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The Implementation of Dynamic Traffic Light Model to Overcome Traffic Congestion in Denpasar - Bali

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Abstract: ***Traffic congestion is a problem that often occurs in a city like Denpasar. Congestion occurs due to the factor of poor government regulations such as the lack of public transport, the increase in the number of vehicles which is not accompanied with the expansion of roads, as well as poor spatial planning of the city. The imbalance in the volume of vehicles crossing the road also contributes to the problem especially at intersections. At every intersection in the city of Denpasar, to avoid accidents, the government installs traffic light. Unfortunately, the traffic light is statically setup with each green light for every direction is given the same time period. This is also predicted to be one of the factors causing congestion in the city of Denpasar, because it does not take into account the density of the volume of vehicles coming from certain directions. From the result of surveys conducted at the intersection of By Pass Ngurah Rai Denpasar, static traffic light contributes to the accumulation of vehicles ranges from 53 to 87 per hour which in turn causes traffic jams. To overcome the bottlenecks that often occur, in this study we propose a dynamic traffic light model which produces green light time difference of 3.986 minutes to 6.543 minutes to every hour with a significance level of $p \leq 0.012 \leq 0.072$ which is able to parse the vehicle density of about 53 to 87 per hour. The dynamic traffic light model is appropriate to be applied at intersections in Denpasar considering regulations related to public transportation and administration area which are less supportive. The density of vehicles which can not be avoided must be parsed quickly so as not to cause traffic jams everywhere.***

Keywords: Dynamic, Traffic Light, regulation, layout region

1. Introduction

Congestion is a regular phenomenon that occurs daily in the city of Denpasar. Congestion occurs due to the factor of unfavorable government regulations such as the lack of public transport, the number of roads that are not comparable with the volume of vehicles as well as bad city planning. The imbalance in the volume of vehicles on the road with the number of road built cause congestion, especially around the intersection.

Traffic light has been installed at every intersection in the city of Denpasar to avoid accidents. Unfortunately, these traffic lights are setup statically with the same proportion of time for each green light from every direction. This is also predicted to be one of the causes of traffic congestion in the city of Denpasar, because it does not take into account the density of the volume of vehicles coming from certain directions.

To overcome the bottlenecks that occur on the main streets in the city of Denpasar, in addition to employ necessary government regulations such as the provision of public transport, it is also imperative to rearrange these existing traffic lights. Traffic lights that have been statically setup, can be changed dynamically where the time given for the green light is adapted to the volume density of vehicles. According Stiadji (2006: 41), this volume density of vehicles on the road is denoted by the number of cars per unit time. So to eliminate the bottlenecks that occur, the priority is to reduce the number of vehicles on one side of the road.

2. Methodology

Mathematical Modelling

Model in modeling a system, according to William F. Lucas (1981), is a reflection or a representation of the real system. The measure of success in modelling is highly dependent on the level of perfection of the model in describing the real system. Mathematically, a model can be viewed from several perspectives as in Table 1.

Table 1: Mathematical Model Based Perspective

No	The point of view of a model	Type of model
1	Functionality	a. Descriptive model b. Predictive model c. Normative model
2	By time reference	a. Static model b. Dynamic model
3	By the degree of certainty	a. Deterministic model b. Probabilistic model
4	Quantitatively	a. Quantitative model b. Qualitative model c. Simulation model

Modelling the green light

The time needed for the green light is adjusted to the flow of vehicles at the intersection by considering the average distribution of the vehicle arrival time on each road as a measure of the density of vehicles. This vehicle density is used as base to calculate the length of time of green light on each road with the following formula.

$$t_x = \frac{L_{jx}}{v_x + Z_x}$$

Where,

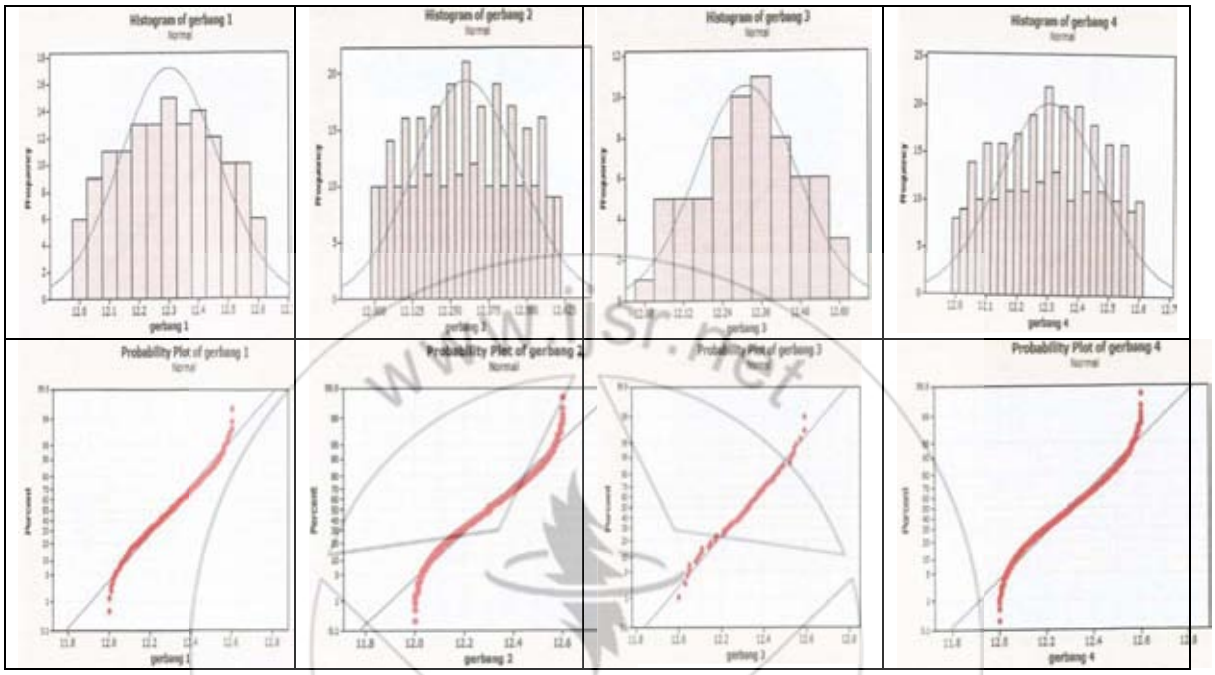
t_x: waiting time of vehicles

L_{jx}: area of the road
v_x: the average speed of vehicles
Z_x: vehicle arrival time distribution

