Optimization based Decision Support System for Reconstructing the Traffic Road (Case Study: PI Intersection Traffic Road, Indonesia)

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Abstract- Traffic road reconstruction is a high cost operation. Lots of parameters with different behavior should be considered to decide the type of reconstruction that will be practically implemented in one traffic area. One of main purposes of the reconstruction is that the new traffic road construction can degrade the road traffic congestion. Through main method analytical hierarchy process (AHP) that is combined with fuzzy logic concept and full-factorial optimization method, the decision support system to select the best decision for reconstructing traffic road was created. AHP was used as a fundamental conception to prioritize the decision parameters, fuzzy logic concept used to require the human language meaning in judgment, and full-factorial optimization used to optimize the decision alternative based on selected parameter. The constructed decision support system based on optimization concept is presented in this paper; where the area surrounding Pondok Indah (Jakarta, Indonesia) was taken as a research object.

Keywords – fuzzy logic, analytical hierarchy process, full-factorial optimization, decision support system, traffic road reconstruction

I. INTRODUCTION

A computer modelling simplifies the problem to be analyzed. A computer model is used to do several scientific experiments through low cost virtual tests and trials [1]. The road traffic congestion is one problem that needs high cost to solve. Moreover, to answer the road traffic congestion problem that needs a traffic road reconstruction, it will consume high budget even to examine the decision implementation.

Loads of parameters have to be considered to select the type of traffic road reconstruction. Road traffic density, vehicle volume, traffic flow velocity, etc. are various examples of parameter benefitted. Those all parameters are interconnected to optimize the road traffic performance as main objective function to find the reconstruction type.

Regarding the researches of traffic road reconstruction, several researches have been conducted. [2] modeled the road network redundancy during disaster mitigation when the road being reconstructed through using link reconstruction analysis. The study focused on performing link redundancy analysis, without taking into account the traffic flow of the network. Specifically regarding relationship between road construction and clean production, [3] compared two methods for road reconstructing in environmental impact factors (e.g. global warming, acidification, and abiotic depletion of fossil fuels). Also [4] studied about road reconstruction plan via integrating heterogeneous data. Based on the study, the decision support system was constructed where there were six types of domestic data.

Furthermore, [5] conducted study in economic and finance area. It was concerning the impact of the local political and socio-economic condition to the capacity of local governments relates to the maintenance of the assets for post-disaster road infrastructure reconstruction, specifically in the post-tsunami reconstruction case in Aceh, Indonesia. It was concluded, that both conditions of political stability and socio-economic highly affect to the investment value and project location of reconstruction respectively. In area transportation systems engineering and information technology, by using simulated annealing optimization method, [6] optimized the activity of road reconstruction. Two level models were used here that strongly relate to reconstruction expense, road saturation and flow. The effective road construction will highly decrease the road traffic congestion.

The paper presents the constructed decision support system based on optimization principle for reconstructing the traffic road in decreasing the road traffic congestion. The system is able to propose the effective decision alternative via parameters behavior based on full-factorial optimization process. The introduction section of this paper is followed by sections research methodology; results, findings, and discussion; and conclusion and further works sequentially.

II. Proposed Algorithm

Area Pondok Indah (PI) with 1.9 km traffic road length was chosen as a research object where its identifiable condition of two intersections and one circle were considered for selecting the type of traffic road reconstruction. The area locates in South Jakarta, Indonesia. There are eight points of main road that their data were empirically captured in three hours of peak time of working day (see Figure. 1.). The objective function that is considered to select the decision is the optimization value of traffic performance coming from four main parameters (i.e. side constraint, traffic service, intersection performance, and queue behavior) with other numerous notified parameters. Especially for capturing the fast moving data (e.g. vehicle speed, traffic density, etc.), the video recording is a method chosen. Overall, the method to collect data empirically coming from [7] was used.

