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Speed limiter integrated fatigue analyzer (SLIFA): engineering design and concept

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Abstract

Main issue in urban transportation system is traffic accident which caused by several factors where there are two factors that has a significant contribution in accident are overspeed and fatigue. Therefore, main objective of this research is to develop Speed Limiter Integrated Analyzer (SLIFA). This device will be controlling the speed by cutting off the fuel supply to the engine when driver's fatigue or speeds are beyond limitation. This research was consists of four steps which are Step 1 is study literature on types of vehicle. Step 2, detail engineering design that is focused in this research. Step 3 is describing the target of SLIFA installation. Step 4 is fabricating and testing of SLIFA on truck and bus in range of July 2017 to January 2018. The result shows the appropriate voltage for speed at 70 km/h is 10.7 volt for limiting the speed. The traffic accident has succesfully decreased up to 47% after SLIFA installed on truck and bus. It can be concluded that the SLIFA application on transportation especially on truck and bus was much recommended to reduce traffic accident and play an appropriate government regulation.

Keywords: *accident, fatigue, SLIFA, speed limiter, transportation*

1. Introduction

Safety belts are generally used for drivers as a vehicle safety tool to reduce traffic accidents but in some cases, there are those that are ignored causing traffic accident. Most of the ignored thing is human error caused by the fatigue in which this topic will be highlighted. Figure 1 shows that the factor of traffic accident that caused by fatigue and over speed is 32% and 15%, respectively, external factor of 29%, technical vehicle of 4% and attitude of 20%. The factor that caused by human and could be solved by engineering imrpovement is fatigue and over speed. Table 1 list the traffic accident in Indonesia from 2011-2013 where the traffic accident is reduced in 2013 of about 93,576 accident cases [1]. Additional information from Indonesia police department most of 9,278 traffic accident cases is from bus [2].

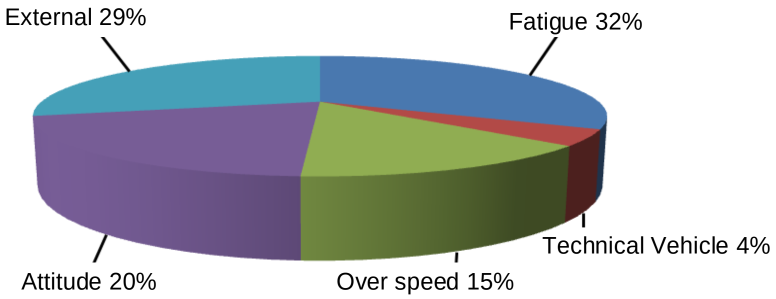

Figure 1. Factors of traffic accidents in Indonesia

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Table 1. Traffic Accident in Indonesia

Year	Total Accidents	Death	Serious Injury	Slightly Injured	Material Loses [IDR Billion]
2011	109,776	32,657	36,767	108,811	286
2012	117,949	29,554	39,704	128,312	298
2013	93,576	23,385	27,054	104,976	234

Therefore, ministry and environment Indonesia through the constitution No. 22, 2009, for hazardous material transportation required speed limited to maximum of 60 km/h in highway and maximum of 30 km/h in non-highway [1]. Ministry of Transportation Indonesia through constitution No. 111, 2015 also issued the regulation of speed limit for commercial buses based on area which consists of maximum speed of 100 km/h in highway, 80 km/h in urban area, 50 km/h in centre of urban area, and 30 km/h in residential area [3]. Moreover, PT. Pertamina Persero also issued the regulation that the maximum speed of the tank truck in highway is 60 km/h that purposed to fuel trucks in PT. Pertamina Persero. For the commercial buses maximum speed limit was referred to Ministry of Transportation. However, there are many drivers who did not obey the regulation. The National Transportation Safety Board found that fatigue become the most frequently cited probable cause of 31% in fatalities to the truck driver crashes. The results suggested that drivers who slept less during their last sleep period in the past 24 h and who experienced split sleep periods were more likely to be involved in fatigue related crashes [4]. Safety driving behavior at high speed, it will increase the chances of a deadly accident. Dinesh Mohan in the trial RTAG-RTI Sub committee Meetings for Traffic Safety Advocacy and Collaboration, and Action Plan and Implementation, 9-11 February 2016, Colombo, Sri Lanka, stated that the effect of speed on fatality increase with increasing speed on the traffic at some driver's vehicles and pedestrians [5]. A study in Jiangxi, China reported the results of 74 studies that a single accident occurred, the most common cause is due to high speed approximately of 38 cases and mainly occurred in rainy conditions were 32 cases, data from the total accidents involving trucks ranks second least 11 cases [6]. Estimations based on the data in Germany suggested that FWSs (Fatigue Warning Systems) would lead to 35% reduction in fatigue related crashes, equal to 2.9% reduction in all crashes [7], a device has been developed to limit speed in order to reduce the level of speed that is applied in the fuel tank truck PT.Pertamna Persero [1], and on the bus also experimented with the installation of a speed limiter to reduce the speed of the driver's accusation that has a bad attitude [3]. In a study and proposed innovation tools have been tried on vehicles that tend to speed can not be controlled, then in the study speed limitation is done by using RFD as a speed control tools [8]. Therefore, from those issues, engineering improvement in truck and bus for controlling the speed and detecting fatigue need to be developed in order to reduce the traffic accident rate in Indonesia.

