ISSN 2347 - 3983
Volume 8. No. 8, August 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter25882020.pdf
https://doi.org/10.30534/ijeter/2020/25882020

Fuzzy-AHP based Decision Support Model for Assessing Public Transport Service

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ABSTRACT

Service level of transporter should be measured objectively. It functioned to increase the quality level of transportation players' service and also be operated to make an objective decision by local or central government. By using combination between fuzzy logic and AHP methods, a decision support model for measuring the public transport level was successfully developed. It was finally able to determine the quality of service level for two types of public transport in area Ciputat district in Indonesia.

Key words: Fuzzy logic, analytic hierarchical process, decision support model.

1. INTRODUCTION

Transportation is a very influential element in the economy. All aspects of national life depend on this sector, which functions for driving, supporting, and driving the economic growth. If the sector is not worked well so it is able to make economy development grow slowly and it's also cannot be enjoyed optimally for all people.

One aspect of transportation that concerns the lives of many people is public transportation. The development of road-based mass public transportation in urban areas in Indonesia is aimed at creating services that are reliable and affordable by all levels of society that use public transport services. In the long run, it is hoped that the existence of reliable public transportation services will be able to reduce the dependency of the community on the use of private vehicles [1].

Referring to the traffic law and road transportation number 14 of 1992, the condition of road-based mass public transport in urban areas in Indonesia is currently not well ordered. The performance of public transport has not been adequate, the quality of service has not been a priority. The main priority right now is cheap public transportation so that it is affordable to all levels of society. But often these reasons are used to reduce the quality of service. Whereas public service must take precedence because it involves the lives of many people. Wards often sacrifice safety, reliability, and comfort, which are the three most important things in transportation [2].

According to [3] explained in transportation services, service quality is the main key that influences consumers in decision making, especially in public services to the community as consumers (Alexandria Brysland, Adrienne Curry.) The quality of services provided to consumers can be measured through analysis which consists of physical evidence (tangible), reliability (reliable), responsiveness, and empathy. We also make the analysis for parameter in the assessment of public transportation services D01 and D02 Ciputat - Pondok Pinang route.

This study aims to make an objective decision on the evaluation of public transport services D01 and D02. From these two objects we will evaluate all aspects of the parameters we have prepared (found in the discussion chapter). This research is expected to be able to make a decision in determining the best service among public transports D01 and D02.

2. THEORETICAL FRAMEWORK

2.1 Fuzzy-AHP Measurement

Based on [4], to assess something using the concept of fuzzy-logic, the main requirement is the availability of membership functions from the value of bias. For nine types of absolute values for pairwise comparison assessments on AHP, the triangular membership function used is as in **Figure 1**. The fuzzy value determined can be seen in **Table 1**. In the triangular membership function, each value consists of three value types: lower, middle, and upper (l, m, and u).

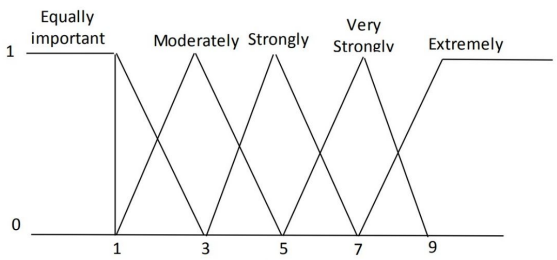

Figure 1: Triangular Membership Function

Table 1: Numerical Rating, Verbal Judgment, and Fuzzy Value

AHP Numerical Ratings	Verbal Judgements	Fuzzy Value
1	Equally important (equ)	(1,1,3)
3	Moderately more important (mod)	(1,3,5)
5	Strongly more important (str)	(3,5,7)
7	Very strongly more important (vstr)	(3,5,9)
9	Extremely more important (ext)	(7,9,9)

2.2 Process of Fuzzy-AHP

Fuzzy-AHP process in a decision support system is started by doing pairwise comparison on each parameter and sub parameter using verbal judgment, with example 2 parameters in **Table 2** [4].

