SPEED AND FATIGUE CONTROL USING SPEED LIMITER INTEGRATED FATIGUE ANALYZER FOR TRUCK AND BUS

HADI PRANOTO

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ABSTRACT

Developing country such as Indonesia reported that from total 6,231 road traffic crashes, over 85% of deaths, and close to 90% of disability in 2015. Large number of road traffic victims were due to by several factors such as external (34%), attitude (24%), fatigue (20%), over speed (17%) and vehicle technical problem such as maintenance short falls (5%). The main objective of this study is to develop the speed limiter that integrated with fatigue analyser and investigate its effect on engine performance, accident rate and user (driver and passenger) perception. The new features were developed through several stages which include determining parameters such as frequency and voltage, speed, driver fatigue parameter by Eye Aspec Ratio (EAR), Mouth Aspec Ratio (MAR) and Heart Rate (HR). The parameters used to formulate the driver Sleepiness Scale (SS), simulation of electronic components, features fabrication, testing and analysis. A device with new features named Speed Limiter Integrated Fatigue Analyzer (SLIFA) was applied and monitored in two transportation companies in Indonesia, namely PT. Pertamina Persero and PT. Pahala Kencana. The monitoring was conducted for one year for pre and post installation of SLIFA. The results showed that after installing the SLIFA, the average speed was succesfully reduced to 70 km/h for truck and 90 km/h for bus. In fatigue detection, the driver reached high EAR of 0.5, MAR of 1.6, HR scale of 95 bpm and high SS of 5.55. Engine performance and fuel consumption analysis showed that SLIFA had no effect in reducing the engine performance nor fuel consumption. As for the accident rate before installing the SLIFA, 51 accident cases were recorded, and after SLIFA installation, only 27 accident cases were recorded. This means that SLIFA was very useful in reducing accident by 47%. Based on satisfaction analysis using questionnaire conducted on the user, regression coefficient of 91.7% indicating a positive remark. Thus, SLIFA is acceptable and recommended to be installed and be marketed.

ABSTRAK

Negara membangun seperti Indonesia merekodkan bahawa daripada 6,231 kes kemalangan jalan raya, lebih 85% daripada kematian, dan hampir 90% daripada kecacatan pada tahun 2015. Jumlah mangsa itu kerana beberapa faktor seperti faktor luaran (34%), sikap (24%), keletihan (20%), kelajuan yang tinggi (17%) dan kenderaan teknikal seperti kekurangan senggaraan (5%). Objektif utama kajian ini adalah untuk mengembangkan alat pengawal kelajuan yang disepadukan dengan penganalisis keletihan dan menyiasat kesannya terhadap prestasi enjin, kadar kemalangan dan persepsi pengguna (pemandu dan penumpang). Alat ini dibangunkan melalui beberapa peringkat seperti pengesahan, penentuan voltan, penentuan parameter, pengesan muka, nisbah mata, nisbah mulut, kadar denyutan jantung dan skala mengantuk (SS), simulasi komponen elektronik dan fabrikasi, ujikaji dan analisis. Penyelidikan ini membangunkan alat baru iaitu *Speed Limiter Integrated Fatigue Analyzer* (SLIFA) yang digunakan dan dipantau oleh dua syarikat pengangkutan besar di Indonesia iaitu PT. Pertamina Persero dan PT. Pahala Kencana. Pemantauan data dilakukan selama 1 tahun, sebelum dan selepas pemasangan SLIFA. Hasilnya menunjukkan bahawa selepas memasang SLIFA, purata kelajuan berjaya dikurangkan kepada 70 km/j untuk trak dan 90 km/j untuk bas. Dalam pengesanan keletihan, pemandu mencapai nilai *Eye Aspec ratio (EAR)* 0.5, *Mouth Aspect Ratio (MAR)* 1.6 dan SS 5.55. Untuk analisis prestasi enjin dan penggunaan bahan api menunjukkan SLIFA tidak menjejas prestasi enjin maupun penggunaan bahan api. Sejauh kadar kemalangan sebelum memasang SLIFA, mencatatkan 51 kes kemalangan dan selepas memasang SLIFA hanya 27 kes kemalangan, bermaksud bahawa SLIFA berkesan mengurangi kemalangan sehingga 47%. Berdasarkan analisis kepuasan menggunakan soal selidik yang dijalankan pada pemandu dan penumpang, pekali regresi 91.7% menunjukkan hasil positif. Oleh itu, SLIFA boleh diterima dan dicadangkan untuk dipasang di pasaran.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL AND ABBREVIATIONS

