MATHEMATICAL ANALYSIS OF HEART RATE FOR DRIVING FATIGUE USING BOX-BEHNKEN DESIGN

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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UTeM
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Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree of Manufacturing Engineering (Hons.)

By

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I hereby, declared this report entitled “Mathematical Analysis of Heart Rate for Driving Fatigue Using Box-Behnken Design” is the results of my own research except as cited in reference.

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Date : 16 July 2022

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the Degree of Bachelor of Manufacturing Engineering (Hons.). The supervisor as follow:

.....

(Associate Professor Dr. Seri Rahayu Binti Kamat)

ABSTRACT

Driver distraction due to fatigue is recognized as one of the major factors of road crashes, leading in thousands of incidents and deaths each year. Fatigue drivers have potential for falling asleep at the wheel, misjudge speed and distance and impair reaction time and decision making, which can result in road accident. Therefore, the main purpose for this study is to develop and validate the regression models to relate the relationship between input process parameters which is driving speed, driving duration, body mass index (BMI), gender and type of road, and an output response which is heart rate that cause driving fatigue. Six qualified and healthy drivers were used as the experiment's respondents: three male and three female. Pulse oximeter SMH-01 has been used in this research as the heart rate monitor. Design Expert 8.0.6 software was used for the regression analysis. The regression model was successfully developed and validated. The results indicate that actual heart rate data from the validation runs fall within the 95% prediction interval and the residual errors are ranging from 0.001% to 3.88%, which in absolute value is less than 10%. The significant parameters that influenced the heart rate were also identified. Heart rate was influenced by the driving speed, driving duration, BMI, gender, and type of road. The author believes that the development of psychophysical factor models for the driver fatigue problem among Malaysian using regression analysis is a new contribution to the body of knowledge.

ABSTRAK

Gangguan pemandu kerana keletihan diiktiraf sebagai salah satu faktor utama kemalangan jalan raya, membawa kepada beribu-ribu insiden dan kematian setiap tahun. Pemandu yang keletihan mempunyai potensi untuk tertidur semasa memandu, salah menilai kelajuan dan jarak serta menjejaskan masa tindak balas dan membuat keputusan, yang boleh mengakibatkan kemalangan jalan raya. Oleh itu, tujuan utama kajian ini adalah untuk membangunkan dan mengesahkan model regresi untuk mengaitkan hubungan antara parameter proses input iaitu kelajuan pemanduan, tempoh pemanduan, indeks jisim tubuh (BMI), jantina dan jenis jalan, dan tindak balas keluaran iaitu kadar denyutan jantung yang menyebabkan keletihan memandu. Enam pemandu yang berkelayakan dan sihat digunakan sebagai responden eksperimen: tiga lelaki dan tiga perempuan. Pulse oximeter SMH-01 telah digunakan dalam penyelidikan ini sebagai pemantau kadar jantung. Perisian Design Expert 8.0.6 digunakan untuk analisis regresi. Model regresi telah berjaya dibangunkan dan disahkan. Keputusan menunjukkan bahawa data kadar denyutan jantung sebenar daripada larian pengesahan jatuh dalam selang ramalan 95% dan ralat baki adalah antara 0.001% hingga 3.88%, yang dalam nilai mutlak adalah kurang daripada 10%. Parameter penting yang mempengaruhi kadar denyutan jantung juga dikenal pasti. Kadar denyutan jantung dipengaruhi oleh kelajuan pemanduan, tempoh pemanduan, BMI, jantina dan jenis jalan raya. Penulis percaya bahawa pembangunan model faktor psikofizikal untuk masalah kelesuan pemandu di kalangan rakyat Malaysia menggunakan analisis regresi adalah sumbangan baharu kepada badan pengetahuan.

DEDICATION

This report is dedicated to

my beloved parents, brother, sisters, and friends

for giving me moral support, cooperation, encouragement also understanding.

Thank you so much

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this Bachelor's Degree Project successfully without difficulty.

Thank you to Profesor Madya Dr Seri Rahayu Binti Kamat, my supervisor from the Faculty of Manufacturing Engineering, for the great mentoring that was given to me throughout the whole project. Besides that, I would like to give a special thanks to my friends who gave me much motivation and cooperation mentally in completing this report. Thanks for the great friendship.

