

## **DESIGN AND DEVELOPMENT OF A TRAFFIC LIGHT SIMULATION MODEL BASED ON ARDUINO MICROCONTROLLER**

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### **ABSTRACT**

Congestion is one of the transportation problems with the highest percentage to occur at every intersection in all corners of the region. Efforts can be made to solve these problems by making the traffic light regulation system (APILL) in general, APILL still uses static cycle time with cable networks as interconnects between lamp poles, making it difficult to adjust the phase and cycle time referring to traffic conditions that tend to be dynamic, even requiring high procurement and maintenance costs for underground cables. Based on the above, the research team wants to create a simulation mockup of APILL whose cycle time and phase can be set through calculations on the Android platform with wireless interconnection, as well as can be used as a learning facility for cadets/I to provide an understanding of the applicable phase at the intersection, to be able to analyze the performance of an intersection and how APILL works on roads.

Keywords: APILL mockup; arduino; phase; traffic performance

### **INTRODUCTION**

Transportation problems are a problem faced by every country, both developed and developing countries. Can be caused by several factors such as lack of traffic infrastructure, accidents and natural disasters, congestion has a tendency to increase social costs in the form of travel costs and time, energy consumption and environmental degradation making congestion a critical problem in developing countries (Ahmadi-Javid & Hooshangi-Tabrizi, 2017). To overcome transportation problems in the form of traffic jams and chaos, efforts are needed to engineer good traffic management so that it can have an impact on the smoothness, safety and comfort of road users when passing through certain areas (Primanto & Puspitasari, 2022). Traffic management is a transportation planning technique that is directly related to field operations and usually does not last too long while simultaneously controlling the optimization of the use of transportation infrastructure. (boltze, Wolfermann, & Fellendorf, 2008; Ajala., 2016).

One effort that can be made to solve transportation problems in the form of congestion is by creating a traffic light regulation system (Jatmika & Andiko, 2014). APILL plays an important role in providing traffic regulation, especially the regulation of phasing and traffic management at an intersection, which at the same time facilitates the intersection between the main road for vehicles and pedestrians and secondary roads so that traffic flows smoothly so that it is guaranteed that a certain capacity can be maintained, even during peak hour traffic conditions. According to Law Number 22 of 2009 concerning Road Transport Traffic, Traffic Signaling Devices or often abbreviated as APILL are lights that control traffic flow at intersections, pedestrian crossings (zebra crossings) and other traffic flow areas. Apart from overcoming congestion in traffic spaces, APILL can also reduce the number of traffic accidents caused by movement between opposing vehicles in a traffic space. Traffic Signaling Devices or often known as APILL are generally a traffic light control system that is designed using human logic or in some cases still uses manual methods (Bagus et al., 2021; (Hewage & Ruwanpura, 2014)). In general, APILL still uses static cycle times with cable networks as interconnections between light poles, making it difficult to adjust phases and cycle times according to traffic conditions which tend to be dynamic, and even requires high procurement and maintenance costs for underground cables (Avatefipour & Sadry, 2018; Moganarangan, N.Balaji, Kumar, S.Balaji, & Palanivel, 2018).

Based on the above, the researcher wants to create a micro-scale traffic light control system in mockup form that is capable of processing cycle time data directly using the Android platform, to then be sent wirelessly to the APILL system and transformed into an electronic signal as an aspect light timer. every intersection. This mockup can also be used as a learning facility for Cadets/I to provide an understanding of the phases that apply to intersections, so that they can analyze the performance of an intersection and how APILL works on road sections.

## **METHOD**

Literature study is a research method used in this research by looking for a number of references from national and international journals, books, scientific articles, which relate to the topics and problems raised, in addition to searching for legal and regulatory aspects which can then be used as a reference in developing APILL simulation mockup. By focusing on the development of system design starting from determining concepts and ideas which are the main characteristics of making simulation mockups of traffic signaling devices which are developed by utilizing Arduino as a controller that translates cycle times originating from the Android platform.

