Proposed Jeepney Fare Using Fuzzy Logic

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Abstract: One of the most popular mode of transportation in the Philippines is jeepney. Despite of its popularity, there is always an issue of losses among jeepney operators and drivers that lead to fares hikes and transport strike. Jeepney fare is a constant debate that needs to be resolved whether there is a need to increase or not. This study aims to develop and propose a standard jeepney fare model in Metro Manila using fuzzy logic. Fuzzy logic provided highly accurate technique to model standard jeepney fare. The factors that were considered in the study are total cost and distance. Total cost includes diesel price, fixed costs, maintenance cost, and operator's profit. A flat fare is applied for the first 4km and increasing fares for every succeeding 1km. The study result shows that fuzzy logic can be used to accurately model the jeepney fare.

Keywords: Fuzzy Logic, Fare, Jeepney

1. INTRODUCTION

Jeepney had been the predominant public transport mode in the country, especially in Metro Manila. It is popular for commuters because of its local availability, intermediate size and capacity, and accessibility (Bayan 1995). It caters to the middle class societies who want to spend less on commuting, especially to those who don't have enough budgets to ride on much expensive public utility vehicles like buses, vans and taxis. Jeepney is one of the cheapest ways of getting to your destinations (Fillone and Montalbo 2007). The present scenario nowadays, as the jeepneys comprise the majority of the transport sector, jeepney operators and drivers are claiming that they will incur big losses unless fares will not increase. This resulted to transport strike if the government will not approve the increase fares. Fares and hikes had been always a dispute among the jeepney operators/drivers, commuters and government officials whether it is reasonable or not.

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection (MathWorks). The fuzzy logic concept is based on IF..THEN inference rules and membership functions for linguistic variables by which it is able to capture vagueness of human behavior efficiently (Pulugurta et. al. 2014). Fuzzy logic and Neural Networks techniques have been applied successfully to different applications for decision support systems. These techniques have many features that make them a particularly appealing and promising approach. Fuzzy logic, which reproduce

the approximate reasoning process of the human mind by representing knowledge via linguistic if-then rules, allows for precise output inference starting from imprecise input (Shleeg and Ellabib 2013).

This study aims to develop and propose a jeepney fare model (SJFM) using fuzzy logic as a basis for fare hikes and rollbacks. In this study, Fuzzy logic with highly accurate technique in the development of precise model such as jeepney fare model was demonstrated. Through this fuzzy jeepney fare model, fare evaluators can determine by how much increase or decrease in the fare prices should be implemented. The factors that were considered in the study are total cost and distance. Total cost includes diesel price, fixed costs, maintenance cost, and operator's profit. A flat fare is applied for the first 4km and increasing fares for every succeeding 1km.

2. METHODOLOGY

2.1 Assumptions and Estimates

In this study, the total cost of jeepney operation per day and the distance travelled of jeepney per day were considered in the formulation of the standard jeepney fare. The total cost is the summation of all cost that include diesel cost, fixed costs, maintenance cost, and operator's profit.

For the diesel cost per day gathered from the survey, the summation of all diesel cost incurred in a 12-hour workday was used. The cost of diesel of Php 31.00 per litre was used with the assumption that jeepney consumes 27 per day or 1 litres of diesel per 4 kilometer. So the cost of diesel per day is approximately around Php 837.00. On the other hand, fixed cost per day is the summation of jeepney unit cost per day, vehicle registration cost per day, route franchise fee per day, and license fee per day shown in equation 1.

$$FC = J + U + R + D \tag{1}$$

Where: FC = fixed cost per day, in Php
J = jeepney unit cost, in Php
U = unit registration fee, in Php
R = route franchise fee, in Php
D = driver's license renewal fee, in Php

The company practices with regard to the mode of payment for sales are usually on cash and instalment basis. The usual number of terms is 1 to 5 years. The retail price ranges from Php 400,000.00 to Php 745,000.00 (Bacero 2009). Computing for the jeepney unit cost per day, the maximum installment period of 5 years and Php 500,0000.00 were used in the study. For the vehicle registration cost per day, a period of 1 year and unit registration cost of Php 2230.00 was used in the study. Based on the Land Transportation Franchising and Regulatory Board, the maximum franchise validity period is 5 years and a franchise fee of Php 30,000.00 was used in the study. Based on the Land Transportation Office, renewal of driver's license is every 3 years with a registration fee of Php 648.00. Therefore, the fixed cost is estimated to be Php 187.50.

Based on the data gathered, the total cost of operations are being increased by events such as jeepney unit malfunction/ defect and during the occurrence of traffic violations. Maintenance cost per day includes spare parts maintenance/replacement cost, and traffic violation cost which estimated to be 0.10 of fixed cost for both parameters.