3. Result and Discussion

In this research, the data is collected at the By Pass Ngurah Rai intersection in Denpasar to determine the arrival level of the vehicles within 60 minutes. The arrival level of the vehicles from the direction of Denpasar towards Suwung Beach, Sanur towards South Kuta, Suwung beach to the city of Denpasar, South Kuta toward Sanur is denoted by Gerbang_1, Gerbang_2, Gerbang_3, and Gerbang_4 respectively.

From our research we get the following results. The number of vehicles entering each gate is 80 vehicles / hour in gerbang_1, 210 vehicles / hour in gerbang_2, 70 vehicles / hour in gerbang_3, and 176 vehicles / hour in gerbang_4.



From the historical data, we can conclude that the arrival of the vehicles in each gate is normally distributed. The following statistical summaries further clarify our claim.

Table 2: Descriptive Stastistics of Gate

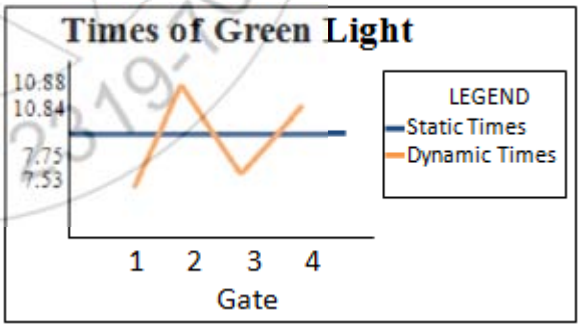
Variabel	Mean	SE Mean	StDev	Variance	Median	Skewness
Gerbang_1	12.301	0.0139	0.166	0.0275	12.300	-0.01
Gerbang_2	12.315	0.0187	0.170	0.0238	12.325	-0.16
Gerbang_3	12.300	0.00938	0.154	0.0289	12.300	-0.00
Gerbang_4	12.306	0.00909	0.167	0.0280	12.300	-0.04

The mean and median are nearly equal and the skewness is close to zero. This indicates that the data from each vehicle arrival gate is symmetrically, continually and normally distributed. The next step is to calculate the length of time (tx) for the green light to be illuminated on each gate. From the calculations of Z probability standard at each gate, we obtain the length of time (tx) as shown in the Table 3.

Table 3: Distribution of Old Time Green Light

Variable	N	df	t_x	mean	p-value
Gerbang_1	80	79	7.75	9.25	0.195
Gerbang_2	210	209	10.88		0.072
Gerbang_3	70	69	7.53		0.009
Gerbang_4	176	175	10.84		0.012

Table 3 shows the distribution of the length of time for the green light on each gate statistically with an average of 9:25 seconds with a significance level of $p \leq 0.009 \leq 0195$. The average length of time is used as the period for the green light on every gate. The ratio of the length of time each gate lit statically and dynamically shown in Figure 1 below.



Seeing the difference of time required at each gate with an average time to switch the green light, and using the data from each vehicle arrival gate then accumulation of vehicles will occur at certain gates as shown in Table 4 below:

Table 4: Ratio of Static Traffic Congestion Impact Light

Variabel	t_x	t_x-t	Density	Rate
Gerbang_1	7.53	-1.72	70	0
Gerbang_2	10.88	1.68	210	87
Gerbang_3	7.75	-1.50	80	0
Gerbang_4	10.84	1.69	176	53

It can be seen that the risk of congestion on gerbang_4 and gerbang_2 are very high with the level of accumulation of

vehicles as much as 30.11% and 41.43% at gerbang_4 on gerbang_2 at each hour with a significance level of $p \leq 0.012 \leq 0.072$. It raises the risk of accumulation of vehicles on gerbang_2 and gerbang_4 which is caused by the equal length of time for the green light at each gate.

In a time periode of 9.25 minutes, as much as 123 vehicles will be unraveled in every gate. Gerbang_4 will leave as many as 53 vehicles, thus it will take about 3986 minutes extra time for each hour in order to be able to parse the vehicl. Gerbang_2 will leave 87 vehicles so that it takes about 6543 minutes extra time for every hour in order to be able to parse the vehicle. This can be done by using dynamic systems applied to the traffic light in the city of Denpasar, thus Denpasar will be freed from traffic congestion.

4. Conclusion

1) Static method for traffic light at the By Pass Ngurah Rai intersection in Denpasar cause accumulation of vehicles on gerbang_4 and gerbang_2 about 53 to 87 cars / hour.
2) By implementing a Dynamic Traffic Light, the accumulation of vehicles will be parsed and can mitigate traffic congestion in Denpasar with a significance level of $p \leq 0.012 \leq 0.072$.

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Author Profile

W. Santiyasa received the title of Drs. And M.Si at Gadjah Mada University in Statistics in 1991 and 2000. Since 1991 worked as a lecturer at the Faculty of Mathematics and Natural Sciences, Udayana University, Bali, Indonesia. Teaching in the field of statistics, computing and information systems. Later develop a variety of research in the field of intelligent systems.