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# Fuzzy eco-DSM for road traffic engineering

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**Abstract.** Numerous efforts have been reasonably done to eliminate the road traffic congestion, however it occurs every working day, particularly in metropolitan. This study positively proposed a model which is not only able to show the effect of road traffic congestion ecologically, but also can recommend the strategy for road traffic engineering with methodically elaborating the environmental attributes as a dominant aspects considered. It is called as ecological decision support model (eco-DSM). To construct the model, two main methods were operated and combined: fuzzy logic and water flow algorithm (WFA). The method fuzzy logic exploited to exterminate the bias facet on parameters, and the WFA utilised to model the road traffic congestion and vehicle flow and to optimize its velocity based on emission calculation. The constructed model itself was designed thru the method object oriented, and the empirical road traffic congestion data of the Juanda Street in Tangerang Selatan city were functioned. Finally, the model showed the simulation result for suggesting the best decision alternative for road traffic engineering.

## 1. Introduction
The road traffic congestion is one challenging trouble to mitigate. It is a common problem that requires an uncommon way to solve [1]. It causes dominantly the journey time uncertainty [2] and increases the fuel consumption [3]. Also, ecologically the number of vehicle contributes to high concentration of air pollutants, particularly for PM10, CO, and SO2; they were significantly higher on a working day [3][4].

The studies correlating to the topic of road traffic congestion, influences, and its solutions are an interesting research to conduct. Many researchers have conducted such studies. [5] expended the NaSch model to learn the effect of congestion on the fuel and emission. Also [3] and [6] similarly conducted the research to see the impact of road traffic congestion on greenhouse gas emissions. Likewise, [7] evaluated the influence of road traffic on noise emissions. The result of the study is able to help underlying the further necessitated enhancements of dynamic road traffic noise models.

Furthermore, [8] researched the link of domestic violence and radical road traffic congestion, specifically in Los Angles (2011-2015). The study result said that the extreme road traffic congestion increases the incident of domestic violence by 9%. Correspondingly, [9] methodically estimated the causal effect of incident duration on drivers' time losses via changes in non-regular road congestion. Its conclusion is incident duration has a strong positive effect on non-regular congestion.

Moreover, [10] offered a novel technique for sensing the road traffic jam. Practically it can be used to enhance the quality of traffic management. The model can supervise the condition of highway (East and West California) traffic congestion. The rigid statistical information of road traffic can be exhibited in detail by the model. [11] developed the model for optimizing the congestion of road network. It is an intelligent model to decide the best road traffic pattern based on time-sensitive analysis. Also, [12] studied and analysed the connection of congestion between road segments based on multi-sources data. The study result is able to facilitate to build road traffic application.

Based on the background, the effective way to solve the problem of road traffic congestion is still going to be explored. Here, the study with main objective to build an ecological decision support model (eco-DSM) for road traffic engineering was academically conducted. In this paper, the novel model is illuminated; it is able to support the decision maker for road traffic engineering via considering common road traffic congestion and environmental aspects in eliminating the road traffic congestion. The paper introduction part is followed by the parts Related works, Research methodology, Result and discussion, and Conclusion and further works.

## 2. Related works
The close similar studies already conducted are what [13] and [1] have done. [13] and [1] used main methods water flow algorithm (WFA) and combination of fuzzy logic and WFA (FWFA) respectively in road traffic engineering to solve a road traffic congestion. They took into account six common road traffic attributes in defining the congestion, i.e. road velocity, road density, road volume, road delay, road capacity, and road saturation degree. Additionally, [14] modelled a road traffic engineering case thru mathematics IT based modelling. The study answered that mathematics IT is a valuable course for the first-year computer science students. [15] modelled a road traffic management also. Here, the built model demonstrates the activities of road traffic management during a special moment, such as major sports event. [15] successfully described the specified attributes of traffic in a road network with the right most lane dedicated to public transport.