AAP	-	Active Accelerator Pedal
AC	-	Alternating Current
ADC	-	Analog to Digital Converter
AIDS	-	Acquired Immune Deficiency Syndrome
AM	-	Ante meridiem
API	-	Application Programming Interface
ASEAN	-	Association of South East Asian Nations
ASLF	-	Adjustable Speed Limitation Function
BIFA	-	British Intenational Freigh Association
^{o}C	-	Celcius
cc	-	Engine Capacity
CFF	-	Critical Flicker Fusion
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
D	-	Detection
db	-	Decibel
DC	-	Direct Current
DET	-	Detection
EAR	-	Eye Aspect Ratio
ECM	-	Electronic Control Module
ECU	-	Electronic Control Units
ES	-	Eye State
F	-	Frequency
FFZ	-	Field Failure Zone
f	-	Farad
FMEA	-	Study of failure mode effect analysis
FWS	-	Fatigue Warning System

g	-	Gallon
GND	-	Ground
GPS	-	Global Positioning System
GTAD	-	Global Trade-Related Technical Assistance Database
h	-	Hour
HIV	-	Human Immunodeficiency Virus
HP	-	Horse Power
HR	-	Heart Rate
IDC	-	International Data Corporation
IEC	-	International Electrotechnical Commission
IRTAD	-	International Road Traffic and Accident Database
ISA	-	Iintelligent Speed Assistant
ISO	-	International Organization for Standardization
ITU	-	International Telecommunication Union
JSON	-	Javascript Object Notation (
kg	-	Kilogram
kHz	-	Kilo Hertz
km/h	-	Kilometer per Hour
kph		Kilometer per Hour
KT	-	Kilometers Travelled
kV	-	Kilo Volt
L	-	Litre
MAR	-	Mouth Aspect Ratio
MIROS	-	Malaysian Institute of Road Safety Research
mm	-	Millimeter
mph	-	Miles per Hour
MS	-	Mouth State
MySQL	-	My Structured Query Language
N	-	Newton
Nm	-	Newton Meter
NO_x		Nitrogen Monoxide
O		Occurrence
OECD/ITF	-	Organisation for Economic Co-operation and Development/International Transport Forum

P	-	Power
PCB	-	Printed Circuit Board
PHP	-	Hypertext Pre-Processor
PLC	-	Programmable Logic Controllers
PM	-	Post meridiem
QR	-	Quick Response
RFD	-	Radio Frequency Decoder
RPN	-	Risk Prority Number
RFID	-	Radio Frequency Identification
RPM	-	Rotation Per Minutes
RTAG-RTI	-	Rotary to Airline Group- Road Traffic Injuries
RTI	-	Road Traffic Injuries
S		Severity
RSL	-	Road Speed Limiters
RTA	-	Road Traffic Accident
SCADA	-	Supervisory Control And Data Acquisition
SHE COP	-	Safety Health and Environment Code of Practice
SLIFA	-	Speed Limited Integrated Fatigue Analyzer
SO_2		Sulfur Dioxide
SS	-	Sleepiness Scale
SRL	-	Safety Regulation Legal
SEV	-	Saverity
TV	-	Television
W	-	Watt
WHO	-	World Health Organization
Ω	-	Ohm

CHAPTER 1

INTRODUCTION

This chapter consists of a discussion on related issues to road accidents in developing countries, especially in Indonesia. Road accident contributed a significant percentage of victims as the statistic in 2015 recorded over 85% of the deaths, and close to 90% of the disability cases was caused by road traffic crashes worldwide. However, the highest rate of accidents was found to be significant in number for truck and bus were mostly caused by human error. Consequently, a new approach for reducing a traffic accident in truck and bus has been conducted by innovation in-vehicle system, which is to control the speed and fatigue of the driver. Review of method and technology for developing the safety device. Review of previous researchers who investigated the safety device for truck and bus. This study contribute to three primary sectors such as the industry, government, and society by finding a way to reduce the accident rate through limiting vehicle speed due to fatigue driver detection and improving the safety level of land transportation sector focus which focused trucks and buses.