## **RESULTS**

By knowing the logical sequence of steps in obtaining the output and all the events or modes described at the design stage in the previous chapter, you can understand the working principle of the proposed APILL mockup system comprehensively, so that a system flow diagram can be drawn up consisting of the process flow for each event/mode. to find out what instructions and execution are carried out in each program flow.

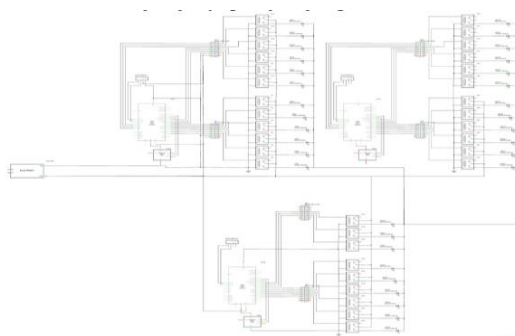


Figure 1. Complete Series of APILL Mockups

All parts of the sub-system are assembled into a complete system to obtain a schematic arrangement of the entire APILL mockup circuit. The schematic image/wiring diagram above is then used as a reference in the installation and installation stages of the electronic components that form the system so that the results of installing the hardware components for each part (sub-system) are obtained.

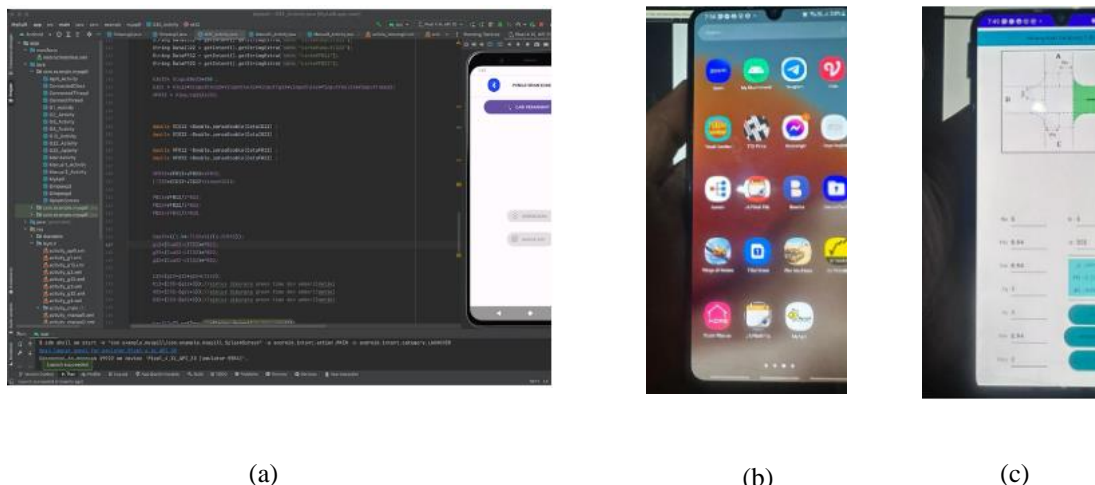


Figure 2. Android Application/Platform Developing Process

By referring to the design concept represented in the Use Case Diagram and Activity Diagram, Android application programming can be carried out using the Android Studio Development Tools with the output being an Apk Installer file with the name myAPILL, with the creation process and implementation results as shown in the image below.

