Optimizing the Bus Schedules in Epifanio Delos Santos Avenue Using Fuzzy Rule-Based System

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***Abstract*—the need for transportation improvement became an issue these recent years in the Philippines, one of the sought solution to this problem is the implementation of intelligent transport system (ITS) which can change the traffic situation especially in Epifanio Delos Santos Avenue (EDSA). Computational intelligence like fuzzy logic system (which is under ITS) was studied to design an intelligent bus schedule that can be a part of the solution in the traffic management problem in EDSA. Through fuzzy logic system a profitable and optimize bus schedule can be created.**

Keywords: Fuzzy logic, Intelligent Transport System, Epifanio Delos Santos Avenue, Computational Intelligence.

I. INTRODUCTION

Epifanio Delos Santos Avenue (EDSA) is a 23.8 km road connecting most of the cities in Metro Manila like, Caloocan, Quezon, San Juan, Mandaluyong, Pasig, Makati, and Pasay as shown on figure 1. EDSA is also the gateway of vehicles travelling from north and south of Luzon and one of the contributor of 2.4 billion transportation cost per day of Metro Manila. From the study conducted by Japan International Cooperating Agency (JICA), by 2030 the estimated traffic cost of EDSA will become 6 billion pesos per day and the volume per capacity ratio of EDSA will increase as shown in figure 2 [1].

The Metro Manila Development Authority (MMDA) implemented the Bus Segregation Scheme in EDSA to eliminate the congestion of buses servicing the different bus stops. Three bus schedules were created, the Bus A, Bus B, and Bus C, the distribution of this schedules are 40%, 40% and 10% respectively [2]. Bus C covers all the bus stops while the remaining bus schedules covers a limited number of bus stops, figure 3 shows the bus stops covers by Bus A and Bus B. From the news report of RPN 9 the average speed in EDSA is around 28 to 30 km/hr. and these record is alarming not only to drivers but also the commuter, one of the sought sources are over population of private and public vehicle especially the buses, ineffective traffic management, and others. To solve the problem, the JICA introduce traffic management design and the implementation of Intelligent Transport System (ITS) which is sighted in "Roadmap for Transport Infrastructure Development for Metro Manila and Its Surrounding Areas" [3].

Different computational techniques can be use or be part of the ITS, one of the techniques is the Fuzzy Logic. Fuzzy Logic was introduced by Lofti Zadeh in 1965 in his paper "Fuzzy Sets" [4]. Fuzzy Logic amathematical system that analyzesanalog input values in terms of logicalvariables that take on continuous values

between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 0 or 1 [5]. Fuzzy logic has three stages, the first stage is fuzzification wherein it converted the crisp value to an equivalent word like low, medium and high. The second stage is the processing of results of first stage using the rules base system. And the third stage is the defuzzification wherein it converts the results of second stage to a crisp value.

In this study the fuzzy logic was used to analyze the different factors that may affect the traffic congestion of public buses and identify the number of servicing bus in a given time and place.