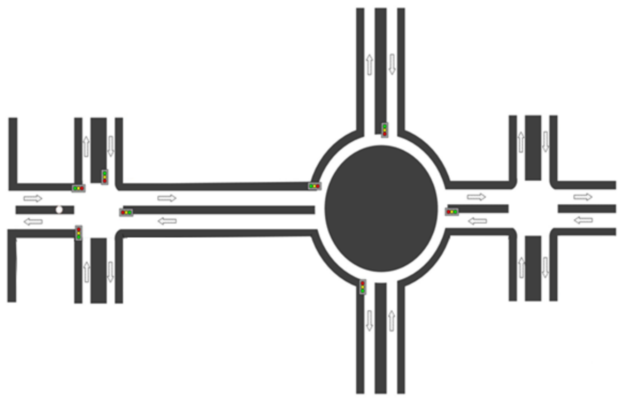

Figure 1. Area configureuration for research object

Fuzzy – AHP was used to prioritize all involved parameters. This method combines two types of approach, fuzzy logic and AHP. Fuzzy logic [8] used to calculate the crisp value based on human justification. The human justification is used to do the pairwise comparison based on AHP calculation concept [9]. Furthermore, the method full-factorial optimization [10] was operated. Principally, all possibilities of objective function result are calculated to obtain the best solution. Here, the decision alternatives with their specific behavior are checked (in sequence) to propose the best value. The best value of the objective function was assumed as the best solution. The model was designed based on the method of object oriented analysis and design [11]. In this paper, two types of tool are delivered. They are class diagram and usecase diagram.

Essentially, all activities in this study are explained in Figure. 2. The research is divided into three main steps; initial and situational analyzing, decision and system analyzing, and system designing and constructing with specified research methods. The research was conducted to reach three types of research objectives.

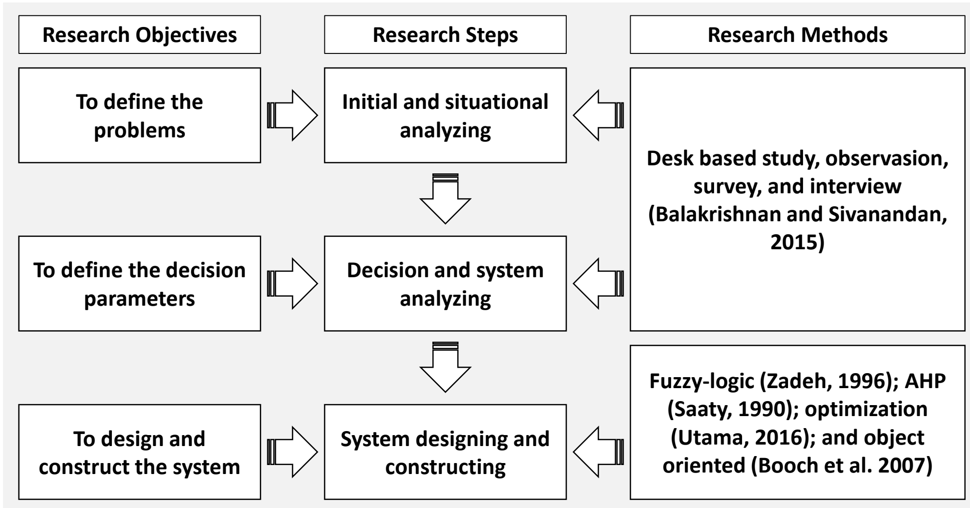

Figure 2. Research activities

III. Results, Findings, and Discussion

3.1. Results and Findings

The hierarchy structure of fuzzy-AHP based on used decision parameters can be seen in Figure. 3; where PED represents a pedestrian, PSV symbolizes a parked vehicle, EEV is an in/out vehicle, and SMV is a symbol of a slow vehicle. The structure consists of three layers decision, parameters, and sub parameters. All parameters and sub-parameters were humanly justified based on fuzzy concept. They all were used in process of pairwise comparison to get priority values. The prioritized values are delivered in the figure. In addition, the fuzzy justification (for example main parameters particularly) is depicted in TABLE 1; where V1, V2, V3, and V4 represent the parameters side constraint, traffic service, intersection performance, and queue behavior respectively. Moreover, the triangular membership function of human judgment (based on fuzzy-logic notion) is revealed in Figure. 4. It consist of five fuzzy languages to explain the importance; equally, moderately, strongly, very strongly, and extremely important.