Table 2: Example of Pairwise Comparison between Two Parameters

	V1	**V2**
V1	equ	mod
V2	not-mod	equ

Furthermore, performing the conversion process of the value for each judgment, and final producing fuzzy values for each pair are mentioned in **Table 3**. (I, m, u) inverse to become (1 / u, 1 / m, 1 / l). Example: V1 vs V2 → Mod = (1, 3, 5). V2 vs V1 → not-mod = (1/5, 1/3, 1/1) = (0.20, 0.33, 1.00).

Table 3: Result of Fuzzy Value Convert

	V1	**V2**
V1	1, 1, 3	1, 3, 5
V2	0.2, 0.33, 1	1, 1, 3

Then, calculating the midpoint (centroid measurement). Each parameter line is calculated midpoint by dividing it into three types of values (lower, middle, and upper). Here are the three types of values: the lower parameter v1 is: (lv1 = √1*x*1 =.); the value of middle parameter v1: is: (mv1 = √1*x*3 =.); the value of upper parameter v1: is (uv1 = √3*x*5 = ..). In calculating the midpoint of the parameter V2, the steps are the same as calculating V1. Calculating the normalization process for each parameter, by adding up each value for each of its lower, middle, and upper values. Example: L total = 1.71 + 0.58 + 0.28 = 0.57; M total = 2.76 + 1 + 0.36 = 4.12; U total = 5.13 + 2.47 + 0.84 = 8.44

The next stage is normalization process. This process is specific to the triangle function, then the upper divisor value is used to divide the lower value of the corresponding parameter, and vice versa, the lower divisor value is used to divide the upper value of the corresponding parameter, but the middle divisor value is still used to divide the middle value of the parameter concerned. Formula: For parameters V = (L / U, M / M, U / L), where U = upper, L = lower, and M = middle.Then doing the de-fuzzification process. To get the value of crisp output (CO). The equation used CO = ½ (au + m + (1-a) l); where a is the degree of optimism (value $0 \geq a \geq 1$, usually value 0.5). In the calculation process the same as the normalization of the upper and lower values are exchanged, for example: V1 = (l, m, u) = 0.5 x (0.5 x u + m (1 - 0.5) l) [4]. After weighting to determine priority parameters and sub-parameters is obtained, then weighting alternative decisions based on data obtained from interviews with experts (in this case study, drivers and transportation department officials / TDO) and national and international journals. This weighting is in accordance with the analysis carried out and has a scale of 0-1.

The final process is to conclude the results of the data to find out the highest value in the calculation results, then to find out and determine which public transportation is the best between D01 and D02, which is then used in supporting decisions. With the formula: (large priority parameter x large priority sub parameter x large value of alternative weights to parameters). Example: 0.5 x 0.5 x 0.6 = 0.15.

3. RESEARCH METHODOLOGY

3.1 Data Collecting

At the stage of collecting data to obtain good and correct data, the data collection techniques that researchers do are: collecting primary data and getting secondary data. In collecting the primary data, this data research was conducted by direct observation to the field, interviews (interviews) as a means or method of collecting data orally by conducting interviews directly with experts who understand about public transportation (in this case study the driver and TDO). Then in gathering secondary data, research data or information through written notes relating to the topic being worked on. This data research was carried out with library research, namely by collecting data from books, e-books, scientific papers, and national or international journals.

3.2 Parameters and Sub-Parameters

In this study, four selected parameter were determined scientifically. The parameters were defined via literature study with [5] method. They are described clearly in **Table 4**; where they were divided into two categories; parameter (par.) and sub-parameter (sub-par.). The selected parameters are reliability, responsiveness, empathy, and tangible with their specific sub-parameters. Then, for AHP process purpose, they were arranged structurally like in **Figure 2**, with decision making as a pick goal is to determine “the best public transportation ”.

