# REGRESSION ANALYSIS OF HEART RATE FOR DRIVING FATIGUE USING RESPONSE SURFACE METHODOLOGY (RSM)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted by the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for a Bachelor Degree in Manufacturing Engineering

by

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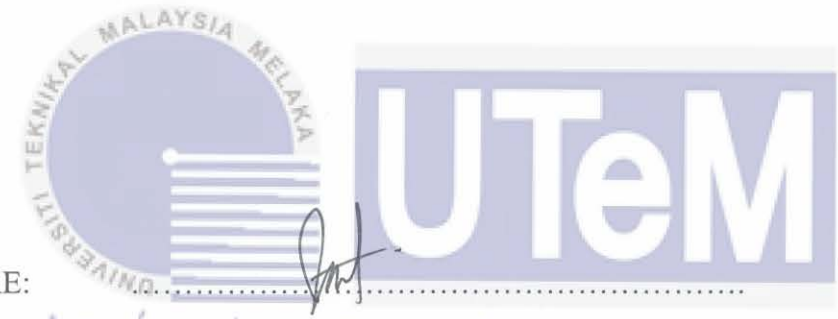
## DECLARATION

I hereby, declared this report entitled "factors affecting users' satisfaction in the work environment in education services facilities in utem" is the result of my own research except as cited in references.



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DATE: 25/7/2022

## APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

.....

**(ASSOCIATE PROFESSOR DR. SERI RAHAYU BINTI KAMAT)**

# ABSTRAK

Di zaman yang serba canggih ini, kenderaan adalah sesuatu yang sangat berguna untuk masyarakat dunia. Sama ada menaiki kenderaan awam mahupun kenderaan persendirian. Hal ini kerana, kenderaan dapat menjimatkan masa dan tenaga seseorang untuk menuju ke destinasi yang ingin dituju. Tidak dinafikan kenderaan mempunyai banyak manfaat dan kelebihan untuk masayarakat, tetapi tidak lupa juga dengan risiko yang boleh merbahayakan keselamatan dan nyawa seseorang jika berlaku kemalangan. Terdapat banyak faktor yang menyebabkan kemalangan. Antaranya adalah keletihan pemandu yang menjadi punca kepada kehilangan tumpuan ketika memandu dan seterusnya menyebabkan pemandu gagal membuat keputusan yang tepat apabila berlaku kecemasan. Ergonomik kognitif, kadang-kadang disebut sebagai kejuruteraan factor manusia dikenal pasti sebagai punca keletihan pemandu di kalangan pemandu di Malaysia. Tujuan penyelidian ini dijalankan adalah untuk membangunkan satu model regrasi berdasarkan kepada faktor-faktor ergonomik kognitif yang menyumbang kepada keletihan dan menyebabkan kehilangan fokus dan gagal membuat keputusan yang tepat. Model yang dibangunkan dapat menghubungkan antara parameter input dan keputusan yang akan dihasilkan.

## ABSTRACT

In this modern era, vehicles are something that is very useful for the world community. Whether riding a public vehicle or a private vehicle. This is because, the vehicle can save a person's time and energy to go to the desired destination. There is no doubt that vehicles have many benefits and advantages for society, but do not forget also the risks that can endanger the safety and life of a person in the event of an accident. There are many factors that cause accidents. Among them is driver fatigue which is the cause of loss of focus while driving and in turn causes the driver to fail to make the right decision when an emergency occurs. Cognitive ergonomics, sometimes referred to as human factor engineering has been identified as a cause of driver fatigue among drivers in Malaysia. The purpose of this research conducted was to develop a regression model based on cognitive ergonomic factors that contribute to fatigue that cause loss of focus and failure to make accurate decisions. The model developed can link between the input parameters and the results to be produced.

## DEDICATION

A special dedication to the Almighty God who made this project a success despite having to face a lot of challenges and problem, and to my beloved parents who are my encouraging source. Also, thanks to my generous supervisor,

Profesor Madya Dr Seri Rahayu Binti Kamat, who guided and encouraged me when encountered with many issues and problems.

## ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my greatest gratitude to the Almighty for his blessings in completing my Final Year Project successfully. Besides, I would also like to extend my sincere appreciation and thanks to my supervising lecturer, Profesor Madya Dr Seri Rahayu Binti Kamat for her excellent guidance in providing me with good ideas and suggestions as well as continuous encouragement throughout the completion of this Final Year Project. The thesis would not have been written successfully without her continuous supervision and guidance.

I am also indebted to all my friends and seniors, especially those who have always remained with me, giving me their best advice to keep me motivated to successfully complete this project. Special thanks to my parents for their support and love non-stop as well as for helping me financially during the completion of this project. Finally, I am grateful to everyone who is directly or indirectly participating in the completion of my Final Year Project. Although the contribution is minimal, it still means a lot to me.

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# INTRODUCTION

This chapter contain of background that explain about information of this project. This chapter also explain about objective that shows about the purposes of this project, problem statement that leads to carry out this experiment. Next, the scope will show about the research scope for number of respondents, respondent weight categories, timing, and gender of the respondent for this experiment.



## 1.1 Background of Study

In this era of modernization, vehicle is one of the most important for human being because it can help human to travel from one place to another place. According to statistics released by the Ministry of Transport Malaysia (MOT), a total of 32,378,174 total motor vehicles were registered in Malaysia in 2020(MOT, 2020). Meanwhile, the increasing number of vehicles also can increase the number of drivers licensed. By the Jabatan Pengangkutan Jalanraya (JPJ) with an increase of 2.86 percent which is 15,810,413 compared to 15,371,130 in 2019. Table 1.1 shows the number of vehicles in Malaysia increasing.

| Type of Vehicles | Amount in 2019 | Amount in 2020 | Increase in % |
|---|---|---|---|
| **Motorcycle** | 14,332,226 | 14,891,585 | 3.98% |
| **Car** | 14,695,664 | 15,240,536 | 3.71% |
| **Bus** | 62,966 | 63,389 | 0.67% |
| **Taxi** | 92,011 | 90,994 | -1.11% |
| **Rental car** | 28,123 | 30,091 | 7.00% |
| **Goods vehicle** | 1,295,486 | 1,325,680 | 2.33% |
| **Other's vehicle** | 718,296 | 735,899 | 2.45% |
| **Total** | **31,214,772** | **32,378,174** | **3.73%** |

Table 1.1: Cumulative number of vehicles by type in Malaysia in 2019-2020

This proves that there are many drivers in Malaysia. This also means number of accidents in Malaysia also can increase. We are living in the century of action for road safety, which implies that the topic of road safety is serious and that the entire globe is fighting to find a solution to the problem of traffic accidents. Every year, more than 1.2 million people die on the world's roads, making road traffic injuries the top cause of death worldwide.(Davidović et al., 2018) Based on the statistic by Ministry of Transport Malaysia (MOT), the number of road accident in Malaysia keep increasing during 2010-2019 (Figure 1.2). In 2014, the ASEAN Transport Minister had appointed MIROS as the ASEAN Road Safety Centre. The center's purpose is to promote and disseminate information on ASEAN road safety concerns, including legislation, standards, data management, and public awareness and education.. In two years, the number of fatalities has been decreasing from 7,152 in 2016 and showed the lowest number at 6,167 in 2019 during 2010-2019 period (Figure 1.3).

