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

Ramon Christhoper DJ. INTAL[a], Elmer P. DADIOS[b], Alexis M. FILLONE[c]

[a] *Gokongwei College of Engineering, De La Salle University Manila ,Taft Ave. Manila City, Philippines*
[a] *Ramon_intal@dlsu.edu.ph*
[b] *MEM Department Head, Gokongwei College of Engineering, De La Salle University Manila, Taft Ave. Manila City, Philippines*
[b] *elmer.dadios@dlsu.edu.ph*
[c] *Civil Engineering Department Head, De La Salle University Manila, Taft Ave. Manila City, Philippines*
[c] *fillonea@dlsu.edu.ph*

Abstract: In the past years, the improvement in the transportation had been an issue in the Philippines. Implementation of intelligent transport system (ITS) is one of the sought solution to this problem which can change the traffic situation especially in Epifanio Delos Santos Avenue (EDSA). This study created a software base guiding system for the bus dispatching system of Intal, Dadios and Fillone (Intal, Dadios, & Fillone, 2014). The bus dispatching system can only predict the best bus station to serve, to earn higher profit but have no capability to determine the maximum number of bus per station. If the supply of bus increases while the passenger's demand decreases, the expected passenger per bus may decrease making the overall profit to decrease. To control the number of bus per station, a guiding system which was based on fuzzy logic theory was proposed in this study. The collinear relation of passenger demand, average loading factor to the output which is the number of bus to deploy per bus stop, indicated a positive results.

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

1. INTRODUCTION

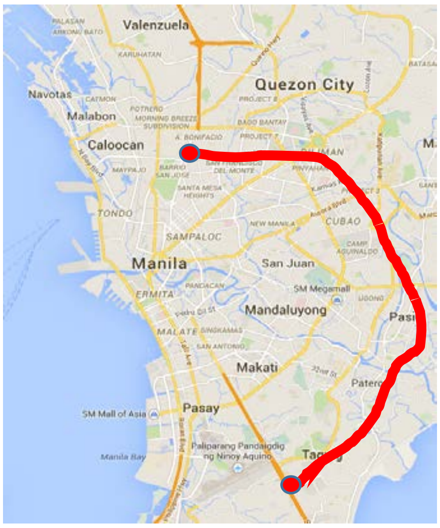
Epifanio Delos Santos Avenue (EDSA) is a 23.8 km road connecting most of the cities in Metro Manila like, Caloocan City, Quezon City, San Juan City, Mandaluyong City, Pasig City, Makati City, and Pasay City as shown on figure 1. EDSA which is the gateway of vehicles travelling from north and south of Luzon is one of the contributor of 2.4 billion transportation cost per day of Metro Manila. Based on the study conducted by Japan International Cooperating Agency (JICA) in 2014, by 2030 the estimated traffic cost of EDSA will increase up to 6 billion pesos per day and the volume per capacity ratio of EDSA will increase as shown in figure 2 (JICA transport study lists strategies for congestion-free MM by 2030, 2014).

To eliminate the congestion of buses servicing the different bus stops in EDSA, Metro Manila Development Authority (MMDA) implemented the Bus Segregation Scheme in EDSA. Three bus schedules were created, Bus A, Bus B, and Bus C, the distribution of these schedules are 40%, 40% and 20% respectively. Bus C covers all the bus stops while the remaining bus schedules covers a limited number of bus stops, as shown in figure 3 (Lazaro., 2013). Based on Radio Philippines Network (RPN 9) news report, the average speed in EDSA is around 36.24

kph. because of the increasing numbers of private and public vehicles especially buses, ineffective traffic management and others (Salaverria, 2009). In 2014 JICA report introduced 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” (JICA transport study lists strategies for congestion-free MM by 2030, 2014).