Table 4: Selected Parameters and Sub-Parameters

No.	Par.	Sub-Par.
1.	Reliability (P1)	Punctuality (P11)
		Security (P12)
		Comfort (P13)
2.	Responsiveness (P2)	Availability of Transportation Services (P21)
		Responsive Aspiration to the customer (P22)
3.	Empathy (P3)	Driver's Attitude (P31)
		Driver's Care (P32)
4.	Tangible (P4)	New Vehicle (P41)
		Seating Facilities (P42)
		Cleanlines (P3)
		Neatness (P4)

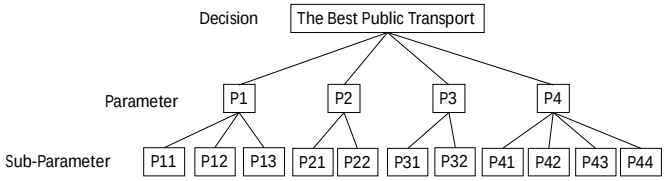

Figure 2: Hierarchical Structure for Selected Parameters and Sub-Parameters

3.3 Research Object

Two types of public transports operated as research object. They are public transport D01 namely city transport for route Kebayoran - Ciputat and public transport D02 namely city transport for route Pondok Labu - Ciputat. Researchers conducted a survey of the two public transports from Ciputat to Pondok Pinang route, with a distance of 4.8 KM.

4. RESULT AND DISCUSSION

The following is a step-by-step discussion of a case study of the assessment of public transport services between routes D01 and D02 that has been carried out. Make a pairwise comparison table using verbal judgment. Paired comparison tables between the main parameters was based on evidence according to expert judgment. They were represented via Tables 5 – 9.

Table 5: Pairwise Comparison for Main Parameter

Par.	P1	P2	P3	P4
P1	equ	str	mod	vstr
P2	not-str	equ	mod	mod
P3	not-mod	not-mod	Equ	str
P4	not-vstr	not-mod	not-str	Equ

Table 6: Pairwise Comparison for Sub-Parameter P1

P1	P11	P12	P12
P11	Equ	vstr	str
P12	not-vstr	equ	Str
P13	not-str	not-str	Equ

Table 7: Pairwise Comparison for Sub-ParameterP2

P2	P21	P22
P21	equ	Mod
P22	not-mod	Equ

Table 8: Pairwise Comparison for Sub-Parameter P3

P3	P31	P32
P31	equ	str
P32	not-str	equ

Table 9: Pairwise Comparison for Sub-Parameter P4

P4	P41	P42	P43	P44
P41	equ	mod	vstr	vstr
P42	not-mod	equ	str	mod
P43	not-vstr	not-str	equ	vstr
P44	not-vstr	not-mod	not-vstr	equ

Furthermore, each parameter and sub parameters were converted into fuzzy value. They are mentioned in **Table 10 – 14**. Then, centroid measurement for each parameter and sub-parameter are mentioned in **Table 15 – 19**.

Table 10: Fuzzy Value Convert for Main Parameters

Par.	P1	P2	P3	P4
P1	(1, 1, 3)	(3, 5, 7)	(1, 3, 5)	(5, 7, 9)
P2	0.14, 0.20, 0.33	(1, 1, 3)	(1, 3, 5)	(1, 3, 5)
P3	0.20, 0.33, 1.00	0.2, 0.33, 1.00	(1, 1, 3)	(3, 5, 7)
P4	0.11, 0.14, 0.20	0.2, 0.33, 1.00	0.14, 0.20, 0.33	(1, 1, 3)

Table 11: Fuzzy Value Convert for Sub-Parameter P1

P1	P11	P12	P13
P11	(1, 1, 3)	(5, 7, 9)	(3, 5, 7)
P12	0.11, 0.14, 0.2	(1, 1, 3)	(3, 5, 7)
P13	0.14, 0.2, 0.33	0.14, 0.2, 0.33	(1, 1, 3)

Table 12: Fuzzy Value Convert for Sub-Parameter P2

P2	P21	P22
P21	(1, 1, 3)	(1, 3, 5)
P22	0.2, 0.33, 1	(1, 1, 3)

Table 13: Fuzzy Value Convert for Sub-Parameter P3

P3	P31	P32
P31	(1, 1, 3)	(3, 5, 7)
P32	0.14, 0.2, 0.33	(1, 1, 3)