2. Research method

In this section will be discussed the method of this research as shown in Figure 2. Step 1 will study how engine conventional and electrical control module (ECM) work. The outcome for this step will give deep understanding about conventional and ECM engine, because the target for the SLIFA installation will be both on conventional and ECM engine. Step 2 will discuss about the fundamentall concept of how SLIFA works, the components, parameters determination and the equation that will be explainedin detail in this paper. The diagram and schematic will be added to give easy understanding and help to point out the target of SLIFA. Starting with fundamental concept, this step describes the speed limiter concept. The speed limiter will respond when parameter determination is fullfiled then trigger the solenoid to cut off the fuel supply into the piston chamber, so that the speed of vehicle will not surpass the speed limit.

Step 3 explains the target of SLIFA that will be installed. SLIFA will be installed with different settings on each engine. The settings are acquired from data calibrated between speed and voltage. Step 4 describes the fabrication of SLIFA started from the components, application software until SLIFA has been ready to be tested. Data analysis will be processed if SLIFA has passed some tests that include Failure Mode Effect Analysis (FMEA), engine performace test, fuel consumption test and exhaust emission analysis. The detail of this research is shown in Figure 2.

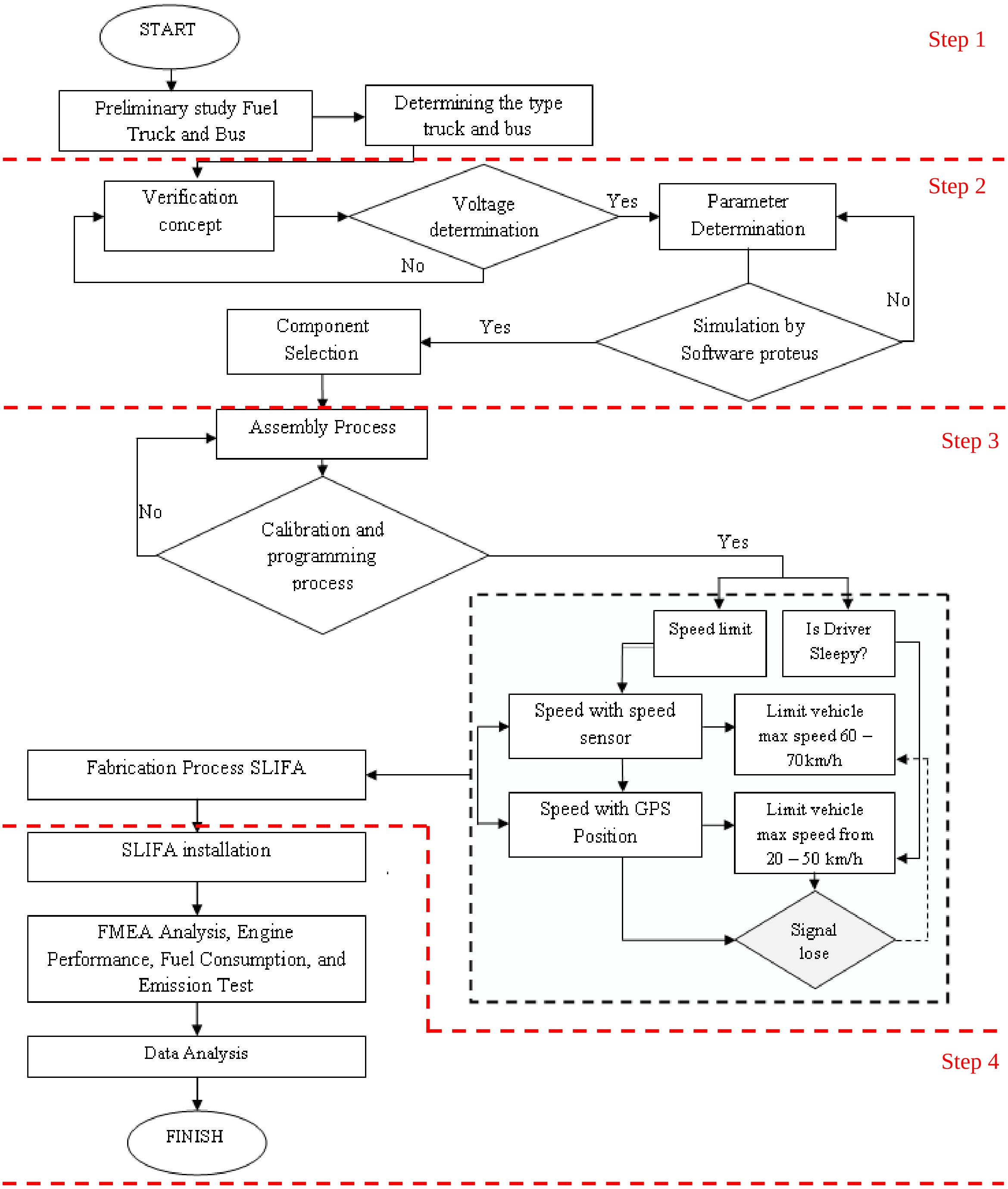

Figure 2. Flowchart of the study

3. Results and analysis

This section will explain more about mechanism of SLIFA, component of SLIFA, Mathematical calculation, assembly process, programming process, development of SLIFA application, connecting SLIFA to the data central and the impact of SLIFA to the bus and truck on traffic accident in Indonesia.

