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# AN INTELLIGENT TRAFFIC LIGHT SYSTEM FOR REDUCING NUMBER OF QUEUING CARS IN COMPLEX ROAD JUNCTION

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Abstract. *This research aims to design a traffic light control system as a part of intelligent transportation system (ITS) with fuzzy logic (FL) approach for typical growing cities in developing countries. Six Months Data Traffic are used for the system decision and validation. Determination of membership functions for two input parameters are taken based on calculation of the highest volumes of traffic flow observation. Output parameter (Op) is calculated based on the calculation of the degree saturation intersections on each road by maintaining existing time on 130 seconds, with Op ideal being* $[-29, 23]$. *The result shows that FL as intelligent systems for traffic management can reduce the density of vehicles in each segment. Future research will be how to implement this result in Internet of Thing (IoT) application.*
**Keywords:** Intelligent traffic, Fuzzy logic, Intelligent transportation system

1. **Introduction.** Makassar City is the third largest city in Indonesia with rapid development in hotels and cuisines, tourism and industries. Nowadays, people in the city have to deal with traffic jam in almost complex junction in the city. *Direktorat Lalu Lintas Polda Sulawesi Selatan* stated that the number of vehicles in Makassar has reached more than 1,460,385 units. This is equal to 39.94% of the total number of vehicles in two provinces that is South Sulawesi and West Sulawesi [1].

Congestion in Makassar often takes place at PLTU Tello intersections, one of the complex junction of three main roads namely Jl. Urip Sumoharjo – Jl. Perintis Kemerdekaan – Jl. Leimena. This intersection connects the residential and educational areas to the city, as well as the main roads of the public transportation. This junction also connects Makassar city to other suburbs in South Sulawesi Province. Not only in rush hour (morning and afternoon), the congestion usually occurs in normal hours, especially on weekdays. This is due to imbalance of the intersection capacity which is no longer able to serve the traffic volume at that random traffic hours. Traffic control system that is called as APILL at PLTU Tello intersection still uses a fixed time control system [2]. The weakness of this system is inability to respond to dynamically changing and unpredictable traffic situations.

One development of ITS is how to improve the performance of traffic control system APILL which can be adjusted to the density of the traffic for each intersection [3]. Traffic control system APILL can be developed by utilizing artificial intelligence, such as fuzzy logic approach. Fuzzy logic can adapt to levels that contain uncertainty, inaccuracies (impreciseness), and noisy elements. Another advantage of fuzzy logic is being able to be applied in the machine with high precision values (crisp) [4]. FL has been conducted also for saturation traffic and gives potential proof in reducing delay [5]. However, none has been conducted for using FL in reducing density in complex junction road which in the early future will be integrated using IoT technology.

Previous research has been conducted to support this smart traffic light research [3]. A novel technique for more reliable automatic counting of vehicles using CCTV is used for data streaming in this research. The consecutive discussions of this paper are research method, analysis and discussion and then conclusion at the end of paper.

## 2. Research Method.

**2.1. Criteria and boundary research.** In research design there are several assumptions that need to be considered, which had been obtained by preliminary survey [1], such as object of the research is three path intersection, phase turnover between the green light signal consisting of two phases, the main path from east to west (Jl. Perintis Kemerdekaan – Jl. Urip) allowing turning directly when it is the red light. While, from south to east it is only allowed to turn right when it is the green light along with from the west turning right towards the south, no restrictions of type of vehicles which passes through the intersection, and the number of vehicles is calculated based on the units of weight vehicles (skr) [2].

Each phase has been set into standard calculation. The green lost time total ($\mathrm{H_H}$) to each intersection can be calculated as the sum of the times between the green light using the equation:

$$\mathrm{H_H} = \sum_{\mathrm{i}} (\mathrm{M_{total}} + \mathrm{K})_{\mathrm{i}}$$

where $\mathrm{M_{total}}$ =Total time of Red Light and K = Constant time imply to each Red Light.

Sum of average (skr) per lap in each period of observation can be calculated by dividing total skr in the observation period by number of the laps, as the following equation:

$$\sum \mathrm{skr_i} = \frac{\sum \mathrm{skr/hour}}{\sum \mathrm{lap}}$$

where $\sum$ skr = Total Number of skr and $\sum$ lap = Total Number of laps.