Table 14: Fuzzy Value Convert for Sub-Parameter P4

P4	P41	P42	P43	P44
P41	(1, 1, 3)	(1, 3, 5)	(5, 7, 9)	(5, 7, 9)
P42	0.20, 0.33, 1.00	(1, 1, 3)	(3, 5, 7)	(1, 3, 5)
P43	0.11, 0.14, 0.20	0.14, 0.20, 0.33	(1, 1, 3)	(5, 7, 9)
P44	0.11, 0.14, 0.20	0.20, 0.33, 1.00	0.11, 0.14, 0.20	(1, 1, 3)

Table 15: Centroid Measurement Result for Main Parameters

Par.	Lower	Middle	Upper
P1	2.46	4.71	9.81
P2	0.51	1.21	2.91
P3	0.49	0.81	2.80
P4	0.14	0.20	0.58

Table 16: Centroid Measurement Result for Sub-Parameter P1

P1	Lower	Middle	Upper
P11	2.46	3.27	5.73
P12	0.69	0.88	1.61
P13	0.26	0.34	0.68

Table 17: Centroid Measurement Result for Sub-Parameter P2

P2	Lower	Middle	Upper
P21	1.00	1.44	2.46
P22	0.58	0.69	1.44

Table 18: Centroid Measurement Result for Sub-Parameter P3

P3	Lower	Middle	Upper
P31	1.44	1.70	2.75
P32	0.51	0.58	0.99

Table 19: Centroid Measurement Result for Sub-Parameter P4

P4	Lower	Middle	Upper
P41	2.92	5.27	10.67
P42	0.84	1.70	4.71
P43	0.42	0.58	1.21
P44	0.13	0.18	0.49

Normalization in the fuzzy-ahp method is divided into two stages. First is calculate the sum of each lower, middle, and upper values to get the total values of lower, middle, and upper (Table 20). Second is stage dividing the upper divisor value by lower value, middle divider value divided by middle value, and dividing lower divisor value by upper value (Table 21 – 25).

Table 20: The Sum of the Lower, Middle, and Upper (Total)

Par. and Sub-Par.	Total Lower	Total Middle	Total Upper
P1, P2, P3, P4	3.60	6.93	16.10
P11, P12	3.41	4.49	8.02
P21, P22	1.58	2.13	3.90
P31, P32	1.95	2.28	3.74
P41, P42, P43, P44	4.31	7.73	17.08

Table 21: Normalization Result for Main Parameters

Par.	Lower	Middle	Upper
P1	0.15	0.67	2.72
P2	0.03	0.17	0.80
P3	0.03	0.11	0.77
P4	0.08	0.02	0.16

Table 22: Normalization Result for Sub-Parameter P1

P1	Lower	Middle	Upper
P11	0.30	0.72	1.68
P12	0.08	0.19	0.47
P13	0.03	0.07	0.19

Table 23: Normalization Result for Sub-Parameter P2

P2	Lower	Middle	Upper
P21	0.25	0.67	1.55
P22	0.14	0.32	0.91

Table 24: Normalization Result for Sub-Parameter P3

P3	Lower	Middle	Upper
P31	0.38	0.74	1.41
P32	0.13	0.25	0.50

Table 25: Normalization Result for Sub-Parameter P4

P4	Lower	Middle	Upper
P41	0.170	0.68	2.47
P42	0.040	0.21	1.09
P43	0.020	0.07	0.28
P44	0.007	0.02	0.11

The process of de-fuzzification or the search for CO values is carried out to get the weight of the parameters that will be the priority parameters in a case study. They mentioned in Table 26 – 30. And, the sub-parameters' weight is mentioned in Table 31.

