IMPLEMENTATION OF FUZZY ANALYTICAL NETWORK PROCESS IN PRIORITIZING TRANSPORTATION PROBLEM

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Abstract The main goal of this research is to help decision-makers in prioritizing transportation problems. Although numerous criteria were identified, the critical problems of transportation are less investigated. To fill this gap, this study was carried out to prioritizing the critical problems of transportation. The approach developed in this study implements fuzzy Analytical Network Process (FANP) to determine the weight for transportation problem criteria and sub-criteria. As a result, the highest rank sub-criteria was identified, which is “Professionalism” (0.203), followed by “Personal vehicle preferences” (0.190) and “E-ticket” (0.145). Although prioritize transportation problems were identified, future research needed to develop alternative strategies for developing transportation improvement strategies.

Keywords: transportation, Jak Lingko, decision support system, fuzzy analytical network process (FANP)

1. Introduction

The transportation problem becomes a highly important discussion whose solution can be sought through various approaches (Sari, 2011; Putra, 2016; Dewi, 2017; Kaslum dan Jinca, 2017; Affandi, 2016; Mardiaman, 2010). Solutions to transportation problems can be determined qualitatively (Putra, 2016; Dewi, 2017; Kaslum dan Jinca, 2017). Putra (2016) conducted an evaluation study of the Trans Sarbagita Bus program in Bali and identified criteria for transportation problems, namely transportation programs that are not a top priority for current transportation policy choices, communication, and coordination of program limitations and dependencies on government budgets, infrastructure and people’s behavior, and culture.

The effectiveness of public transportation services can be identified by using the approach of Richard M. Steers’ open system perspective model (Dewi, 2017). Dewi (2017) identifies four characteristics of the effectiveness of public transportation services, namely organizational characteristics, environmental characteristics, and management practices. Criteria for transportation problems that have been identified are cooperation, socialization, quality and professionalism, service, and safety (Dewi, 2017). Community participation and safety factors become very important criteria in transportation problems (Mardiaman, 2010).

Another approach in identifying transportation problems is the SWOT analysis (Kaslum and Jinca, 2017). Kaslum and Jinca (2017) identified criteria for transportation problems, namely intra and intermodal transportation systems that have not been integrated, difficult passenger access, lack of schedules regarding arrival and departure times, as well as waiting times and long travel times. Following technological developments, several e-transportation system problems include several criteria, i.e. the availability of electronic tickets, regulation of fuel levels and pollution of exhaust emissions, service, and safety (Affandi, 2016). The identification of the main transportation problems can be determined using the multi-criteria decision-making method (MCDM) (Sari, 2011). Sari (2011) developed a model for determining long-term transportation planning priorities by using a multi criteria decision-making approach (MCDM). The planning model considers energy, environmental, social, economic, technological, and political criteria using the

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This study evaluates the transportation program located in DKI Jakarta, namely Jak Lingko. During the trial period, January 2018 until the first quarter, the number of passengers in the Jak Lingko route of Andara – Lebak Bulus had the lowest number of passengers compared to the other four routes (Dinas Perhubungan, 2018). Besides, based on data from Dinas Perhubungan (2018), other problems faced by Jak Lingko operations is the ticket price which is considered too low to cover operations, operator and owner income, fleet, and card reader. Moreover, Jak Lingko has another obstacle that is the number of buses or fleet that limited (Setiyadi, 2019).

Based on the survey and information given above, it is very necessary to analyze transportation problems in Jak Lingko program. Therefore, this study leads to how the priority of transportation problems is determined. The approach is done by implementing fuzzy Analytical Network Process (FANP) in identifying the weight for each criterion and sub-criteria. The purpose of this study is to prioritize transportation problems using FANP method to assist long-term strategic planning to improve the Jak Lingko-3 program for Andara – Lebak Bulus route of DKI Jakarta.