Degree of Saturation (DJ) is calculated using equation:

$$\mathrm{DJ} = \mathrm{Q/c}$$

Q = total number of vehicles that passes the junction (traffic flow)
c = maximum capacity of traffic

**2.2. The structure of fuzzy traffic light controller.** Fuzzy traffic light controller structure consists of four parts: input, fuzzy logic controller, output and traffic light controller as shown in the following figure. Figure 1 shows design for development of research [8]. There are four parts: input, fuzzy logic controller, output and the traffic light controller. Part fuzzy logic controller has task to that how input data is processed in fuzzy using fuzzification mechanism, fuzzy inference based on fuzzy rules and the final process with defuzzification mechanism. Output defuzzification is sent to the traffic light control to be processed as a variable time as a lighting of the green. Defuzzification result as a crisp value can be a negative value to reduce (decrease), zero (constant) or positive to add (increase).

Strategy on fuzzy traffic light control in this research is how fuzzy logic controller generates green light signaling the time value at the turn of phase to reduce, maintain or increase the time the green light signals in phase applicable at the traffic light at this time.

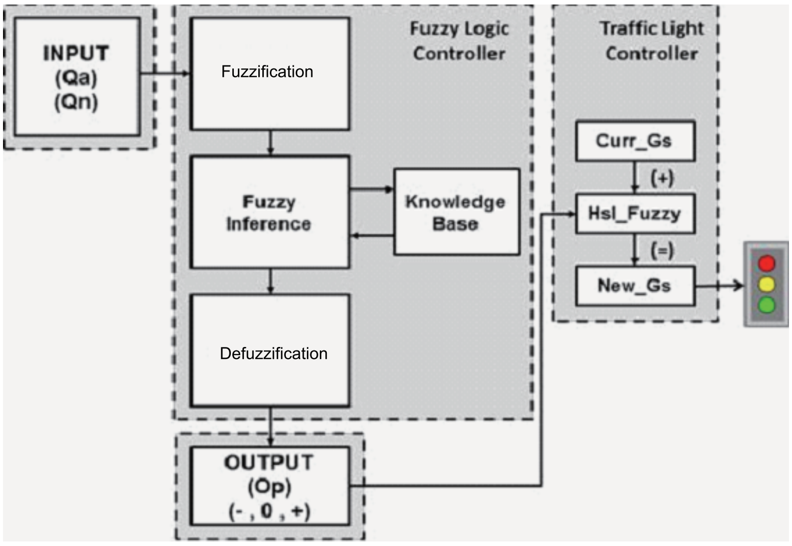



Figure 1. Fuzzy traffic light control structure [8]

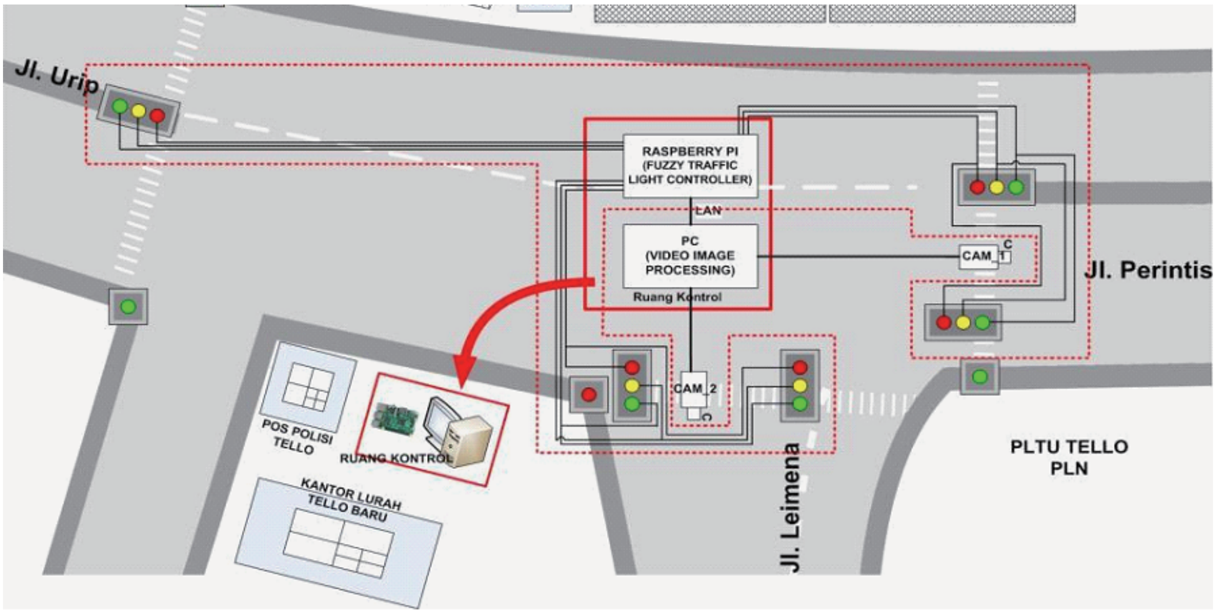



Figure 2. Schematic diagram of fuzzy traffic light control

2.3. **Schematic diagram of fuzzy traffic light control.** Implementation system plan on the field with schematic diagram concept is in Figure 2.

