FWFA Optimization based Decision Support System for Road Traffic Engineering

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Abstract. Several ways and efforts have been already conducted to formally solve the road traffic congestion. However, the objective strategy type of road traffic engineering could not be proven truly. Try and error is one inefficient way in road traffic engineering to degrade the level of congestion. The combination between fuzzy-logic and water flow algorithm methods (called FWFA) was used as a main method to construct the decision support system (DSS) for selecting the objective strategy in road traffic engineering. The proposed DSS can suggest the most optimal strategy decision in road traffic engineering. Here, a main traffic road of Juanda in area Ciputat, Tangerang Selatan, province Banten, Indonesia; was selected as a research object in this study. The constructed DSS for road traffic engineering was structurally delivered in this paper.

1. Introduction

Road traffic engineering is one way to reduce the traffic congestion level. Where, the congestion is an ordinary problem that needs an extraordinary way to solve [1], particularly in big cities’ main road network [2]. However, the implementation of traffic engineering practically is the other problem. The high cost effect of the implementation will appear. Thus, the engineering strategy has to be selected objectively and firstly executed in a model domain before in a real implementation.

Conceptually, many approaches have been offered to answer the congestion problem thru research projects conducted in several countries. [3] proposed an approach to mitigate the motorway traffic congestion by installing an auxiliary lane. They develop a model to simulate the implementation of solution. [4] implemented the expert system for dynamic traffic light control to improve the condition of road traffic congestion. Furthermore, [5] developed the quantitative system analytic model for traffic controlling. The model was predicted can improve the air quality and solve the problem of traffic congestion.

In addition, [6] constructed an intelligent vehicle system to reduce the traffic congestion. The constructed system aimed to maintain the homogenous vehicle movements in minimalizing the congestion. The system was based on mobile device practically. Also [7] proposed the solution strategy to mitigate a traffic congestion with diversion and lane restrictions. Finally, [8] used the binary logit model to reduce road traffic congestion and air pollutant. Can be concluded that by encouraging the students and employees to use the public transport, the congestion can be conceivably downgraded.

This paper presents the construction of decision support system (DSS) based on fuzzy water flow algorithm (FWFA) that is used to mitigate the congestion via selecting the road traffic engineering
strategy. The strategy in engineering a road traffic in one main traffic road in Indonesia was recommended. To deliver it structurally, the section introduction is followed by sections related works, research methodology, results and discussion, and conclusion and further works.

2. Related Works
Numerous researchers have previously used water flow algorithm (WFA) as their research main method, exclusively in computer modeling area. [9] started to use WFA to optimize bin packing problem. Compared to genetic algorithm (GA) method, WFA was more proven optimal. [10] implemented WFA algorithm in segmenting text and detecting reference text line. The WFA method was modified version, especially in expansion values of water flow specified angle and unwetted image frames function enlargement. [11] also did their research in manufacturing field. They used WFA to solve the problem in building the layout of manufacture. WFA was ever operated as well to solve the problem of travelling sales problem [12] and finding the shortest path [13]. And lastly, WFA was functioned as main method of optimization model in answering the road traffic congestion [1].

3. Research Methodology
This study (where the activities are described clearly in Figure 1) is expanded version of [1] research. It was conducted by using main traffic road in area Tangerang Selatan (province Banten, Indonesia) as an object of the research. Through using [14] method, the empirical data in pick time (6 a.m. to 10 a.m.) of five working days (Monday to Friday) was extracted becoming data source of the research.

![Figure 1. Research Activities](image)

The main method used in developing the system is the combination of WFA [9] [1] and the concept of fuzzy-logic [15]. The WFA operated to model the traffic condition and also to seek the best decision alternative (via optimization process). While, the concept of fuzzy-logic used to parameterize and prioritize all involved parameters in the model. Here, we found a judgment for seeing the urgency of decision alternatives coming from experts’ point of view. We required the multi expert judgment and convert it to crisp-output value then. The value used as the coefficient of decision alternatives.

The object oriented method [16] was used to document the constructed system. Two diagrams explicitly used in this study is usecase and class diagrams. The usecase diagram is used to describe the communication pattern between system and actors. Where, the actors theoretically could be human and/or system actors. While, the class diagram depicts the interconnection among classes in system which explains the classes’ behavior (attributes and operations).

4. Results and Discussion

4.1. The Constructed System
The usecase diagram of the constructed system is shown clearly in Figure 2. Here, there are two types of human actor (i.e. expert and local government) and a system actor (i.e. traffic center management information system). There are five usecases here: Extracting Data, Parameterizing, FWFA Optimizing, Making Decision, and Reporting. Three experts involve in the system to justify
the urgency of decision alternatives. Through fuzzy and de-fuzzy process, the decision coefficients are produced. The actor Local Government involves in parameterizing, optimizing, decision making, and reporting. Instead, the actor is who has responsibility to implement the decision. Whereas, the system actor Traffic Center MIS provides all data and information required by the system. Theoretically, the usecase diagram signifies the components of decision support system [17], and ever used by [18] as well; the usecase Extracting Data (with its actor) represents the data base management component, the usecases Parameterizing and FWFA Optimizing symbolize the model base management component; and the usecases Making Decision and Reporting characterize the user interface base management.