2. Research Methodology

Prioritizing transportation problem requires a decision-maker to put forward his individual preferences. At the beginning of prioritizing transportation, researchers need to determine the initial criteria based on relevant literature. Second, aligning the initial criteria with company conditions and determining interdependence between criteria through the brainstorming process and filling out the questionnaire. The brainstorming process involved two parties including Jak Lingko-3 South Zone Field Coordinator and Jak Lingko-3 passengers. The next step is to compute the weight of each criteria and sub-criteria, constructing pairwise comparison matrix and calculating consistency ratio (CR). The consistency ratio should below 0,1 to indicate the decision of decision-maker is consistent. To compute the consistency ratio (CR) we apply the Super Decision software. Fuzzy ANP is the extended form of ANP that requires every measurement scale being converted using a Triangular Fuzzy Number (TFN). Moreover, calculating the weight for each criteria, dependencies, and forming the supermatrix should be done. To compute the final weight, we defuzzify the TFN value of all criteria. Each step can be seen in Figure 1.

![Research method flowchart](image)

3. Results and Discussion

From the literature review and after conducting the interview and brainstorming session, four criteria with thirteen sub-criteria were chosen as Jak Lingko-3 main problems. The criteria and sub-criteria are presented in Table 1.
Table 1 Criteria and Sub-criteria

| Code | Criteria      | Code | Sub-criteria       | References                          |
|------|---------------|------|---------------------|-------------------------------------|
| E    | Economy       | E1   | Budget              | Putra (2016)                        |
|      |               | E2   | Infrastructure      | Putra (2016)                        |
|      |               | E3   | E-ticket            | Affandi, Achmad, et.al (2016)       |
| S    | Social &      | S1   | Personal vehicle preferences | Putra (2016) |
|      | Culture       | S2   | Program socialization | Dewi, Nabila Ulfa (2017) |
|      |               | S3   | Community participation | Mardiaman (2010) |
| M    | Fleet         | M1   | Intra and intermodal system | Kalsum, Ummu & Jinca, Yamin (2017) |
|      | Management    | M2   | Accessibility       | Dewi, Nabila Ulfa (2017)            |
|      |               | M3   | Schedule            | Dewi, Nabila Ulfa (2017), Affandi, Achmad, et.al (2016) |
|      |               | M4   | Waiting time        | Mardiaman (2010), Affandi, Achmad, et.al (2016) |
| K    | Worker        | K1   | Professionalism     | Dewi, Nabila Ulfa (2017)            |
|      | Characteristic| K2   | Service             | Dewi, Nabila Ulfa (2017), Affandi, Achmad, et.al (2016) |
|      |               | K3   | Safety              | Mardiaman (2010), Affandi, Achmad, et.al (2016) |

Fig 2 Interdependence among criteria

Each criteria represent Jak Lingko-3 main problems, for instance, Jak Lingko-3 has constraints on program limitations and dependence on the government budget, inadequate infrastructure during program implementation, and lack of an electronic ticketing (e-ticket) system. These economic factor is one of the critical problems in the eyes of passengers regarding to the difficulty of passengers in using the program, especially the limitations of e-ticket. According to the South Zone Field Coordinator, community behavior and culture prefer to use private vehicles over public transportation, the lack of socialization to the community about Jak Lingko-3 program, and community participation in the program are considered as obstacles for to running the Jak Lingko-3 program. People are still reluctant to

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use public transportation because of social and cultural factors. Others, intra and intermodal transportation systems that have not been integrated, difficulties in accessing passengers to bus stop facilities, unclear schedules regarding arrival and departure times, waiting times, and transportation times become critical problems for passengers to participate in the Jak Lingko-3 program regarding fleet management. Last, the quality and professionalism of workers, both drivers and fleet operators, service and passenger safety are crucial factors, given the lack of standards or procedures in terms of service and safety of this program.

The overall problems that have been explained above are related to one another. In identifying the correlation of each sub-criteria, the interview process has been carried out and interdependencies between sub-criteria can be determined. The decision-maker filled in a questionnaire to determine the interdependence among criteria. The interdependence among criteria are presented in Figure 2.

Based on questionnaire filled by the decision-maker, we noted that each sub-criteria interrelated to the other sub-criteria. For example, “Budget” is related to “Infrastructure”, this implies that the budget reduction will affect the infrastructure owned by Jak Lingko-3. Another example is “Professionalism” related to “Personal vehicle preferences”, this implies that the increase in employee professionalism will have an impact on the tendency to use private vehicles or public transportation.