3.1. Mechanism of SLIFA

Main function of SLIFA is to monitor two parameters which are fatigue and speed. The schematic diagram of SLIFA is shown in Figure 3. To see the logic of SLIFA more clearly, the schematic will be described as shown in Figure 3. The SLIFA working with three (3) major factors which are heart rate sensor, image acquisition and speed sensor coupled by GPS position. For fatigue detection was divided into 2 which are heart rate and image acquisition where the heart rate is related to the temperature of the driver and image acquisition is consists of face detection, mouth and eye detection [9]. Speed sensor is linked with GPS position in order to sincronize the speed limit in each area. When the driver in fatigue condition based on heart rate and image acquisition as well as the vehicle in over speed, the frequency was sent to the pedal where it converted to the voltage and it will connect with alarm. There are two condition either driver decelerate the speed or not. When the driver decelerates the speed, the alarm will be turn off automatically, meanwhile if not decelerate, fuel consumption will be reduced by fuel cut-off solenoide which effect to the auto-decelerate the speed up to allowable speed based on goverenment regulation.

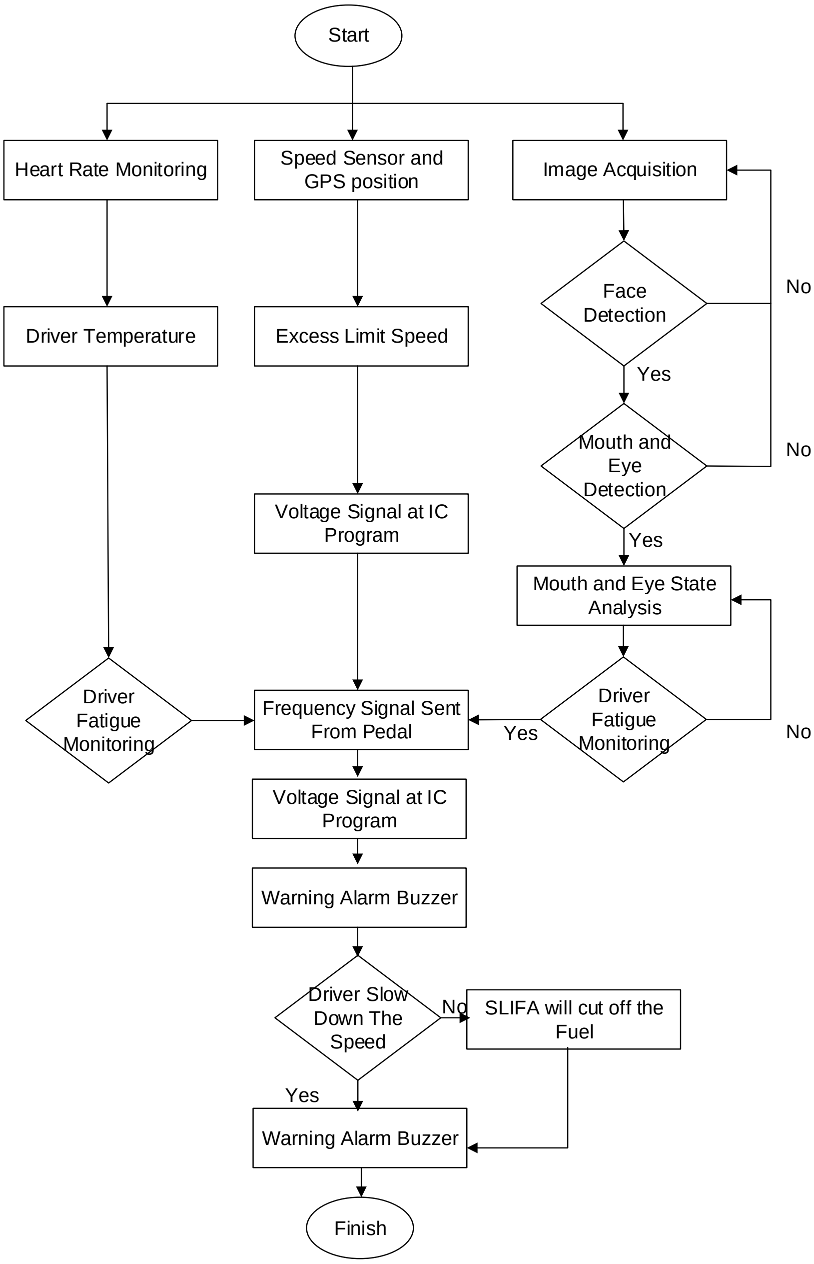

Figure 3. Limiter speed schematic

3.1.1. SLIFA Sleepiness Scale

There are three parameters measurement to measure fatigue there are: heart rate, temperature and driver's face. Using these parameters will be combined as SLIFA Sleepiness Scale (SSS) to decide if the driver is fatigue. SSS is defined as shown in (1) [10]: Definition ES, MS, and HR is eye state, mouth state, and heart rate respectively as shown in (1). For calculation of ES and MS will use as shown in (2) and (3) and the ES and MS linguistic value is listed in Table 2 and Table 3, respectively [1-3]. To determine the fatigue, camera measures the eye and mouth state of the driver as show in Figure 4 and Figure 5 [11].

$$SSS = \frac{(EAR\ Scale +\ MAR\ Scale) +\ HR\ Scale}{2} \tag{1}$$

$$ES = \frac{Left\ Eye\ ES + Right\ Eye\ ES}{2} \tag{2}$$

$$MS = \frac{\|p2 - p6\| + \|p3 - p5\|}{2\|p1 - p4\|} \tag{3}$$

Table 2. ES Linguistic Value [1-3]

No.	Float ES Range	ES Linguistic Value
1	<2	Low
2	2-5	Medium
3	>5	High

Table 3. MS Linguistic Value [1-3]

