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Research Paper

Decision Support in Asphalt Production with Triangular Fuzzy Number

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ABSTRACT: *The construction of highway infrastructure is growing rapidly to support the mobility needs of the society. Generally, flexible pavements dominate the construction of new roads and road preservation by relying on hot mix asphalt materials. Therefore, the demand for production of hot mix asphalt mixtures is still very large to sufficiently expand the road network in Indonesia. The purpose of this study is to analyze the optimization of the production system at a hot mix asphalt company for flexible pavement projects. An analytical approach based on artificial intelligence with fuzzy logic is used in this research because of the many advantages of this method, especially when it comes to decision making. The main steps in the analysis of fuzzy systems are fuzzification, inference and defuzzification. The data comes from asphalt company and expert judgment who are related with road project. The results of the analysis give a multi input single output (MISO) fuzzy system. It was found 4 fuzzy inputs, namely the demand of hot mix, liquid asphalt materials, coarse aggregate materials, and fine aggregates, while the fuzzy output was the amount of production. Fuzzy input and output were represented in its membership functions. The mapping process between input and output fuzzy delivered 81 fuzzy rule sets based on interviews and expert judgment. The developed system of hot mix production is used to support decision making in production efficiency.*
KEYWORDS: *Triangular Fuzzy Number, Decision Support, Production System*

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I. INTRODUCTION

Highways are one of the transportation infrastructures for people's mobility with an important role in economic, social, cultural, environmental, political, defense and security activities (Anonim, 2004)(Anonim, 2011)(Aulia, 2011)(Pandey & Sarajar, 2017). Road infrastructure is growing rapidly in the procurement of new projects and preservation activities where flexible pavement layers are still the most preferred among all road projects. Flexible pavements are more comfortable for drivers than rigid pavements, due to the good adaptation of the asphalt layer when it comes into contact with the vehicle wheels, but the weakness of flexible pavement is vulnerable to the influence of climate and weather factors. Flexible pavement uses liquid asphalt material as a binder between coarse and fine materials, so it is called hot mix asphalt (Pandey & Sarajar, 2017)(Sahrianto, 2016).

High rate in road project activities with flexible pavement has contributed to the development of the Asphalt Mixing Plant (AMP) as a place for mixing all hot mix materials and a supplier for highway project implementation (M Hadi, 2022). Asphalt production is uncertain depending on project demand. In certain periods it is very high, but in other periods is low. This condition causes inefficiency in production or overload in certain periods, due to limited capacity owned by the company. Therefore, it is necessary to analyze production optimization for hot mix companies in order to reach effective and efficient results (Chandra, 2014). Generally, optimization problems are related to decision making. Likewise, in the case of hot mix asphalt production, it is highly dependent on the changing demand for asphalt mixtures and material stocks that can be provided by suppliers cannot always be realized as needed.

Decision-making analysis will be more precise and realistic using the basic human knowledge approach (Gunduz, M., Birgonul, T., & Ozdemis, 2017)(Javadi, M., Saeedi, G., & Shahriar, 2017)(Winanda,

L.A.R, Arifin, A., Adi, T.J., Arrofiqi, F., 2020). Fuzzy system is a system that is developed based on the logical thinking and human perception. The basic assumption of the system is that the way of human thinking in distinguishing things is very subjective and uncertain. The results are more logic although not as precise as exact numbers. Fuzzy analysis is widely applied to make decisions in various work cases (Winanda, L.A.R, Arifin, A., Adi, T.J., Arrofiqi, F., 2020)(Valaskova, K., Kliestik, T., & Misankova, 2014).