Moreover, a network model is then developed based on the relationships between and within these criteria using Super Decision software.

The next step is to identify consistency ratio (CR) for each criteria and sub-criteria. Consistency ratio (CR) =< 0.1 indicate the respondent is considered consistent in assessing the problem.

| Table 2 Consistency ratio (CR) each criteria and sub-criteria |
|--------------------------------------------------------------|
| CR                                                          |
| All criteria                                                | 0.0227 |
| Economy sub-criteria                                        | 0.0516 |
| Social and culture sub-criteria                             | 0.0025 |
| Fleet management sub-criteria                               | 0      |
| Worker characteristic sub-criteria                          | 0      |

From table 2, we noted that all criteria and sub-criteria have CR =< 0.1, it represents that respondent is consistent in assessing the problem.

To calculate the weight of each criteria and sub-criteria, formerly, we develop the fuzzy pairwise comparison matrix for each criteria and sub-criteria using triangular fuzzy number (TFN). Fuzzy pairwise comparison matrix for all criteria and each sub-criteria can be shown as follows.
Table 3 Fuzzy pairwise comparison matrix for all criteria

|        | Economy | Worker characteristic | Fleet management | Social & culture |
|--------|---------|-----------------------|------------------|------------------|
| Economy| 1.1.3   | 1.2.4                 | 1.1.3            | 1/9.1/9.1/7      |
| Worker characteristic | 1/4.1/2.1/1 | 1.1.3 | 1/3.1/1.1/1 | 1/9.1/9.1/7 |
| Fleet management | 1/3.1/1.1/1 | 1.1.3 | 1.1.3 | 1/9.1/9.1/7 |
| Social & culture | 7.9.9 | 7.9.9 | 7.9.9 | 1.1.3 |

Table 4 Fuzzy pairwise comparison matrix for sub-criteria of “Economy”

|        | Budget | Infrastructure | E-ticket |
|--------|--------|----------------|---------|
| Budget | 1.1.3  | 1/9.1/9.1/7    | 1/9.1/9.1/7 |
| Infrastructure | 7.9.9 | 1.1.3 | 1/4.1/2.1/1 |
| E-ticket | 7.9.9 | 1.2.4 | 1.1.3 |

Table 5 Fuzzy pairwise comparison matrix for sub-criteria of “Social & culture”

|                                      | Personal vehicle preferences | Program socialization | Community participation |
|--------------------------------------|------------------------------|-----------------------|-------------------------|
| Personal vehicle preferences         | 1.1.3                        | 5.7.9                 | 4.6.8                   |
| Program socialization                | 1/9.1/7.1/5                  | 1.1.3                 | 1.1.3                   |
| Community participation              | 1/8.1/6/1/4                  | 1/3.1/1.1/1           | 1.1.3                   |

Table 6 Fuzzy pairwise comparison matrix for sub-criteria of “Fleet management”

|                                      | Intra and intermodal system | Accessibility | Schedule | Waiting time |
|--------------------------------------|-----------------------------|---------------|----------|--------------|
| Intra and intermodal system          | 1.1.3                       | 1.1.3         | 1.1.3    | 1.1.3        |
| Accessibility                        | 1/3.1/1.1/1                 | 1.1.3         | 1.1.3    | 1.1.3        |
| Schedule                             | 1/3.1/1.1/1                 | 1/3.1/1.1/1    | 1.1.3    | 1.1.3        |
| Waiting time                         | 1/3.1/1.1/1                 | 1/3.1/1.1/1    | 1/3.1/1.1/1 | 1.1.3 |

Table 7 Fuzzy pairwise comparison matrix for sub-criteria of “Worker characteristic”

|        | Professionalism | Service | Safety |
|--------|-----------------|---------|--------|
| Professionalism | 1.1.3          | 7.9.9   | 7.9.9  |
| Service    | 1/9.1/9.1/7     | 1.1.3   | 1.1.3  |
| Safety     | 1/9.1/9.1/7     | 1/3.1/1.1/1 | 1.1.3 |