For operator's profit, it is estimated to be 0.40 of fixed cost. The summary of the total cost is shown in table 1.

Table 1. Total Cost Summary

Parameter	**Total Cost per day (Php)**
Diesel Cost	837.00
Fixed Cost	
Jeepney Unit Cost	500,000.00/1825days
Unit Registration Cost	2230.00/365days
Route Franchise Fee	30,000.00/1825days
Driver's Licence Fee	648.00/1095days
Maintenance Cost	
Spare Parts Replacement Cost	0.1(FC)
Violation Cost	0.1(FC)
Operator's Profit	0.4(FC)
Total Cost	1312.00

For the distance travelled considered in this study, a total distance of 12km per trip with a flat fare for the first 4km and increasing fare for additional or succeeding 1km. Jeepney operates 9 trips per day with an average ridership of 45 persons per trip.

2.2 Fuzzy Rule-Based System Diagram

The fuzzy logic in MATLAB was used to generate program of the jeepney fare fuzzy rule-based system shown in figure 1. Mandani fuzzy inference system was used in the study. Mamdani type is widely accepted for capturing expert knowledge (Kaur and Kaur 2012). It allows describing the expertise in more intuitive, more human like manner. Input parameters include the total cost of jeepney operations per day and total distance travelled per trip. And the output is the standard jeepney fare.

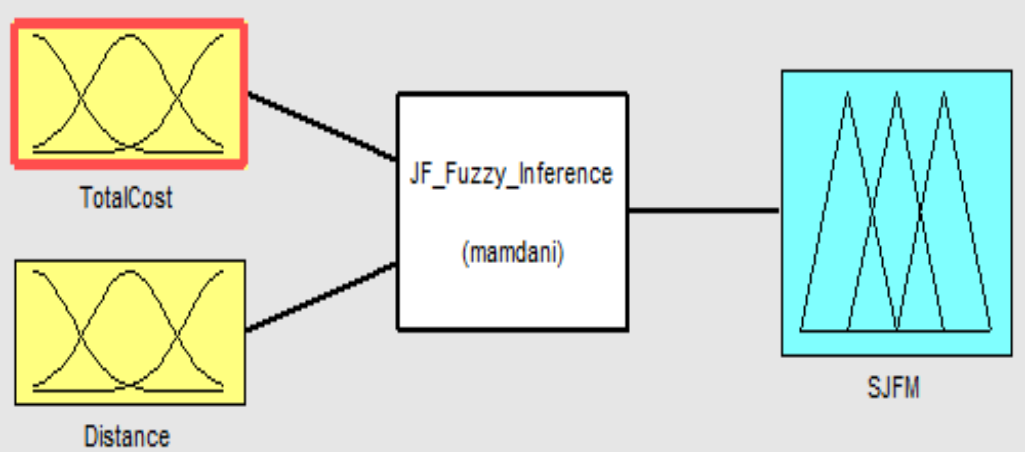

Figure 1. Jeepney fare fuzzy rule-based inference sytem

2.3 Fuzzy Sets

There are 2 fuzzy sets used in the study, which are the total cost and distance. For the total cost, there are 5 membership functions which are very low, low, average, high and very high respectively, which is shown in figure 2. On the other hand, distance is composed of 9 membership functions, which are the first 4 kilometres, 8 memberships' functions with additional or incremental of 1kilometre shown in figure 3.