II. METHODOLOGY

The analysis needs step by step activities to ensure proper completion according to research objectives. The first step begins with extracting information from books, journals and other supporting literatures. The data taken from hot mix asphalt companies and interview with experts. The primary data comes through an interview process with the production manager of hot mix asphalt company and secondary data comes from production data of hot mix asphalt, the capacity of plant and hot mix asphalt demands. The data collection is complemented by interviews with experts involved in road projects. The initial stage of analysis on a fuzzy system is fuzzification by changing crisp/number variables into linguistic variables as fuzzy input. The process is continued with the inference process by mapping the input into the output based on the arranged fuzzy rules. The final stage of the analysis is defuzzification, which is returned back the linguistic outputs into the final result in exact/crisp numbers (Winanda, L.A.R, Arifin, A., Adi, T.J., Arrofiqi, F., 2020)(Winanda, L.A.R, Adi, T.J., Anwar. N.A., Wahyuni, 2017)(Widodo, P. P., & Handayanto, 2012). One of the crucial steps in fuzzy analysis is the determination of fuzzy sets which are represented in the form of membership function curves. The most commonly used form of the curve is the triangular fuzzy number because this curve is widely applied to various problem solving with precise output (Figure 1) (Winanda, L.A.R, Arifin, A., Adi, T.J., Arrofiqi, F., 2019). Fuzzification starts with the identification of input and output variables according to the results of data collection in the form of numbers/crisp. The analysis is continued by generating the inference engine through a number of fuzzy rules that have been identified.

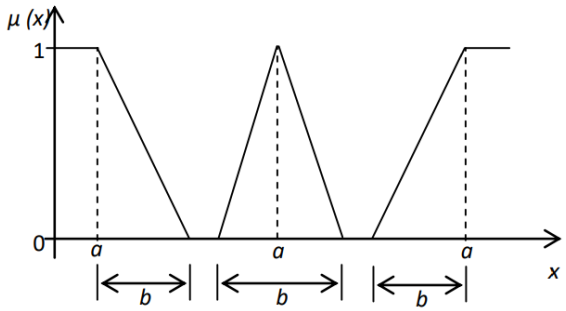

Figure 1. Triangular Fuzzy Number

III. RESULTS AND DISSCUSSION

The results of data collection are arranged and sorted from the smallest value in the data recapitulation table. Input in the form of a request for an asphalt mixture of 83 data. Material inventory consists of three types, namely liquid asphalt material with a total of 11 data, 52 data for coarse aggregate and 98 data for fine aggregate. The output of this analysis is production data of 33 data. The entire fuzzy system that is composed consists of 4 input variables with 1 output variable (multi input single output/ MISO).

According to rounding off the lowest and highest data values for each variable, a fuzzy set universe is generated. The universe of asphalt mix demand variable set is [23; 288]. For the universe of the set of liquid asphalt material availability [18; 144], coarse aggregate [30; 200], and fine aggregate [24; 192]. The production as an output variable has a universal set [0; 320]. Each variable is divided into some level of categories which is generated from the universe of fuzzy sets (domains). This study uses three domains for each variable. The domains in this study were analyzed based on the results of compilation data of the lowest data values, the lower quartile (Q1), the median (Q2), the upper quartile (Q3) and the highest data values. The description of all fuzzy number as listed in table 1.

Tabel 1. Fuzzy Number

Function	Variable	Categories	Universe	*Domain*
Input	Demand	Small	[18; 288]	[23; 140,76]
		Medium		[91,30; 206,48]
		Large		[140,76; 288]
	Liquid Asphalt	Limited	[18; 144]	[18; 59,41]
		Available		[54; 108]

Function	Variable	Categories	Universe	*Domain*
		Large		[59,41; 144]
	Coarse Aggregate	Limited	[30; 200]	[30; 32,64]
		Available		[31,76; 33,46]
		Large		[32,64; 200]
	Fine Aggregate	Limited	[24; 192]	[24; 33,5]
		Available		[32,59; 34,52]
		Large		[33,5; 192]
Output	Production	Small	[0; 320]	[0; 160]
		Medium		[75; 245]
		Large		[160; 320]

The development of fuzzy sets is used to represent each membership function of the identified variables. The membership function is described in a curve that is related to each other according to the universe with the degree of each membership's interval is between 0 to 1. The representation of fuzzy input and fuzzy output as shown in Figure 2 and Figure 3.