1.1 Research background

Over 1.2 million people died each year on the world roads that divided by regions which are Africa, America, South-East Asia, Europe, Eastern Mediterranean, and Western Pacific. Africa has the highest Road Traffic Injuries (RTI) death rate in the world. RTIs are expected to become the number one cause of death for children aged 5 -15 years of age in the near future and the number twoπ leading cause of premature death in young men (Feng *et al.*, 2016). The endemic problem of RTIs disproportionately affecting the socioeconomically disadvantaged in Sub-Saharan Africa (SSA) is exacerbated by the limited access to healthcare and limited resources and infrastructure to adequately respond to this problem. In 2017, the review included 310,660 RTI cases across 13 SSA countries (Joao *et al.*, 2017). In addition, there was nearly 150,000 death from road traffic injuries for 2013 in the region of America (WHO, 2015b) and almost 85,000 deaths from road traffic injuries in the World Health Organization (WHO). While 95% of the population was covered by comprehensive laws in line with best practice for seat belts, only 47% of the population was adequately protected by laws for speed, 45% for helmet use, 33% for drink–driving and 71% for the use of child restraints (WHO, 2015c). There were 323,296 deaths from road traffic injuries in the Western Pacific in 2013, 64% involved vulnerable road users (motorcyclists 34% of total road traffic deaths, pedestrians, 23% and cyclists, 7%) (WHO, 2016). The summary of road traffic fatality rates per 100,000 population divided in each region is shown in Figure 1.1, where the highest rate is the Africa region with a value of 26.6%.

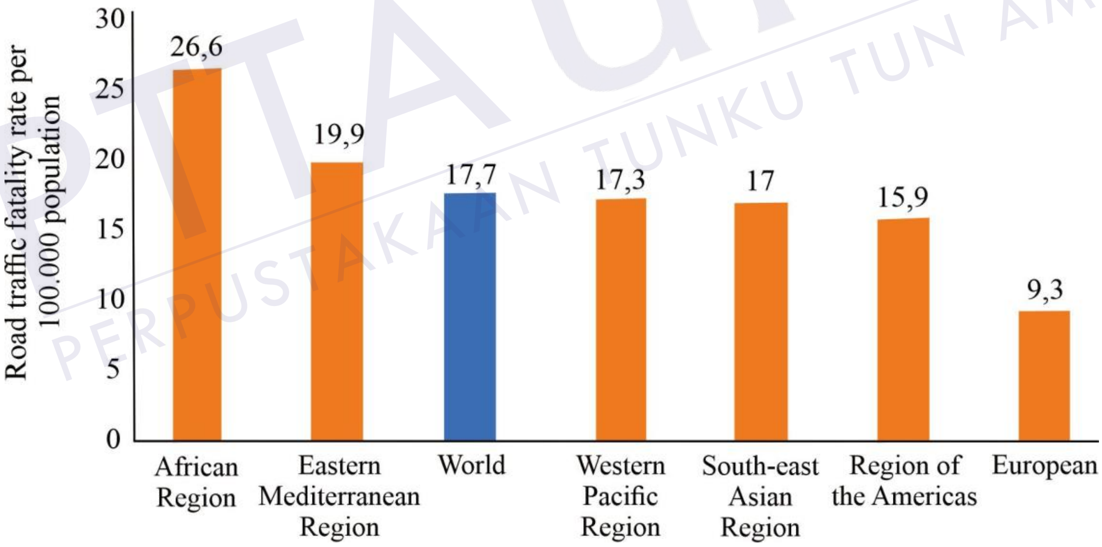

Figure 1.1: Road traffic fatality rates per 100 000 population (WHO, 2015d)

Road traffic accident had caused the losses in human lives, the economic and social costs, which resulted in the influence of road safety enhancements to the societies. Tremendous efforts have been dedicated by transportation researchers and practitioners to improve road safety (WHO, 2015a). This study focus was on the South East Asia region, especially in Indonesia. In 2015, 556 fatalities from 6,231 accident cases occurred in Jakarta. It may be due to the recklessness of the drivers or excessed speed while driving or fatigue. Several other cases were found to be related to attitude, lack of enforcement by the traffic police of which essential steps must be carried out against violators of speed in order to improve the safety of traffic safety to the community. Traffic accident in Indonesia for 2016 is listed in Table 1.1.

