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Analyzing Specialized Views of Transportation Under Mean Safety By Using Fuzzy Inference Sysytem

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ABSTRACT
Transportation is an essential part in social, industrial and economical process that encounters to the increasing of level of vechile which leads to increasing demand and deterioration of transportation infrastructure as well as others. The transportation expert may be asked to support a decision, determine a preference, rank influencing factors, or assess alternatives through various methods including surveys, interviews, panel meetings, and expert analyses. In many of these cases, before the experts render their opinion they formulate it through the use of linguistic information and their own subjective decision criteria. An efficient method to analyze subjective and linguistic information employed by people, whether expert or layman is to apply a fuzzy set concept. The primary strength of a fuzzy approach is that it is applicable for the analysis of human knowledge and subjective human perception, which are represented by linguistic terms rather than numerical terms, and the deductive process. The fuzzy inference system, which mimics the human perception and decision making processes, is a deductive process of mapping given inputs to certain outputs based on fuzzy membership functions and fuzzy rules. It has been widely applied in various analysis of subjective and ambiguous information.
KEY WORDS: Fuzzy Inference System, Fuzzy Membership Functions, Fuzzy Geometric Index, Fuzzy Mean Safety Index

I. FUZZY INFERENCE SYSTEM

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: membership functions, fuzzy logic operators, and if-then rules. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic.

Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems. Fuzzy inference systems have been applied in various areas. However, many studies reported limitations of the conventional fuzzy inference system when dealing with multiple variables .The number of rules in a conventional fuzzy system increases exponentially with the number of variables involved.

II. HIERARCHICAL FUZZY SYSTEM

Generally , three or four variables are the maximum number that can be considered as part of a conventional fuzzy inference system. One of the ways to solve this “rule-explosion problem” is to use a fuzzy inference system with a hierarchical structure called a hierarchical fuzzy system. This is because transportation user perception regarding transportation service or safety is usually affected by many factors, such as roadway geometry, traffic flows, driver characteristics, and other driving conditions. It may not be able to be determined by only a few factors. Also, each driving condition has many sub elements. For example, geometric conditions consist of many measures of cross section elements, horizontal and vertical alignment, and roadside environments. To select variables to be used for the fuzzy inference system, the five highest ranked variables and the variables for which data were available in the mean safety database were considered. Since the crash data were used for corroborating the results of the proposed fuzzy inference system, the availability of each variable in the database was also a critical issue in this variable selection procedure. Additionally, current design manuals were reviewed to select relevant variables for the fuzzy inference system. For the current mean barrier warrant in the Arkansas State Highway and Transportation Department (AHTD) Guide, average daily traffic and mean width are employed. These two variables have been known as the most critical factors in assessing mean safety. From these reviews, five variables to evaluate geometric conditions and one variable to evaluate traffic flow conditions were selected. The five geometric variables were mean width, horizontal curvature, operating speed, mean cross-slope, and shoulder width. average daily traffic was used to describe the traffic flow condition.

III. FUZZY MEMBERSHIP FUNCTIONS

A triangular membership function is specified by three parameters {a, b, c}, and the precise appearance of the function is determined by the choice of parameters

Scale	a	b	c	d
Strongly disagree	**-**	**0**	**0.100**	**0.200**
disagree	**0.100**	**0.200**	**0.325**	**0.475**
Neither agree nor Dis-agree	**0.325**	**0.475**	**0.525**	**0.675**
Agree	**0.525**	**0.675**	**0.750**	**0.950**
Strongly agree	**0.750**	**0.950**	**1**	**-**