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Table 3 shows fuzzy pairwise comparison matrix for all criteria. Also, fuzzy pairwise comparison for each sub-criteria should be done. Table 4 represents fuzzy pairwise comparison matrix for “Economy” criteria. This table shows high scale in the comparison between infrastructure and budget as well as e-ticket and budget. Moreover, table 5 shows fuzzy pairwise comparison matrix for “Social & culture” criteria. This table indicated the high scale in comparing personal vehicle preferences and program socialization. From table 6 above, fuzzy pairwise comparison matrix for “Fleet management” criteria. Last, fuzzy pairwise comparison matrix for “Worker characteristic” criteria represents on the following table. From table 7, a comparison between professionalism and both good service and security shows that professionalism is more important than service and security.

After the fuzzy pairwise comparison matrix is calculated, the next step is to compute the supermatrix formation to analyze the transmission of influence along all paths defined in the network and to obtain the overall fuzzy priorities of the elements (Asan et. al, 2012). Moreover, the final weight is calculated by carrying out the defuzzification process. The fuzzy numbers are transformed into crisp global priority values using Eq. (1) (Asan et. al, 2012).

\[
I^A\left(\overline{s}_{ni}\right) = \frac{1}{2} \lambda \left(m_{ni} + u_{ni}\right) + (1 - \lambda) \left(h_{ni} - m_{ni}\right)
\]  \hspace{1cm} (1)

Where \( \lambda \in [0,1] \) is an index of optimism that represents the decision-maker’s risk tolerance (Asan et. al, 2012). A larger \( \lambda \) specifies a higher degree of optimism (Asan et. al, 2012). Finally, the normalized relative importance vector \( w_i = (w_{i1}, ..., w_{iq})^T \) for a particular cluster \( i \) (composed of decision elements) is derived by the following equation:

\[
w_{ni} = \frac{I^A\left(\overline{s}_{ni}\right)}{\sum_{q_i}I^A\left(\overline{s}_{ni}\right)}, \hspace{1cm} i = 1,..., q
\]  \hspace{1cm} (2)

The criteria or sub-criteria with the highest normalized importance values, and thereby having the highest rankings, are the most critical criteria or sub-criteria in the decision problem (Asan et. al, 2012). The final weight can be shown as follows.

| Criteria                  | Defuzzification | Weight |
|---------------------------|-----------------|--------|
| Professionalism           | 0.68            | 0.203  |
| Personal vehicle preferences | 0.62          | 0.190  |
| E-ticket                  | 0.47            | 0.145  |
| Infrastructure            | 0.29            | 0.091  |
| Intra and intermodal system | 0.23          | 0.073  |
| Accessibility             | 0.21            | 0.065  |
| Waiting time              | 0.19            | 0.063  |
| Schedule                  | 0.17            | 0.059  |
| Program socialization     | 0.10            | 0.031  |
| Community participation   | 0.09            | 0.029  |
| Service                   | 0.08            | 0.025  |
| Safety                    | 0.07            | 0.022  |
| Budget                    | 0.04            | 0.014  |

From table 8, we noted that “Professionalism” has the highest weight on transportation problems (0.203). Based on the interview, this is justified by the workers who must have special requirements before working as a driver and should follow the operational standards in working as a driver. The second highest weight is followed by “Personal vehicle preferences” (0.190), this result shows that Jak Lingko is a very appropriate program to make people switch from personal vehicles to public transportation, therefore, it will overcome the problem of congestion in Jakarta. Moreover, the third-highest weight is “E-ticket” (0.145). The availability of e-ticket for Jak Lingko program is an important sub-criteria because it will affect the number of Jak Lingko passengers.

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4. Conclusion

This research implemented fuzzy ANP to prioritize transportation problems to improve the Jak Lingko-3 program. As a result, “Professionalism” (0.203) is the highest weight, followed by “Personal vehicle preferences” (0.190) and “E-ticket” (0.145). Although several criteria have been identified and weighted, this research has a limitation that is the data may not be able to be reused for the next step because of its dependencies on time variables and this research only represent a transportation problem in Jakarta and only one route of public transportation Jak Lingko. To cover this limitation, certain method needs to be developed with a wider area. Furthermore, this research needs to be continued to identify strategies for improving the Jak Lingko-3 program.

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