APPLICATION OF THE FUZZY REASONING THEORY TO THE TRAFFIC CONFLICT TECHNIQUE AT INTERSECTIONS

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Abstract: Traffic engineers, safety specialists, and researchers concerned with traffic safety have shown a great deal of interest in the Traffic Conflict Technique (TCT). TCT is considered to be a reliable and inexpensive tool, as it can be used to diagnose safety and operational deficiencies and evaluate improvements in a timely and efficient manner.

Fuzzy reasoning theory, introduced in this paper, is based on the surveyor decisions as inputs in the form of linguistic variables that are derived from membership functions. The membership functions are formulas that are used to determine the fuzzy set to which a value belongs and the range of membership within the set. The variables are then matched with the preconditions of linguistic rules (fuzzy logic rules), and the response of each rule is obtained through fuzzy implication. To perform compositional rule of inference, the response of each rule is weighted according to the confidence of degree of membership of its inputs, and the centroid of the responses is calculated to generate the appropriate output.

As a result, the new methodology used in this paper is beneficial in that it will help to minimize the level of variation in the data collected by surveyors during traffic conflict studies.

Key Words : Accident Analysis, Traffic Conflict Technique, Fuzzy Reasoning Theory

1. INTRODUCTION

Traffic accident data are often not suitable for diagnosing safety problems at intersections or for evaluating the effectiveness of improvements. The Traffic Conflict Technique (TCT) was developed in the 1970s to supply and to solve this history data problem. Viewed simply, a traffic conflict is a traffic event involving the interaction of two vehicles where one or both drivers may have to take evasive action to avoid a collision. [1] S. R. Perkins & J. I. Harris used TCT effectively to evaluate the access control technique of road capacity in a commercial area and to evaluate the safety degree of dangerous sections. [5] In the United Kingdom, GM applied TCT to analyze the capacity of intersections. Its finding was that, in devising measures to improve safety at intersections, analysis of traffic conflict data was more appropriate than analysis of traffic accident data. Yoshitaka MOTODA et al. studied the application of TCT on roads. They concluded that concluded that not only could TCT be used for evaluating road safety in a short time, but that it offered advantages in terms of repeatability, reliability and practical application. [3]

In Korea, TCT has been receiving a great deal of attention recently in evaluating traffic safety at intersections. The most developed TCT in our country is a paper entitled "a study of safety evaluation by using traffic conflict technique at an intersection". [6] This research was based on the Swedish TCT. It make a prediction model that can apply to other intersections in Korea, and it calculates the conversion factor (π) as model parameter. However, in the existing developed TCT model the variation of data collected by surveyors were occurred. Thus, when using this TCT, the analyst must recognize and adjust for such variations when conducting her analysis.

In this light, the authors of this paper applied fuzzy reasoning theory to the TCT in response to this problem, then developed a prediction model to estimate accident occurrence using the developed approach. Also, through the application the developed TCT to the seven intersections in the field, the proposed model was identified its usefulness. To our knowledge, this approach has not been developed in our country. Moreover, the new constructed TCT is beneficial in that it will help to minimize the level of variation in the data collected by surveyors.

2. APPLICATION OF THE FUZZY REASONING THEORY TO THE TRAFFIC CONFLICT TECHNIQUE

2.1 Need of Fuzzy Reasoning Theory

In evaluating the safety of roads and intersections by the number of traffic accidents in traffic conflict technique field, the distance between cars and vehicle speed were the variables used. [6] Figure 1 is the individual knowledge area of surveyors themselves. The data was collected by highly trained surveyors. Even if surveyors witness the same event at same time, there was a variance in the obtained data [7], because the distance and the speed that were detected by surveyors individually.

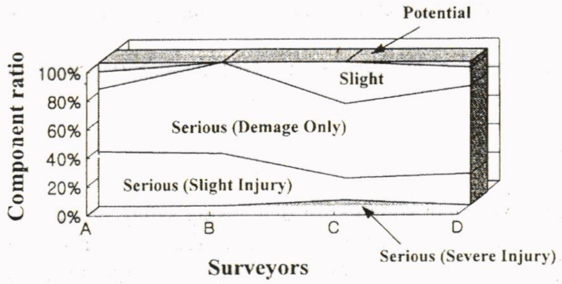

Figure 1 : Comparison of individual surveyors' knowledge of conflict severity

Also, with conflict situations, because environmental factors distributed around the road users may have an effect on the distance and the speed, they must be included in the analysis.

In this study, fuzzy reasoning theory is used to construct a reasonable prediction model that takes into account environmental factors, distance between cars, and travel speed. The study then systematically refines the collected data and makes the prediction model to estimate the number of accidents from the number of conflicts.