Figure 2 shows schematic diagram of fuzzy traffic light controller which is embeeded in a Raspberry Pi. Each direction is represented as Qa for east and Qn for south. The control room is placed close to the junction of each traffic light. Further process is shown in Figure 3.

2.4. **Flowchart of fuzzy traffic light controller.** Figure 3 shows flowchart of implementation fuzzy traffic light controller system. Each group is divided into two phases. Both phases are signalling in turn based on time continously and simultaneously. The flowchart shows how a phase is processing and followed by another phase based on result from fuzzy calculation.

From Figure 3, there are 4 parts of fuzzy traffic light controller, i.e., 1) definition and initializing system, 2) check phase status and retrieve parameter input Qa and Qn, 3) fuzzy logic controller processing and 4) traffic light controller.

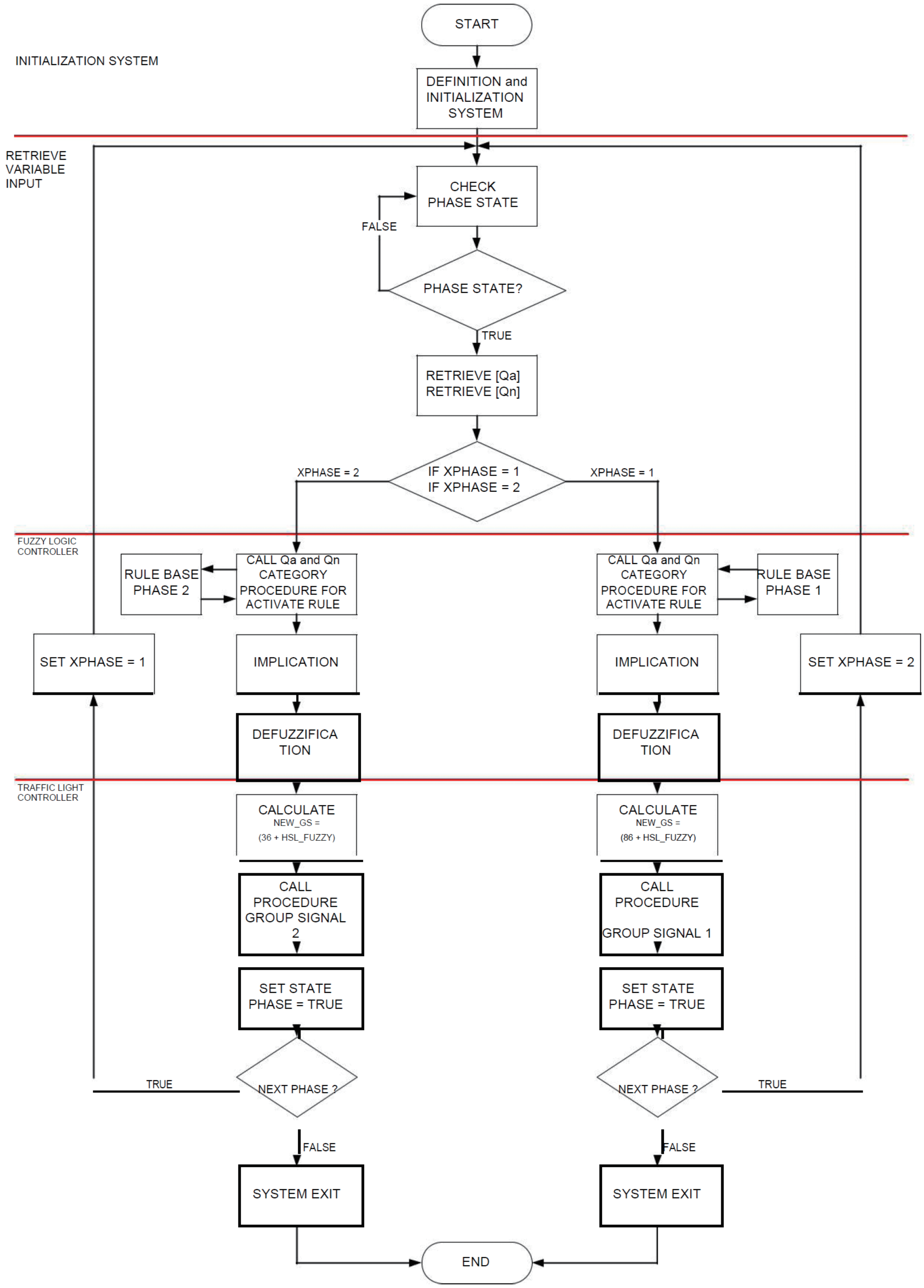



Figure 3. Flowchart of fuzzy traffic light controller

## 3. Results and Analysis.

3.1. **Sub Section 1.** PLTU Tello intersection can call as 322 intersection, i.e., intersection with three paths which consists of 2 path of major road (Jl. Perintis – Jl. Urip/east to west) and 1 path of minor road (Jl. Leimena/south to east), as like Figure 4 below.

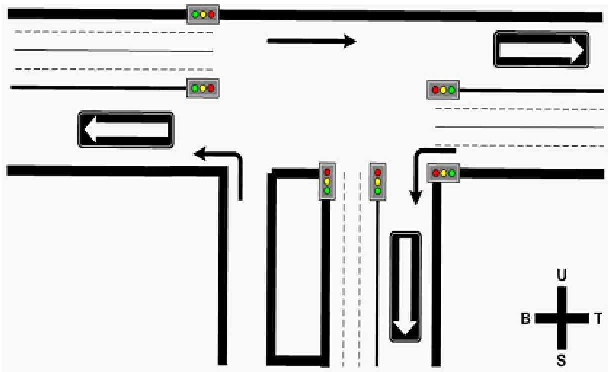
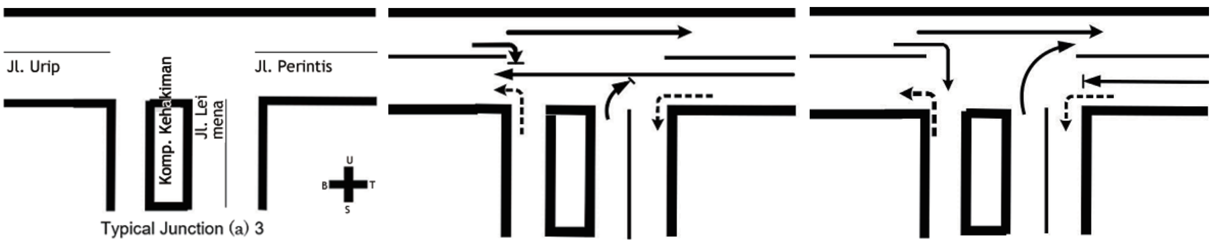



Figure 4. Illustration of 322 intersection