As real sample data that will be used to test the success of the APILL Mockup System, the data is processed as a parameter in determining the intersection cycle. In this research, intersection performance data is used which is in accordance with the characteristics of the designed mockup. The intersection performance data used is the Petitenget – Kerobokan intersection (four intersections), the Surakarta Ring Road (four intersections) and the Kwanji intersection (three intersections). To determine the performance of intersections they can be classified into two types, namely signalized intersections and unsignalized intersections. In determining and analyzing the performance of signalized intersections, several indicators are needed such as basic saturation current value ( $S_0$ ), saturation current value ( $S$ ), comparison of traffic flow with saturation flow ( $RQ/S$ ), cycle time ( $c$ ), green time ( $H$ ), capacity ( $C$ ), degree of saturation ( $DJ$ ). In calculating traffic flow, units of pcu/hour are used which are divided into two conditions, namely protected traffic flow and opposed traffic flow which are based on signal phase and right turning movements .

a. Calculation of Saturated Current Assessment

The saturation flow value can be interpreted as the magnitude of the queue departure traffic flow from within an approach during the same conditions (SMP/hour). Determining the saturation current ( $J$ ) is obtained from the process of multiplying the basic saturation current value ( $J_0$ ) with the adjustment factor indicator for deviations from existing conditions from ideal conditions. The saturation current value ( $J$ ) can be determined using the following formula.

$$J = J_0 \times F_{HS} \times F_{UK} \times F_G \times F_P \times F_{BK_i} \times F_{BK_a}$$

$$J = 3000 \times 0.94 \times 0.94 \times 1 \times 1 \times 1.04 \times 0.98$$

$$J = 2704.11$$

Information:

FHS is the correction factor  $J_0$  due to side obstacles in the road environment

FUK is a correction factor J0 related to city size

FG is the correction factor J0 due to the longitudinal slope of the approach

FP is the correction factor J0 due to the distance of the stop line at the approach point to the first parked vehicle

FBKi is the correction factor J0 due to traffic flow turning left

FBKa is the correction factor J0 due to traffic flow turning to the right

b. Adjustment factor

1. City Size Adjustment Factor

Petitenget - Kerobokan intersection is one of the intersections in Badung Regency, Bali. Badung Regency itself has a population of 526,029 people. So for the correction factor for city size, a value of 0.94 is used.

2. Side Obstacle Adjustment Factor

Correction Factors for Road Environment, Side Obstacles, and Non-Motorized Vehicles  
The influence of road environmental conditions, side obstacles, and the magnitude of the KTB flow, due to activities around the intersection on the basic capacity are combined into one side resistance correction factor value, thus obtaining a side resistance correction factor of 0.94 for the Petitenget - Kerobokan intersection.

3. Left Turning Flow Ratio Correction Factor

FBKi or left turn correction factor is determined as a function of the left turn ratio or RBKi. This calculation applies to the analysis of intersections with a protected approach type without special conditions for continuing left turns.

$$F_{BKi} = 1,0 + R_{BKi} \times 0.16$$

$$F_{BKi} = 1,0 + 0.14 \times 0.16$$

$$F_{BKi} = 0.98$$

So the correction factor for the right turn ratio at the north foot of the intersection, the Petitenget - Kerobokan intersection is 0.9.

4. Right Turning Ratio Correction Factor

FBKa or correction factor due to right turning traffic can be calculated by multiplying the right turning flow ratio for protected intersection types, without medians, two-way road types and the effective width is determined by the entry width.

$$F_{BKa} = 1,0 + 0.17 \times 0.26$$

$$F_{BKa} = 1.04$$

So the correction factor for the right turn ratio at the north foot of the intersection, the Petitenget - Kerobokan intersection is 1.06.

5. Current to Saturation Current Ratio

When calculating the ratio of current to saturation current, there are several things that need to be taken into account if there is a continuous left turning current condition ( $LE = LK$ ) and the number of phases the intersection has (protected or opposed).  $R_{q/j}$  at the north foot of the Petitenget - Kerobokan intersection can be calculated using the formula.

$$R_{q/j} = \frac{q}{j}$$

$$R_{q/j} = \frac{2704.11}{617} = 0.23 \text{ smp/hour}$$

6. Cycle Time and Green Time

To determine the green time in a phase, a cycle time value is needed as a fixed time control system

$$s = \frac{(1,5 \times W_{HH} + 5)}{(1 - \sum R_{q/j} kritis)}$$

$$s = \frac{(1,5 \times 20 + 5)}{(1 - 0.64)} = 99 \text{ second}$$

Information:

$S$  is is the cycle time, in seconds.  
 $W_{HH}$  is the amount of green time lost per cycle, in seconds  
 $R_{q/h}$  is the current ratio, namely the current divided by the saturation current,  $q/J$ .  
 $R_{q/h} \text{ critical}$  is the highest  $R_{q/j}$  value of all approaches departing at the same phase  
 $\sum R_{q/h} \text{ critical}$  is the drift current ratio (equal to the sum of all critical  $R_{q/J}$  of all phases) in that cycle.

$W_{Hi}$  is determined using the equation:

$$W_{Hi} = (s - W_{HH}) \times \frac{(1,5 \times W_{HH} + 5)}{(1 - \sum R_{q/j} kritis)i}$$

$$W_{Hi} = (98 - 20) \times \frac{(1,5 \times 20 + 5)}{(1 - 0.64)} = 21 \text{ seconds}$$

On the northern approach to the Petitenget - Kerobokan intersection, the green time calculation results were 21 seconds.



Figure 3. Phase diagram at each intersection

The calculation steps carried out to determine the green time at each approach are applied to all other intersection approaches to find the total cycle time. The following is the acquisition of green time at each intersection which is described in the form of a phase diagram above.

c. Green Timing in Applications

The APILL application is a tool that transfers data wirelessly using Bluetooth technology so that it can be processed by the device and displayed on a previously created model. The output issued by the application is the result of calculating the cycle time for an intersection by entering data in the form of indicators such as effective width, adjustment factors such as city size factors, side obstacle factors, slopes, parking factors

and traffic flow that must be input for each approach to an intersection. . The first result that will be issued is a calculation of the adjusted current, basic current and current ratio.

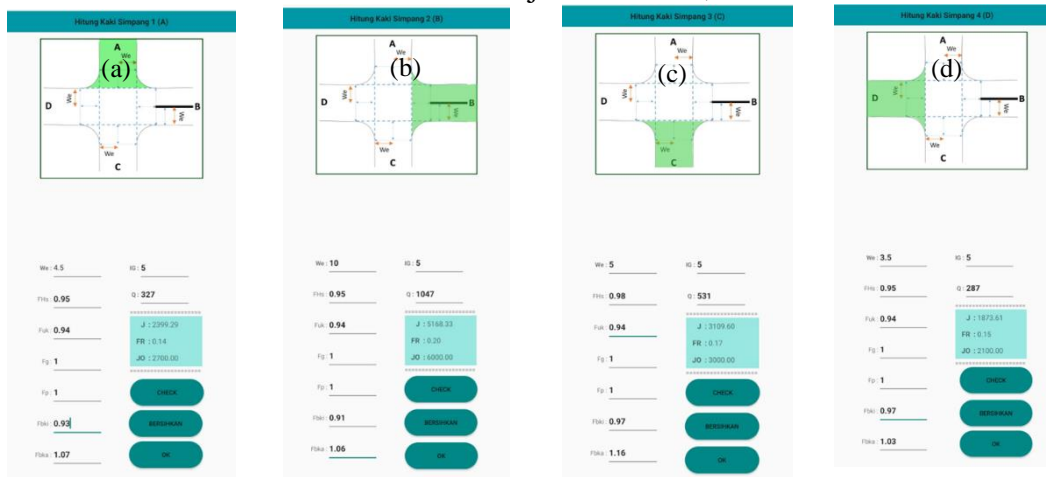


Figure 4. Input Adjustment Factor Data (a) Intersection Foot 1, (b) Intersection Foot 2, (c) Intersection Foot 3 and (d) Intersection Foot 4

After inputting the data at each intersection leg, the cycle time for each intersection will be displayed and the command will automatically carry out the settings on the model that has been previously connected using Bluetooth device search and the menu will be directed to the display of cycle calculation results and phase pattern determination as shown. shown in Figure 6.2 which is the result of calculations at the Petitenget - Kerobokan intersection which has 4 APILL (protected) phases, getting a total cycle time of 104 seconds. Through this stage, it can be seen that the calculation operations obtained from the application are in accordance with what was expected and determined in the design process.