No.	Float MS Range	MS Linguistic Value
1	<0.5	Low
2	0.5-0.8	Medium
3	>0.8	High

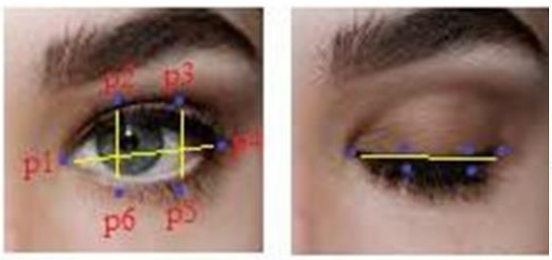

Figure 4. The calculation of area for ES

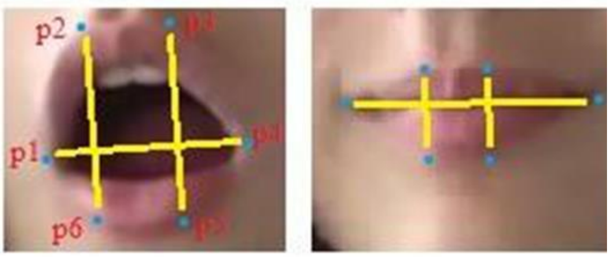

Figure 5. The calculation of area for MS

The calculation of MS and ES will be stored in the memory. After the value of MS and ES are obtained, the value of HR is obtained from heart rate sensor then compared to the characterization of HR as in the Table 4 [12]. When three parameters have been recorded in the memory, each value of parameter will be added to determine the SSS. The value of SSS will be doing comparison to Table 5 then the fatigue will be determined by its scaling. It could be seen from Table 5. there are some of scaling to determine the level of fatigue [13].

Table 4. The Characterizatioin of HR of the Driver in SLIFA Clasification [12]

No.	Heart rate (dB)	Condition	Temperature(^{o}C)
1	100-120	Normal Condition	37
2	<80 and >100	Fatigue Detected	<34 and > 38

Table 5. The Scale of SSS to Determine the Fatigue [13]

SSS	Respond Time (s)	Decision
1	0.03	Fatigue undetected
2	0.03	Fatigue undetected
3	0.03	Fatigue undetected
4	0.03	Fatigue undetected
5	0.03	Fatigue undetected
6	0.8	Fatigue detected
7	0.8	Fatigue detected
8	0.8	Fatigue detected
9	0.8	Fatigue detected

To find out I (AVG) that flow in each point 1-4, as shown in Figure 6. I (AVG) is electric current. The amount of current that flows in point 4 through R1 are the same as I (AVG) then to find out Vout, as shown in Figure 6. I_3 can be obtained as shown in equation (4) (5). Based as shown in equation (6), the signal frequency obtained from rotation output of transmission gear on speed sensor if value of R_1, V_cc, and C_3 are known. To obtain the frequency, input the value V_{cc} is 12 V, resistant value is 1000 and capacitor value is 10.000 f. Data showed the frequency value that is converted into voltage as speed in Table 6. This table will be used as calibration frequency to voltage.

Table 6. Calibration Value of Frequency to DC Voltage

No.	Frequency to Voltage Test	
	Frequency [kHz]	$V_{cc\ out}$ [DC Volt]
1.	0	0
2.	85.5	1.02
3.	120.5	1.20
4.	240	2.8
5.	359.5	4.31
6.	479	5.74
7.	598.5	7.18
8.	718	8.61
9.	837.5	1.0
10.	957	1.14

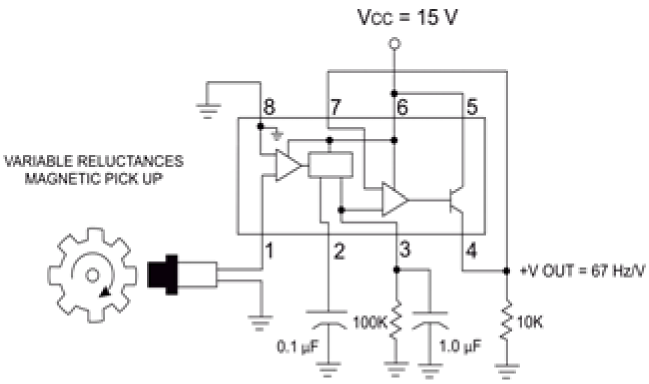

Figure 6. Minimum component tachometer diagram

3.2. Analysis of equation

Tachometer is used to convert frequency signal to voltage[9]. Basically, the minimum circuit of tachometer is shown in Figure 6. To find V_{out}, it could be used as shown in (4), (5), (6):

$$I_3 = I\ (AVG) \quad (4)$$

$$I_3 = Q/t = (Q\ charge + Q\ discharge)/(1/f) = 2 \times Q \times f = 2 \times C_3 \times (V_{cc}/2) \times f = C_3 \times V_{cc} \times f \quad (5)$$

$$V_{out}=I\ (avg)\ x\ R_1=C_3\ x\ V_{cc}\ x\ f\ x\ R_1 \quad (6)$$

3.3. SLIFA System Development

The SLIFA system in this study consists of the SLIFA device, the SLIFA server, and the SLIFA client application. The SLIFA device works as a sensor for capturing data, meanwhile SLIFA server collecting all of data from SLIFA devices, and SLIFA client can be used for monitoring data of SLIFA devices.

3.3.1. Programming the SLIFA Devices

The SLIFA device composes from the speed limiter system, and the fatigue analyzer system. The speed limiter system was installed by four sensors and GPS location, the sensors are speed sensor, rpm sensor and temperature sensor and SS as Fatigue detection. The SLIFA device will be bundling into one board, so the implementation of the SLIFA system that make it easy operation by the user. The architecture of SLIFA system as described as shown in Figure 7.