Table 1.1: Traffic accident in Indonesia (Traffic Police, 2017)

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
2014	83,237	16,329	18,384	54,406	143
2015	46,788	11,693	13,527	52,488	117
2016	26,487	7,417	3,206	32,319	55

Road accidents have resulted in economic loses of around 2.9% in the gross national income of Indonesia. This value is much greater than estimated by the United Nation Health Agency, which was 2% (WHO, 2015a). Factors that cause traffic accidents were mainly due to disorderly conduct recorded at 27,035 cases, 21,073 cases as a result of carelessness and 9,278 cases of exceeding the speed limit.

The increasing number of accidents are also in separable from the growing number of motor vehicles that are not proportional to the ratio of the road,which further damages the road infrastructure in various states of Indonesia.

In the past decade, Malaysia shows similar crash patterns with other developing countries in the world. The increasing number of vehicles and drivers were associated with the total number of road accidents (Nurul huda and Jamilah, 2010). Developing countries account over 85% of the deaths, and close to 90% of disability caused by road traffic crashes worldwide. Based on the world rankings, Malaysia is ranked at 46th of 172 countries regarding to the occurrence of deaths in registered vehicles due to traffic accidents (Community Road Accident Database, 2015). Exposure analysis has been widely used to explain the variation, which led to why certain group of people have a higher risk of accidents than others. The most common parameter is the number of kilometres travelled (KT) because the risk of accidents is influenced by the amount of travel performed (Nurul huda *et al.*, 2012; Zarir *et al.*, 2012). The other three common causes of road accident are speeding (32.8%), careless driving (28.2%) and careless overtaking (15.1%). The factors are mainly influenced by drivers, which contribute to 76.1% of all traffic accident.

There are some factors which led to traffic accident in small percentages such as road condition (3%) and tailgating (3.8%) (Redhwan and Karim, 2010). Those factors cause the high number of accidents reported in Selangor, followed by Johor and other states, as shown in Figure 1.2.