Figure 5. Cycle time results for the Petitenget - Kerobokan intersection

## DISCUSSION

### a. Power Supply Testing

The power supply circuit is used to provide power to all electronic components within the system, designed with a terminal voltage of 5V for the Arduino and 12V for the APILL lights.

The testing procedure is carried out by measuring the nominal voltage under open circuit conditions (no load) as well as under load conditions using a digital multimeter. The voltage measurement results are presented in the following table.

Table 1.  
 Power Supply Testing

No	Loading Conditions	Required voltage	Measurement results	Deviation
1	No load (Open Circuit)	5V	5.09 V	1.8 %
2	With load (On-Load)	5V	4.98V	0.4 %
3	No load (Open Circuit)	12V	1.209 V	1.8 %
4	With load (On-Load)	12V	1.198 V	0.4 %

Through the test results above, it can be seen that the deviation in the power supply circuit voltage under no-load conditions is 0.09V or 1.8% and under load conditions it is 0.02 V or 0.4%, so the supply voltage of the power supply circuit it can still be said to be stable and able to meet the overall system voltage requirements.

b. Relay Module Testing

Relay testing is carried out to test the function of the relay as an electronic switch to regulate the activation of aspect lights which allows the use of external power so that the logic output in the form of an electrical voltage between 0 and 5V from the microcontroller is not directly connected to the sub-system and does not provide excessive current load on the microcontroller. The relay used is a positive trigger 5VDC single pole dual throw (SPDT) type with a maximum rating of 30V/10A. The test method is to provide a logic value to the relay trigger input and then take measurements at the relay pole terminal. The measurement results are shown in the following table.

Table 2.  
 Module Relay Testing

No	Relays	Signal Trigger	Output Voltage	LightAspect
1	Input 1	I	4.94V	<i>Light up</i>
		0	0V	<i>Blackout</i>
2	Input 2	I	4.94V	<i>Light up</i>
		0	0V	<i>Blackout</i>
3	Input 3	I	4.94V	<i>Light up</i>
		0	0V	<i>Blackout</i>
4	Input 4	I	4.94V	<i>Light up</i>
		0	0V	<i>Blackout</i>
5	Input 5	I	4.94V	<i>Light up</i>
		0	0V	<i>Blackout</i>
6	Input 6	I	4.93V	<i>Light up</i>
		0	0V	<i>Blackout</i>

Through the test results in the table above, it can be seen that all the relays in the module will conduct the source voltage according to the trigger voltage through logic operations on each trigger input pin to the relay pole pin, where if pole 1 receives a 5VDC voltage, the aspect light will light up if the pole is given logic. 0 then the aspect is off, this shows that the function and role of the relay module can run well according to the design aims and objectives.

c. Bluetooth Module Testing

The test is carried out to determine the success of the data connection/communication between Arduino and Bluetooth. The test is carried out by checking the Arduino serial monitor to see whether data transmission from the Android platform is read on the Arduino or not. The test results can be seen in the following image.