Figure 2. The Usecase Diagram of the Constructed System

The configuration of classes’ interconnection of the constructed system is obviously presented in Figure 3. Indeed, it consists of seven main classes; TrafficRoad, UTurn, TrafficLight, Vehicle, Decision, ConsideredParameter, and FWFAOptimization. To produce the best decision (class Decision), all considered parameters (class ConsideredParameter) of traffic road (class TrafficRoad) are determined. The value of each parameter is empirically coming from the vehicle (class Vehicle) behavior. The best decision itself is generated from process of FWFA optimization (class FWFAOptimization). Also, physically, one traffic road can be configured by defining a number of u-turn (class UTurn) and traffic light (class TrafficLight).

Furthermore, in this study, three types of vehicle are taken into account. They are light vehicle (class LightVehicle), heavy vehicle (class HeavyVehicle), and motorcycle (class Motorcycle). The class LightVehicle is representing several types of public (class PublicTransport) and private (class PrivatTransport) transport vehicle, e.g. mini public transport (angkot in Indonesia), small bus, etc. The class HeavyVehicle symbolizes the heavy vehicles certainly, such as truck, big bus, etc. By using FWFA optimization method, based on a lot of the best decision alternatives (class BestDecisionAlternative), the final decision technically is generated. The FWFA optimization method principally utilizes the membership function. A triangular membership function is a membership function type used in this study (class TriangularMF) which correlates to limit value (class LimitValue).

In addition, there are six direct parameters that are considered in this study. Where each parameter has unique behavior and needs other detailed variables. Classes RoadVelocity, RoadDensity, RoadVolume, RoadDelay, RoadCapacity, and RoadSaturationDegree represent velocity, density, volume, delay, capacity, and saturation degree of the traffic road respectively. The class RoadDelay is specifically generated from three types of delay; traffic delay (class TrafficDelay), geometry delay (class GeometryDelay), and stop point delay (class StopPointDelay). Empirically, all parameters are considered and measured based on day (class Day) and rush-hour time.
of each day (class Time). The class diagram that describes the detailed classes of class ConsideredParameter is illustrated in Figure 4.

![Class Diagram](image1)

Figure 3. Main Class Diagram of the Constructed System

![Class Diagram](image2)

Figure 4. Detailed Classes of Class ConsideredParameter

Nine operations are mechanically determined in class FWFAOptimization. The operations FuzzyProcessing() and DefuzzyProcessing() are used to adjust the coefficient (output crisp value) of the decision alternatives. Where, the input crisp values are coming from the experts’ judgment (three expert persons). Principally the mechanism to require the experts’ judgment is needed, because it will enrich the final decision objectivity. Technically, the coefficient affects the final relative value of traffic velocity that represents the value of each decision alternative.

By using a triangular membership function (with three fuzzy languages to explain the decision importance; not significant, medium, and significant), the coefficient of six decision alternatives (strategy alternatives of traffic engineering) u-turn elimination, public transport stop point, public transport elimination, motorcycle elimination, traffic light manipulation, and contraflow are 0.43, 0.40, 0.07, 0.05, 0.03, and 0.02 respectively. While, seven other operations (Splitting, Moving, Merging, Evaporating, Precipitating, ObtainingBest, and Comparing) and also all mathematical calculations concerning WFA operation are scientifically functioned based on [9] that also ever implemented by [1].

Based on more than 130 decision alternatives that have been checked by using FWFA optimization model (where the optimization process is started from the smallest coefficient) of the constructed system, the highest traffic velocity (in relative value) will be reached (see Figure 5) when the public transport vehicles halt in the right place. It means, the strategy to maintain the public transport to stop in the recognized right place (e.g. bus stop, etc.) is the best decision for road traffic engineering.
(compared to the other strategies, see Figure 6). It is predicted can improve the traffic velocity three
times approximately (from normal velocity 8.64 km/h).

![Figure 5. The Alternatives of the Best Decision Produced from FWFA Optimization](image1)

![Figure 6. Decision Alternatives Comparison](image2)

4.2. Discussion
The different decision was proposed here compared to [1]. [1], by using WFA optimization,
recommended the u-turn eliminating as the best decision to be taken. It can improved the traffic flow
until more than four times. However, when the same data were entered in this proposed FWFA based
DSS, where the importance of decision alternatives was allowed to be judged by several experts, the
decision alternative to endorse the public transport vehicle to stop in the right place was selected as the
best solution. On the other hand, implicitly, the proposed system uses several objective functions of
optimization model coming from [1]. As, to select the best decision, the value of objective function of
each decision alternative is a value compared. Where practically, the value of objective function
characterizes the road traffic velocity.

5. Concussion and Further Works
FWFA is a method that combines the concept of fuzzy-logic and water flow algorithm method. It was
used to develop the optimization model that is a part of the constructed DSS. The best decision was
proposed as a road traffic engineering to decrease the level of traffic congestion; where it is related to
the road traffic velocity. In addition, the concept of fuzzy-logic was practically used to reform the value
of expert judgment in determining the urgency value of decision alternatives. It was technically
embedded to WFA based optimization model [1] to expand the model. And, the extended model was
operated to develop the constructed DSS.

Ecological parameters (eco-parameters), e.g. air pollution degree, CO content in air, fuel
consumption level, etc. are attracting parameters to be reasonably taken into account. The consideration
will become a new idea of the further study. Besides, other parameters, such as type of city or the parameter of citizens’ behavior in driving, can affect the strategy for road traffic engineering.

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