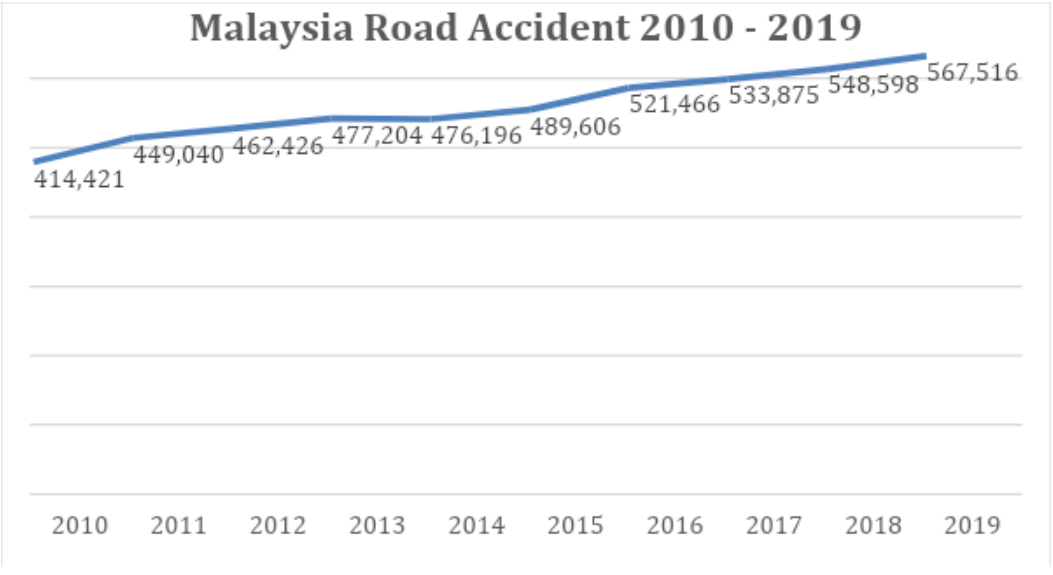



Figure 3.2: Malaysia Road Accident 2010 – 2019

| Years | Percentage |
|---|---|
| 2010-2011 | +8.35% |
| 2011-2012 | +2.98% |
| 2012-2013 | +3.2% |
| 2013-2014 | -0.21% |
| 2014-2015 | +2.82% |
| 2015-2016 | +6.51% |
| 2016-2017 | +2.38% |
| 2017-2018 | +2.75% |
| 2018-2019 | +3.45% |