## 3. Research methodology
Essentially, the same steps with [1] in running this study was used. Three types of study objective by using particular stages and methods for each goal (see Figure 1) were operated. Firstly, the literature review and deep discussion to learn the previous studies were conducted. Here, the methods desk based research and literature study were used. Secondly, the empirical data was surveyed, observed, collected and analysed. The area in the main traffic road of Juanda street in Tangerang Selatan (Province Banten, Indonesia) is a precise area taken as a research object. It is a supporting traffic road for the Indonesia's capital Jakarta. It directly intersects with Jakarta outer ring (JOR) road; where both traffic roads are as congested roads frequently. Finally, the model was constructed. In the last stage, the combination of fuzzy logic [16] and WFA [1] (FWFA) and object oriented [17] methods were scientifically benefited.

To collect the empirical data, [18] method, that replicated by [1] and [13], practically used. The data of road traffic velocity were collected in the definitive time (in the morning from 6:00 am to 10:00 am and in five working days on 15 – 19 May 2017). Here, the vehicle movement was recorded via video cameras in five minutes for each record and the result was converted to hour (for time) and kilometre (for distance) unit measurement.

The model conception of [1] is not only a fundamental thinking for constructing the model in this study, the equivalent types of common road traffic parameters were also functioned. Six common parameters used here are road velocity, road density, road volume, road delay, road capacity, and road saturation degree. However, other imperative aspects regarding environment were theoretically measured. The best decision alternative is selected based on the road traffic velocity influencing the arithmetic mean value of emission (via fuel consumption measurement). Seven types of emission measured in this study are $NO_X$, $CO$, $CO_2$, $PM_{10}$, $SO_2$, $N_2O$, and $CH_4$. They are verified to be usually functioned in research

regarding climate change and environmental aspects which taken from two academic resources: [19] for parameter $PM_{10}$ and [20] for the others.
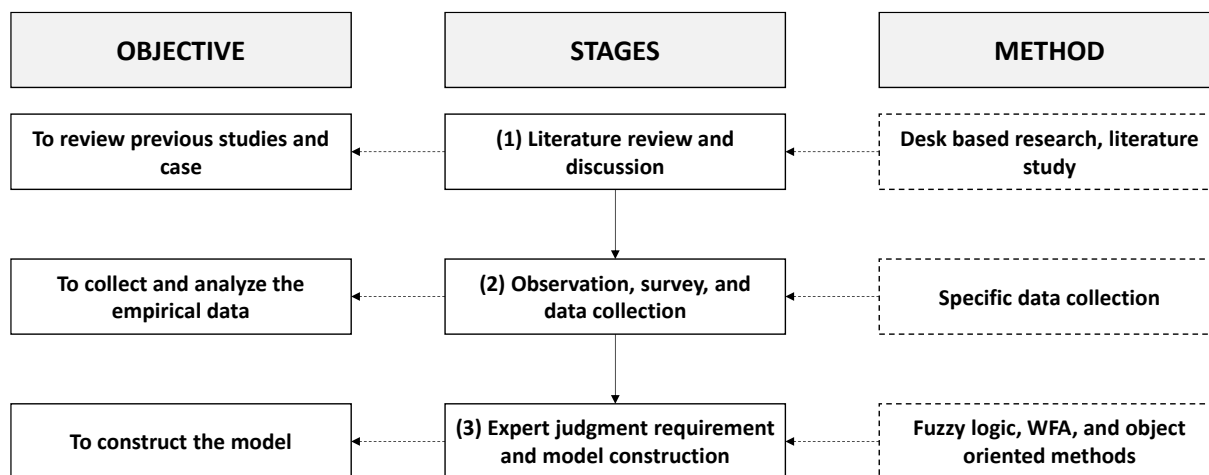


Figure 1. Stages of the research

## 4. Result and discussion

### 4.1. Model Analysis
The fundamental analysis for the created model is coming from [1]. The study conclusion said that the high vehicle velocity on the traffic road indicates high level of road traffic flow equivalently and low level of road traffic congestion conversely; and the vehicle velocity increase is able to undoubtedly affect a number of air emission reduction. Thus, the model for road traffic engineering based on environmental aspects is constructed. Here, the constructed model is capable to recommend the road traffic engineering thru considering the calculation seven selected environmental aspects.