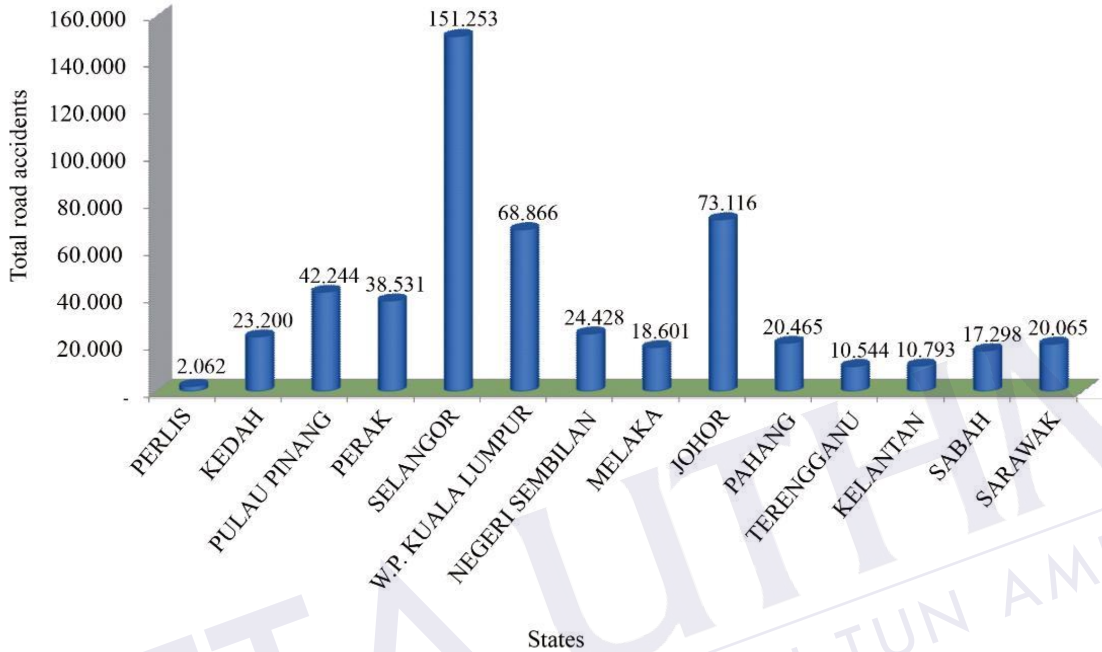

Figure 1.2: Total road accidents by States, Malaysia, 2016
(Ministry of Transport, Malaysia, 2017)

Malaysia has also developed and implemented the Road Safety Plan of Malaysia 2014-2020 in the effort to reduce the number of road accidents. This plan is designed to achieve a set of outcomes through a holistic approach and effective implementation of comprehensive strategies. Prediction of reducing road fatalities after the implementation of the plan isas shown in Figure 1.3.

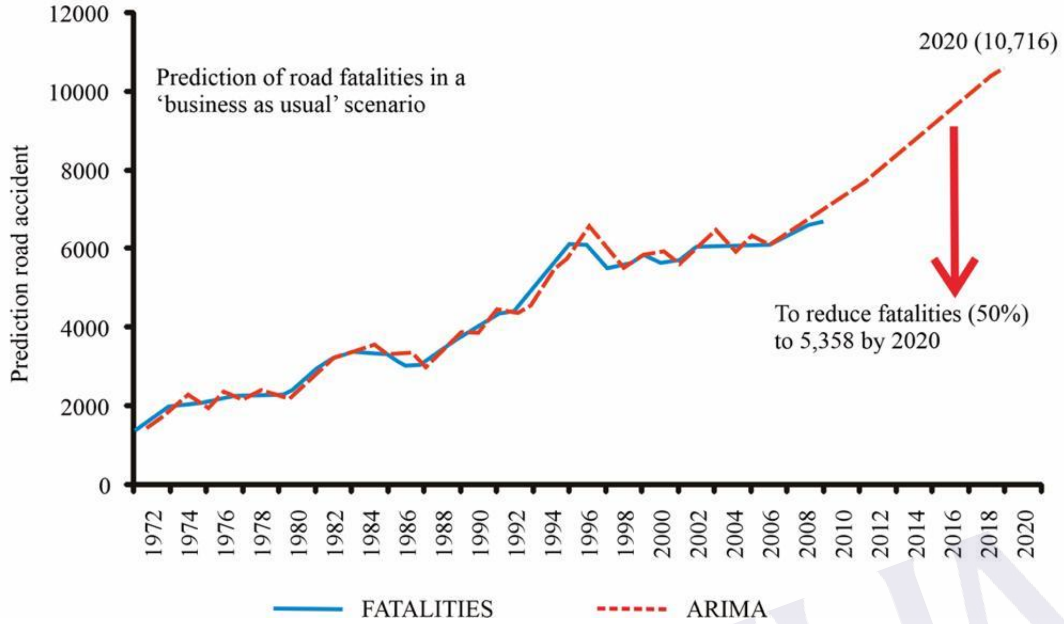

Figure 1.3: Target reduction of road fatalities (MIROS, 2014)

The target of the Malaysia Ministry of Transport for 2020 is to decrease the fatalities up to 5,358 fatalities. Since 1972, there has been an increment of fatalities for every years. However, through this plan, the increment of fatalities is hoped to be decreased. To support this plan, there are five (5) strategic pillars included in the Road Safety Plan of Malaysia 2014-2020. The main objective is to reduce the projected death due to a road accident in 2020 by 50% from 10,716 to 5,358 fatalities.