Table 1.2: Malaysia Road Accident percentage 2010-2019

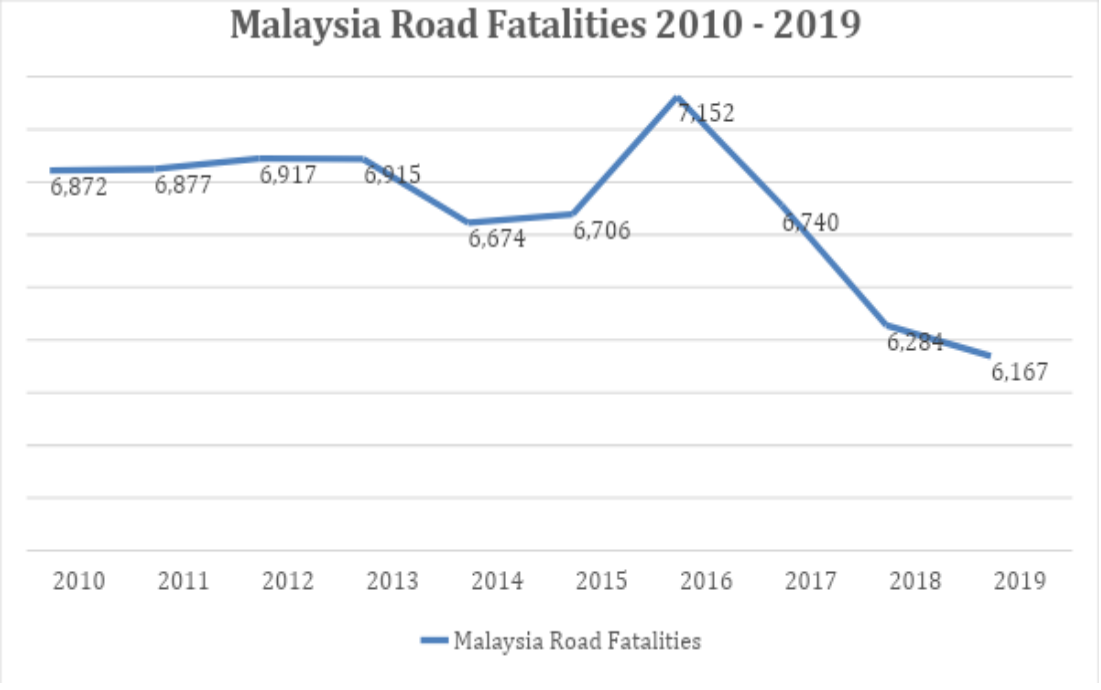



Figure 1.3: Malaysia Road Fatalities 2010 - 2019

| Years | Percentage |
|---|---|
| 2010-2011 | +0.07% |
| 2011-2012 | +0.58% |
| 2012-2013 | -0.03% |
| 2013-2014 | -3.49% |
| 2014-2015 | +0.48% |
| 2015-2016 | +6.65% |
| 2016-2017 | -5.76% |
| 2017-2018 | -6.77% |
| 2018-2019 | -1.86% |

Table 1.3: Malaysia Road Fatalities percentage 2010 - 2019

There are many factors that cause to road accident. The factors include vehicle condition road structure, weather, and human factor itself. In fact, more than 500,000 of Malaysians died because of accident on road and mostly road accident cases came from driver's behaviour, road condition, equipment failure and infrastructure. The topic surrounding road accidents is growing extra; every year over five millions of people in the world a violent death and a quarter of these are traffic accident victims (WHO, 2015) However, improvements in automotive technology in terms of the safety have reached a high level. Road design and signage have also been upgraded, where multiple blackspots have been found and studies to minimise the causes of road accidents have been performed. However, it was found that the number of accident rates keep increasing time

by time. 70% of road fatalities occur in developing nations, where the population is less developed, killing 1.17 million people a year. Pedestrian are responsible for the 65 percent of those murdered on the road, 35 percent are pedestrians under the age of twenty-five. Every year, an estimated 23–34 million people are killed or seriously injured as a result of road accidents.(Khairul Amri Kamarudin et al., 2018)

Based on previous research, focus on the relationship between fatigue and driving performance. Attention to the performance of drivers in the transportation of oil and gas is very important. This would lead to more safety on the road. (Al-Mekhlafi et al., 2020). For this research focus on decision making and focus while driving. There are two types of situations when someone drive on road whether the driver already familiar to taking that route or first time to going through that route. Both situations have different focus level when go through that route. If the driver usually used that road, the driver already knows the condition of the road and that will give opportunity to the driver to focus on certain place. This also can give the driver to make right decision making. So, the driver will drive at high speed because already know where the obstacle or bad road condition. While the driver for the first time using that road will be more focus when go through that route because the driver unfamiliar with that road. This driving activity involve the brain and the muscle to control the can using arms and legs. Brain can function properly with enough amount of glucose and oxygen level. After using brain too much without rest, oxygen that supply to brain and muscle will decreased. Consequently, this can make the driver fatigue and will affected the driver focus and decision making that can lead to accident.



Fatigue is an extreme tiredness that will happen to those who do not get enough rest after working for a very long period. Ideally, seven to eight hours is a sufficient duration to an adult to get enough rest after an intense working hour.(RoSPA, 2001) After leaving workplace, most people will drive their own car to go home. In the worst condition, the drivers that have fatigue after going through the working hours will be nodding off or have micro sleep cannot control the car. Accidents caused by fatigued drivers have a higher fatality rate and more environmental damage than those caused by alert drivers. Driver fatigue has been linked to car accidents ((Sikander & Anwar, 2019)). This can impact the reaction time and decision making thus will increase the chances of accident to occur.