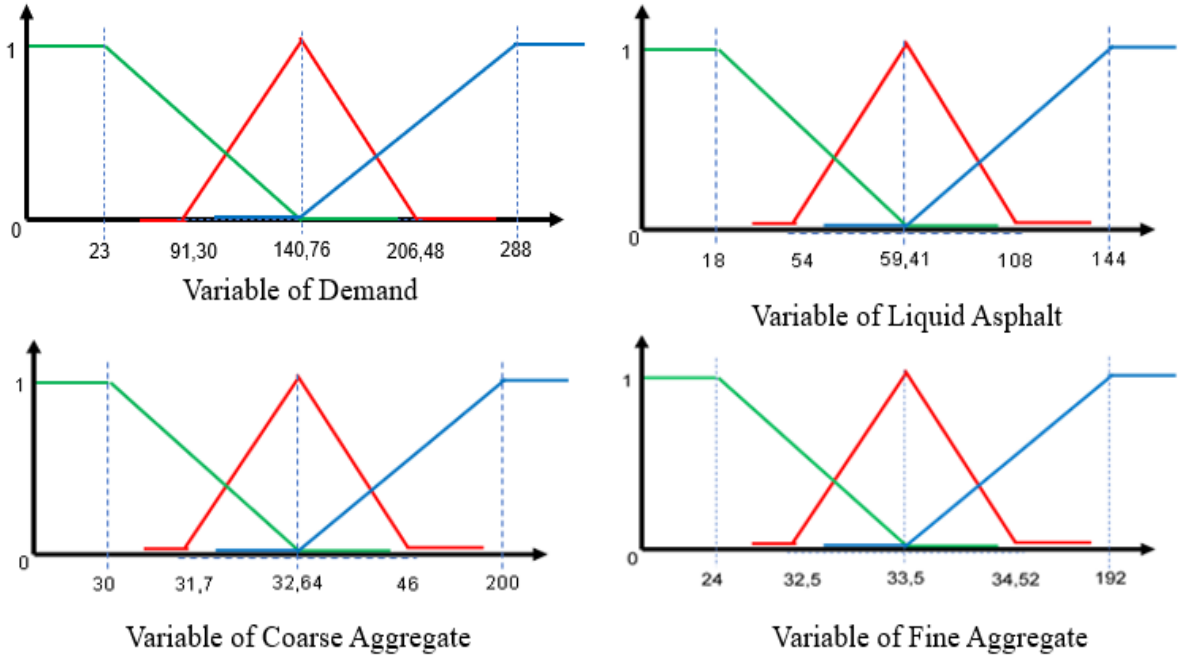

Figure 2. Fuzzy Input Variables

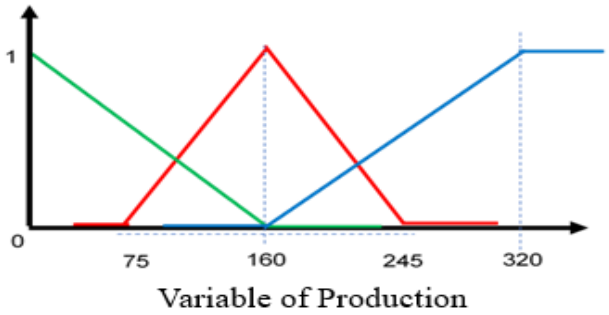

Figure 3. Fuzzy Output Variable

After the mapping of fuzzy input and output is carried out, it is continued with the fuzzy inference system through fuzzy rule sets in *IF – THEN* equations. In this analysis, fuzzy rules were developed based on interviews with asphalt hot mix companies and supported by expert opinions, which are related to the flexible

pavement road project sector. Based on the input and output variables, 81 fuzzy rules are formed as shown in table 2.