2.2 Construction of Fuzzy Reasoning Theory

(1) Variables
Humans have their own individual ways of perceiving objects. Each person thinks about a certain object unconsciously using her own knowledge base, and then makes a decision and takes action. This study applied the fuzzy reasoning theory to TCT in order to grasp the characteristics of the surveyors' direct information that the conflict severity is related the distance and the speed.[2] The distance between cars is affected by the position of the surveyors, the weather, the standpoint of the surveyors and the observation distance of the surveyors. The speed of running cars is influenced by traffic volume, the density, the traffic situation, the traffic conditions, the psychological state of drivers and the position of surveyors. The conflict severity is related to these two variables.

If surveyors have not enough information about an association object, uncertainty will be occurred. This uncertainty can be expressed by the fuzzy set and this concept can be used for modeling of the surveyors' knowledge.

(2) Decision-Making Process
Figure 2 diagrams the decision-making process. The most general type of fuzzy rule would be something like the "IF A_i, THEN B_i" rule. All the rule i of A_i has a joint area with the input $A*$, and the result of $B*$ is calculated by using the approximating reasoning structure.

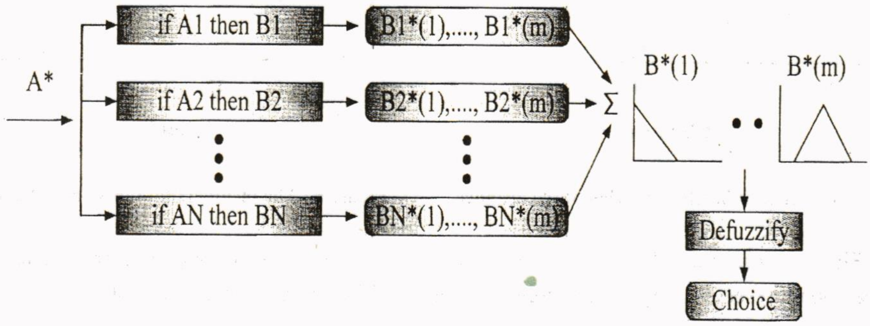

Figure 2: The decision-making process of fuzzy reasoning

Even if the current input is not exactly correct, the approximating reasoning structure helps the calculation process. The result is calculated into defuzzification by preparation of each B_i*.

Once these steps are completed, a final decision is made.

(3) Membership Function

In making the decision-making process model, general rules such as those in Figure 3 were established. When given the S items as a linguistic condition (ex. Short, Middle, Long) and the N items as a linguistic condition (ex. Slow, Average, Fast), the number of total reasoning rule are resulted in S^N.

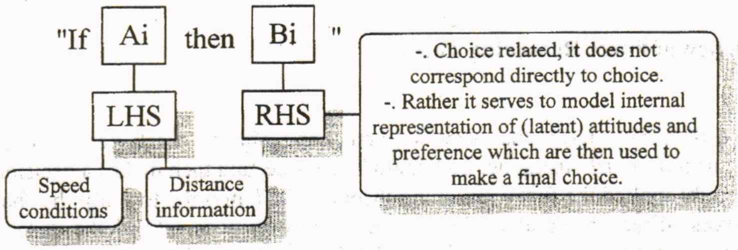

Figure 3 : The general rule of fuzzy reasoning system

Where, the Left Hand Side (LHS) of this rule is A_i, and the Right Hand Side (RHS) is B_i. In this paper, two LHS were used: one LHS was the distance between cars and was expressed as A_1 = {Short, Middle, Long}; the other LHS was the speed of running cars and was expressed as A_2 = {Slow, Average, Fast}. Figures 4 & 5 were expressions of each A_1 and A_2.

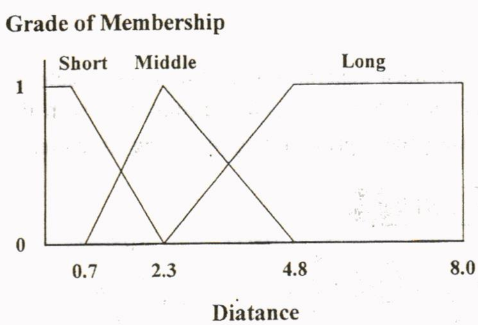

Figure 4 : The membership function of the distance

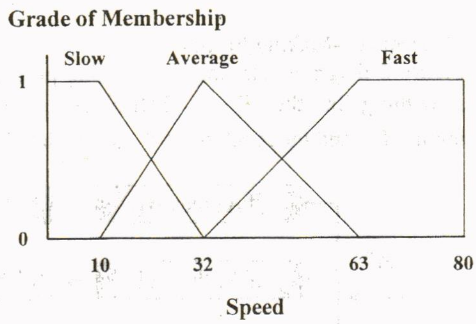

Figure 5 : The membership function of the speed

Also, Figure 6 was the RHS (B_i), composed of the five choice levels ranging from one to five. Choice one represents a very high degree of severity, while choice five, the lowest.