### 4.2. Constructed model
The high level of the constructed model is technically symbolised via influence diagram (Figure 2), where the relationship among entities is configured thru class diagram (Figure 3). Figure 2 depicts the correlation among parameters involved in the model. Six common road traffic parameters affect the road traffic velocity, where it (via fuel consumption measurement) influences the average value of emission then. The objective of the model is to decide the best type of road traffic engineering based on the optimum total emission value to avoid the road traffic congestion.

Figure 3 mechanically describes the relationship of entities involved. The central of entity in the constructed model is the class TrafficRoad (traffic road) which consists of the classes UTurn (u-turn), TrafficLight (traffic light), and StopPoint (stop point of public transport vehicle, e.g. buss halt). The class TrafficRoad is also illustrated strictly by the class ConsideredParameter (considered parameter, where it is openly portrayed by influence diagram in Figure 1).
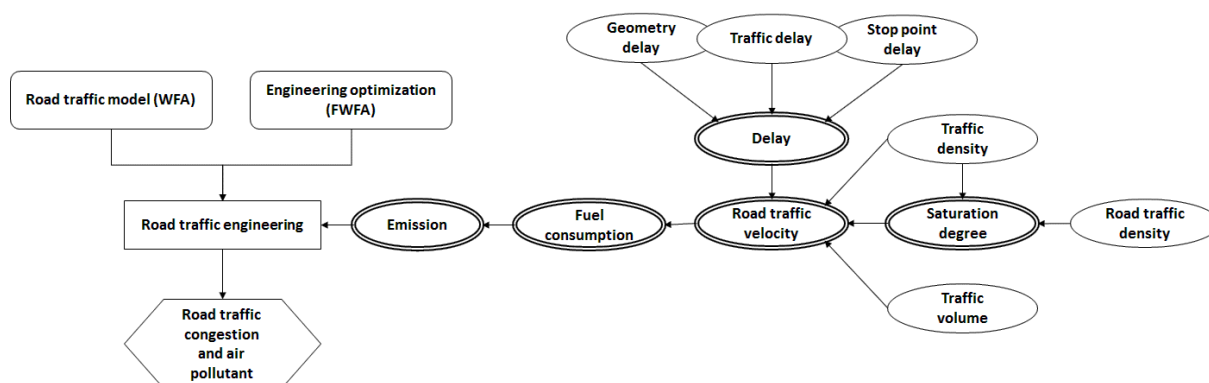
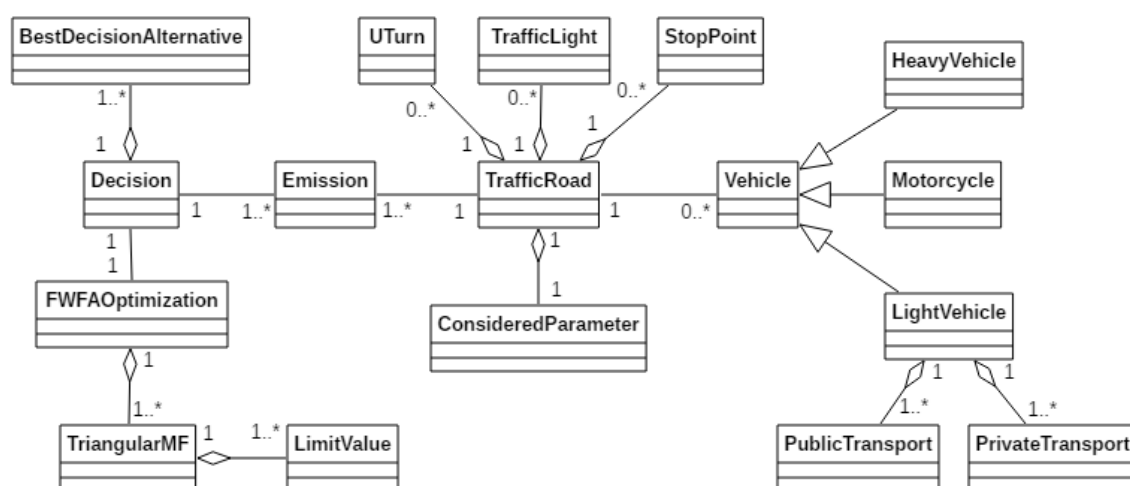Figure 2. Influence diagram of the constructed model's parameters involved