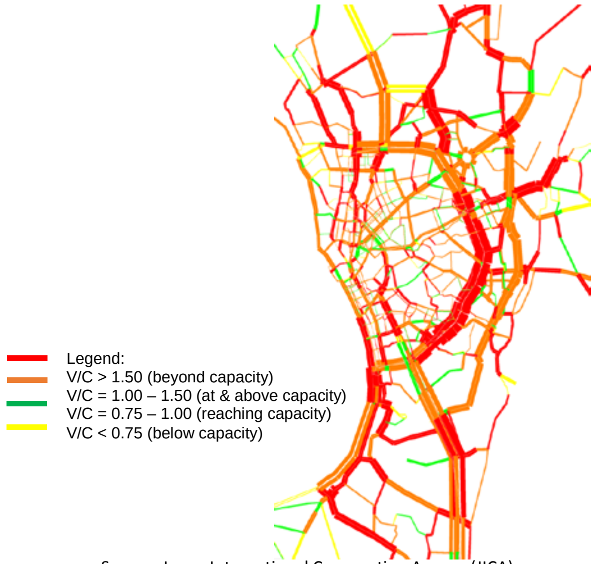
Different computational techniques can be use or be part of the ITS, one of the techniques is the Fuzzy Logic. Fuzzy Logic was introduced by Lofti Zadeh in 1965 in his paper “Fuzzy Sets” (Zadeh, 1965). Fuzzy Logic a mathematical system that analyzes analog input values in terms of logical variables that 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 . Fuzzy logic has three stages, first stage is fuzzification wherein it converted the crisp value to an equivalent word like low, medium and high. Second stage is the processing of results of first stage using the rules base system. And 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. The factor are loading factor, traveling speed (Cheng & Chang, 1999) and passengers demand .



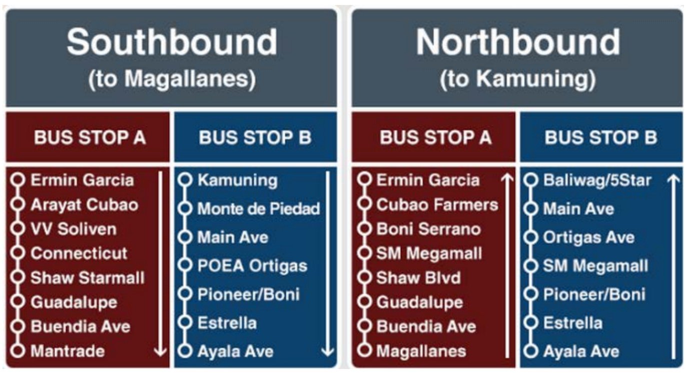
Source: google map

Figure 1. Map of Epifanio Delos Santos Avenue



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

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

2. OBJECTIVE OF THE STUDY

The study was governed by a main objective, create a software base system that will guide the bus dispatching algorithm on the number of bus to be deploy on a given bus stop at a specific time.

1) To create an intelligent rule system that will optimize the MMDA Bus Segregation Scheme.
2) Eliminate the congestion of buses in bus stops covered by the MMDA Bus Segregation Scheme.

3. REVIEW ON SELECTED LITERATURE

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 (Jiuh-Biing, 2005).

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 (Aziz, Hayat, Hammadi, & Borne, 1999).

Cheng and Chang implemented a fuzzy logic approach in solving the problem in bus scheduling. They 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. The uncertainty in the daily variation in the supply and demand of buses was their objective in this research and found out that the ruled based form facilitates the adaptation to a specific operation environment and the system can be applicable to urban bus system[6] – note give more details on this (Cheng & Chang, 1999).

Research aims to model a new way of schedule pattern for public utility buses that will maximize the carrier’s profit while minimizing the travelling time and congestion in different bus stops. The proposed new bus schedule was created based on the genetic algorithm that will maximize the bus carrier’s profit at the same time minimizing the congestion of public utility buses (PUBs) in EDSA. Theoretically, the result of the was successful, it abled to identify the bus stations that should be serve to gain a higher profit but the downside is that it has no capability to limit the number of bus per bus stations at a given time (Intal, Dadios, & Fillone, 2014).

The fuzzy logic which is a ruled-based system was also used by Lo and Chang. They introduced the Fuzzy bus holding system (FBHS) for mass rapid system in real-time. Their study aim to improve the bus waiting time, reduce the passeneger waiting time and traveling time. the results showed that the overall passeneger waiting time and performance of the MRT-bus transfer system was improved (Lo, Chang, Kuo, & Kuo, 2009).