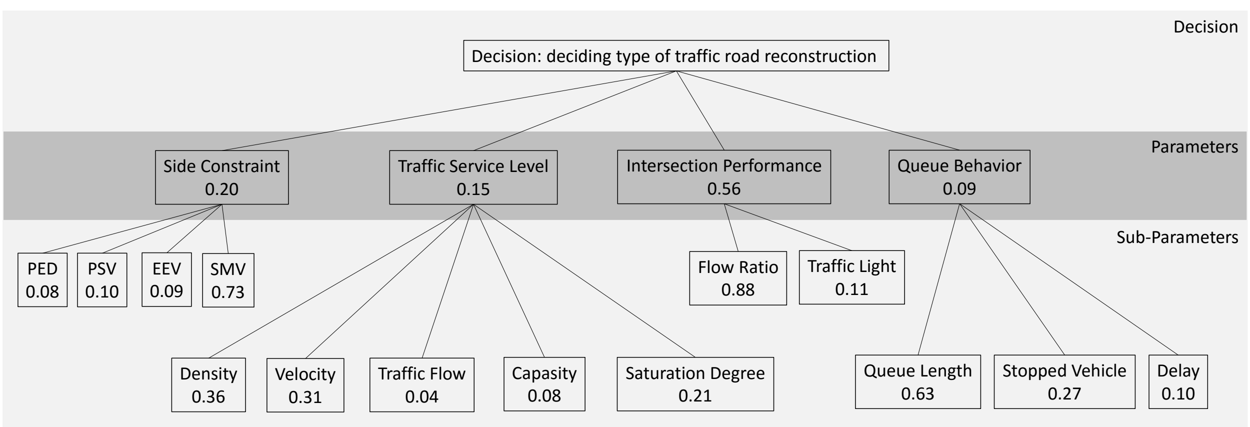

Figure 3. Hierarchy of decision parameters

Four central decision parameters strongly relate to other sub-parameters. Parameter traffic side constraint is a road traffic performance that is influenced by traffic road side activity. Where the road side activity is featured by four other sub-parameters [12]. The traffic service level theoretically interconnects many aspects. In this study, five sub-parameters are defined. The parameter intersection performance reflects the performance of two other sub-parameters, flow ratio and traffic light performance. Finally, the queue behavior describes three parameters, queue length, number of stop score of vehicle, and delay.

Table -1 Fuzzy Judgement for Main Parameters

	V1	V2	V3	V4
V1	E	S	M	M (inv)

V2	S (inv)	E	M (inv)	VS (inv)
V3	M (inv)	M	E	S (inv)
V4	M	VS	S	E

E = equally important, M = moderately important, S = strongly important, VS = very strongly important, Ex = extremely important, inv = inverse

Figure. 5. describes the class structure of constructed system. The class structure is configured based on Booch's object oriented concept [11]. Mainly, there are eight main interrelated classes in the system. Class `TrafficRoad` is a central class of the model. It consists of four fundamental classes that depict the parameters used in the system; where each class also describes the interconnected parameters inside. The process of pairwise comparison of parameters is represented by operation `pairwiseCompare()` of each child class of class `TrafficRoad`. The process decision making to select which decision alternative must be selected for reconstruction implementation is conducted in class `ReconstructingDecision` through its several operations. In the class diagram, the relation multiplicities are described as well. They are illustrated via four types of relationship; 1 (one and only one), 0..1 (zero or one), 0..* (zero or many), 1..* (one or many), and * (many).