This paper defined the severity according to the conflict situation as indicated below. This severity was based on the several events that could occur among road users.

- Severity S1 : Very High Serious Conflict
- Severity S2 : High Serious Conflict

- Severity S3 : Serious Conflict
- Severity S4 : Slight Conflict
- Severity S5 : Potential Conflict

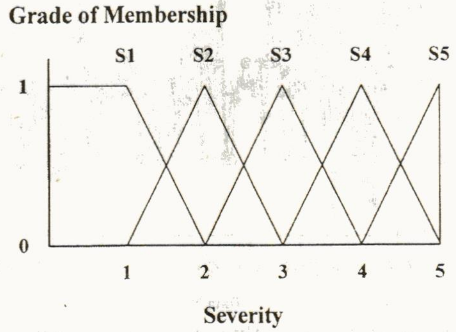

Figure 6 : The membership function of the severity degree

(4) Rules
This paper used very simple and general rules. For example, "If the distance is short and the speed is high, then the severity is very high serious conflict (S1)." Or, "If the distance is middle and the speed is average, then the severity is serious conflict (S3)." Table 1 is the rule matrix of the fuzzy reasoning process.

Table 1: The rule matrix of the fuzzy reasoning process

Distance \ Speed	Fast	Average	Slow
Short	S1	S2	S3
Middle	S2	S3	S4
Long	S3	S4	S5

(5) Defuzzification
The fuzziness item of linguistic values in the initial stage was defuzzified to a real value. The equation below, called the centroid method, was used in this paper for defuzzification.

$$Z_0 = \frac{\int y\mu_{B^*}(y)dy}{\int \mu_{B^*}(y)dy} \quad (1)$$

2.3 Distribution of the Fuzzy Reasoning Results

As a result of analyzing the prediction model with fuzzy reasoning, the dispersion of data was drawn on Figure 7. To calculate the result, this paper used the Min-Max method of Mamdani and the 50% overlap of the membership function and a mean value of conflict data.

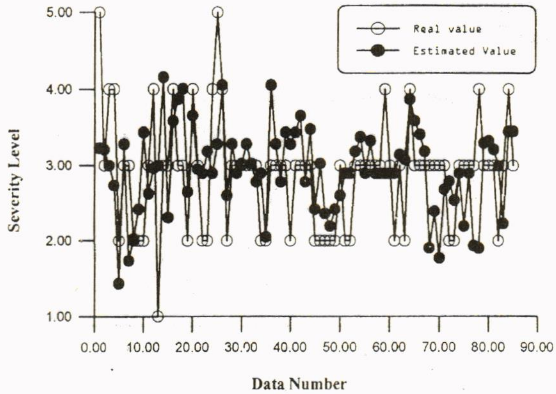

Figure 7 : Comparison of the real values and each output of the proposed model

3. CASE STUDY

3.1 Outline of Case Study

Figure 8 is the research site and the seven signal intersections with four legs examined in this paper. More than thirty traffic accidents occurred at each of these intersections each year. Each of these intersections has high potential for traffic accident occurrence. All of the intersections are similar in terms of geometric characteristics, number of lanes, signal time rates, traffic assignment type and maximum legal speeds.

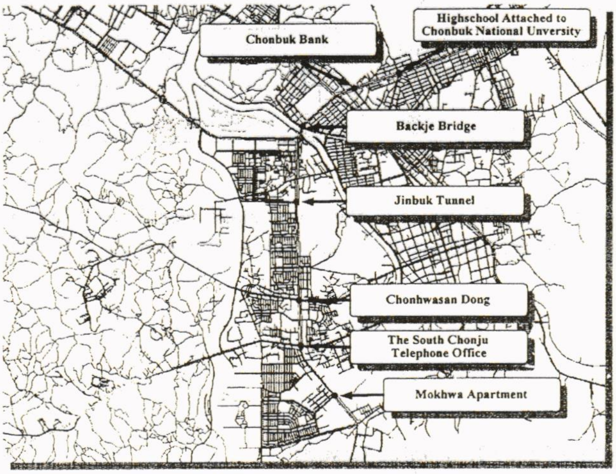

Figure 8 : The research site and intersections

3.2 TCT with Existing Method

Data for 238 traffic accidents and 85 conflicts were analyzed. According to the occurrence section of accidents and conflicts, in the case of inside of intersections 107 accidents data were analyzed. For other cases (inflow sections, outflow sections, etc.), 131 accidents data were analyzed. For cases occurring on the inside of intersections, the data from 12 conflicts were analyzed. For other cases, data from 73 conflicts were analyzed.