Tabel 2. Fuzzy Rule Sets

No.	Input Variable				Output Variable
	Demand	**Liquid Asphalt**	**Coarse Aggregate**	**Fine Aggregate**	**Production**
1	Small	Limited	Limited	Limited	Small
2	Small	Limited	Limited	Available	Small
3	Small	Limited	Limited	Large	Small
4	Small	Limited	Available	Limited	Small
5	Small	Limited	Available	Available	Small
6	Small	Limited	Available	Large	Small
7	Small	Limited	Large	Limited	Small
8	Small	Limited	Large	Available	Small
9	Small	Limited	Large	Large	Small
10	Small	Available	Limited	Limited	Small
11	Small	Available	Limited	Available	Small
12	Small	Available	Limited	Large	Small
13	Small	Available	Available	Limited	Small
14	Small	Available	Available	Available	Small
15	Small	Available	Available	Large	Small
16	Small	Available	Large	Limited	Small
17	Small	Available	Large	Available	Small
18	Small	Available	Large	Large	Small
19	Small	Large	Limited	Limited	Small
20	Small	Large	Limited	Available	Small
21	Small	Large	Limited	Large	Small
22	Small	Large	Available	Limited	Small
23	Small	Large	Available	Available	Small
24	Small	Large	Available	Large	Small
25	Small	Large	Large	Limited	Small
26	Small	Large	Large	Available	Small
27	Small	Large	Large	Large	Small
28	Medium	Limited	Limited	Limited	Small
29	Medium	Limited	Limited	Available	Small
30	Medium	Limited	Limited	Large	Small
31	Medium	Limited	Available	Limited	Small
32	Medium	Limited	Available	Available	Small
33	Medium	Limited	Available	Large	Small
34	Medium	Limited	Large	Limited	Small
35	Medium	Limited	Large	Available	Small
36	Medium	Limited	Large	Large	Small
37	Medium	Available	Limited	Limited	Medium
38	Medium	Available	Limited	Available	Medium
39	Medium	Available	Limited	Large	Medium
40	Medium	Available	Available	Limited	Large
41	Medium	Available	Available	Available	Large
42	Medium	Available	Available	Large	Large
43	Medium	Available	Large	Limited	Large
44	Medium	Available	Large	Available	Large

No.	Input Variable				Output Variable
	Demand	**Liquid Asphalt**	**Coarse Aggregate**	**Fine Aggregate**	**Production**
45	Medium	Available	Large	Large	Large
46	Medium	Large	Limited	Limited	Small
47	Medium	Large	Limited	Available	Small
48	Medium	Large	Limited	Large	Medium
49	Medium	Large	Available	Limited	Small
50	Medium	Large	Available	Available	Large
51	Medium	Large	Available	Large	Large
52	Medium	Large	Large	Limited	Medium
53	Medium	Large	Large	Available	Large
54	Medium	Large	Large	Large	Large
55	Large	Limited	Limited	Limited	Small
56	Large	Limited	Limited	Available	Small
57	Large	Limited	Limited	Large	Small
58	Large	Limited	Available	Limited	Medium
59	Large	Limited	Available	Available	Medium
60	Large	Limited	Available	Large	Medium
61	Large	Limited	Large	Limited	Medium
62	Large	Limited	Large	Available	Large
63	Large	Limited	Large	Large	Large
64	Large	Available	Limited	Limited	Small
65	Large	Available	Limited	Available	Medium
66	Large	Available	Limited	Large	Medium
67	Large	Available	Available	Limited	Large
68	Large	Available	Available	Available	Large
69	Large	Available	Available	Large	Large
70	Large	Available	Large	Limited	Medium
71	Large	Available	Large	Available	Large
72	Large	Available	Large	Large	Large
73	Large	Large	Limited	Limited	Small
74	Large	Large	Limited	Available	Medium
75	Large	Large	Limited	Large	Medium
76	Large	Large	Available	Limited	Large
77	Large	Large	Available	Available	Large
78	Large	Large	Available	Large	Large
79	Large	Large	Large	Limited	Medium
80	Large	Large	Large	Available	Large
81	Large	Large	Large	Large	Large

The representation proceeds of 4 fuzzy inputs, 1 fuzzy output and a series of 81 fuzzy rules become the basis for supporting production decisions for hot mix asphalt companies. All items provide an integrated assessment of considerations in making the right and economical decisions. Thus, the company is expected to minimize losses due to overproduction, as well as decreased branding due to inability to serve demand in consequence of insufficient inventory and production capacity.

IV. DISSCUSSION

In this analysis, the hot mix production process became the basis for initial identification by describing the types of hot mix asphalt forming materials, along with their availability in the stocking yard.