Table 26: Result of De-fuzzification Process for Main Parameters

Par.	CO	Normalized CO
P1	1.05	0.65
P2	0.29	0.17
P3	0.25	0.15
P4	0.05	0.03

Table 27: Result of De-fuzzification Process for Sub-Parameter P1

P1	CO	Normalized CO
P11	0.85	0.73
P12	0.23	0.19
P13	0.09	0.08

Table 28: Result of De-fuzzification Process for Sub-Parameter P2

P2	CO	Normalized CO
P21	0.78	0.65
P22	0.42	0.35

Table 29: Result of De-fuzzification Process for Sub-Parameter P3

P3	CO	Normalized CO
P31	0.81	0.74
P32	0.28	0.26

Table 30: Result of De-fuzzification Process for Sub-Parameter P4

P4	CO	Normalized CO
P41	1.00	0.65
P42	0.38	0.25
P43	0.11	0.07
P44	0.03	0.02

Table 31: Sub parameter weights

Par. & Sub-Par.	D01	D02
P1		
P11	0.50	0.60
P12	0.20	0.40
P13	0.60	0.30
P2		
P21	0.50	0.50
P22	0.30	0.30
P3		
P31	0.60	0.30
P32	0.40	0.20
P4		
P41	0.40	0.20
P42	0.40	0.30
P43	0.40	0.40
P44	0.40	0.40

Weighting Reasons are explained here. Punctuality means travel time using public transportation [6]. According to field survey data, the trip distance is 4.8 KM and in a busy road condition D02 public transport takes 27 minutes and public transport D01 takes 29 minutes. Then, Security means provides a sense of security from crime [7]. According to the results of interviews with drivers, on public transportation D02 is very rare because drivers remind passengers to pay attention to their luggage. While public transportation D01 is more common because drivers do not appeal to passengers for their luggage. Comfort is about comfort of the chair provided [6]. According to the results of interviews with the driver, D01 provides a more comfortable seat because the vehicle used is still quite new (in 2011) compared to D02 that uses a carriage vehicle (in 2000).

Furthermore, availability of transport services is regarding availability of transport [6]. The results of observations in the field, D01 and D02 are equally easy in getting the transport fleet. Responsiveness of customer aspirations is about drivers are willing to respond to passenger requests [7]. The results of interviews with transport drivers D01 and D02, the driver did not really care about the comments of passengers on the public transportation. Then, driver attitude is discussing about drivers are friendly and polite [7]. The results of interviews with drivers show that D01 public transportation drivers are more-friendly with passengers because drivers like to invite passengers to communicate.

Moreover, driver concern for customers is about drivers are willing to help passengers [7]. According to the results of the interview, the D01 public transportation driver once helped passengers who were being robbed to show the driver cared about the passenger. Fleet novelty is a good and decent vehicle [7]. According to an interview with a driver, public transportation D01 uses a granmax-vehicle in 2011 which can be said to be quite new compared to public transportation D02 that uses a 2000 vehicle. Seating facilities means comfort and flexibility of seating [6]. Based on field observations, public transport D01 uses a wider granmax vehicle than public transport D02 uses a carriage vehicle. Cleanliness is regarding cleanliness of floors and shuttles [6]. The results of observations in the field, on the same public transport between D01 and D02 there is no garbage but the glass looks dirty. Finally, Neatness is about facilities in the vehicle [7]. Facilities on both public transport D01 and D02 are the same, only having neatly installed seats like public transport in general without additional facilities.

Table 32 shows the comparison between to public transports based on parameter P1. The result also described clearly via Figure 3 and 4 (in bar-chart and pie-chart respectively). Also with parameters P2, P3, and P4. They represented by Table 32 – 34 and with Figure 5 – 10.