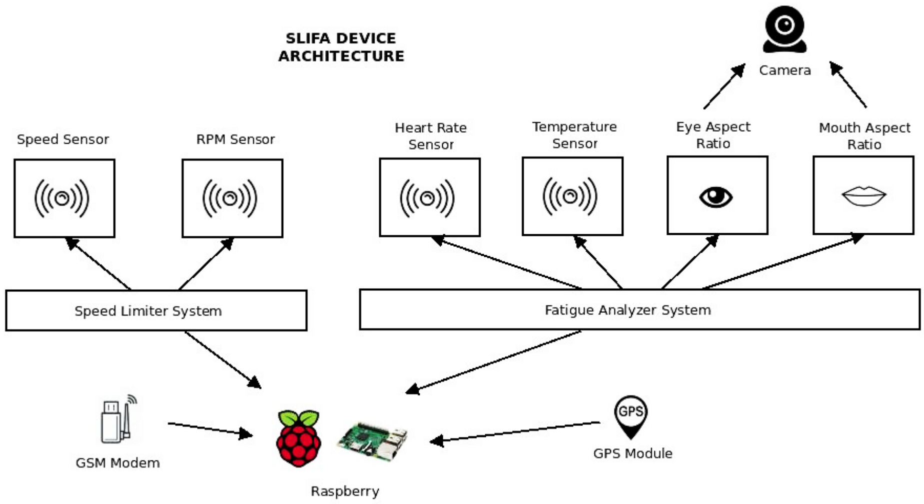

Figure 7. Architecture of SLIFA device

The developed speed limiter will read the speed of the vehicle and also connected with the engine rotation. These two data will be used as parameters from the speed limiter device. The speed limiter consists of sensor to read these two data from the vehicle, and save the data to the storage devices.

The fatigue analyser system was equipped with two sensors, the first sensor is temperature sensor, and the second sensor is heart rate sensor. The temperature sensor will sense the temperature from the driver; meanwhile the heart rate sensor will take the heart rate value from the driver.

The main device for SLIFA system is a Raspberry Pi, and some sensors needed by the system. All the sensors connected to Raspberry board, and the manage all of sensor for getting data needed by SLIFA system. The sensor will be facing the object to be measured, such as the SSS; the scale will be closed implemented to the object. Raspberry Pi sends the data to the SLIFA server via internet.

3.3.2. Programming the SLIFA Devices

The server was used for collecting data from SLIFA devices installed in the vehicles. The purpose for collecting the data from the devices are for reporting and also for sharing the data to the SLIFA client application based on request from the client. The Server provides APIs for client to communicate, especially for requesting data.

The server was developed with PHP programming with laravel framework, and MySQL was used as the database management software. The production of server will be host in a hosting; therefore the server can be access widely for the authenticated client. The architecture of SLIFA server describe as shown in Figure 8.

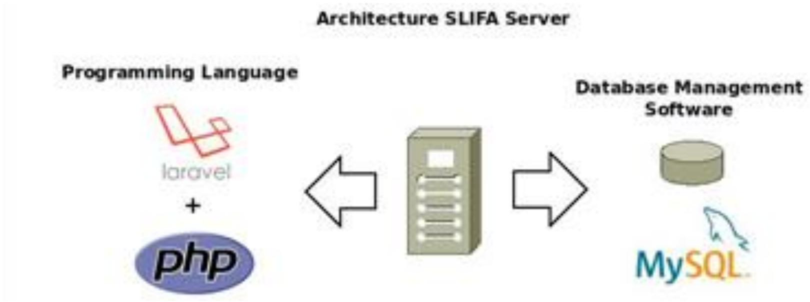

Figure 8. Architecture of SLIFA server

From the Figure 8 the server builds with the software engineering principles. The analysis of server requirement is needed to achieve the goal of this server and also the programming skills for developing the server one of the requirements that cannot be ignored. The development of this server will be scheduled for 2 months. The main functions for this SLIFA Server are: Collecting data from the SLIFA devices, Provide the API for the SLIFA client, Provide the report for the stakeholder who can access the SLIFA server, Setting the master data for SLIFA, Registering the User for SLIFA.These 5 main functions must be conducted in SLIFA server, and also there are some feature that are standard in application, so the functions will not be list in this report.

3.3.3. Development of SLIFA client

SLIFA Client is an android based application. This application was intended to monitoring the SLIFA Devices based on the user who authorized to monitor the devices. Therefore, one user can monitor a lot of devices, and this setting can be done only from the SLIFA server. For the future will be developed SLIFA client for IPhone.

The communication between the SLIFA client and SLIFA Server was held via API (Application Programming Interface). The APIs located in SLIFA Server, and the SLIFA Client accessing the APIs with special key, based on user login, and request the API based on the data needed by user. The APIs are in JSON (Java script Object Notation) format, so the SLIFA Client must parse the data and then process the data to be information, and show the information in interface for user. The Architecture for the SLIFA Client as shown in Figure 9.

Figure 9. Architecture for SLIFA client

SLIFA Client developed by Android platform, and the programming language is Java. Java is the native language for Android; the benefits for developing this application with native language are more secure, support all of Android feature, and more lightweight. XML was used for designing user interface in SLIFA Client. XML used in this application for providing the responsive context, especially for a lot of size for Android smartphone, this technology can cover this problem.

