FUZZY LOGIC APPLICATION IN TRANSPOTATION PROBLEMS

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Abstract

The study of transportation problem can be considered as a very interesting area as it deals with many different decision alternatives. In many occasions, those decision criteria require judgments from experts in specific areas, such as methods of pavement rehabilitation, techniques in performing transportation maintenance, transportation planning, signal controls, and etc. In the real world, most of these issues are characterized by the uncertainty, ambiguity, or imprecise sets of information, which can be difficult to be translated into numerical values, so called the crisp values. Therefore, it is necessary to have a tool to handle this kind of problems.

Over the past few decades, there are a variety of models that were designed to solve complicated traffic and transportation problems. Though, these techniques utilized various formulations and equations (objective knowledge) in desire to find the optimal and feasible solutions to such kind of problems, they cannot be utilized in a very complicated dimension where the inputs are both objective knowledge and subjective knowledge (linguistic information). In this ambiguous environment, Fuzzy logic seems to be the most appropriate technique.

Key words: Fuzzy Logic, Transportation application, Transportation Problem

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1. INTRODUCTION

Transportation is an essential part in social, industrial and economical process that encounters to the increasing of level of vehicle which leads to increasing demand and deterioration of transportation infrastructure as well as others. Settling these things can help to improve smoothly and effectively in many areas. So, transportation problem is essential to deal with and required decision alternatives from experts such as the rehabilitation and maintenance, transportation planning, signal controls and etc. which mentioned below. However, most of these issues are characterized by uncertain, ambiguity, imprecise and also difficult to be solved by crisp value, therefore, we need a tool to cope with these kinds of problem. Over the past few decades, there are a variety of mathematical models using various formulations and equations (objective knowledge) to settle such kinds. Actually, in real problems they used approximated number instead of crisp one for input parameter because it is impossible to use fixed value to describe complicated traffic and transportation. For example, when estimating the speed and costing time between two nodes, we will express in term that "around 20 minutes for 40kilometers". We cannot be able to process to answer exactly that: "18 minutes 20seconds for 38.27 kilometers". Nevertheless, to solve these problems we have to record over the long period of time with various values and cannot ignore the linguistic information to evaluate all of options and fulfill as much as possible of real conditions. So that, we do need a technique to present the linguistic information and crucial thing is using a suitable solution to link objective knowledge and subjective knowledge (linguistic information). Fuzzy logic is an absolutely corresponding concept with this case.

This paper aims to present the basic factors of fuzzy logic theory, fuzzy logic system, application of fuzzy logic in transportation problems and also be enlarged for future research in this field.

2. FUZZY LOGIC THEORY

"Fuzzy means not well-known or not clear enough, or their closer significance depends on subjectivity, estimation, and even the intuition of the person who is describing these terms " (Zdenko Kovacic and Stjepan Bogdan, 2005). In general, Fuzzy control is found to be superior in complex problems with multi- objective decision. 1965, L.A. Zadeh published his famous paper "Fuzzy Sets" in Information and Control providing a new mathematical tool which enables us to describe and handle vague or ambiguous notions such as "a set of all real numbers which are much greater than 1", "a set of beautiful women," or "the set of tall men". The main idea of fuzzy set theory is quite intuitive and natural. Instead of determining the exact boundaries as in an ordinary set, a fuzzy set allows no sharply defined boundaries because of generalization of a characteristic function of a membership function" (Swain et al. 2006).

2.1. FUZZY SET

Fuzzy set is characterized by values from zero to one, with 0 representing no membership and 1 representing complete membership in a set. To be more specific,

x: a real no, $x \epsilon F$

$\mu_F(x)$: a membership function of set F that assigns value to every $x \epsilon F$ into [0, 1]

$F= \{x, \mu_F(x) \mid x \epsilon F\}$

There are 4 forms: Triangular, Trapezoidal, Gaussian and Bell-shaped form which used more than others.