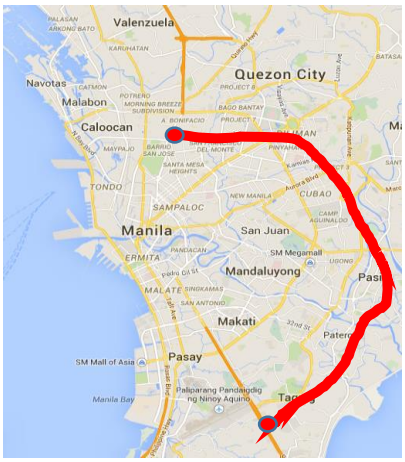
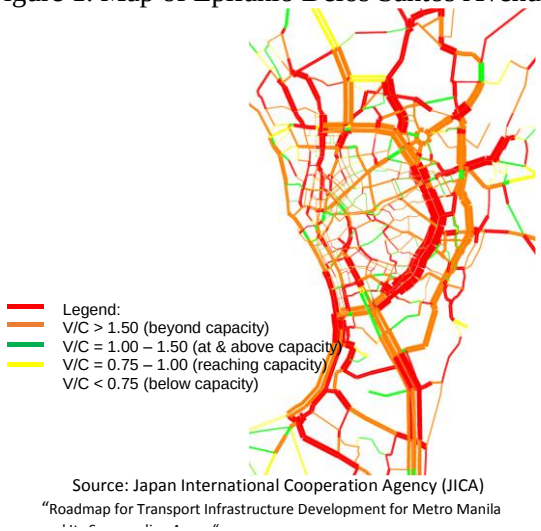
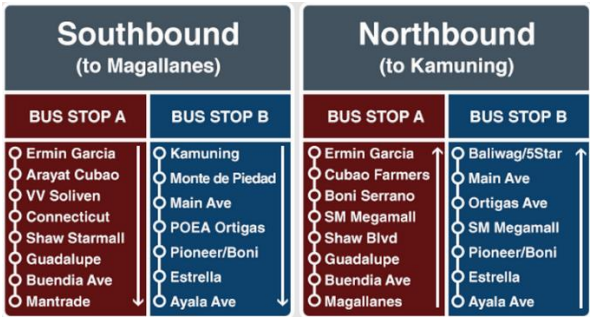


Figure 1. Map of Epifanio Delos Santos Avenue



Source: Japan International Cooperation Agency (JICA)
"Roadmap for Transport Infrastructure Development for Metro Manila

Figure 2. Volume per Capacity Ratio in Metro Manila by 2030



Source: http://www.mmda.gov.ph/Bus-Segregation-FAQ.html

Figure 3. Bus Stops Cover by Bus A and Bus B schedules

II. OBJECTIVE OF THE STUDY

To determine the success of the study the following objective should be achieve.

1. To create an intelligent rule system that will optimize the MMDA Bus Segregation Scheme.
2. Maximize the profit of the bus carriers using the fuzzy rule based system.
3. Eliminate the congestion of buses in bus stops covered by the MMDA Bus Segregation Scheme.

III. REVIEW ON SELECTED LITERATURE

Chang and Cheng (1995), constructed a knowledge-based expertise that is based on the survey results from the experts to identify the uncertainty in the demand of the buses. A total of 25 fuzzy rules where created and used the load factor, load factor variation and average travelling speed. These inputs will be used to determine the need for extra trip or additional trip of bus[6]. In the study of Sheu entitled "A Fuzzy Clustering Approach to Real-Time Demand Responsive Bus Dispatching Control", he used two methods to determine the dispatching time of buses, the short term forecasting of passenger demands using the time series prediction model and the identification of service strategies coupled with the associated bus service segments using the fuzzy clustering technologies in

response to the variance in the passenger demand attributes and traffic condition. The applicability of the methods was successful according to the results of Sheu [7]. Hayat and Borne presented the Aid Decision Making Fuzzy System to know the decision in the bus deployment in the urban network using the fuzzy sets theory. The rules formulated are from the experts and operators of the bus networks [8].

IV. METHODOLOGY

A. Assumptions

The study used some assumptions to clearly state the conditions and parameters used the formulation and design of the system or the study.

1. The bus used in the study was air-conditioned with maximum sitting capacity of 60 seats.
2. Used the MMDA Segregation Scheme as the bus scheduling model that will be optimize by the fuzzy rule-based system.
3. Covered only the bus stations identified in the MMDA Bus Segregation Scheme.
4. The travelling speed used in the study was from the data from mmdatraffic.interaksyon.com. The table 1 illustrate the translation of speed.
5. Passenger's Demand is measured in the number of passenger per minute and the maximum value is 100 passenger per minute. The data was gathered by monitoring the passenger flow in front of bus stop near Makati Phil. Stock Exchange building at 5:00 pm in the month of November 2014.
6. Loading factor in every bus stations was based on the surveyed data gathered by De La Salle University (DLSU) Civil Engineering Department headed by Dr. Alexis Fillone.
7. The maximum number of passenger per bus was limited to 125% of the maximum seating capacity.
8. The bus fare rate was based on LTFRB which is 12 pesos for first 5 kilometer (for air-conditioned bus) and 1.82 pesos for the succeeding 2 kilometer [9].
9. Fuzzy logic software in Mathlab was used.