3.3.4. Integrating the Devices and the Application

After the SLIFA device and the SLIFA Server, and SLIFA Client have already developed, the next step is to integrate all of them into one bundle system. The architecture to integrate all of these devices describe as shown in Figure 10.

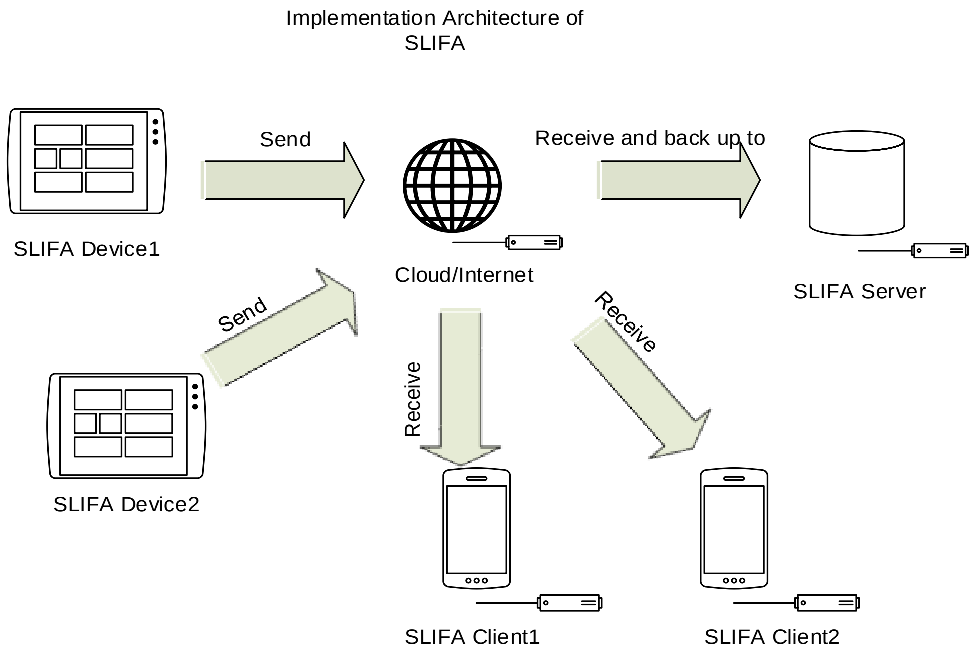

Figure 10. Implementation architecture for SLIFA system

Figure 10 shown the development of SLIFA will be used internet of things (IOT) to monitor and data acquisition real time based on internet connection [2]. With this connection, data will be monitor and stored at data central. Image processing algorithm will be used to recognize and scale the fatigue level of the driver. There are some algorithms in image processing such as hybrid ant colony and image reconstruction [14,15].

The mechanism to integrate both of them physically using the Universal Serial Bus (USB) cable, and programmatically using serial programming. The SLIFA device connected as client device, while the PC or Computer installed with SLIFA application act as a server [16]. The architecture to integrated these two devices describe as shown in Figure 11. The implementation of integration for SLIFA system is shown in Figure 12. The Notebook installed with SLIFA application and the SLIFA device will be shown the flow of how to integrate and operate the SLIFA System as shown in Figure 13.