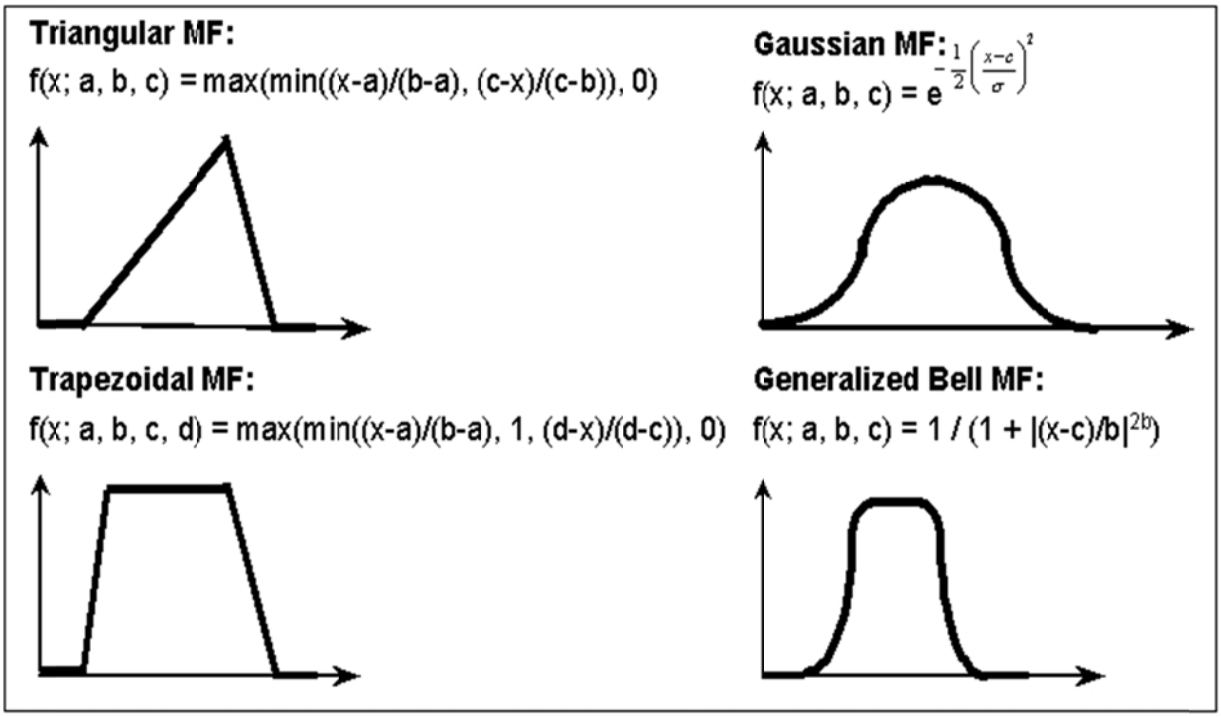

Figure 1: Four popular kinds of fuzzy logic membership funtions..

Source: http://wing.comp.nus.edu.sg/pris/FuzzyLogic/DescriptionDetailed2.html

2.2. FUZZY SET LINGUISTICS

One powerful aspect of fuzzy sets is the ability to deal with the linguistics quantifiers or hedges such as *more* or *less*, *very*, *not very*, *slightly*, etc., correspond to modification in the membership function of the fuzzy set involved. Depending on the application, fuzzy hedges may be defined in different ways to meet the requirements of the process being controlled.

2.3. FUZZY LOGIC CONTROLLER (FLC)

According to Jun Yan et al. (1994), the main elements of FLC are a fuzzification unit, a fuzzy logic reasoning unit, a knowledge base and a defuzzification unit. The fuzzy knowledge

base contains two types of information: a data base defining the membership function of the fuzzy sets used as values for each system variable and a rule base which essential maps fuzzy values of the input to fuzzy values of the output.

Input variables are often crisp value. Then, these crisp values will be map into fuzzy set to corresponding fuzzy values in fuzzification. Inference engine consists of rule base and data base. These rules are expressed in an If-Then format. And the most basic one is Single- Input-Single – Output (SISO). Depending on the complicating of fuzzy system, the amount of variables will change.

Fuzzy rule form: IF x is A THEN y is B

Fuzzy knowledge base consists of a number of fuzzy rules with several sentence connectives, namely AND, OR and ALSO:

IF x1 is A1 OR x2 is A2 AND x3 is A3 THEN y1 is B1 ALSO y2 is B2

With "If" part is called antecedent part describing causes and the rest one is called a consequent part describing results.