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LIST OF ABBREVIATION

a.m.	-	Ante meridiem
AHP	-	Analytic hierarchy process
ANOVA	-	Analysis of Variance
ASEAN	-	Association of Southeast Asian Nations
BMI	-	Body mass index
CDC	-	Centres for Disease Control and Prevention
DS	-	Dempster-Shafer
DSS	-	Decision Support System
DF	-	Degree of Freedom
DGM	-	Deep generic model
ECG	-	Electrocardiograms
EEG	-	Electroencephalograms
EMG	-	Electromyograms
EOG	-	Electrooculograms
HRV	-	Heart rate variability
MCO	-	Movement Control Order
MIROS	-	Malaysian Institute of Road Safety Research
MS	-	Mean Square
n.d.	-	No date
NHTSA	-	National Highway Traffic Safety Administration

NN	-	Neutral network
NSC	-	National Safety Council
OSA	-	Obstructive sleep apnea
p.m.	-	Post meridiem
RMP	-	Royal Malaysian Police
SMSS	-	Sequential model sum of squares
SS	-	Sum of Square
UTeM	-	Universiti Teknikal Malaysia Melaka
WHO	-	World Health Organization

LIST OF SYMBOLS

%	-	Percentage
bpm	-	Beats per minute
km/h	-	Kilometer per hour
mph	-	Miles per hour

CHAPTER 1

INTRODUCTION

The introduction is essentially to highlight certain initial views and thoughts that are related to the reasons of study is deliberated in this chapter. Background study fundamentally contains a study of mental stress on road geometry for driver fatigue. Furthermore, the literature of problem statement that led to the selection of the research title. Furthermore, there are the objectives that will be achieved as a result of the outcomes. Finally, the study's scope and significance must be considered.

1.1 Background Study

Driver distraction due to fatigue is recognized as one of the major factors of road crashes, leading in thousands of incidents and deaths each year. World Health Organization reported that, over than 1.3 million road fatalities occurred every year are mainly due to fatigued driving. U.S. Centers for Disease and Control and Prevention (CDC) described driver fatigue as a public health epidemic. Fatigue is a state of intense exhaustion caused by a lack of sleep over a period of time, whether as a result of mental or physical activity or disease. The driver might not realize when he or she is fatigued as the symptoms of fatigue are difficult to determine. Túlio De Mello et al. (2013) identified sleep-related problem is one of the major contributors to fatigue. Ideally, most healthy adults need around 7.5 to 9 hours of good quality sleep every night. However, hectic social life, work commitment and sleep-related problems like sleep fragmentation and sleep apnea tend people to not reach that

quota. Those who pay less attention to sleep time and always have sleep debt or sleep deficit will result in sleep deprivation. Drivers with sleep debt risk have potential for falling asleep at the wheel, misjudge speed and distance and impair reaction time and decision making, which can result in road accident. If a driver experience micro-sleep-short for 4.6 seconds, while travelling at 55 mph, the car will travel the length of an entire football field without a driver control (Walden, 2012).

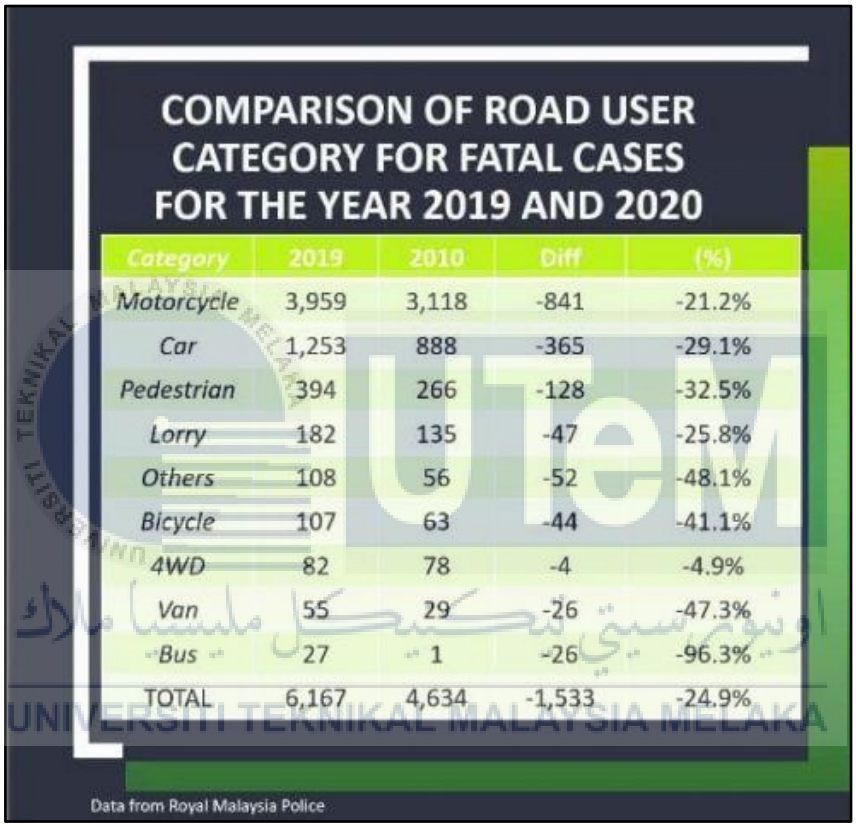

Figure 1.1: Comparison of road user category for fatal cases for the year 2019 and 2020 (Lye, 2021).