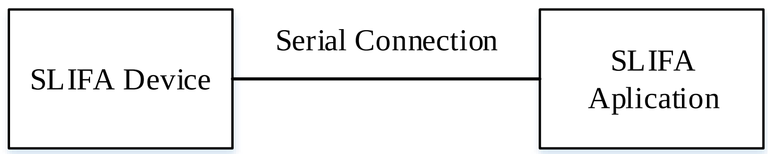

Figure 11. Architecture of Integration for SLIFA System

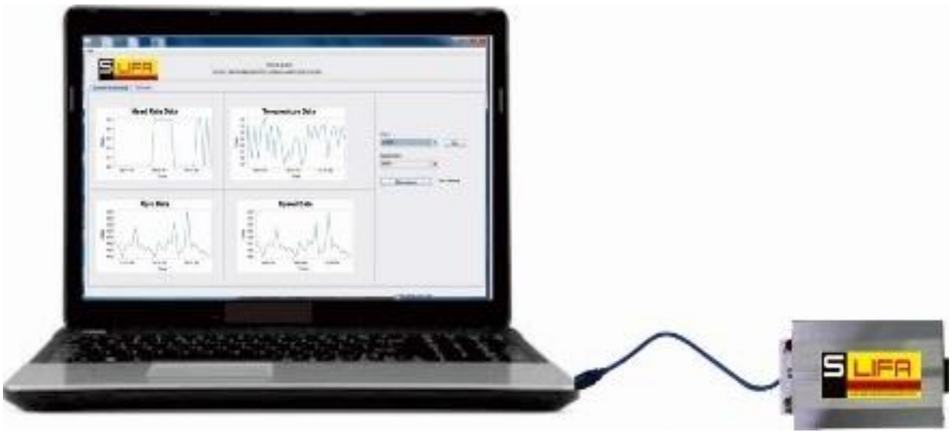

Figure 12. Architecture of Integration for SLIFA System

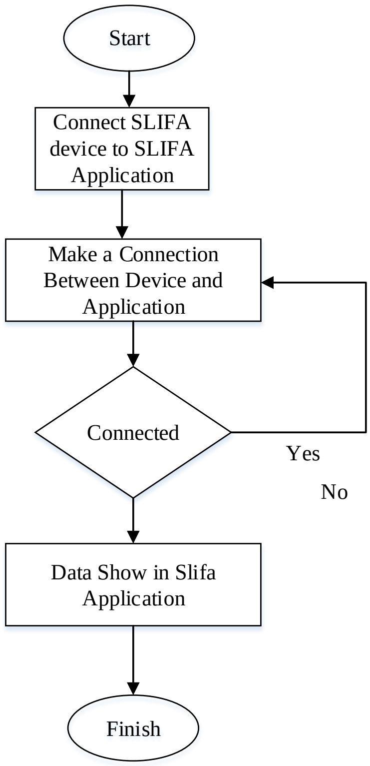

Figure 13. Flow of Integration for SLIFA System

3.4. Components of SLIFA

SLIFA has several components that compiled in electrical circuit which consists of IC data program, IC comparator, processor, data logger and relay. Complete block circuit in SLIFA as show in Figure 14. IC data program changes the frequency of the signals from the speed sensor into a voltage while IC comparator provides a voltage signal to the transistor base. For the processor, SLIFA is equipped by Arduino UNO to process data from all sensors. Data logger is added to process and send data to SD card. Relay will be used as an actuator to break the voltage engine motor stop when overspeed.

There are three sensor and camera that is incorporated in SLIFA such as temperature, heart rate, speed and rotational speed (rpm) sensor. Camera will be used to monitor the fatigue while speed and rpm sensor will be used to monitor the speed. The last component is buzzer as indicator for the driver to slowdown the speed.

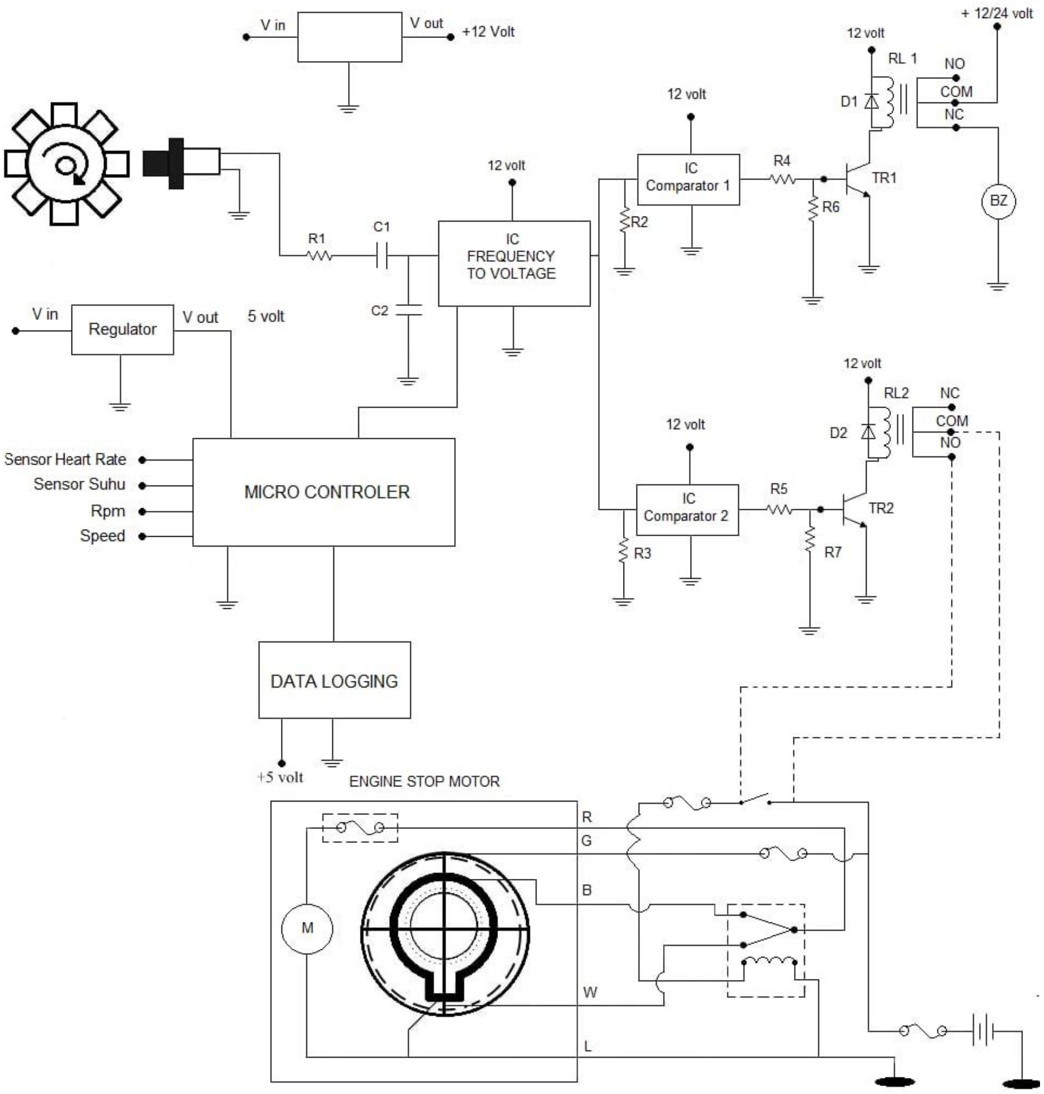

Figure 14. Completed block circuit of the SLIFA

3.5. Assembly main component SLIFA

SLIFA is made and developed in Indonesia. The assembly of electronics components as the main component have high accuracy and existing cover meter as shown in Figure 15 with dimensions of 100 x 50 mm (Length x width). One purpose is to use special component materials that reduce the error rate when SLIFA is in operation. The rafted components are packaged in an aluminum cover to develop a good shape and can absorb heat when SLIFA operates. The cover or component housings are lined with insulators to prevent short cuts. The cable length is at least 2 meters to connect to the mainstream and to the speed sensor. Differences in dimensions and length of cable have difficulty in the fabrication process because based on the engine maker that will be installed SLIFA.