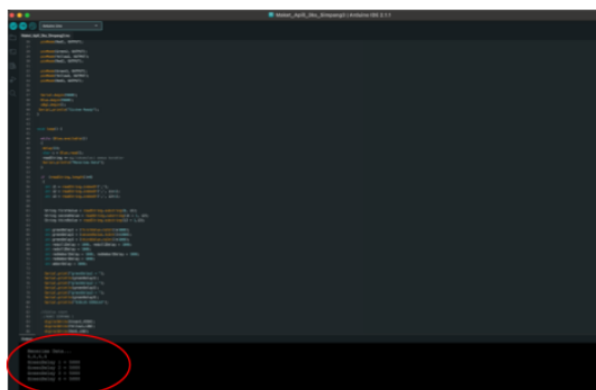


Figure 6. Testing Bluetooth data via serial monitor

Through the image above, it can be seen that the data sent from the Android platform can be received well on the Arduino side, marked by the appearance of cycle patterns and greentime cycle times which are ready to be executed by the Arduino.

d. Test Input Data Accuracy

The process of testing input data on the application and existing conditions issued by the model is carried out to determine the accuracy and validation of calculations carried out both by application input, processing assistance from Excel software and output issued by the APILL model. Data trials were carried out 3 (three) times to see the consistency of the system, then the accuracy value was calculated using the following equation.

$$\% \text{ accuracy} = 1 - \frac{\text{Reference Value} - \text{Measured Value}}{\text{Reference Value}} \times 100$$

The measurement and calculation data for all intersection legs at each intersection, including intersections 1, 2 and 3, are described in the following table.

Table 3.  
 Simpang One Trial (Petitenget – Kerobokan)

BTS 1

Intersection	Intersection Foot	Direction	Calculation	Experiment 1			Experiment 2			Experiment 3		
				H	K	m	H	K	m	H	K	m
1	1	North	Excel	28	3	68	28	3	68	28	3	68
			Application	28	3	68	28	3	68	28	3	68
			Mockup	28	3	68	28	3	68	28	3	68
	3	South	Excel	25	3	71	25	3	71	25	3	71
			Application	26	3	71	26	3	71	26	3	71
			Mockup	26	3	71	26	3	71	26	3	71
	2	East	Excel	10	3	87	10	3	87	10	3	87
			Application	10	3	87	10	3	87	10	3	87
			Mockup	10	3	87	10	3	87	10	3	87
	4	West	Excel	16	3	81	16	3	81	16	3	81
			Application	16	3	81	16	3	81	16	3	81
			Mockup	16	3	81	16	3	81	16	3	81

Table 4.  
 Try the Second Intersection (Ring Road)

BTS 2

Intersection	Intersection Foot	Direction	Calculation	Experiment 1			Experiment 2			Experiment 3		
				H	K	m	H	K	m	H	K	m
2	1	North	Excel	17	3	85	17	3	85	17	3	85
			Application	18	3	83	18	3	83	18	3	83
			Mockup	18	2.9	83	17.9	2.9	82.8	18	3	82
	3	South	Excel	22	3	80	22	3	80	22	3	80
			Application	22	3	79	22	3	79	22	3	79
			Mockup	22	3	79.1	22	2.8	79.3	22	2.9	78.8
	2	East	Excel	26	3	76	26	3	76	26	3	76
			Application	25	3	76	25	3	76	25	3	76
			Mockup	24.9	2.9	75.9	24.9	2.9	76.3	24.9	2.9	76.4
	4	West	Excel	19	3	83	19	3	83	19	3	83
			Application	19	3	82	19	3	82	19	3	82
			Mockup	19	2.9	82	19.1	3	82	19	2.9	82.5

Table 5  
 Trial of the Third Intersection (Kwanji Intersection)  
 BTS 3

Intersection	Intersection Foot	Direction	Calculation	Experiment 1			Experiment 2			Experiment 3			
				H	K	m	H	K	m	H	K	m	
2	1	North	Excel	17	3	85	17	3	85	17	3	85	
			Application	18	3	83	18	3	83	18	3	83	
			Mockup	18	3	83	18	3	83	18	3	82	
		3	South	Excel	22	3	80	22	3	80	22	3	80
				Application	22	3	79	22	3	79	22	3	79
				Mockup	22	3	79	22	3	79	22	3	79
	2	East	Excel	26	3	76	26	3	76	26	3	76	
			Application	25	3	76	25	3	76	25	3	76	
			Mockup	25	3	76	25	3	76	25	3	76	
	4	West	Excel	19	3	83	19	3	83	19	3	83	
			Application	19	3	82	19	3	82	19	3	82	
			Mockup	19	3	82	19	3	82	19	3	82	

Through the test table at each intersection, an accuracy graph can be obtained which shows the success of the APILL Maket system as shown in the following figure.