4. CONCEPTUAL FRAMEWORK

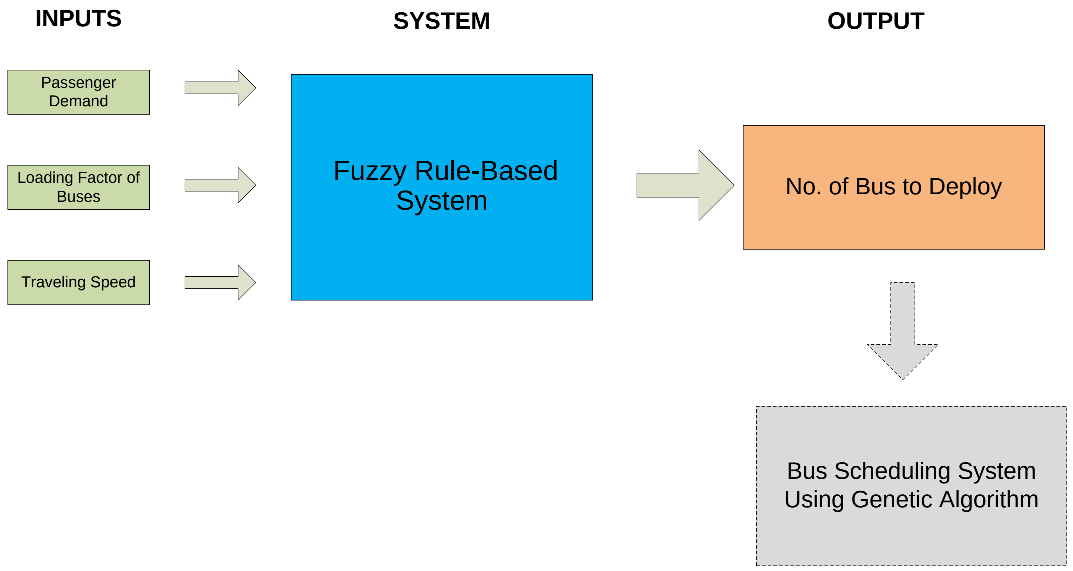


Figure 4. Conceptual Framework of Fuzzy Rule-Based System

Figure 5 illustrate the concept of this study. The Fuzzy Ruled-based system will be the guiding algorithm that control the number of bus to deploy in a given bus stop in EDSA. The output of the Fuzzy system will be part of the input parameters of the bus dispatching system of Intal, Dadios and Fillone (Intal, Dadios, & Fillone, 2014).

5. THEORETICAL FRAMEWORK

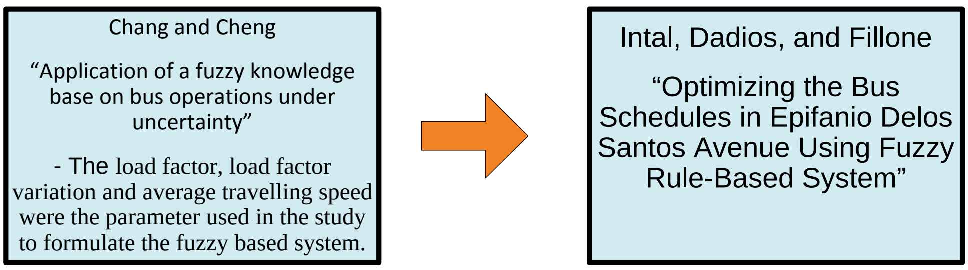


Figure 5. Theoretical Framework of Fuzzy Ruled-Based System

The framework of this study was based on the study of Cheng and Chang (Cheng & Chang, 1999). The loading factor and the travelling speed which were used in their study were incorporated in this study. The Number of passenger or passenger demand was included to test its applicability in the decision making on forecasting traffic needs.

6. METHODOLOGY

6.1. 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 to be optimize by the fuzzy rule-based system (Bus-Segregation, 2014).
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 (Metro Manila Traffic Navigator, 2014). 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) Fuzzy logic software in Mathlab was used.

6.2. Fuzzy Rule-Based System Diagram

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

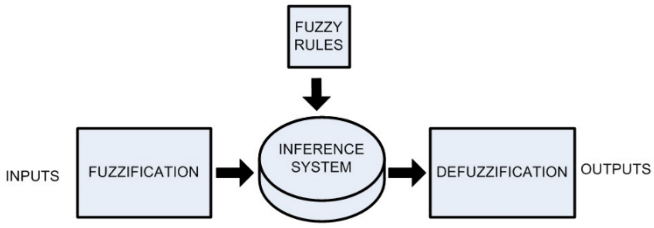


Figure 4. Fuzzy Rule-Based System Diagram

6.3. 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.