Assembly process consist of soldering temperature sensor, heart sensor, gps module, and relay into raspberry pi. Raspberry used as microcontrol that give command to activate and deactivate fuel cut off in terms of speed limiter function. Raspberry was completed by Sim card and memory card. Sim card was used for internet connection via internet provider, and memory card used as data storage. Raspberry pi is also integrated with gps module, camera and angine speed sensor in vehicle using wire. In addition, buzzer was connected as an actuator to give warning when fatigue detected. The product of SLIFA device is shown in Figure 16. And the technical drawing of SLIFA is shown in Figure 17.

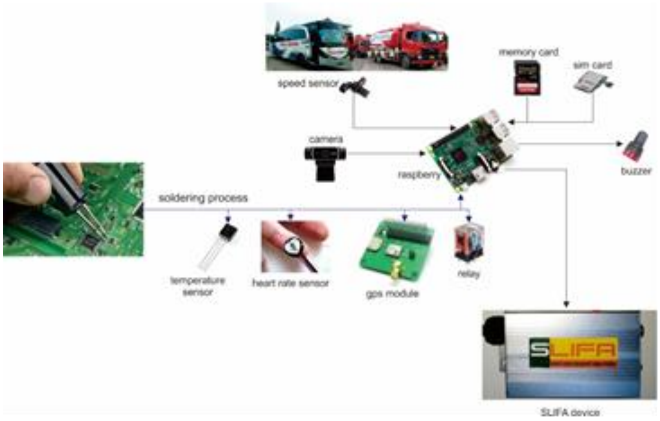

Figure 15. Picture of the electronics SLIFA circuit

Figure 16. SLIFA device

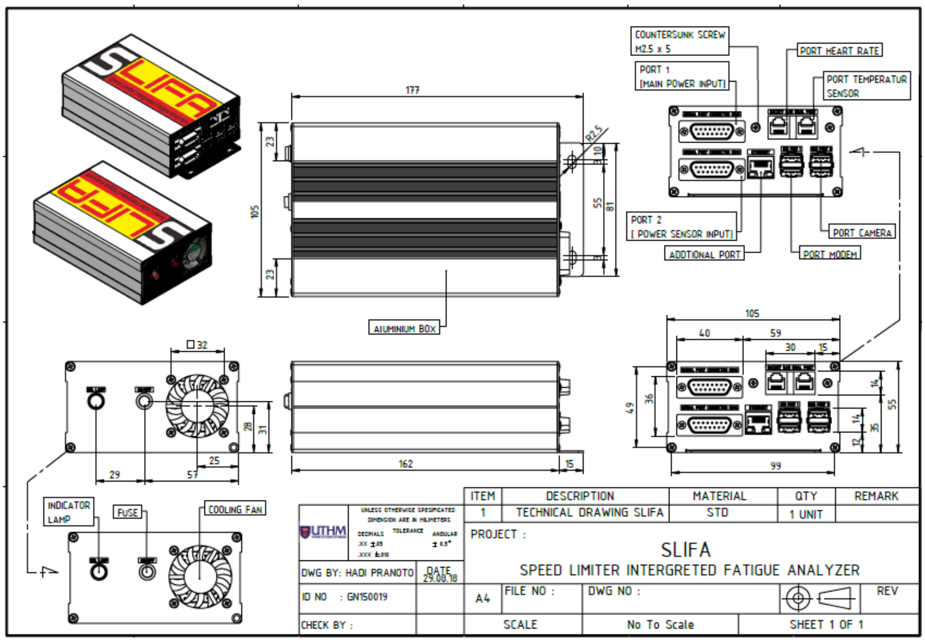

Figure 17. Technical drawing of SLIFA

3.6. Effect of SLIFA on Reducing Traffic Accident

Based on the observation that has been conducted to observe the decline of accident potential from January 2017 to January 2018, it shows after SLIFA installation on truck and bus, SLIFA gives the significant effect on decreasing traffic accident from 51 to 27 cases as listed in Table 7.

Table 7. Shift of incident period January 2017–January 2018

	Shift of Incident			
	Period Jan – June 2017 (Before SLIFA installation)		Period July 2017 – Jan 2018 (After SLIFA installation)	
	Percentage	No. of accident	Percentage	No. of accident
Morning	20%	10	19%	5
Afternoon	33%	17	48%	13
Night	25%	13	26%	7
Daylight	22%	11	7%	2
Total Cases	100%	51	100%	27

Data shows that in range of July 2017 to January 2018 after SLIFA installation on truck and bus, the number of incidents report decrease up to 47%. Before SLIFA installed, there are 51 cases of incidents report and after SLIFA installed the number of incidents report in the same period of time is just 27 cases. Although most of accidents always happened in the afternoon time due to many people on the road after working hours that increase of the number of vehicles in the road, which is improving the possibility of traffic accidents.

4. Conclusion

SLIFA is a divice to limit the speed that is installed on vehicle based on certain condition (overspeed and fatigue). Engineering design of SLIFA has considered some aspects to ensure this device works perfectly.

The development of SLIFA has been successful and it applied on truck and bus. The monitoring of traffic accident process has been conducted during January 2017 to January 2018. The results show that after SLIFA installation, traffic accident was reduced significantly up to 47% as compared to before SLIFA installation on truck and bus.

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