Figure 3. Class diagram of the constructed model

There are 137 decision alternatives of road traffic engineering which are categorised into six categories, i.e. contra flow, public transport (angkot in Bahasa) elimination, traffic light manipulation, stop point reduction, u-turn reduction, and motorcycle elimination. The simulation shows that there are 28 decision alternatives gathered into search list (see Figure 4). The figure portrays the list of the best alternative candidates produced from all searching loops of the model. Logically, the model is going to save the current value of emission (produced by one decision alternative) if it was smaller than previous smallest one. From 137 loops, the model has recorded 28 candidates that naturally sorted from the highest to lowest. Here, the best decision alternative for road traffic engineering has been able to be taken, it is motorcycle elimination with total value of emission 23.93 kg/h. It is only 34% of the concentration of air pollutant in the normal road traffic condition. It means the road traffic can get the best condition (with the smallest total emission in the air) if the decision maker (local government) eliminate the motorcycle in that area (main road).
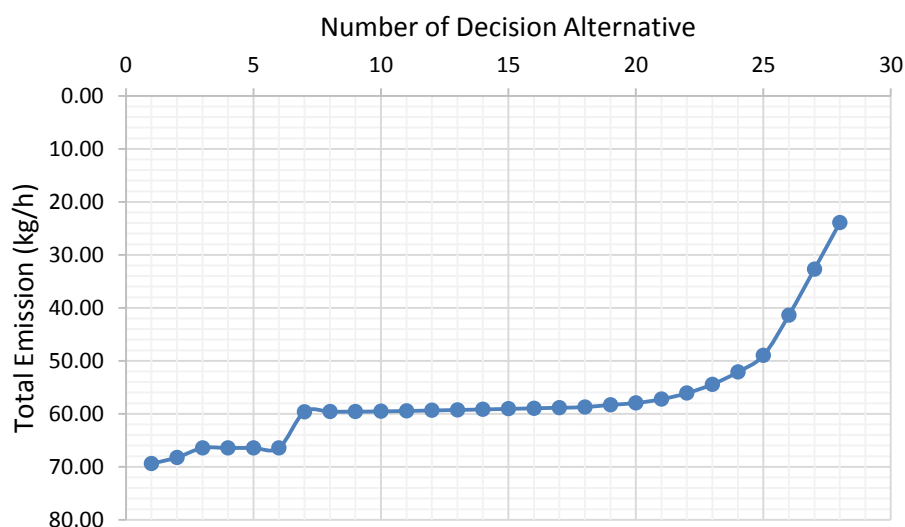
Figure 4. The graph of total emission in search list based on FWFA optimization result

Furthermore, Figure 5 shows the graph when the selected decision is compared with other decision alternatives. It describes the comparison of best emission value resulted by each alternative based on six decision alternatives for road traffic engineering strategy. It is the other information look of Figure 4; where the best value of emission categorized by strategy. Here obviously exhibited that the decision for eliminating motorcycle gives the smallest total value of emission. It should be the best decision precisely.
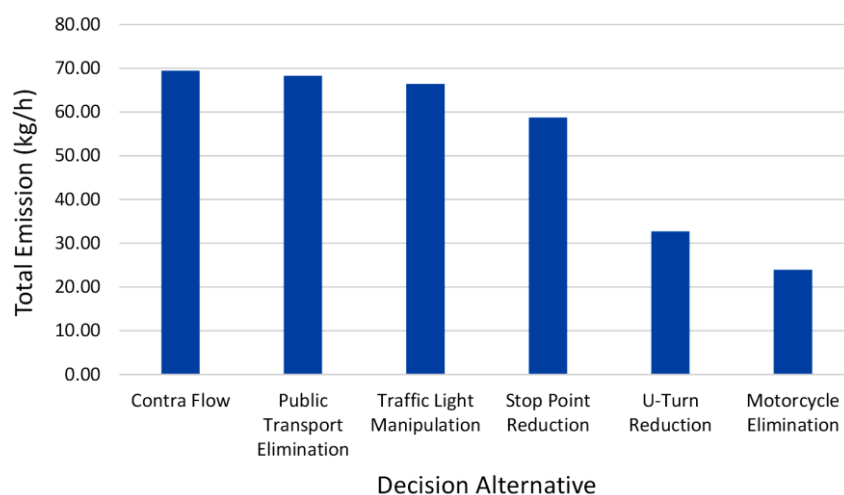