6.3.1. Average Loading Factor

Average loading factor of buses was based on the surveyed data in EDSA from DLSU Civil Engineering Department in August 2014. 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 5 is the membership function for the loading factor.

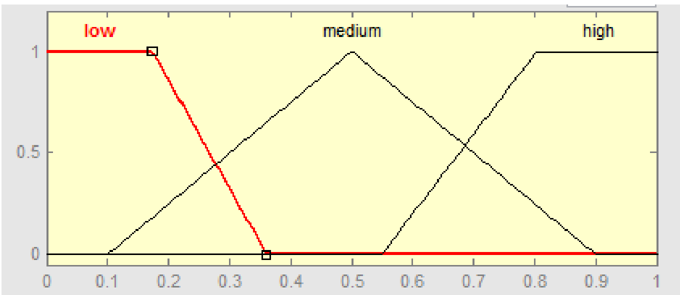


Figure 5. Loading Factor Membership Function.

6.3.2. 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 6.

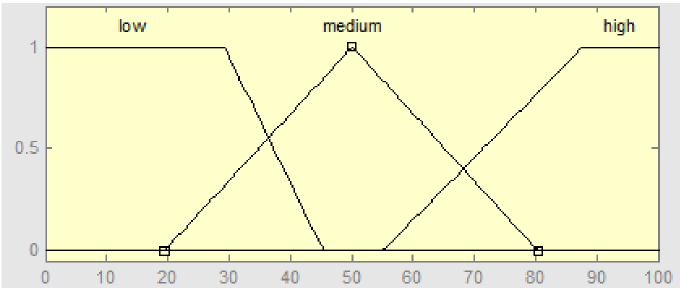


Figure 6. Passenger's Demand Membership function.

6.3.3. Average Travelling Speed

The effect of travelling speed in bus congestion and passenger's demand is inversely proportional. Decreasing the travelling time of bus will result in an increase in number of waiting 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.

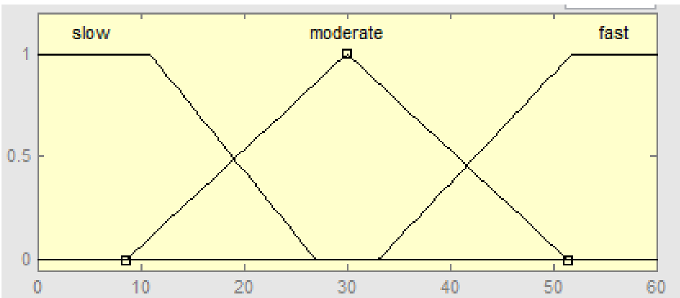


Figure 7. Average Travelling Speed Membership function

6.3.4. 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.

Table 2. Fuzzy 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

6.4. Defuzzification

Defuzzification involves translation of resulting membership output to a crisp value. This study used 5 membership functions (as shown in the figure 8) to clearly state the exact number of seats needed in bus. 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.

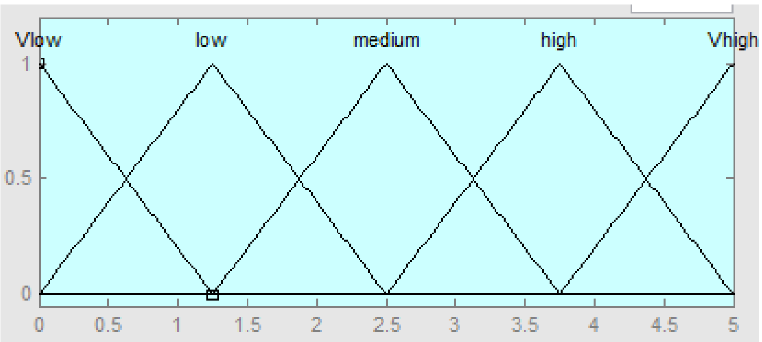


Figure 8. Membership Function of the Fuzzy Output

7. RESULTS OF THE STUDY

The data gathered from the survey and data from the internet traffic monitoring system (Metro Manila Traffic Navigator, 2014) were then inputted to Fuzzy Rule-Based System to determine the no of bus that should serve the station.