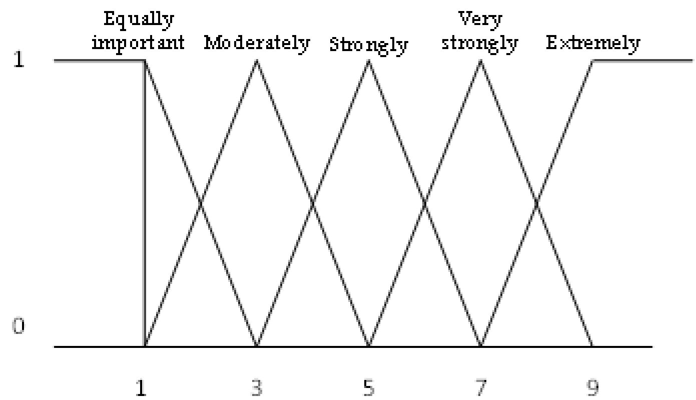

Figure 4. Membership function for fuzzy judgement

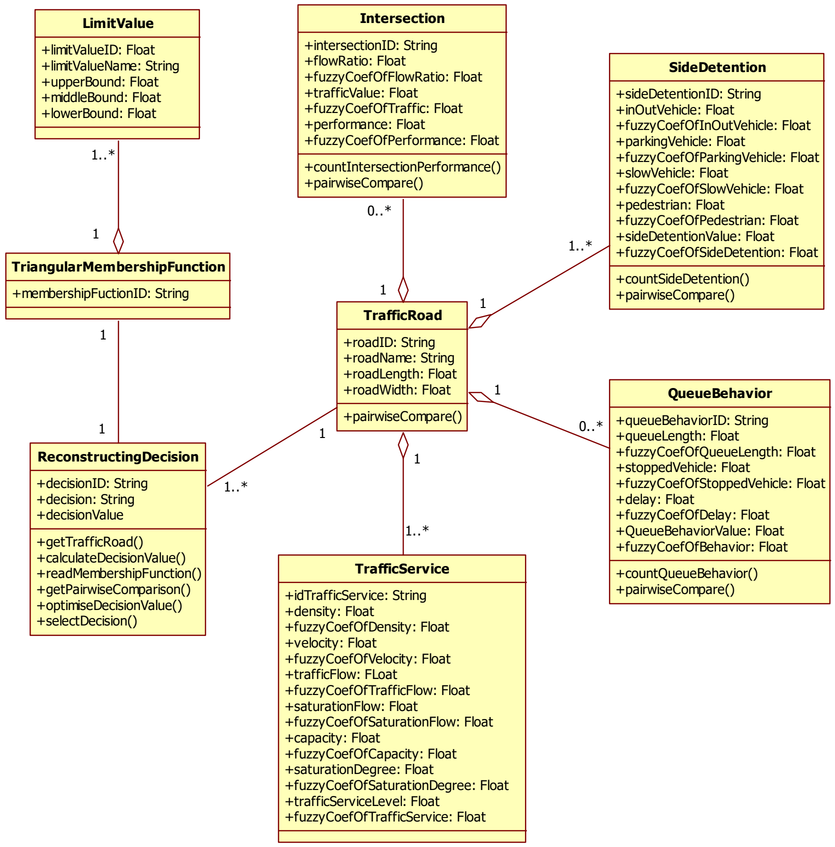

Figure 5. Class diagram of constructed system

Furthermore, Figure. 6. (usecase diagram) portrays the actors of the model. The model has two direct human actors, `Governor` and `PublicServiceDepartment`. `Governor` has responsibility in all usecases of the system, exclusively in making decision (usecase `Generating Decision`). The second one, `PublicServiceDepartment`, can interact with system through usecase `Optimizing`, where the system will select the best alternative of decision.

The design for the structure of main system dashboard is represented in Figure. 7. The structure demonstrates the information composition in one screen environment. It facilitates easily the decision makers to see information and take decision. All information that are given in colorful indicators will make the decision makers drill across and compare them to each other simply. Moreover, the actors can find the person who responsible to one specific data by right-clicking the data and selecting the responsible person. The comparison of all or several decision alternatives can also be displayed on the screen via bar chart graph; and the best decision will be appeared with its optimization indicator.