The determination of phase and time signalling traffic lights at the junction consists of two phases as follows.




(a) (b) (c)

Figure 5. Phase rules on PLTU Tello intersection: (a) PLTU insection type, (b) phase 1, (c) phase 2

Phase 1. In this phase, the green light signals active are for a moving vehicle from Jl. Perintis Kemerdekaan – Jl. Urip (east to west), while active red light signals to vehicle from Jl. Leimena – Jl. Perintis (south to east) and from Jl. Urip – Komp. Kehakiman (west to the south). In this phase it also allowed left turn directly, either from Jl. Perintis – Jl. Leimena (east to south) from Komp. Kehakiman – Jl. Urip (south to west) and continuing straight road of Jl. Urip – Jl Perintis (west to east).

Phase 2. In this phase, the active green light signals are to the vehicle from Jl. Leimena – Jl. Perintis Kemerdekaan (south to east) and the vehicle from Jl. Urip – Komp. Kehakiman (west to the south), while the red light signals active for Jl. Perintis – Jl. Urip (east to west). In this phase it also allowed the road to continue to turn left direction of Jl. Perintis – Jl. Leimena (east to south), Komp. Kehakiman – Jl. Urip (south to west), and the road to continue straight on Jl. Urip – Jl. Perintis Kemerdekaan (west to east).

3.2. **Sub Section 2.** To determine criteria for design of fuzzy logic controller, the following analysis performance of PLTU Tello intersection is as below.