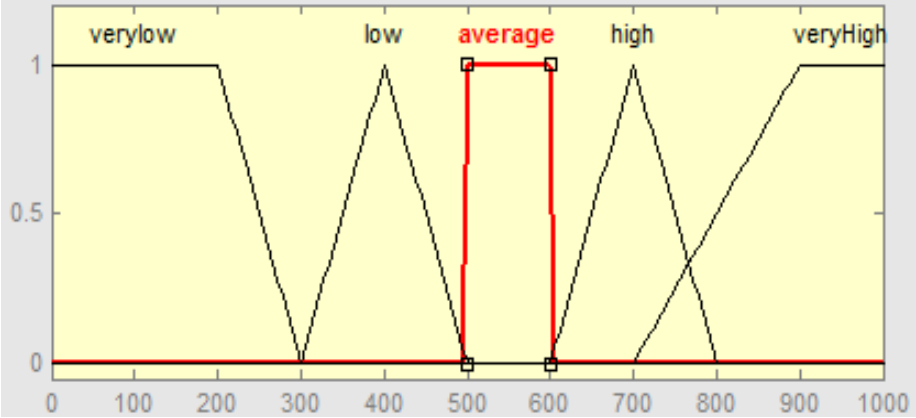

Figure 2. Total cost membership function

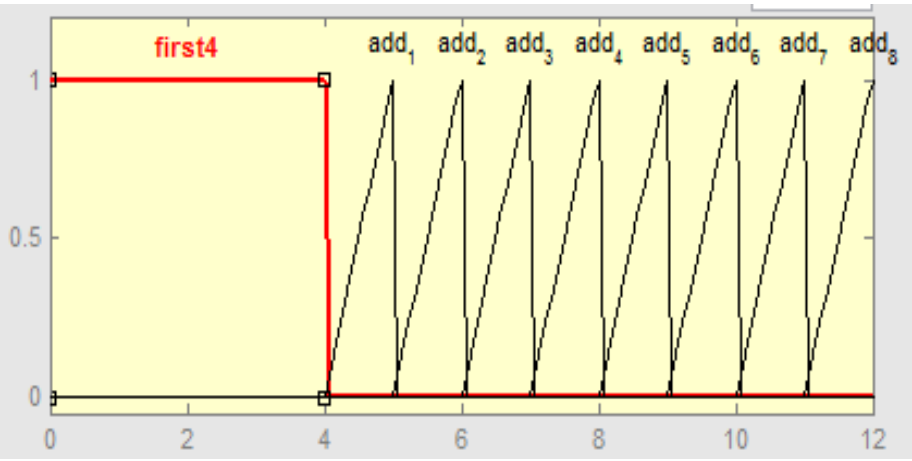

Figure 3. Distance membership function

2.4 Fuzzy Rules

The fuzzy rules will preside and control the principle of the whole fuzzy system in my study. It shows the conditions, the if, and then. A fuzzy implication rule describes a generalized logic implication relationship between inputs and outputs. The foundation of a fuzzy implication rule is the narrow sense of fuzzy logic (Yen and Langari1999). In this study, there are 53

fuzzy rules which are shown in Table 2.

Table 2. Fuzzy Rules

Condition	If		Then
	Total Cost	**Distance**	**Jeepney Fare**
1	very low		low
2	very low	first 4km	low
3	very low	add1	decrease
4	low		decrease
5	low	first 4km	decrease
6	average	first 4km	minimum
7	average	first 4km	minimum
8	very low	add2	minimum
9	low	add1	minimum
10		add1	increase1
11	very low	add3	increase1
12	low	add2	increase1
13	average	add1	increase1
14	high	first 4km	increase1
15		add2	Increase2
16	very low	add4	increase2
17	low	add3	increase2
18	average	add2	increase2
19	high	add1	increase2
20	very high	first 4km	increase2
21		add3	increase3
22	very low	add5	increase3
23	low	add4	increase3
24	average	add3	increase3
25	high	add2	increase3
26	very high	add1	increase3
27		add4	increase4
28	very low	add6	increase4
29	low	add5	increase4
30	average	add4	increase4
31	high	add3	increase4
32	very high	add2	increase4
33		add5	increase5
34	very low	add7	increase5
35	low	add6	increase5
36	average	add5	increase5
37	high	add4	increase5
38	very high	add3	increase5
39		add6	increase6
40	very low	add8	increase6
41	low	add7	increase6
42	average	add6	increase6
43	high	add5	increase6
44	very high	add4	increase6
45		add7	increase7
46	low	add8	increase7
47	average	add7	increase7
48	high	add6	increase7
49	very high	add5	increase7

50		add8	high
51	average	add8	high
52	high	add7	high
53	very high	add6	high

2.5 Defuzzification

Defuzzification involves conversion of the out membership function to a crisp value. There were 11 membership functions used in the study to determine the exact jeepney fare shown in figure 4. The result can be used to set the minimum, increase, and decrease of jeepney fare.