Thestrategic pillars are as listed below:

i. Road safety management
ii. Safer mobility and roads
iii. Safer vehicles
iv. Safer road users
v. Post-crash management

The Ministry of Transportation in Indonesia has also targeted to reduce the number of traffic accidents. Therefore, the ministry has 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 the residential area (Regulation Ministry of transportation, Republic of

Indonesia, 2015). Moreover, PT. Pertamina Persero (2013) has also issued a regulation for the maximum speed of tank truck in the highway at 60 km/h. For commercial buses, the maximum speed limit is as referred by the Indonesia Ministry of Transportation. However, there are many drivers who still disobey the regulation.

Several factors found to cause traffic accident, such as external (34%), attitude (24%), fatigue (20%), over speed (17%) and technical vehicle (maintenance shortfalls) (5%) as listed in Table 1.2 are based on the National General Safety Plan, (2010). Other factor includes the significant growth of vehicles and industries, which increase the possibility of higher road fatalities (Tjahjono, 2010). The factors that influence traffic accidents in Indonesia are listed in Table 1.2.

Table 1.2: Factors of traffic accidents in Indonesia
(National General Safety Plan, 2010)

Factor of traffic accidents	Percentage (%)
Fatigue	32
Over speed	15
Attitude	20
External	29
Technical vehicle	5

Trucks and busses are the main concern in this research as both are public transportations used by society. Fuel trucks require safety driving since compliance it distributes fuel, a hazardous material if an accident happens. While the bus is a form of mass transportation that requires a high standard of safety as fatigue and over speed have been identified as main factors of a traffic accident involving the vehicle. Therefore, there are needs to develop adevice or tool as an alternative solution to solve that problem. The advancement of new technology and features in the automotive sector has provided a medium to improve the safety level in truck and bus through the installation of speed limiter system on truck and bus.

The use of a speed limiter system on trucks and buses has gained researchers interest to study the impact of crushs reduction and pedestrian fatalities (Gawad and Mandourah, 2015). They found that the speed control system provided significant benefits such as reduction of maximum speed and speed variance. Hanowski *et al.*, (2012) investigated the impact of road speed limiter on approximately 138,000 commercial trucks and discovered more than 15,000 accidents after the installation. The results show that speed limiter has a positive influence as it is a low-cost technology and is not cost-prohibitive for the owner. Meanwhile, Liu *et al.*,(2017) investigated the fatigue detection on drivers that did not integrate speed limiter. On the other hand, according to Feng *et al.*,(2016) and Gawad and Mandourah, (2015) explored the usage of speed limiter to control the speed among the young and older drivers. These studies explored the use of speed limiter and fatigue detection independently. According to Feng *et al.*,(2016); Zhang *et al.*,(2015); Meng *et al.*,(2015a); Yassierliaa *et al.*,(2015); Liu *et al.*,(2017); Christian, (2015) and Matírnez *et al.*,(2013) a device to control the road accident such as speed, age of the driver, quality of sleep, fatigue and suffering the physical health separately has been developed. Therefore, this study was aimed to develop additional new features for the safety device by combining excessive speed and fatigue control detection. The implication of these features has the potential to reduce road accident number, especially for trucks and buses.

1.2 Problem statement

Christian (2015) discussed the impact of speed limiter on the reduction of crashes and pedestrian fatalities. According to Hanowski *et al., (*2012), they identify the impacts of implementing Road Speed Limiters (RSL) on commercial vehicle fleet operations that involve approximately 138,000 trucks and 15,000 read accidents. They found positive benefits for RSLs in reducing the accidents and non-cost-prohibitive for owners (Hanowski *et al.*, 2012). Driver monitoring system devices are implemented to detect the fatigued state of the driver through continuous monitoring of the driver’s eyes and mouth (Yassierliaaa *et al.*, 2015; Zhang *et al.*, 2015). The first problem of this study is that there is still a high number road accident because the existing speed limiter was unable to control the speed and detecting fatigue at the same time due to it being developed separately. Therefore, between speed limit and fatigue control can not be integrated.

In the early seventies, Ford Motor Company assigned patents concerning maximum vehicle speed limiter for a vehicle that has a pedal connected to a carburettor throttle valve through a linkage means. These patents were based on mechanical and electromagnetic-circuit systems. A proposed product namely

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