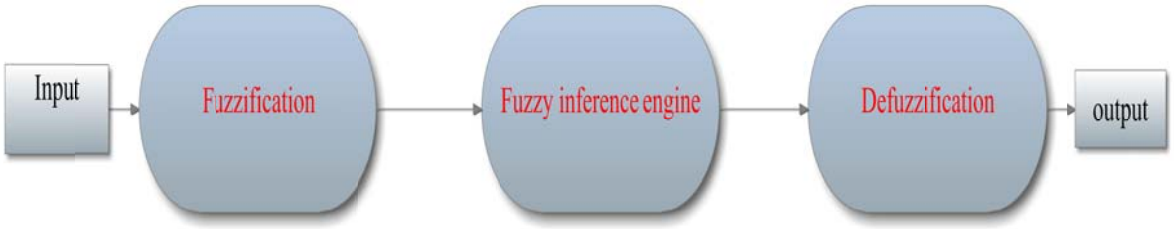

Figure 2: Fuzzy logic system.

In next step, the inference engine combines and maps fuzzy sets onto fuzzy set to get a fuzzy output set. During defuzzification, one crisp value is chosen for the output variable by taking a weighted average of the various recommendations by 2 ways: Center of Gravity (COG) defuzzification and Center Average (CA) defuzzification.

3. FUZZY LOGIC APPLICATION IN TRANSPORTATION PROBLEMS

Since fuzzy logic was introduced in 1965 by Professor Lotfi Zadeh, it was applied successfully to a wide range of many areas. Recently, several authors observe, that fuzzy logic is a useful technique in real-life transportation problems, starting from Pappis and Mamdani (1977) who applied fuzzy logic to control an intersection of two one-way streets or others used fuzzy logic in decision making system such as Gianluca (2011) and Brito et al. (2012). These application will be classified particularly as below.

3.1. TRAFFIC SIGNAL CONTROL

There are a lot of papers which introduced about Fuzzy logic's application such as checking various signal timing algorithm for travel vehicle and pedestrian at intersection of different complication. Fuzzy logic had helped to control traffic signal situation including multiple solution and vehicle's movements. In other ways, fuzzy control achieved in problem where mathematical modeling is difficult to solve but an experienced human can conduct this process, it is also useful in complex issues with multi-objective problem. As noted, from Pappis and Mamdani (1977)'s work, Chiu and Chand (1993) distributed architecture in which each intersection independently adjusts its cycle time, phase split, and offset using only local traffic data collected at the intersection. Jarkko and Esko (2003) had applied fuzzy logic to the performance of signalized intersection-the combination of time value, environmental effect and traffic safety to be exact- to control a signalized isolated pedestrian crossing in a minimum waiting time and also with a minimum risk of rear-end collisions, as well as managing multi-phase vehicle control. Actually, traffic signal control's main function is maximizing the effect of existing traffic system without new road rehabilitation, safe traffic condition and decreasing delay, air and noise pollution. Apparently, signal control is essential to maintain the safety and quality of traffic condition. Successful managing this process may in turn lead to minimize the transportation time and cost, and CO_2 emission.

3.2. TRANSPORTATION MAINTENANCE AND REHABILITATIONT

Nowadays, transportation infrastructure plays an important part in development of economy in private and development of the country in general. So, it does need to maintain and test regularly to preserve the construction in safety condition and guarantee vehicle's movement. However, because of limited budget annually, the authority has to choose options with highest priority that reputedly a making decision process. Another factor to concern in maintenance is that most of road system had not been structured with real design, in turn lead to the lack of sustainable road network. Suitable allocation of such kind of public infrastructure inquires a careful and sensible judgment as well as a systematic and scientific method. Chen and Gerardo (2008) have used fuzzy logic as a module to a schedule rehabilitation activities for Life-cycle Cost Analysis (LCCA).