B. Fuzzy Rule-Based System Diagram

The fuzzy logic in Mathlab was used to create the program for the Fuzzy rule-based system.

C. Fuzzy Sets

The study used three fuzzy sets, the average loading factor, passenger's demand and average travelling speed. With the help of the study of Chang and Cheng, the following sets was identified.

1. Average Loading Factor

The surveyed data from DLSU Civil Engineering Department, conducted on month of August 2014 was the basis on the average loading factor for the 30 bus stops in the MMDA Segregation Scheme. The loading factor will determine the number of seats available to the passengers the higher the number the lower the capability to serve all the passengers when the passenger's demand is high. The loading factor is the ratio of passengers over the seating capacity of a bus. Figure 4 is the membership function for the loading factor.

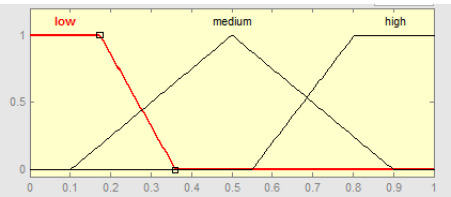


Figure 4. Loading Factor Membership Function.

2. Passenger' Demand

The passenger's Demand in every bus stops was based on the survey conducted by DLSU Civil Engineering Department. To identify the maximum passenger's Demand, the author conducted a survey in bus stops near in Makati Phil. Stock Exchange building at 5:00 pm in the month of November 2014. The membership function for

Passenger's Demand was shown in figure 5.

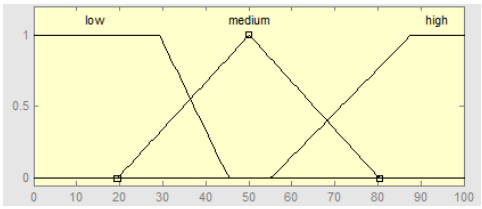


Figure 5. Passenger's Demand Membership function.

3. Average Travelling Speed

The effect of travelling speed in bus congestion and passenger's demand is inversely proportional. Decreasing the travelling time may increase the number of passengers waiting. 60kph was chosen as the maximum speed of bus in EDSA, this speed was the implemented maximum speed in EDSA. The figure 6 illustrate the membership function for travelling speed.

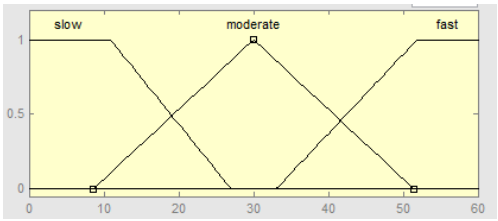


Figure 6. Average Travelling Speed Membership function

D. Fuzzy Rules

The fuzzy rules will govern the totality of the whole fuzzy system in my study. The defined rules were based on the experts decision making knowledge gather from the related literature sought in the previous chapter. The table 2 below shows the constructed rules.

Condition	if			Then
	Passenger Demand	Ave Loading factor	Ave speed	No. of serving bus
1	Low	Low	Low	V Low
2	Low	Low	Medium	V Low
3	Low	Low	High	V Low
4	Low	Medium	Low	V Low
5	Low	Medium	Medium	V Low
6	Low	Medium	High	V Low
7	Low	High	Low	Low
8	Low	High	Medium	Low
9	Low	High	High	V Low
10	Medium	Low	Low	Low
11	Medium	Low	Medium	Low
12	Medium	Low	High	V Low
13	Medium	Medium	Low	High
14	Medium	Medium	Medium	Medium
15	Medium	Medium	High	Medium
16	Medium	High	Low	V High
17	Medium	High	Medium	V High
18	Medium	High	High	High
19	High	Low	Low	Medium
20	High	Low	Medium	Medium
21	High	Low	High	Low
22	High	Medium	Low	V High
23	High	Medium	Medium	High
24	High	Medium	High	Medium
25	High	High	Low	V High
26	High	High	Medium	V High
27	High	High	High	V High

Table 2. Fuzzy Rules

E. Defuzzification

Defuzzification involves translation of the resulting membership output to a crisp value. The study used 5 membership functions (as shown in the figure 7) to clearly state the exact number of needed seats. The succeeding system can used these results to identify the number of bus that will be deploy on that bus stop at a given time depending also on the loading factor of the buses.