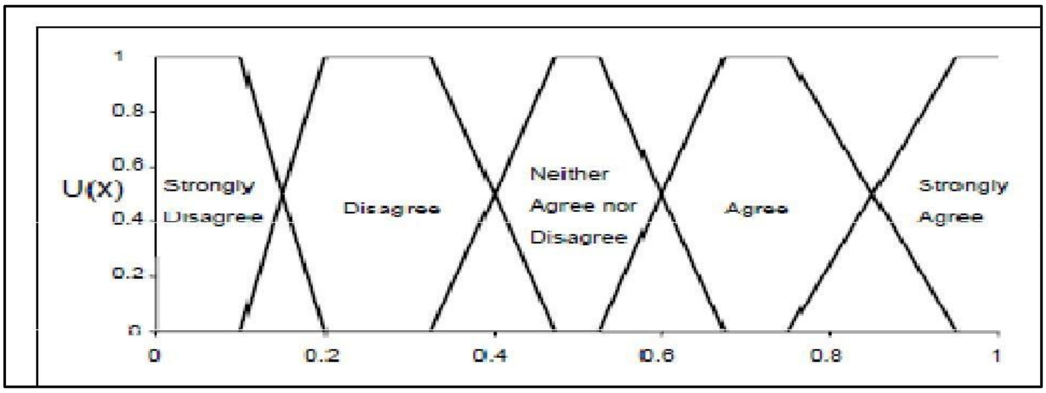

Figure 1.Fuzzy Membership Function of Five Scales Linguistic Statement.

Generally, the methods of formulating fuzzy membership functions can be classified into three approaches: constructing the membership functions through the analyst's judgment, constructing the membership functions through experiments, or constructing the membership functions from a given numerical data set. Selecting a method to determine the membership functions depends on many conditions including the characteristics of the study and the available data set associated with the study.

In this study, the method based on analyst's judgment was used to determine the fuzzy membership functions. It is the most common means used to construct fuzzy membership functions because of its simplicity and wide applicability. In this method, an analyst employs their own knowledge and information gleaned from relevant literature to compose the membership functions. In the proposed study, fuzzy membership functions for the selected variables were constructed through four resources: the authors' own knowledge; a review of the experts' opinion; a review of the literature and the state of the practice related to transportation safety, typically mean safety; and a basic review of the roadways for which crash data were collected. A review of relevant literature and associated practice is usually the most significant resource for determining reasonable and appropriate fuzzy membership functions in the analyst intuition method. Since there are few studies that have investigated the relationship between controlling factors and the general safety effects of the selected variables were also reviewed. Through a review of the experts' opinion regarding the influence of the various factors on mean safety, the relative importance of each factor was investigated. This relative importance was used to determine the weight of each variable. A basic review of the roadways within the crash database was conducted without any statistical analysis. The variable type (e.g., binary, continuous), the number of classes for each variable, and the range of values were mainly considered in this review. Using these resources, two types of fuzzy membership functions were determined. The first fuzzy membership functions represented how significantly each factor influences mean safety. The second fuzzy membership functions represented the relative importance of each geometric factor.

IV. FUZZY MEMBERSHIP FUNCTION FOR CONTROLLING MEAN SAFETY

The fuzzy membership function for the six factors influencing mean safety was accomplished through the review of references and common engineering judgment. They were then slightly modified to reflect expressways because the review results represented general or universal information regarding driving environments and not specifically the driving environments of Arkansas. The first variable, average daily traffic (ADT) represents the traffic condition. Average daily traffic is known as a significant factor influencing mean safety, and it is used as one of two criteria of the mean barrier warrant. The mean barrier warrant in the AHTD Guide uses two categories to determine the barrier installation guideline. For average daily traffics less than 15000, barrier is optional, but for average daily traffics greater than 15000, barrier is warranted, depending on the mean width. In the expert survey, four categories: 10000 to 25000, 25000 to 50000, 50000 to 80000, and greater than 80000, were considered to investigate the safety effects of the traffic flow condition.

The second variable is mean width which represents a geometric condition. Mean width is one of the most significant factors used to evaluate mean safety in conjunction with average daily traffic. To determine the fuzzy membership function for mean width, AHTD's Guide, and other references were reviewed. In AHTD's Guide, mean barrier warrant is based on three categories of mean width. Barrier is warranted for means less than 25ft, and barrier is not considered for means greater than 50ft. Barrier is optional for means between 25ft and 50ft. However, the creation of the fuzzy membership function for horizontal curvature and mean cross slope was restricted to reflect the review results. The previous studies emphasized that various features of horizontal curvature can affect roadway safety as mentioned above. Given their findings, the fuzzy membership functions representing the effect of horizontal curvature on mean safety should be determined by taking into consideration various features of a horizontal curve. Three condition levels, poor, fair, and good, have commonly been used for evaluating the effect of horizontal curves on safety in previous studies. However, the mean crash data used for comparison with the safety index, which is based on the proposed fuzzy inference system, included only the presence of horizontal curvature as binary information, such as 0 for no curve and 1 for a curved alignment. Due to this limitation of the database, the fuzzy membership functions for horizontal curvature were determined with just two levels in this study even though it is not as desirable as the multi-condition level described above. The mean cross slope data in the crash database was also binary data with 0 indicating flatter than 6:1 and 1 indicating steeper than 6:1. This limitation of the mean crash database necessitated the creation of two levels of fuzzy membership functions, such as poor and acceptable or steeper and flatter for mean cross slopes steeper than 6:1 or flatter than 6:1, respectively.