3.3. ACCIDENT ANALYSIS AND PREVENTION

Traffic Accident has being an urgent problem which be affected by many factors such as climate, driving condition, traffic's level, etc. These make solving these problem become complex and uncertainly. Besides, safety cost cannot be specify, also cannot be measured without fuzziness. Akiyama et al. (1993) cited that when evaluating certain alternative factor such as feeling of safety, driving comfort, etc., must be taken into account. The author used incremental cost-benefit analysis with fuzzy constraints and dynamic programming with fuzzy constraints to solve this problem.

3.4. TRANSPORTATION DECISION AND INVESTMENT

Traffic management always is a complicated problem in society. Many papers have mentioned this issue in many directions: road management, road safety, traffic violation, etc. These things can conflict in nature, therefore, there's a need to make a specific and reliable decision system to help decision makers for analyzing some pieces of information and give recommendation about what they should do. Indeed, fuzzy logic can be applied in simulating an artificial intelligence system. In recent time, there are some authors using fuzzy logic in decision process, for example, fuzzy logic used as synthetic evaluation and to justify highway alignment choices in environment impact study analysis which explore innovation in integrating infrastructure and land using planning for transportation corridors (Gianluca Dell'Acqua., 2012).

Besides, in the area of transportation investment, Tzeng et al. (1993) considered Transportation Investment project selection with fuzzy multi- objective with idea which showing the possibilities of using fuzzy set theory in transportation investment plans. David and Pandian (2011) cited that fuzzy logic method attempts to simultaneously minimize the total product and transportation cost and total delivery time with reference to budget constraints and available supply, machine capacities at each sources as well as forecast demand and warehouse spa constraints at each destination. Ojha et al. (2010) applied fuzzy logic for comparing and minimizing total transportation cost together with minimize transportation time. Their goal is to consider two transportation models (GA and MOGA) in a fuzzy environment using inference and formulate two models with fuzzy relation under fuzzy logic.

4. FUTURE RESEARCH AND CONCLUSION

Up to now, there are some applications combining fuzzy logic and analytical hierarchy process (AHP) to solve transportation problem, especially the project which need to choose options with higher priority. For example, Danial Moazami et al. (2011) used AHP as the first step to absolute measuring of priority and then fuzzy logic model will be applied to become the best and most logical prioritization engine. This kind of model can be used in calculating and minimizing budget of maintenance and investment in the future direction research. This paper have concerned partially about this. However, this paper has not compared between using fuzzy logic in past work and recent work to recognize the development in applying this method in control and inference problem as well as finding the gap in past work to develop.

Table 1: Classification of paper by areas of research.

Area	Title	Author	Pub. year
Traffic signal control	Adaptive Traffic Signal Control Using Fuzzy Logic	Chiu, S and Chand, S	1993
	Traffic Signal Control on Total Fuzzy Similarity based Reasoning	Jarkko Niittymaki, Esko Turunen	2003
	A new approach for fuzzy traffic signal control	Y.S. Murat, E. Gedizlioglu.	2002
	Fuzzy logic applications for traffic control “an optimum and adaptive controlling application"	Fani Bhushan Sharma, Ajay Sharma, Nirmala Sharma	2010
	Self-Organizing Traffic Control via Fuzzy Logic	Chiu, S and Chand, S	1993
Transportation maintenance and rehabilitation	Pavement rehabilitation and maintenance prioritization of urban roads using fuzzy logic	Danial Moazami, Hamid Behbahani, Ratnasamy Muniandy	2011
	Calibrating Fuzzy-Logic-based Rehabilitation Decision Models Using the LTPP Database	Chen Chen and Gerardo W. Flintsch.	2008
Accident analysis and prevention	Traffic signal installation by the expert system using fuzzy set theory for inexact reasoning	Chang, Y.H., Shyu, T.H	1993
Transportation decision and Investment	Using fuzzy inference system to optimize highway alignments	Gianluca Dell’Acqua	2011
	Transportation policies for single and multi-objective transportation problem using fuzzy logic	A.Ojha, Shyamal Kr. Mondal, Manoranjan Maiti	2011
	Transportation planning with modified S-curve membership functions using an interactive fuzzy multi-objective approach	David Peidro and Pandian Vasant	2011
	Transportation investment project selection with fuzzy multi-objectives	Tzeng, G.H., Teng, J.-Y	1993

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