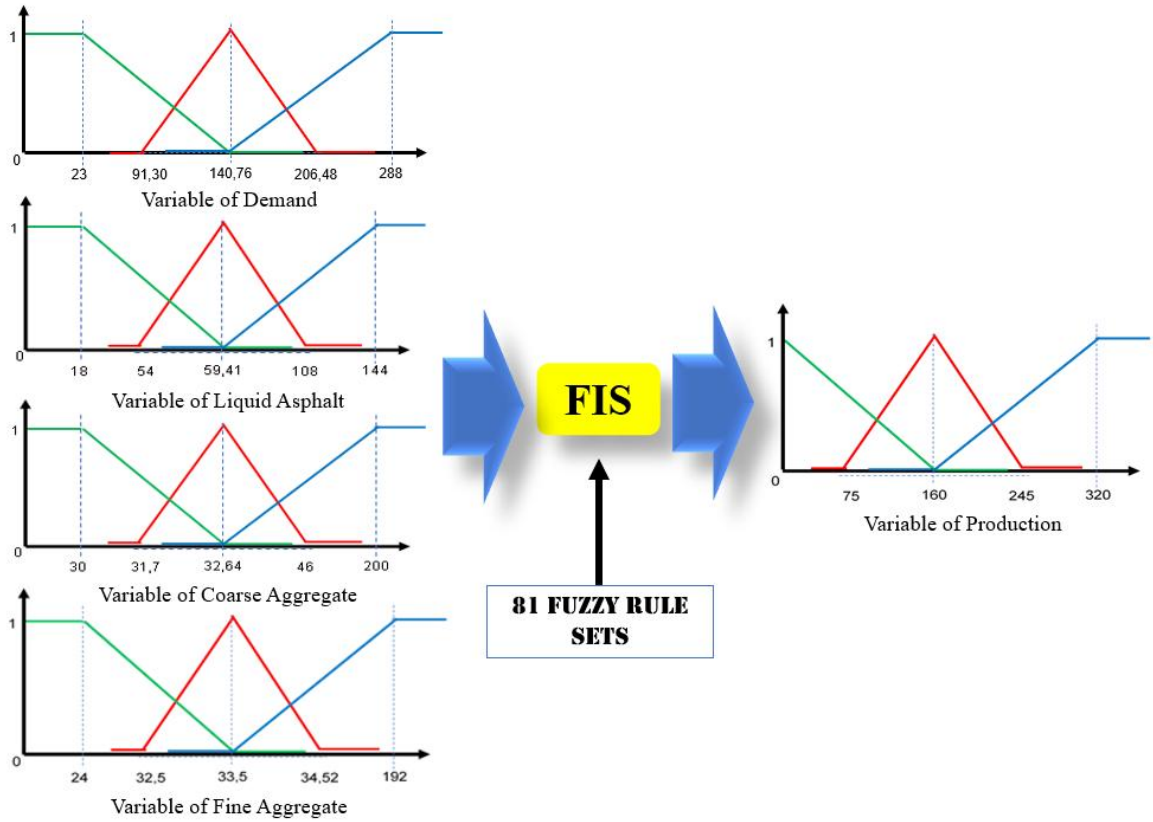

Figure 4. Fuzzy Inference System

Hot mix asphalt consists of liquid asphalt material, coarse aggregate material and fine aggregate material with a specific composition. Therefore, the material requirements for the production process and the availability of each of these materials from suppliers greatly affect the amount of hot mix asphalt production. The amount of hot mix asphalt based on the request of the road project is the basis for further consideration in production activities related to the ability of AMP equipment to produce hot mix asphalt. Analytical approach with the fuzzy method is proven to make decisions related to the amount of production based on the demand, in order to achieve efficiency and effectiveness for the company. The representation of fuzzy inference system as presented in figure 4. According to all stages of the fuzzy analysis system, starting from fuzzification, then continuing with generating the inference engine using a number of fuzzy rules and ending with the defuzzification stage, the right production decisions will be achieved and profitable for the company.

V. CONCLUSION

A decision support system for the production of hot mix asphalt is required for effectiveness. By describing and defining the availability of hot mix asphalt materials and the demand from road construction projects, 4 input and 1 output variables can be determined to support the decision of asphalt production. The variables are presented in the form of a fuzzy triangular number curve and used to generate the formation of fuzzy rule sets to run the fuzzy inference engine. Through the arrangement of a fuzzy inference system for hot mix asphalt production, the decision support has been developed and can be used as a decision-making analysis. Further analysis is still needed to observe the effect of each variable on the recommended decision by simulating the identified fuzzy inference system.

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