Lap of PLTU Tello intersection is 28 laps. The number is known by dividing the observation time per period (1 hour/3600 sec) with lap time for all phases being 130 seconds.

$$\sum \text{siklus} = (3600 \text{ seconds})/(130 \text{ seconds}) = 27.69$$


FIGURE 6. Phase time of light signal

TABLE 1. Existing time (recapitulation time rules)

| The path | $H_H$ | C | $H_i$ |
|---|---|---|---|
| Jl. Perintis | | | 86 |
| Jl. Leimena | 8 | 130 | |
| Jl. Urip | | | 36 |

It rounded to 28 laps.

TABLE 2. Summary of traffic flow (Q)

| No | Observation Time | Traffic Flow (skr) Jl. Perintis | Jl. Leimena | Jl. Urip (BKa) | Jl. Urip (Lrs) |
|---|---|---|---|---|---|
| 1 | 06:00-07:00 | 1839 | 625 | 153 | 1390 |
| 2 | 07:00-08:00 | 2478 | 1177 | 181 | 1931 |
| 3 | 08:00-09:00 | 2097 | 1002 | 178 | 1822 |
| 4 | 13:00-14:00 | 1776 | 640 | 103 | 684 |
| 5 | 14:00-15:00 | 1714 | 757 | 120 | 805 |
| 6 | 15:00-16:00 | 1946 | 726 | 117 | 1849 |
| 7 | 16:00-17:00 | 1970 | 697 | 111 | 1874 |
| 8 | 17:00-18:00 | 1881 | 704 | 109 | 1787 |

(shaded) The highest number

Calculations for the highest traffic flow are based from Table 2:

$$\sum \text{skr}_i = \frac{2478}{28} = 88.50$$

Table 2 above explains that the average queuing of traffic peak periods (07:00 to 08:00) is 89 skr to Jl. Perintis, 43 skr to Jl. Leimena and 7 skr to Jl. Urip (BKa). The data are the basis in forming the input variable interval queues at Jl. Perintis between $[0, 89]$ and Jl. Leimena between $[0, 43]$, while for data traffic flow on Jl. Urip, the phase and timing coincide with those of Jl. Leimena, so that when compared, data traffic flow on Jl. Leimena is the reference because it is larger than the data on Jl. Urip. If Jl. Perintis as roads were observed and Jl. Leimena as the roads are reviewed, the result Qa is minimal interval $[0, 89]$ and Qn is minimal interval $[0, 43]$.

In the explanations related to the degree of saturation, it is necessary to test the first variation of the addition or subtraction of time green signal ($H_i$) on the reviewed road (Jl. Perintis) and the observed road (Jl. Leimena). The goal is to measure the impact on the degree of saturation not exceeding $> 0.85$. Testing is done by reducing the time and adding green signal ranging from $-30$ s/d to $+25$ by maintaining a lap of 130 seconds.

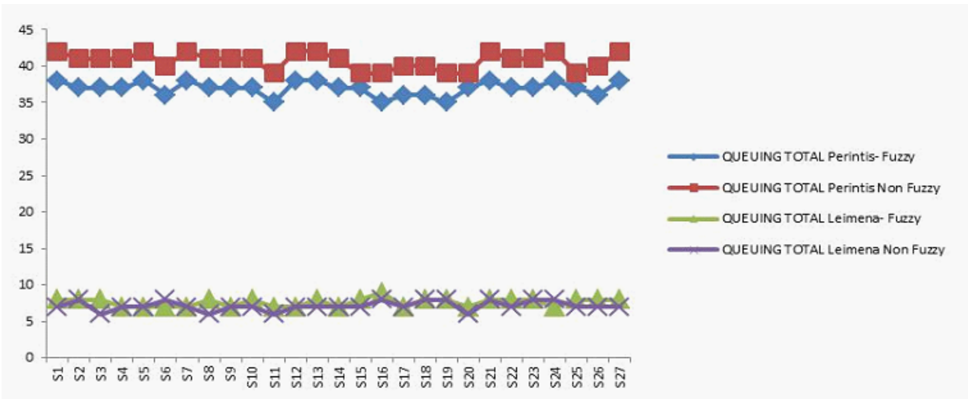
The degree of saturation particularly for low traffic flow after reduced 29 seconds becomes DJ $= 0.84$ ($< 0.85$) on Jl. Perintis that can be tolerated, while on Jl. Leimena degree of saturation decreases DJ $= 0.19$ and 0.09 for Jl. Urip. The same thing after being added with 23 seconds to the green light signal, the degree of saturation at Jl. Leimena DJ = 0.82 (< 0.85) and Jl. Urip to 0.43, can be tolerated.