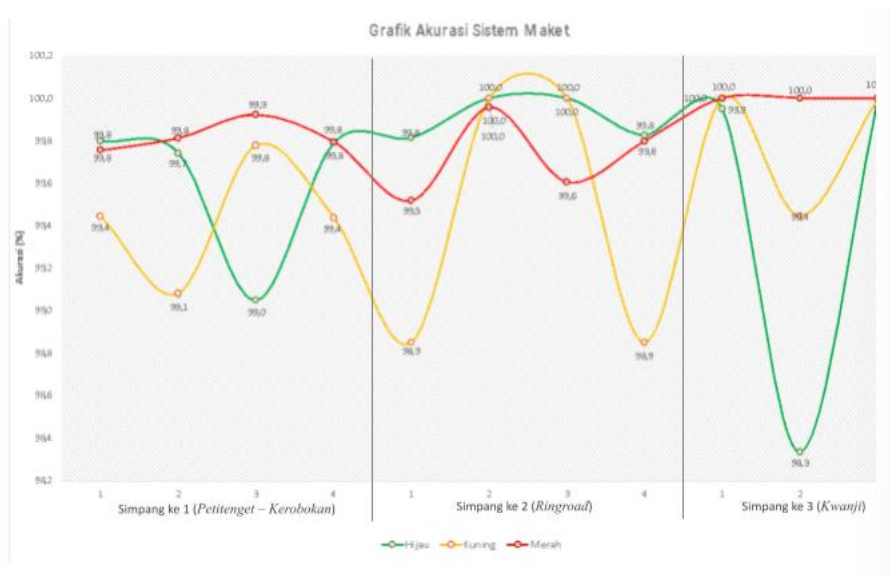


Figure 7. Mockup System Accuracy Chart

Through the test results outlined in the graph above, it can be seen that the time allocation for each light at each intersection has very good accuracy and is in the range of 98.3% SD. 100% with an overall average of 99.7%. The intersection with the highest average accuracy is at intersection 2 (ringroad) and intersection 3 (kwanji) worth 99.7% and the intersection with the lowest accuracy is at intersection 1 (Petitenget – Kerobokan) worth 99.6%. From the trial data above, it shows that the results of direct calculations with the help of Microsoft Excel software which is used as a reference value (actual value) and the results of time validation using a time counter have a good level of agreement with very high accuracy values, this is proven by the calculation results. Between the application, Excel software and

the implementation of the time issued by the model, there is a very small difference in numbers and is less than 1 second. Differences in results that occur in the testing process can be caused by several factors such as the tester's accuracy in targeting the counter time calculation (stopwatch). Then the second factor is the difference in rounding of values (rounding) carried out in the Excel software tool and rounding that occurs in the application.

## CONCLUSION

The design and construction of the APPIL simulation mockup has been carried out using the Arduino Uno control device using the Android platform as a data input device in setting the time and cycle pattern at each leg of the intersection and the HC-05 Bluetooth module as a wireless serial communication medium. The research method and process is carried out through sequential stages starting from theoretical study, concept preparation, design process and troubleshooting to analysis and drawing conclusions. The test was carried out by validating the cycle time with a time counter (stopwatch) and the results obtained were that the average accuracy of the cycle time calculation implemented in the APILL model was 99.7% for all intersections with all red, yellow and green aspect lights. , these results can be said to be accurate with an error tolerance of 0.3%, so that the Apill model system can be said to be able to translate the patterns & cycle times sent from the Android platform into the appropriate sequence of changing aspect lights at each intersection.

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