Table 32: Transporter Comparison based on Parameter P1

P1		
Sub-Par.	**D01**	**D02**
P11	0,365	0,438
P12	0,038	0,076
P13	0,048	0,024

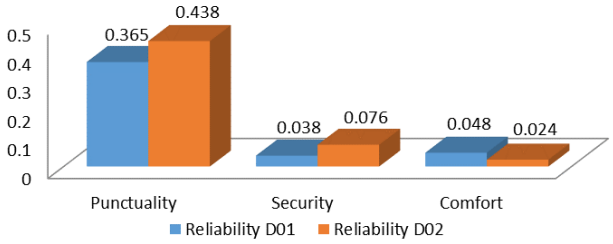

Figure 3: Bar-Chart for Transporter Comparison with P1 Sub-Parameters

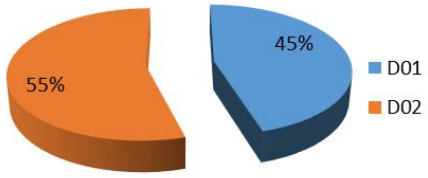

Figure 4: Pie-Chart for Transporter Comparison with P1 Parameter

Table 33: Transporter Comparison based on Parameter P2

P2		
Sub-Par.	**D01**	**D02**
P21	0.325	0.325
P22	0.105	0.105

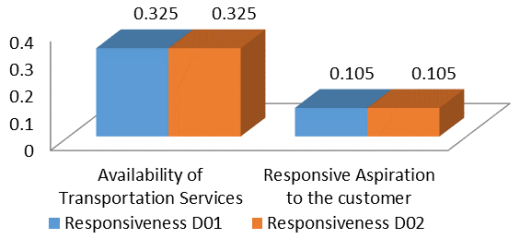

Figure 5: Bar-Chart of Transporter Comparison with P2 Sub-Parameters

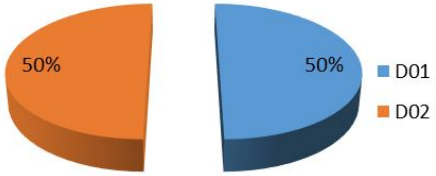

Figure 6: Pie-Chart of Transporter Comparison with P2 Parameter

Table 34: Transporter Comparison based on Parameter P3

P3		
SubPar.	**D01**	**D02**
P31	0.444	0.222
P32	0.104	0.052

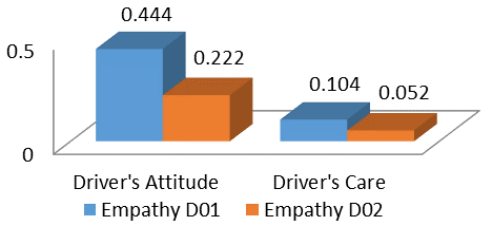

Figure 7: Bar-Chart of Transporter Comparison with P3 Sub-Parameters

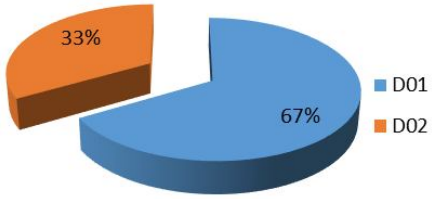

Figure 8: Pie-Chart of Transporter Comparison with P3 Parameter

Table 35: Transporter Comparison based on Parameter P4

P4		
Sub-Par.	**D01**	**D02**
P41	0.260	0.130
P42	0.100	0.075
P43	0.028	0.028
P44	0.008	0.008