The Malaysian Institute of Road Safety Research (MIROS), (2021) has exposed road crash data for 2020, which showed a decrease of 24.9 % compared to 2019 data. Based on data obtained from PDRM, last year recorded 4,634 deaths due to road accidents, compared to 6,167 deaths in the previous year.

The newest figure represents a reduction of 1,533 deaths, although it must also be highlighted that the whole country over the previous year and remains currently under the Movement Control Order (MCO), which has restricted the movement of people on the roads. Deaths involving motorcyclists were still the majority with 3,118 cases and followed by car

passengers with 888 deaths. Pedestrians recorded 266 deaths; trucks with 135 deaths; other vehicles with 108 deaths and bicycles with 107 deaths. For 4WD vehicles, vans and buses, the data showed 82, 55 and 27 deaths, respectively.

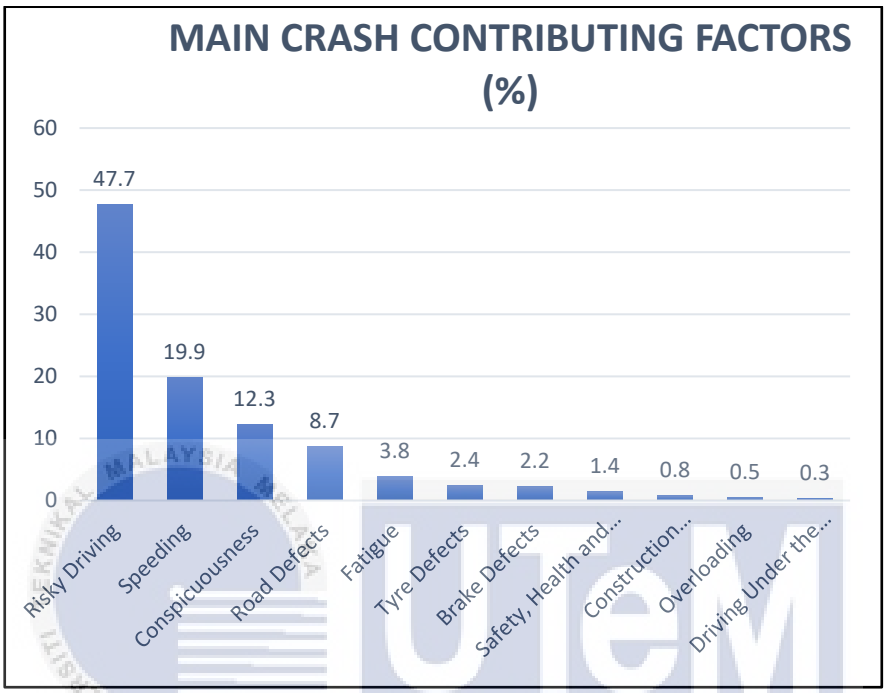

Figure 1.2: Crash contributing factors from 2014 until 2016 (MIROS, 2020).

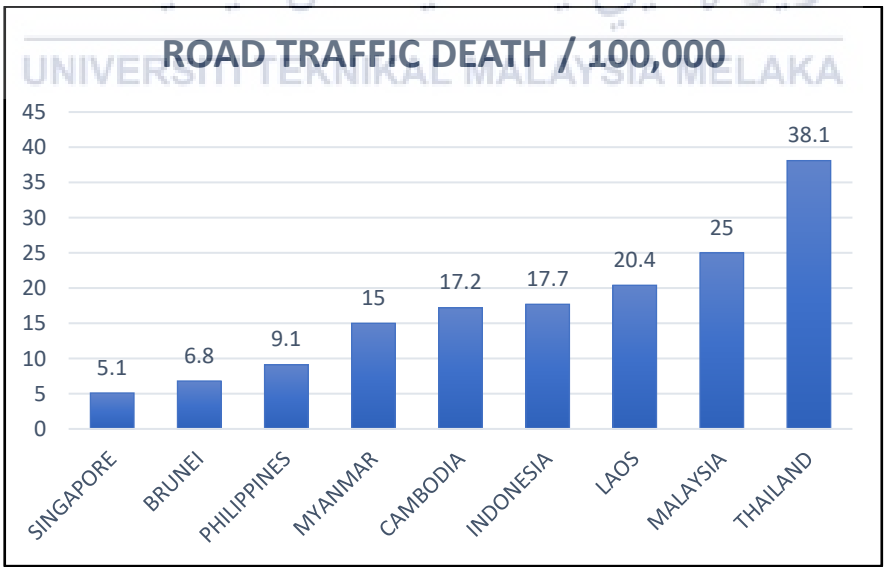

Figure 1.3: Malaysia's rates of death in comparison to other countries in the region (Abdelfatah, 2016).