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

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

7.1. 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 or bus with 15 available seats can serve the station plus the .26 or a bus with 4 available seats can serve the station per minute. 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.

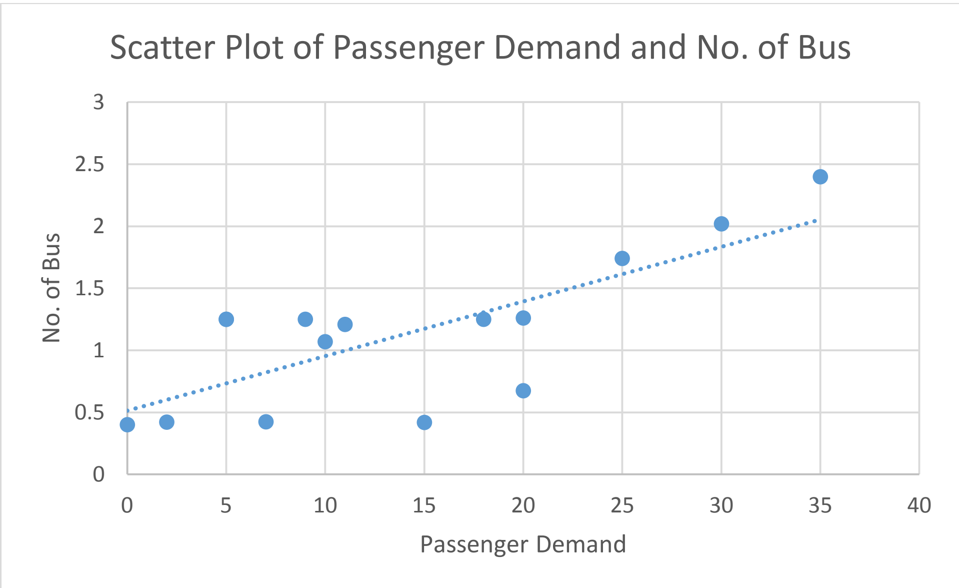


Figure 9. Scatter Plot of Output and Passenger Demand

The figure 9 showed that the output which is the number of bus to deploy and the passenger's demand have a collinear relationship. The value of Pearson's correlation coefficient of the two variables was 0.755619 which was above the minimum (the minimum correlation coefficient for this set of data was 0.516398). This value only indicate that the passenger demand can be a useful parameters to identify the number of bus to deploy.

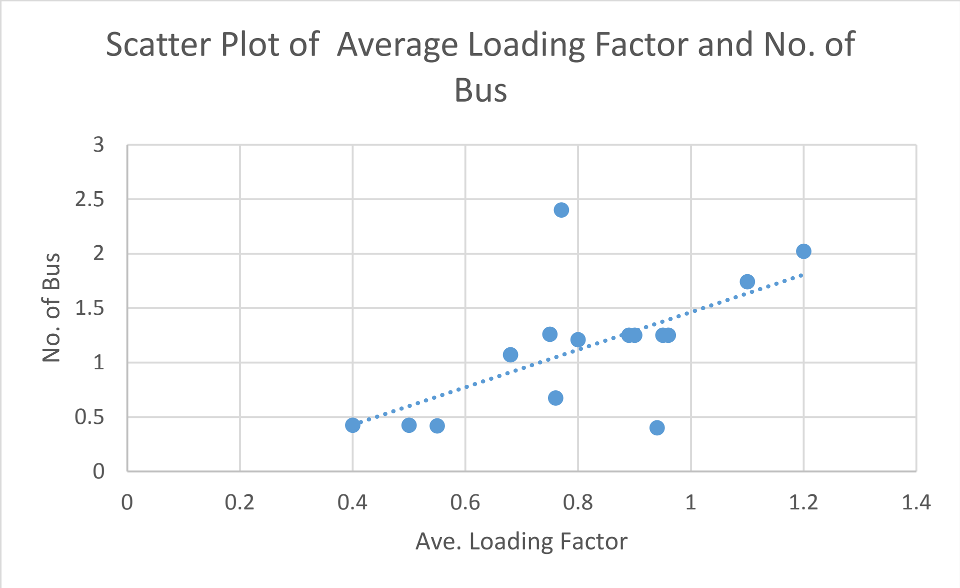


Figure 10. Scatter Plot of Output and Average Loading Factor

The average loading factor was another parameter that can be used to identify the number of bus. The collinear relation was 0.623105 and above the minimum number for the relationship between two variables to exist.