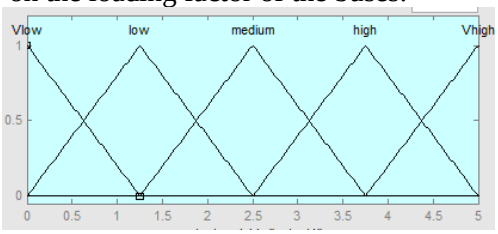


Figure 7. Membership Function of the Fuzzy Output

V. RESULTS OF THE STUDY

The data gathered from the survey and data from the internet traffic monitoring system were then inputted to Fuzzy Rule-Based System to determine the no of bus that should serve the station.

Bus Stop	Passenger Demand	Ave Loading Factor	Speed	No. of bus (output)
kamuning	20	75	20	1.26
Ermin Garcia	10	68	15	1.07
monte de piedad	7	50	15	0.424
arayat cubao	15	55	10	0.418
main ave	18	90	10	1.25
vv soliven	9	95	25	1.25
connecticut	11	80	15	1.21
poea ortigas	25	110	15	1.74
shaw starmall	30	120	15	2.02
pioneer / boni	35	77	15	2.4
guadalupe	20	76	60	0.674
estrella	5	96	30	1.25
buendia ave	5	89	30	1.25
ayala ave	0	94	60	0.4
mantrade	2	40	60	0.423

Table 3 Results of the Fuzzy Rule-Based System for 7 am bus dispatching

A. Analysis of the Results

For kamuning station the number of bus predicted by the fuzzy system was 1.26, it means that a bus with .75 loading factor can serve the station plus the .26 is then be solve and became .26(.75) + .75 = .945, .945 bus can also serve that station at that time. Therefore two bus with .75 and .945 loading factor will serve the kamuning station. Through the fuzzy rule-based system, a bus can have a loading factor of 1.0 in every bus stop at a time bus as a consequence the number of serving bus at the current state will decrease. The probability of earning a higher profit also increase.

VI. CONCLUSION

The Fuzzy Rule-Based System in this study successfully achieve the target objectives, the result shown that the system can determine the number of bus in every station and these number of bus were optimized. Limiting the number of bus in compensation, the buses were optimize to achieve a higher profit. The uncertainty of the condition was solve through the use of the expert's knowledge database which it was used to formulate the fuzzy rules. In general, the capability of fuzzy rule-based system in intelligent transport system for EDSA was tested with enough results to determine its effectiveness.

VII. REFERENCES

[1] "Roadmap for Transport Infrastructure Development for Metro Manila and Its Surrounding Areas". Retrieved from http://www.jica.go.jp/philippine/english/

[2][3] "MMDA Bus Segregation System". Retrieved from www.mmda.gov.ph.

[4] Zadeh, L. A. Fuzzy sets. Information and Control, **vol.** 8(3), pp. 338-353, 1965.

[5] Retrieve from https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Fuzzy_control_system.html

[6] J Cheng; Y Chang, "Application of a fuzzy knowledge base on bus operations under uncertainty", IEEE International Volume: 3, 1999, Page(s): 1355 - 1360 vol.3

[7] J.H Sheu, "A fuzzy clustering approach to real-time demand-responsive bus dispatching control", Fuzzy Sets and Systems, Volume 150, Issue 3, 16 March 2005, Pages 437–455

[8] S. Hayat, P. Borne and et al, "New strategy for the aid decision-making based on the fuzzy inferences in the traffic regulation of an urban bus network", Systems, Man, and Cybernetics, 1999. Page(s): 1069- 1073 vol.6

[9] "Bus Fare Rate for Metro Manila" Retrieve from www.ltfrb.gov.ph