## 1.2 Objective

1) To investigate the driving fatigue based on heart rate with different condition of the road (uphill/downhill and straight road).
2) To analyze the data of the heart rate that cause driving stress with different condition of the road (uphill/ downhill and straight road).
3) To develop and validate the regression models using Design Expert System based on the heart rate with different condition of the road (uphill/downhill and straight road).

## 1.3 Scope

The scope for this research is focus on the overweight or obesity drivers which has Body Mass Index (BMI) more than 24.9 and less than 29.9. All the respondent for this research is men only. This research has been done in the Ergonomic lab in Faculty of Manufacturing, UTeM by using the driver simulator. The respondent will use the driver simulator to feels the real experience of driving a car. The simulation will include different type of road which is winding & up/down hills. Meanwhile, the respondent will use output parameter to detect the brainwave of the respondent while drive the simulator. This research also focusses on decision making and focus while driving. The respondent also will use Perodua Bezza for real driving experience.

# CHAPTER 2
# LITERATURE REVIEW

The purpose of literature reviews it to obtain understanding and details of the existing research conducted by other researcher around the world to a certain topic or area of study based and to present the idea in the form of the written report.

## 2.1 Driving Fatigue

A state of extreme tiredness caused on by an insufficient amount of rest after a long period of work. Adults require seven to eight hours of sleep every night in order to fully recover from a long day at work. Having a sleep problem is a condition in which the body is unable to manage its own sleep patterns. Fatigued drivers may fall asleep at the wheel and lose control of the car in a worst-case situation. Responding and making decisions can be slowed down, increasing the risk of an accident. If a driver falls asleep for just four seconds while traveling at a speed of 100 km/h the car will have gone 111 meters without a driver in control (Royal Commission, 2015).

According to previous study, physiological signs such as heart rate are reliable markers of driver fatigue. When fatigue causes a stress reaction in organs, the cardiovascular nervous system will adapt properly. Long distance driving is a major cause of fatigue related accidents on freeways and other large roads. Long distance driving causes severe decrease the driver attentiveness and performance, which might threaten transportation safety. (Ting, P. H et al, 2008). Driver fatigue has been identified as a major cause of serious accidents which leads to reduced driving performance efficiency (Nailul Munna Abang Abdullah et al, 2011) Hence, early detection of driver fatigue is very important in order to reduce the number of accidents. Driver fatigue may be identified by detecting the heart rate of the driver

with a wearable device or by extracting face characteristics from the driver using an RGB camera. Nevertheless, a wearable device is inconvenient and uncomfortable for the driver, and the detection accuracy of an RGB camera may be impacted by light, spectacles, and head tilt. (Du et al, 2021).

**Table 2.1**: Driving Fatigue from previous research

| Author | Title | Findings |
|---|---|---|
| Guanglong Du, Tao Li, Chunquan Li , Peter X. Liu , and Di Li (2020) | Vision-Based Fatigue Driving Recognition Method Integrating Heart Rate and Facial Features | Early detection of driver fatigue is very important in order to reduce the number of accidents. Driving fatigue can be detected by measuring drivers' heart rate with a wearable device or extracting their facial features with an RGB camera. However, a wearable device causes inconvenience and discomfort to the driver, and an RGB camera's detection accuracy may be affected by light, glasses, and head orientation |
| Ruben Buendia, Fabio Forcolin, Johan Karlsson (2019) | Deriving heart rate variability indices from cardiac monitoring—An indicator of driver sleepiness | Driver fatigue is considered to be a major contributor to road traffic crashes. Cardiac monitoring and heart rate variability (HRV) analysis is a candidate method for early and accurate detection of driver sleepiness. |



## 2.2 Pulse Oximeter

A pulse oximeter is a device that is often placed on the tip of the index finger. In order to determine the oxygen saturation level and pulse rate of the blood, it makes use of laser beams. The oxygen saturation level provides information on the amount of oxygen that is carried by the blood. It is a straightforward examination that does not cause any discomfort in order to evaluate the efficiency with which oxygen is being transported to your extremities, such as your arms and legs.