V. HIERARCHICAL FUZZY INFERENCE SYSTEM

The hierarchical fuzzy inference system were compared with observed crash data for the purpose of validation. For this application, the Arkansas mean safety database was used per the previous discussion. This database included various elements, such as crash type, severity, and roadway inventory data. Out of those data, the number of crashes and the inventory data of the six variables used in the fuzzy inference system described above were applied. However, since the safety database did not include an operating speed but posted speed, posted speed was used as a surrogate input variable in place of operating speed. Through the developed hierarchical fuzzy inference system and a defuzzification procedure, Fuzzy Mean Safety Index for each roadway segment were produced and compared with the observed mean crash data of the same roadway segments. First, the relationship between average daily traffic and Fuzzy Geometric Index of the given roadway segments was examined. Through this procedure, the fuzzy partition and rule mapping conducted for the upper level fuzzy inference system were verified. The data for the roadway segments reflect the results of the partition and rule-mapping relatively well. Most of the roadway segments FGI ranged from 0.2 to 0.8 and their average daily traffics vary widely. The minimum average daily traffic is 500 and maximum average daily traffic is 80000 vehicles per day. However, most of the roadway segments have less than 15000 average daily traffic. There were many other mean safety factors that were not used in this study due to the limited availability of data, such as weather, radius of horizontal curves, and factors regarding drivers. However, the hierarchical fuzzy inference system can produce an indicator, Fuzzy Mean Safety Index, which explains well the degree of mean safety on expressways. It is one of the advantages of the fuzzy approach to analyze with incomplete information. Therefore, it can be concluded that the hierarchical fuzzy inference system, in terms of Fuzzy Mean Safety Index values, reflect well the real mean crash problem, and the incorporated transportation expert opinions appear to be valid.