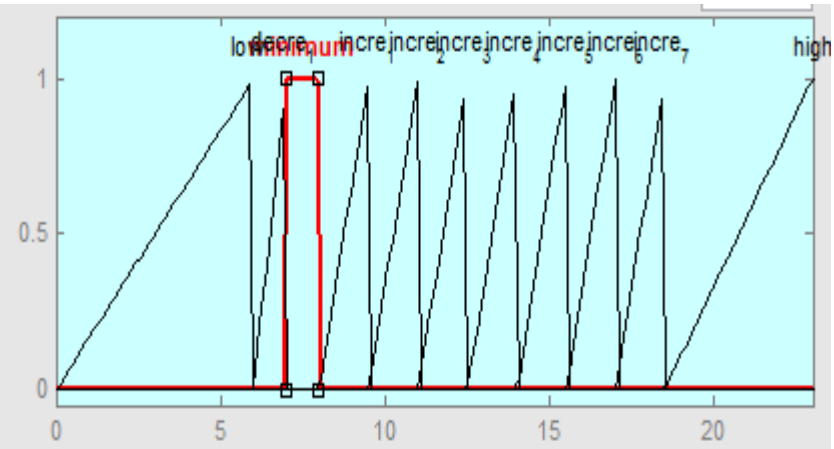

Figure 4. Jeepney fare membership function

3. RESULTS AND DISCUSSION

The scenario that will be shown in this study is the increasing total cost of the jeepney as well as increasing distance travelled by the jeepney. The results were obtained during the simulation of jeepney fare rule-based inference system was shown in table 3.

Table 3. Jeepney fare results based on fuzzy rule- based system, constant total cost with increasing distance

Total Cost (Php)	**Distance (km)**	**Fuzzy Logic Jeepney fare (Php)**	**LFTRB Jeepney fare (Php)**
506.00	4	7.48	8.00
513.75	5	8.19	10.00
521.50	6	8.73	11.50
529.50	7	9.57	13.00
537.00	8	9.98	14.50
544.75	9	10.9	16.00
552.50	10	11.2	17.50
560.25	11	12.2	19.00
568.00	12	17.6	20.50

The result shows that as the total cost and distance increases, the jeepney fare increases also. The result of fare of jeepney for a distance of 4km with a total cost of jeepney of Php 506.00 is Php 7.48 while the current jeepney's minimum fare set by LFTRB for the first 4km is Php 8.00. Moreover, it was observed in this study that in every 2 kilometres increase of distance, the jeepney fare increase of about Php 1.25 compared to the LFTRB fare matrix of additional Php 1.50 for every succeeding kilometre. Also, it was observed in this study that the increase cost of fuel has minimal effect on the jeepney's fare, while the increase of distance have a significantly effect on the fare of the jeepney.

Figure 5 illustrates the surface view in the three-dimensional view of the relationship between the input, which are the total cost of the jeepney per day and the distance travelled of the jeepney and the output, which is the jeepney fare.

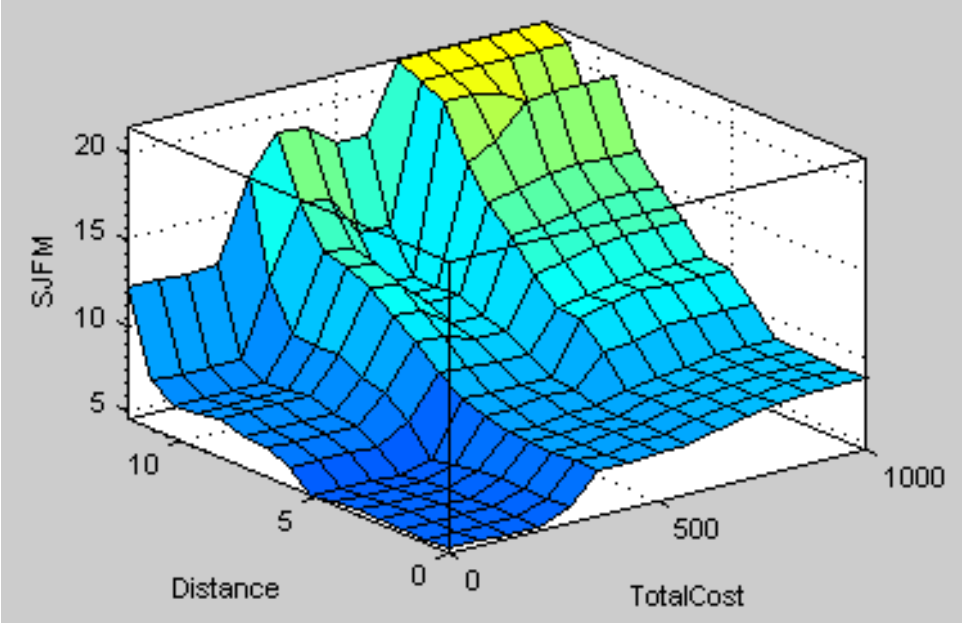

Fig. 5. Surface view of the total cost, distance and jeepney fare

Figure 6 illustrates the surface view in the two-dimensional view of the relationship between the total cost of the jeepney per day and the jeepney fare. The total cost is directly proportional to the jeepney fare. While figure 7 illustrates the surface view in the two-dimensional view of the relationship between the distance travelled of jeepney per day and the jeepney fare. After 4km, the graph shows that the distance is directly proportional to the jeepney fare.