Figure 2.2a: Example of new model Finger Pulse Oximeter

Figure 2.2b: Example of old model of Finger Pulse Oximeter

Oxygen is essential to the continued functioning of all biological processes, systems, and organs. If cells do not receive sufficient oxygen, they will begin to malfunction and will eventually die. Cell death can lead to organ failure, which shows itself physically as a wide variety of symptoms. The body transports oxygen to the organs by filtering it through the lungs. The lungs then distribute oxygen into the blood via hemoglobin proteins in red blood cells. These proteins provide oxygen to the rest of the body. Pulse oximetry can be used to assess the degree to which hemoglobin proteins are saturated with oxygen. The oxygen saturation test is a popular test that is used to determine the amount of oxygen that is reaching the organs. The amount of oxygen in the air should be at a saturation level of between 95 and 100 percent. Oxygen partial pressures that are lower than 90 percent of the capacity of the atmosphere. If the source level is too low, there is a possibility that a medical emergency

will arise. Some medical professionals use pulse oximetry to determine whether or not it is safe for their patients to engage in physical activity, while others may suggest that their patients wear a pulse oximeter while they are working out in order to ensure that their patients' safety. The use of pulse oximetry in combination with a stress test is another option that is open to doctor.

**Table 2.2**: Pulse Oximeter used in previous research

| Authors | Title | Findings |
|---|---|---|
| Jing, D., Zhang, S., & Guo, Z. (2020). | Fatigue driving detection method for low-voltage and hypoxia plateau area: A physiological characteristic analysis approach | Fatigue driving is one of the main reasons for fatal crashes and highway accidents for drivers. Driving fatigue detection method based on monitoring psychological indicators is an effective method to avoid traffic accidents. The driver's heart rate (HR) and blood oxygen saturation (SpO2) data were obtained in low-voltage and hypoxia plateau area by driving fatigue test, that is, field driving fatigue test and drug intervention fatigue driving test. |
| Barua, T., Jahan, E., & Salma, U. (2020). | an overview on heart rate monitoring and pulse oximeter system | This device is able to produce highly reliable test results for both heart rate and SpO2 level. Our designed device has the advantage that it can be used by nonprofessional people at home to measure the heart rate and SPO2 level easily and safely. |



## 2.3 Concept of the Cognitive Factor

### 2.3.1 Decision making

Decision making is a process to make choice for something that have many option by identifying a decision, gathering information, and assessing alternative resolutions. Organized information and alternative definitions provided by a step-by-step decision-making approach can help someone make more deliberate and considered decisions. There are numerous aspects that play a role in a person's decision-making process. An individual's age and socioeconomic level are also important determinants. A belief in personal relevance is also a significant influence in the decision-making process. They all play a role in the decision-making process and in the decisions that are ultimately made.

Nowadays, there are many drivers on roadway. Due to the fact that they are distracted by a variety of factors both inside and outside their vehicle, today's drivers are more prone to make poor judgments while driving.

**Table 2.3.1**: previous study for decision making that affected driving performance

| Authors | Title | Findings |
|---|---|---|
| (Terai et al., 2015) | An experimental study on the difference in drivers' decision-making behavior during manual and supported driving | Driver decision-making qualities are different while driving with manual or automated control, according to this study. When utilising driving assistance systems, people were more careful when making lane change judgments, but their sensitivity to danger circumstances may have decreased as a result. |
| (X. Wang et al., n.d.) | Driver's Behavior and Decision-Making Optimization Model in Mixed Traffic Environment | According to this article, When a driver is making a decision in a complicated mixed traffic environment, he or she is actually analysing a lot of information from outside sources, like the outside environment, his or her own information (like speed, temperament, driving characteristics, and task), and information from inside the vehicle. |



### 2.3.2 Focusing

There are more and more things that can keep drivers from paying full attention to the road. Distracted driving is becoming more and more of a problem. It can happen when driver drunk or tired, eat, or use a device while driving. When people text while they drive, it is very common. It's easy to lose focus on the road while commuting or travelling. Bring your focus back to your surroundings if it wanders. Driver fatigue causes loss of focus.