Also, according to the road user variables of accidents and conflicts, in the case of the vehicle-to-vehicle 210 accidents data were analyzed, and in the case of vehicle-to-pedestrian 28 accidents were analyzed. Moreover, in the case of vehicle-to-vehicle, 78 conflicts data were analyzed and in the case of vehicle-to-pedestrian 7 conflicts data were analyzed.

Even if so many conflict data are obtained, only several data relate to high serious degree, which are possible to relate the traffic accidents. So, to set a critical range this paper used the Time to Accidents (TA_{min}) as minimum value to avoid the traffic accidents. However, if only the TA_{min} value is used in establishing the critical value when finding serious conflicts among the collected conflict data, the range of this critical value is too wide. Thus, in order to solve this problem, the researchers propose utilizing the 1.5sec perception reaction time that was discovered by Johannson and Rumar [4] in order to make the model for predicting the number of accidents on two kinds road surface (dry, wet), as shown below in Figures 9 & 10.

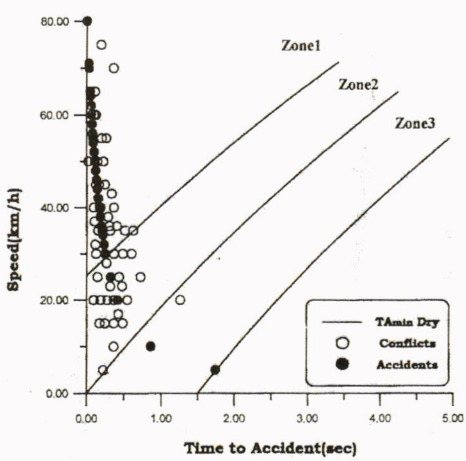

Figure 9 : The existing prediction model to estimate the number of traffic accidents (Road surface: dry)

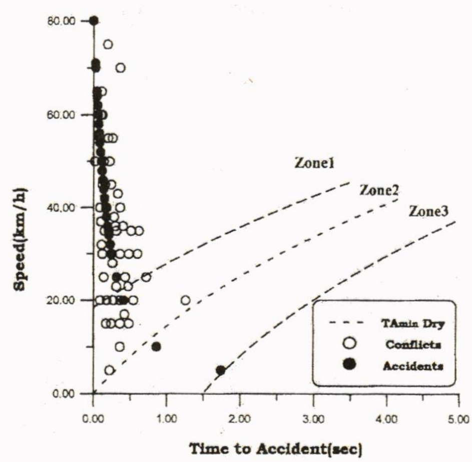

Figure 10 : The existing prediction model to estimate the number of traffic accidents (Road surface: wet)

- The calculation result of the Conversion Factor (π)

The parameters of each zone were calculated by equations (2) & (3); the results are shown in Table 2. Viewed in the Table 2, the parameter coefficient of zone 1 is larger than zone 2, proving that zone 1 is more closely related to traffic accidents than zone 2.

$$AN = CN \times \frac{24}{H} \times 365 \times 2 \times \pi \qquad (2)$$

$$\pi = \frac{AN}{CN} \times \frac{H}{24} \times \frac{1}{365 \times 2} \quad (3)$$

where, AN : number of accidents (AADT)
CN : number of conflicts (number/observation time)
H : total observation time of surveying conflicts (time)
π : conversion factor

Table 2 : Calculation result of the conversion factor (π) by existed TCT

	Road surface (dry)	Road surface (wet)
Zone 1	0.001325	0.001240
Zone 2	0.000240	0.000254
Zone 3	0.002740	-

3.3 TCT with Fuzzy Reasoning Theory

In order to develop the prediction model to estimate the number of accidents with the fuzzy reasoning theory, this study set up the comparison zone as shown below in Figures 11 & 12 between the accident data and the conflict data, and this paper calculates the parameter of the conversion factor (π) as shown in Table 3.