MIROS (2020) reported that Fatigue is the fifth highest factor out of eleven accident contributors in Malaysia from 2014 to 2016. The data reported by World Health Organization (WHO) depicts that Malaysia is listed as the second highest country in its region, Association of Southeast Asian Nations (ASEAN) in road fatality rate (Abdelfatah, 2016). According to the Royal Malaysian Police (RMP) and Malaysia Institute of Road Safety Research (MIROS), the number of road accident in Malaysia is increased alarmingly since 2010 until 2019 with 414,421 and 567,516 respectively (Ministry of Transport Malaysia, n.d.).

Since fatigue is a dangerous and common occurrence, advance warning technology for sensing driver fatigue has received a lot of interest. In the past few years, there are number of approaches in fatigue detection and monitoring system like vehicle-based for instance steering wheel rotation and lane tracking monitoring system (Sahayadhas et al., 2012); 2) behavior-based using optical sensor and video cameras techniques like eyes closure and blink rates and facial expressions (Jo et al., 2014; Kang, 2013); 3) physiological-based measures like electrocardiograms (ECG), electromyograms (EMG), electrooculograms (EOG) and electroencephalograms (EEG) (Jianfeng et al., 2015; Wang et al., 2015); and 4) detection using heart rate variability (Vicente et al., 2016)

The purpose of creating fatigue warning technology is to create an autonomous fatigue detection device that can be incorporated into a sub device of a human vehicle interaction system to help with driving safety. This might help to reduce the huge losses caused by driver fatigue. Fatigue identification based on physiological signs has recently received a lot of attention. Previous research has demonstrated a relationship between fatigue and the electrocardiogram (ECG) signal and its derived statistics, which includes information on heart rate (HR), heart rate variability (HRV), and breath frequency. This research, though, solely emphases at heart rate (Ni et al., 2022).

Road monotony may be divided into two categories in the context of driving: roadside diversity and road design. Research have shown that both characteristics of monotony have been linked to driver attentiveness and concentration (Farahmand & Boroujerdian, 2018). Both characteristics of monotony have been linked to driver attentiveness and concentration in studies. Thiffault and Bergeron (2003) tested the impact of modifying the roadside ambience on driver attentiveness using a driving simulator (line monitoring and steering wheel motions are used to index the data.). In the repetitive setting,

the authors noticed a quicker decline in attentiveness over time (Thiffault & Bergeron, 2003). The objective of this project is to develop and validate the regression models to relate the relationship between input process parameters and an output response based on heart rate that cause driving fatigue. Road conditions such as monotonous and winding road, driving duration and speed of car as well as body mass index (BMI) will be emphasized in this research to study fatigue on the driver himself.

1.2 Problems Statement

In contrast to the abstract and background research, a few situations must be reviewed prior to studying the effects of mental stress on road geometry of driver fatigue. First, the U.S. National Highway Traffic Safety Administration (NHTSA) reported that every year, around 100,000 traffic accidents and 71,000 injuries related to driver drowsiness, out of which more than 1,300 are fatal (Sacco & Farrugia, 2012). Second, fatigue drivers have potential for falling asleep at the wheel, misjudge speed and distance and impair reaction time and decision making, which can result in road accident (Min et al., 2017). Third, there is no study link the relationship of driving duration, road condition, speed of car, BMI, and gender on driver stress base on heart rate measurement. Last but not least, the previous studies are more focus on using driving simulator to analyse the driver's heart rate than driving on real road.

1.3 Objectives

i. To identify significant parameter that affecting the heart rate in driving fatigue on monotonous and winding road condition.
ii. To identify mathematical analysis of heart rate for driving fatigue using Box-Behnken designs.

iii. To develop and validate the regression models to relate the relationship between input process parameters and an output response based on heart rate that cause driving fatigue.

1.4 Scope

The scope of this research is only focused on car drivers only. The characteristics of the respondents will be set on every gender which is male and female, aged 20 to 25 years, and have a body mass index (BMI) of healthy, overweight and obesity. The experiments will be conducted on monotonous and long roads, winding roads and take 15 to 30 minutes by using Perodua Bezza. Heart rate variability will be measured using an oximeter at each predetermined speed such as 80km/h and 100km/h.