**Table 2.3.2**: focusing affected driving performance based on other research

| Author | Title | Findings |
|---|---|---|
| (Regan, 2003) | Driver distraction | According to estimates, inattentive or distracted driving is a contributing factor in around one-quarter of all vehicle accidents in the United States. |

## 2.4 Experimental Parameter

### 2.4.1 Independent variable

#### 2.4.1.1 Duration driving

Driving for a long period of time or on a long journey is a big contributing reason to any road accidents that are related to muscle and mental fatigue. To put it another way, the brainwave is the wave generated by the internal part of the brain and this corresponds to the level of oxygen in biochemical reactions that occur in every cell. Oxygen will be used as a fuel for the reaction of energy generation, which is carried out by the mitochondria, which convert glucose into energy. The longer time passes, the lower the brain's oxygen supply. As a result, the rate at which energy is produced will change. The energy will subsequently be put to work in the process of cognitive decision-making.

The longer time a driver spends behind the wheel, the lower their brain's oxygen levels will become, making them feel sleepy. Recent research suggests that the more time spent in bed, the more tired one becomes. A driver's risk of an accident increases with time due to a decrease in their attentiveness, vigilance, and driving performance while behind the wheel of their vehicle. When a driver's muscles and brain begin to weary, he or she will be more likely to cause an accident. When a person does the same thing for an extended amount of time, their desire to drive diminishes, and boredom sets in. As a result of the driver becoming less vigilant, performance will suffer. Fatigue driving has long been recognised as a significant risk factor in traffic accidents, with around 15 percent of all traffic accidents in China being caused by fatigue, particularly among long-distance commercial coach drivers. (L. Wang & Pei, 2014)



**Table 2.4.1.1**: Driving duration affected driving performance by other journal

| Authors | Title | Findings |
|---|---|---|
| Al-Baraa Abdulrahman Al-Mekhlafi, et al (2020) | The relationship between fatigue and driving performance | Road environment and driving period might also influence driving performance because of fatigue. Driving fatigue crashes are not only a matter of spending too long behind the wheel, |

| | | |
|---|---|---|
| | | but sometimes fatigue can also be caused by too little sleep and stress or daytime fatigue |
| Lianzhen Wang, & Yulong Pei (2014) | The impact of continuous driving time and rest time on commercial drivers' driving performance and recovery | According to the findings of this study, both driving duration and rest time have substantial effects on driving performance and driver recovery during a certain period of time. These impacts are distinct from one another. |

#### 2.4.1.2 Road condition

Distractions while driving have been found as a significant contributing factor to car accidents (Omid Dehzangi, 2015). Insufficient road conditions can result in more than a bumpy ride. Roads can deteriorate to the point of hazard. Potholes, uneven road surfaces, fractured concrete, exposed rebar, sinkholes, and road cracks are all examples of this. If a driver hit a large pothole, the tire may burst, forcing the vehicle into another lane, and colliding with another vehicle. Uneven road surfaces can cause a driver to lose control of their vehicles, resulting in a crash or rollover accident that may result in serious injury to the driver, passengers, and pedestrians. Besides, if the driver use unfamiliar road also can bring accident if the driver does not focus and give more attention on road.

Simulated driving tests will be conducted on two types of roads, uphill and downhill, as part of this study. The subject will have a different experience and, as a result, the data collected will be different. Because the road surface in Malaysia is not flat and straight, it provides a more realistic picture of what it's like to drive on the road there. A wide range of road conditions is used to ensure that the data gathered is as accurate as possible.