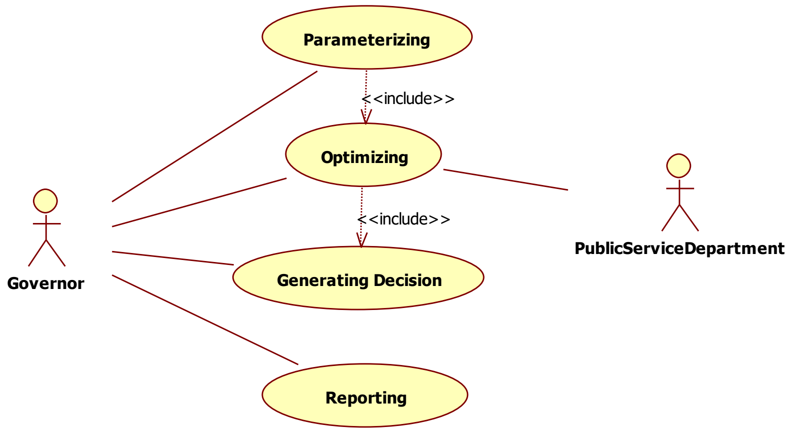

Figure 6. Usecase diagram of constructed system

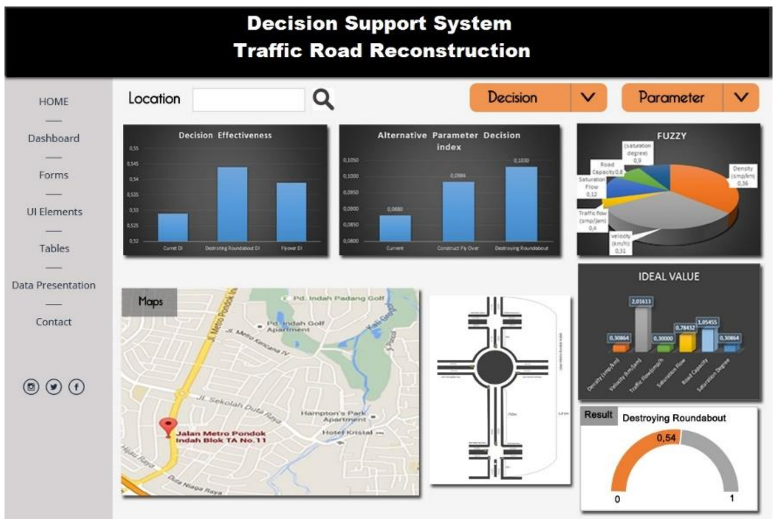

Figure 7. Design of main system dashboard

All parameters (based on empirical data) were computed. By setting the ideal value, the result of computation is compared with the ideal values to get the performance value by using equations (1) and (2). The equation (1) is used to get the performance value when the ideal value is maximum (PV_{max}), and the equation (2) is operated to get the performance value where the ideal value is minimal (PV_{min}) [10].

$$PV_{max} = \frac{V_{current}}{V_{MaxIdeal}} \qquad (1)$$

$$PV_{min} = \frac{V_{MinIdeal}}{V_{current}} \qquad (2)$$

Finally, the values were multiplied with fuzzy coefficient to get final performance value. Through virtual experiment, five performance values of road traffic of decision alternatives (after reconstruction) can be seen in Figure. 8. Based on optimizing process via full-factorial method, the alternative “developing the flyover” and “developing the underpass” have the highest value of decision. It means, the implementation of both traffic road reconstructing decisions can improve the performance value of traffic, it is approximately more than 185%. While in scenario, the traffic condition will be still in only “middle good” condition (the performance value is only around 0.58) after taking the reconstructing decision.

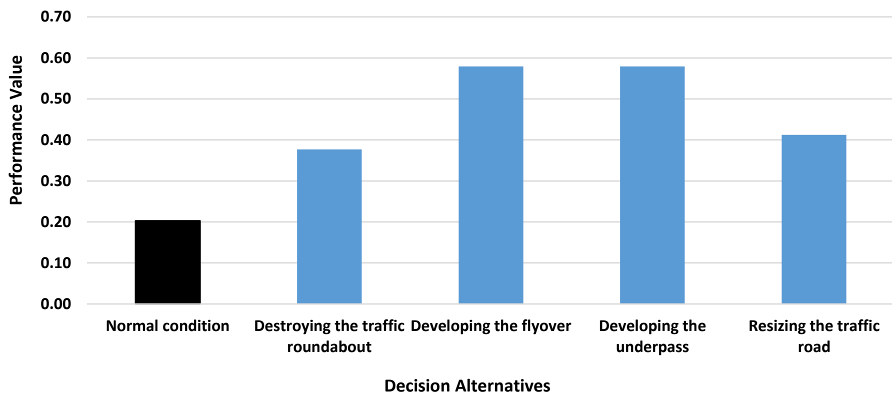

Figure 8. Performance value of decision alternatives

3.2. Discussion

Likewise, [4] developed a decision support system. It was developed for road administration particularly for planning the road reconstruction. Through the system, the users can discover the problem and estimate the traffic accident in the national highway, thus they can propose the proposal for improvement. Based on data behaviors (six types of combined heterogeneous data), the decision can be objectively proposed. However, the study did not obviously explain the scenario of decision making, scenario concerning how a decision based on interconnected data can be selected by the users as the best decision. On the other hand, our study show how the users can select the best solution, it is definitely according to the best value of road traffic performance. As presented in Figure. 8., the users absolutely know which the best solution must be taken.

In a different case, [5] only focused on capacity of local government in traffic road infrastructure reconstruction. Their study did not measure or predict the successfulness of the reconstruction result. However, in our study, we can predict how much positive the reconstruction can improve the traffic road performance then. It exposed the significantly upgraded value 185% that compared with the normal condition (before reconstruction).

IV.CONCLUSION

4.1. Conclusion

A decision support system was produced. It could be used to select the best decision based on several parameters to decide the type of traffic road reconstruction. Four direct parameters were considered in the model that strongly relate to many other parameters. The system can propose the objective decision based on the highest value of performance of road traffic. The user-friendly design of main system dashboard presents the interactive facility for decision makers to communicate with the system.

4.2. Further Works

Other parameters, such as amount of fuel consumption (owing to the congestion condition of road traffic), level of CO2 contribution to environment, and air pollution cost; can be realized in the model of the system. They can enrich the objectivity of the decision made. Those Parameters can be used as a fundamental parameters to consider environmental aspect in making decision. Multi objectives also can be realized in the system; beside road traffic performance value, the CO2 degree, air pollution cost, or fuel consumption can be considered to select the most objective decision for traffic road reconstruction.

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