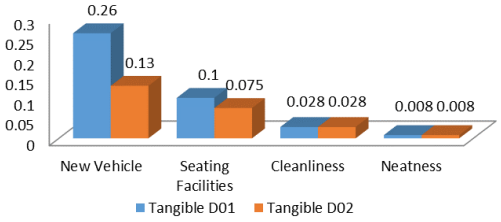

Figure 9: Bar-Chart of Transporter Comparison with P4 Sub-Parameters

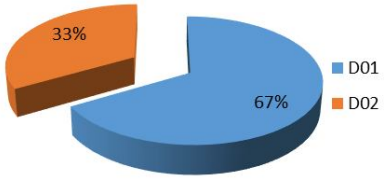

Figure 10: Bar-Chart of Transporter Comparison with P4 Parameter

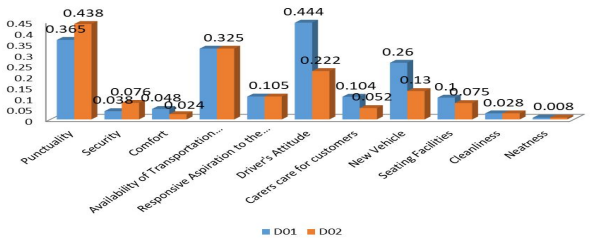

Figure 11: Bar-Chart of Transporter Comparison with All Sub-Parameters

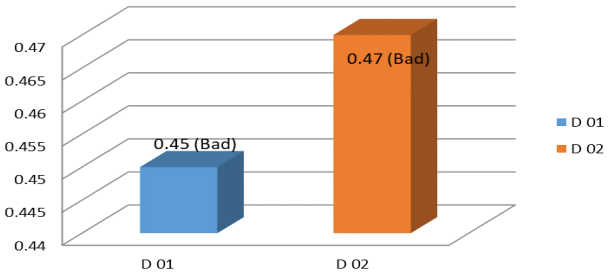

Figure 12: Bar-chart Conclusion Results of Parameters Calculation using the Fuzzy-AHP Method

Moreover, Figure 11 presents all sub-parameters' comparison for D01 and D02. Then, Figure 12 is the final result of research on public transportation assessment D01 and D02 Ciputat - Pondok Pinang route with a distance of 4.8 KM, taking into account several parameters which are subdivided from several sub parameters using the Fuzzy-AHP method. It can be concluded that the values of both city transportation (public transport) D02 and D01 are poor based on assessment criteria. With values D01: 0.45 and D02: 0.47. The final result is also able to be measured via other conception of fuzzy logic like ever executed by [8] or [9].

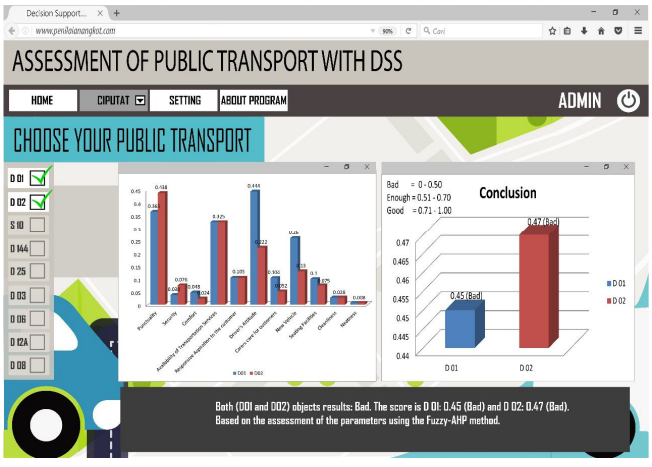

Figure 13: Dashboard of the Constructed Model

Figure 13 is a dashboard of the constructed model. The dashboard layout contains the assessment of all parameters D01 and D02 contained in the form of bar graphs. In the bar graph, it can be seen that the parameter values of D01 and D02 do not differ greatly. Many of the D01 graphs are superior to the D02 graph, but in this assessment, the value of a sub parameter has a different value / weight. So the results of the calculation of the two objects by considering the parameters produce a value of Bad (Bad) seen from the predetermined value criteria, with values D01: Bad (0.45) and D02: Bad (0.47).

On the left side of the dashboard, there are public transport routes that can be selected one or more to be assessed according to existing parameters. Then, there is the location menu, where on the dashboard there is a Ciputat text that is intended that is the type of existing public transport and can be assessed in the area. Then, there are several menus such as Home, Location, Settings and About Programs. The Home menu here functions to return to the initial dashboard view of this system and contains information and explanations about public transport ratings. Next, the Settings menu to provide settings and the About Program Menu to find out the version of the system we are using. Whereas in the upper right hand corner, there is a user name and a Power or Log out button that functions to exit when it has finished using the public transportation service assessment system that is currently running.

5. CONCLUSION AND FURTHER WORK

The fuzzy-AHP based DSM was successfully developed. It considers four parameters and eleven sub-parameters. The model was able to scientifically measured two types of public transporters in area Ciputat, Indonesia. Based on measurement, they still have bad aggregated-value. It means, the public transporter in such an area still needs to be improved in selected indicators.

The other parameters are possibly analyzed to enrich the model. Such as driving quality, safety, and also assurance. Also, other methods for decision making are still opened to be considered to enrich the model in the next study.

ACKNOWLEDGEMENT

We would like to thank BINUS University who has supported our works, particularly BINUS graduate program, Master of Computer Science.

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