_3$) | 10 | 9 | 10 |
| Flood barrier/ Barrage/ Flood gate/ Flood wall ($A_4$) | 2 | 1 | 2 |
| River basins/ Watershed ($A_5$) | 9 | 10 | 8 |
| Retention pond ($A_6$) | 5 | 6 | 5 |
| Catchment areas ($A_7$) | 3 | 2 | 4 |
| Vehicle Condition ($A_8$) | 4 | 4 | 3 |
| Driver's Experience ($A_9$) | 6 | 7 | 6 |
| Driver's Psychology ($A_{10}$) | 8 | 8 | 9 |

The relationships between ranking of alternatives retrieved by experts and the proposed method are summarized in Table 13.

**Table 13.** Correlation values between the linguistic decisions with output ranking from experts

| **Spearman Correlation** | **$D_1$** | **$D_2$** | **$D_3$** |
|---|---|---|---|
| Extended IT2FTOPSIS | **0.976** | **0.915** | **0.976** |
| IT2FTOPSIS | 0.067 | -0.067 | 0.224 |

Bold value indicates the highest correlation value

As shown in Table 13, the extended IT2FTOPSIS method gives 0.976 correlations to the linguistic appraisal of the first expert's decision, 0.915 correlations to the linguistic appraisal of the second expert's decision, 0.976 correlations to the linguistic appraisal of the third expert's decision. The method proposed by Chen and Lee (2010) gives 0.067 ($D_1$), -0.067 ($D_2$), and 0.224 ($D_3$) correlation values.

For all the correlation values, the extension method which employs positive and negative IT2TrFN's linguistic scales, and hybrid averaging approach gives higher Spearman Correlation value than when using IT2FTOPSIS. The higher the correlation value, the closer the user's decision to the output from the proposed system. This shows that our proposed system using the hybrid IT2 fuzzy theories provides a better correlation by having a much closer group decision to the human experts when compared to the other fuzzy theories.

The idea to define positive and negative IT2TrFN scales from the extension IT2FTOPSIS permits the system to capture more uncertainties in the evaluations and provide the highest correlation value. The results clearly show that the more the theory can evaluate the uncertainties, vagueness and conflict, the higher correlation value can be determined between the real output data. This also shows that the combination of positive and negative IT2TrFN linguistic scales and hybrid averaging approach method is useful in the production of enhanced extension IT2FTOPSIS systems. The proposed system in this paper is capable of managing problems in decision making process to identify the causes of road accident.

## Conclusion

Selecting the causes of road accidents requires consideration of the experts' preferences. However, there are high levels of conflicts faced in the selection process. There is a need to employ decision making systems which can consider the various experts' preferences. In this paper, we used the extended IT2FTOPSIS method which provides a comprehensive valuation from a group of experts based on the aggregation of experts' opinions and preferences. The theories of positive and negative IT2TrFNs' linguistic scale and hybrid averaging approach method are effective in dealing with imprecision and vagueness in road accident decision problems. We carried out experiments involving three Malaysia Government agencies to evaluate seven different causes of road accidents based on four main criteria. We found that Speeding Behaviour is ranked first, followed by Reckless Driving, Road Environment, Road Condition, Drivers' Age, and Drivers' Health. Drivers' Gender is ranked last. The extended IT2FTOPSIS better agrees with the experts' decision compared to existing IT2FTOPSIS which gives lower correlation values. The extended IT2FTOPSIS which is based on positive and negative IT2TrFNs linguistic scale and hybrid averaging approach have a better ranking compared to the decision system based on IT2FTOPSIS. In our future work, we aim to apply general type-2 membership functions in order to reach higher levels of uncertainties in road accident decision making system. The general type-2 fuzzy application aggregates the various experts' opinions into a unique approval which represent the uncertainty distribution (in the third dimension) associated with the experts. The utilization of general type-2 is expected to increase the agreement values between the IT2FTOPSIS system and experts' decision. The higher the agreement values, the more the control decision system can mimic a group of human's decision in selecting the causes of road accidents.

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