The data in the above explanation is intended to be a reference target output fuzzy results not leading to the degree of saturation intersection > 0.85. So the value of the variable output interval (Op) may be formed with intervals Op: $[-29, 23]$.

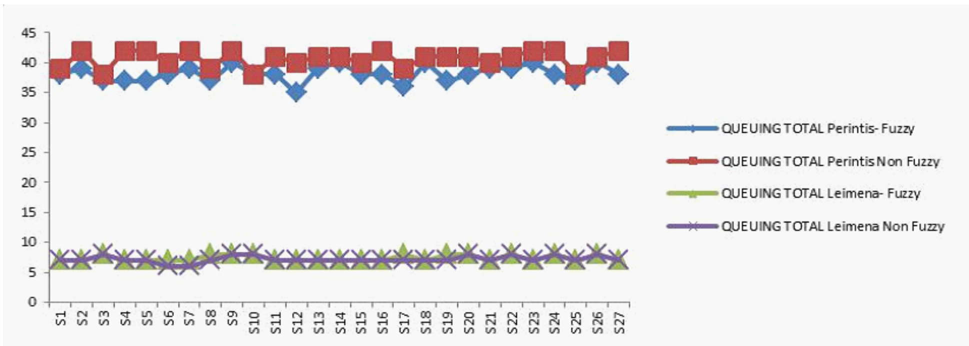
3.3. **Sub Section 3.** Average number of vehicle in Jl. Perintis is 54 and Jl. Dr. Leimena is 29. Green light time on phase 1 is 92 sec and phase 2 is 27 sec. Phase 1 is green light signal on Jl. Perintis – Jl. Urip. Phase 2 is green light signal on Jl. Leimena – Jl. Perintis.

TABLE 3. Fuzzy and Non Fuzzy on phase 1

| | QUEUING TOTAL | | | |
|---|---|---|---|---|
| Cycle | Perintis wt FL | Perintis Non FL | Leimena wt FL | Leimena Non FL |
| S1 | 38 | 39 | 7 | 7 |
| S2 | 39 | 42 | 7 | 7 |
| S3 | 37 | 38 | 8 | 8 |
| S4 | 37 | 42 | 7 | 7 |




(a)




(b)

FIGURE 7. (a) Fuzzy and Non Fuzzy chart phase 1; (b) Fuzzy and Non Fuzzy chart phase 2

From Figure 7(a) and 7(b) above from simulation system result can be explained that the number of queues of the vehicles using fuzzy logic is lower than that using non fuzzy logic system; it can be seen from square and diamond lines as non-fuzzy simulation and fuzzy simulation as cross and triangle lines. The fuzzy simulations show that traffic flow of simulation with fuzzy is more effective than simulation without fuzzy. Then the fuzzy

TABLE 4. Fuzzy and Non Fuzzy phase 2

| | QUEUING TOTAL | | | |
|---|---|---|---|---|
| Cycle | Perintis Fuzzy | Perintis Non Fuzzy | Leimena Fuzzy | Leimena Non Fuzzy |
| S1 | 38 | 42 | 8 | 7 |
| S2 | 37 | 41 | 8 | 8 |
| S3 | 37 | 41 | 8 | 6 |
| S4 | 37 | 41 | 7 | 7 |

logic as intelligent systems for traffic management traffic can reduce the density of vehicles in each segment.

4. **Conclusion.** Fuzzy traffic light control is created with two input variables (Qa, Qn) and 1 output variable (Op). Based on analysis of the volume of vehicle traffic on Jl. Perintis Kemederkaan and Jl. Leimena, domain of fuzzy sets is $[89, \infty]$ to Qa (Jl. Perintis Kemerdekaan) and $[43, \infty]$ to Qn (Jl. Leimena).

The testing results on the degree of saturation at PLTU Tello intersections indicate that the reduction of green light time for each maximum phase are $-29$ seconds for the reductions and 23 seconds for additions. Reduction or additions on one phase can affect the timing of other phases. The variable output that can be formed by the interval is $[-29, 23]$.

Based on the simulation with using fuzzy logic control, the fuzzy logic as intelligent systems for traffic management traffic can reduce the density of vehicles in each segment. Future research will develop system with Internet of Things technology, since all traffic light systems will need to have ability in communicating with each other and sharing statistical traffic calculation for each junction.

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