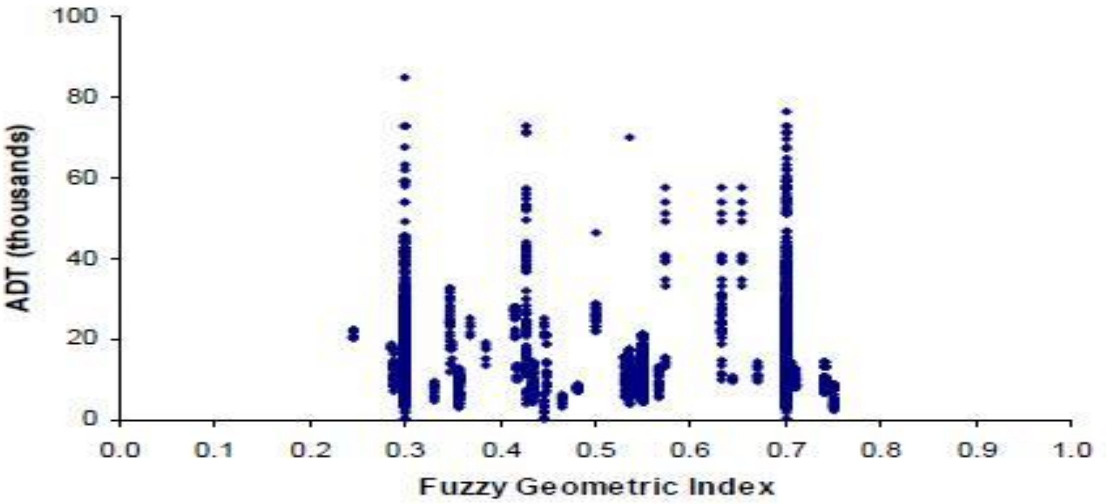

Figure 2. Fuzzy Geometric Index

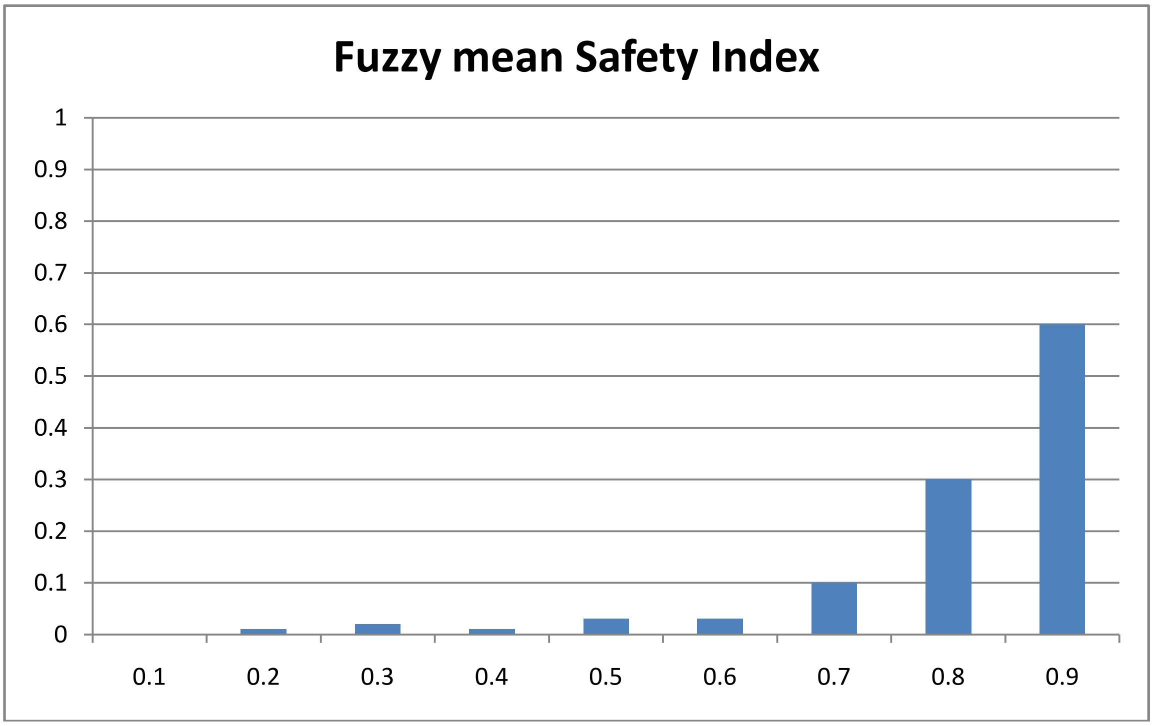

Figure 3 : Fuzzy Mean Safety Index

VI. CONCLUSION

Generally, transportation experts use linguistic information and their own subjective decision criteria to formulate and express their opinion. However, it is difficult to aggregate those linguistic and subjective experts' opinions using conventional methods. This method allows for the analysis and aggregation of the subjective and linguistic expert opinions taking into consideration the unique characteristics and decision criteria of an individual expert.

By this method, variables in the hierarchical fuzzy inference system were selected through the transportation expert survey results of a previous study. The fuzzy membership functions for the selected six variables were constructed using common engineering knowledge garnered from a review of the experts' opinions, a review of the references related to transportation safety, and the authors' own knowledge. The fuzzy weighted average method was used in the process of formulating the fuzzy inference system to avoid the difficulty of fuzzy rule mapping with a large number of variables. The incorporated experts' opinions regarding mean safety were finally expressed by hierarchical fuzzy inference system as an indicator of the degree of mean safety. Since the roadway type used in this study was the Interstate highway and expressway, most of roadway segments in the database have relatively favorable driving conditions. For this reason, most of the roadway segments were less than 0.5 fuzzy mean safety index. To avoid a biased interpretation of the results from the unbalanced data, the mean of crash frequency and the crash rate were used for the validation process. The mean of frequency increases exponentially with an increase of hierarchical fuzzy inference system. The developed hierarchical fuzzy inference system based on experts' opinions was evaluated as the system that can explain relatively well the degree of mean safety for Interstate highways and expressways.

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