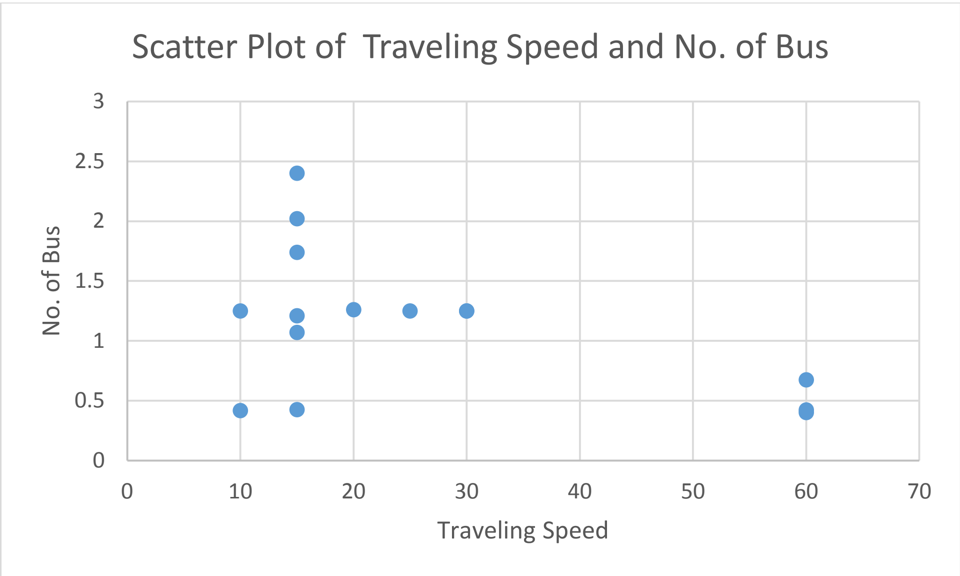


Figure 11. Scatter Plot of Output and Traveling Speed

There was no strong relationship between the output and the traveling speed as shown in the figure 11 and the computer correlation coefficient which is -0.49818.

8. CONCLUSION

The Fuzzy Rule-Based System in this study successfully achieve the target objectives, the result showed that the system can determine the number of bus in every station per minute. And the strong relationship of passenger's demand and average loading factor only indicate the applicability of these parameters in determining the number of bus to deploy.

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.

9. REFERENCES

Aziz, S., Hayat, S., Hammadi, S., & Borne, P. (1999). 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*, 12-15.

Bus-Segregation. (2014). Retrieved from MMDA: http://www.mmda.gov.ph/Bus-Segregation-FAQ.html

Cheng, J.-H., & Chang, Y.-H. (1999). Application of a fuzzy knowledge base on bus operations under uncertainty. *Fuzzy Systems Conference Proceeding*, 22-25.

Intal, R. D., Dadios, E. P., & Fillone, A. M. (2014). Maximizing the bus carrier's profit in Epifanio Delos Santos Avenue using genetic algorithm. *Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 2014 International Conference on*, 1-6.

JICA transport study lists strategies for congestion-free MM by 2030. (2014, September 2). Retrieved from Japan International Cooperation Agency: http://www.jica.go.jp/philippine/english/office/topics/news/140902.html

Jiuh-Biing, S. (2005). A fuzzy clustering approach to real-time demand-responsive bus dispatching control. *Fuzzy Sets and Systems*, 437-455.

Lazaro., J. (2013, January 7). Retrieved from Rappler: http://www.rappler.com/rich-media/19258-infographic-how-to-find-the-right-bus-on-edsa

Lo, S.-C., Chang, W.-J., Kuo, P.-C., & Kuo, C.-Y. (2009). The simulation of MRT transfer system based on bus holding strategies with platform constraints. *Systems, Man and Cybernetics*, 11-14.

Metro Manila Traffic Navigator. (2014, December). Retrieved from http://mmdatraffic.interaksyon.com/system-view.php

Salaverria, L. (2009, July 8). Retrieved from Inquirer Headlines: http://newsinfo.inquirer.net/inquirerheadlines/metro/view/20090708-214545/Average-vehicle-speed-on-Edsa-is-3624kph