Figure 5. The graph of total emission for all decision alternatives

Additionally, the model successfully constructed is able to deliver all information types produced by the result of each calculation. For example, Figure 6 is an example model dashboard to show the result of emission calculation for each decision alternative (A) and final decision alternatives that can be seen for each emission (B). The model also can deliver all information by selecting the type of traffic road.
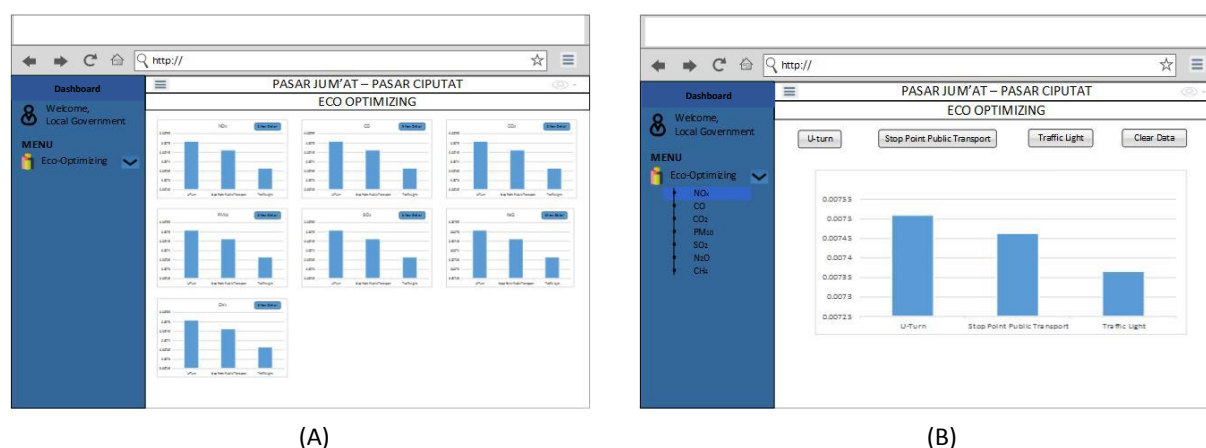
|  (A)  |  (B)  |

Figure 6. The examples of model dashboard

### 4.3. Discussion

This research is an extended study of [1]. The basic conception of their constructed model, and also all parameters they used were adopted. Nevertheless, the ecological aspects in constructing the model were considered. The emission measurement in the constructed model was involved. Seven types of emission were involved, and the process for seeking the best decision alternatives was based on its calculation. Even though, the decision was optimised based on emission calculation, the best value of total emission also gave the best value of road traffic velocity. It meant, the model suggested the best decision alternative for road traffic engineering not only for downgrading the total value of emission, but also for reducing the road traffic congestion level. On the other hand, the study of [1] differently showed that the reduction for stop point of public transport as the best decision to reduce the road traffic congestion; where it gave the highest value of road traffic velocity. It happened probably as the empirical data for this study was collected in the different observation time.

### 5. Conclusion and further works

The ecological decision support model (eco-DSM) was academically created. The model is able to suggest the best alternative for decision maker in road traffic engineering. The model is extended version of the [1] study, where the constructed model recommends the best road traffic engineering not only to reduce the congestion level, but also degrade the concentration of air pollutant.

The study has already exposed the result of model simulation, where from 137 decision alternatives, 28 alternatives has been folded into virtual search list. Finally, the decision to eliminate motorcycle from main traffic road of Juanda Street in Tangerang Selatan (Province Banten, Indonesia) is the best decision in road traffic engineering. It is almost 200% better air condition than normal air condition and 2,200% better condition of road traffic congestion than the normal one.

Additionally, other optimisation methods have high opportunity to be learnt and embedded to the model, e.g. ant colony optimisation, hill-climbing, and simulated-annealing. They are possibly able to be combined with the method used in this study too. Also, the study to build the model that links the road traffic engineering with human health is going to be motivating study to do.

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