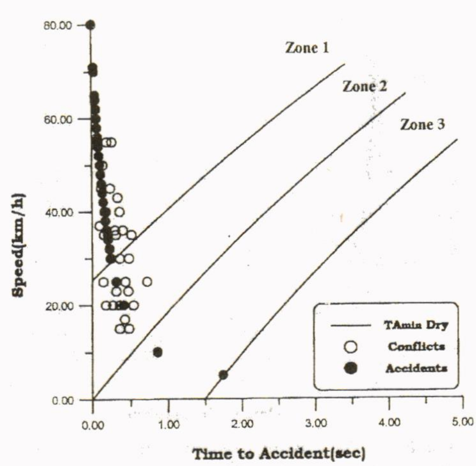

Figure 11 : The proposed prediction model to estimate the number of traffic accidents (Road surface : dry)

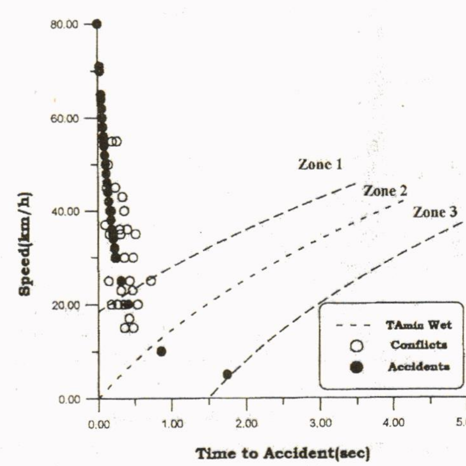

Figure 12 : The proposed prediction model to estimate the number of traffic accidents (Road surface : wet)

- The calculation result of the Conversion Factor (π)

Table 3 shows the results of applying the fuzzy reasoning theory to traffic conflict techniques. This parameter can't apply to all intersections for estimating the number of accidents, but it can be applied at analogous intersections to the traffic conditions and the traffic situation of the research intersections in this paper.

$$AN = CN \times \frac{24}{H} \times 365 \times 2 \times \pi \quad (4)$$

$$\pi = \frac{AN}{CN} \times \frac{H}{24} \times \frac{1}{365 \times 2} \tag{5}$$

where, AN : number of accidents (AADT)

CN : number of conflicts (number/observation time)

H : total observation time of surveying conflicts (time)

π : conversion factor

Table 3 : Calculation result of the conversion factor (π) by the proposed model

	Road surface (dry)	Road surface (wet)
Zone 1	0.003038	0.002320
Zone 2	0.000327	0.000489
Zone 3	-	-

4. CONCLUSION

This paper created a new methodology for evaluating the safety of intersections using the fuzzy reasoning theory, and applied the proposed model to seven signal intersections in Chonju City. To apply the fuzzy theory, this paper sets up the five severity choice levels to check in the conflict surveying field. After applying this proposed approach, the conversion factor (π) was calculated, and conclusions were reaches as follows:

1. When applying the fuzzy reasoning theory to traffic conflict techniques, because the collected data were systematically refined, this proposed approach minimized the deviation of collected conflict data by about seventy percent, and made a good model for predicting the number of traffic accidents.

2. As a result of constructing the prediction model to estimate the number of traffic accidents with this proposed approach, this paper calculated the conversion factor (π) as like zone 1 > zone 2. This results serve as proof that zone 1 is more serious and dangerous than zone 2,because zone 1 has a highly co-relation to the traffic accidents.

As the above findings demonstrate, by applying the fuzzy reasoning theory to traffic conflict techniques, anyone trained in conflict surveying can evaluate the safety of road and intersections. Below is a list of further study topics based on the proposed approach:

1. Examination of the approach's application to different types of intersections.
2. Application of the Genetic Algorithm (GA).
3. Examination of application of the automatic detection.

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REFERENCES

[1] Hydén C. (1987) **The Development of a Method for Traffic Safety Evaluation: The Swedish Traffic Conflicts Technique.** Sweden.

[2] Moon N.G. (1992) **Application of Fuzzy Theory and Knowledge Engineering to the analysis of Traffic Flow Characteristics on the Urban Arterial Roads.** Doctoral Thesis, Hiroshima Universiy.

[3] Motoda, Y., *et al.* (1992) Application of Traffic Conflict Technique to Road Administration. **Journal of the Japan Society of Civil Engineering, No.440/IV-16, pp.101-108.**

[4] Papacostas (1987) **C.S. Fundamentals of Transportation Engineering.** Prentice Hall, Inc.

[5] Perkins S.R. and Harris J.I. (1986) Traffic Conflict Characteristics Accident Potential at Intersections. **Highway Research Reocrd Number 225,** Traffic Safety and Accident Research 6 Reports.

[6] Soobeom L. and Insuk G. (1999) A Study of Safety Evaluation by Using Traffic Conflict Technique at an Intersection. **Journal of Korean Society of Transportation, Vol. 17 No.4,** October.

[7] Wonchul, K. (2001) **Development of a Safety Evaluation Method at Intersections.** Master Thesis, Wonkwang University.