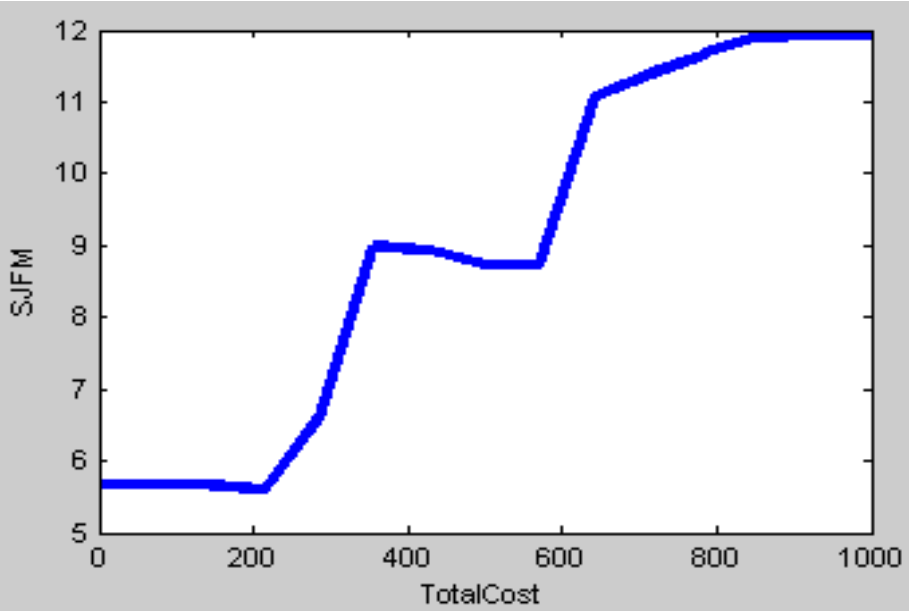

Figure 6. Relationship between jeepney fare and total cost

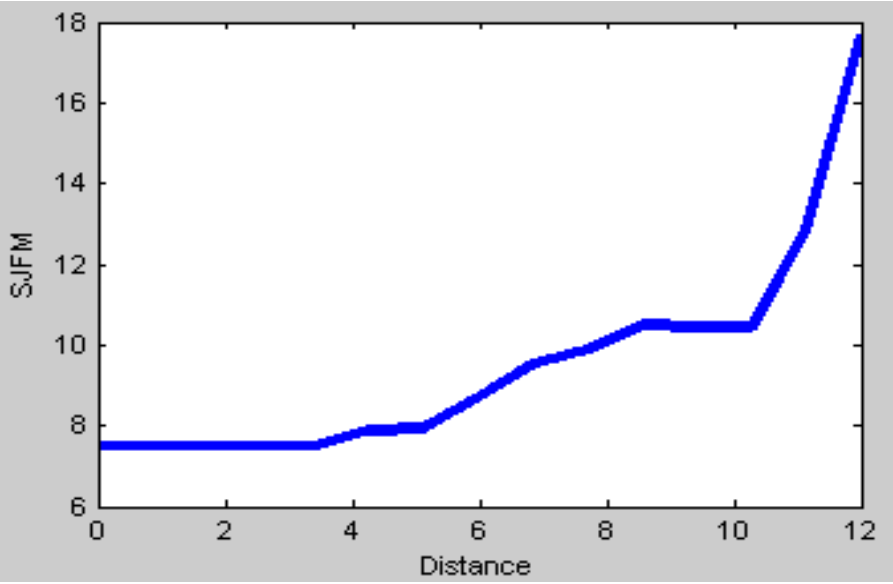

Figure 7. Relationship between jeepney fare and distance

Based on the figures above, the jeepney fare fuzzy ruled-based inference system responded to the operational changes as determined by the input quantities working variations. The jeepney fare fuzzy ruled-based inference system works and responds to the input value changes efficiently.

4. CONCLUSION

This paper developed and proposed a jeepney fare model using fuzzy logic. Based on the results of this study, jeepney fare can easily determine using fuzzy ruled-based inference system without formulating mathematical equations. The jeepney fare fuzzy ruled-based inference system responded efficiently as the total cost and distances changes their values. The study found out that the increase cost of fuel has minimal effect on the jeepney's fare, while the increase of distance have a significantly effect on the fare of the jeepney. Finally, it can be concluded that the jeepney fare fuzzy ruled-based inference system developed in this study can provide estimates and simulates the increase and decrease of jeepney fare based on the total cost of the jeepney per day and the total distances travelled by jeepney.

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