Table 2.4.1.2: Road condition affected driving performance by previous research

| Authors | Title | Findings |
|---|---|---|
| SzeSeen Kee, Shamsul Bahri Mohd Tamrin, YongMeng Goh. (2010) | Driving Fatigue and Performance among Occupational Drivers in Simulated Prolonged Driving | Driving fatigue, which is described as a feeling of drowsiness due to extended driving period, monotonous road condition, adverse climatologically environment or drivers' individual characteristics are direct or contributing factor to road accidents. Subjective feeling of fatigue which combined with negative effects on performance due to time spent on cognitively demanding tasks. |

### 2.4.1.3 Driving Speed

Driving speed is one of the factors that will lead to accident. Driving slowly or driving fast will affect the driving performance. High driving speed is may not a considerable mental workload to drivers even if that speed caused anxiety to driver. Drivers who have somewhat driving experience are familiar with driving situation and speed (Doori Jo, 2014). Malaysia has one of the highest accident rates in the world. One of the contributing elements to the country's high accident rate is Malaysian drivers' bad habits of speeding without considering the risks. (NORZALIHA BINTI JUSOH, 2013)



**Table 2.4.1.3**: Speed affected driving performance by previous journal

| Author | Title | Findings |
|---|---|---|
| Doori Jo, Sukhan Lee, and Yubu Lee (2014) | The Effect of Driving Speed on Driver's Visual Attention | According to the result of this research, the relationship between driving speed and the driver's visual attention should be understood in terms of the maximum field of view that can be balanced against the maximum amount of visual information that a driver can take in/handle against the speed of the vehicle. |
| Norzaliha. (2013) | Driver Attitude Towards Road Safety | Dangerous driving behaviours such as speeding, sleepiness, using a cell phone, and driving aggressively have been identified as |

| | | |
|---|---|---|
| | | important contributors to road accidents in Malaysia. |
| (Jinfei Ma, 2018) | The Relationship Between Drivers' Cognitive Fatigue and Speed Variability During Monotonous Daytime Driving | During the experiment, the average driving speed of all competitors was 72 kilometres per hour, which was similar with the pace of the lead car. |
| Yuping LU, Yu CUI (2015) | Driver's stress physiological characteristics when front vehicle cut in | research on the relationship between stress response and physiological index mainly concentrated on the influence of one's own driving factorson stress response, such as different age, driving age, gender and personality, but speed of to directly influence the severity of stress |



### 2.3.1.4 Body Mass Index (BMI)

The body mass index (BMI) is a measurement of body fat that is dependent on an individual's height in addition to their weight. This measurement is used for both adult men and women.

| BMI | Weight status |
|---|---|
| Below 18.5 | Underweight |
| 18.5-24.9 | Normal weight |
| 25.0-29.9 | Overweight |
| 30.0-34.9 | Obesity class I |
| 35.0-39.9 | Obesity class II |
| Above 40 | Obesity class III |

Figure 2.3.1.4: Weight status based on BMI

**Table 2.3.1.4:** BMI effect Heart Rate based on previous articles

| Author | Title | Finding |
|---|---|---|
| Thalys Sampaio Rodrigue, and Levindo José Garcia Quarto (2018) | Body Mass Index May Influence Heart Rate Variability | Numerous factors may have impact on HRV indices, including sex, insulin resistance, body mass index (BMI), hyperlipidemia, hypertension, ischemic and non-ischemic cardiomyopathy, and smoking status |

## 2.4.2 Dependent variable

### 2.4.2.1 Stress

Stress is defined as an emotional or physical state of stress. It can be triggered by any event or thought that causes you to feel annoyed, furious, or scared about something. Stress is your body's response to a difficult or demanding situation. Stress can be beneficial in short bursts, such as when it assists you in avoiding danger or meeting an important deadline. The ability to drive safely and driver likelihood of getting into an accident are both affected by the amount of stress from driver experiencing when driver are out on the road. In the past, stress-related characteristics were measured using sensors such as a person's heart rate and the conductivity of their skin.



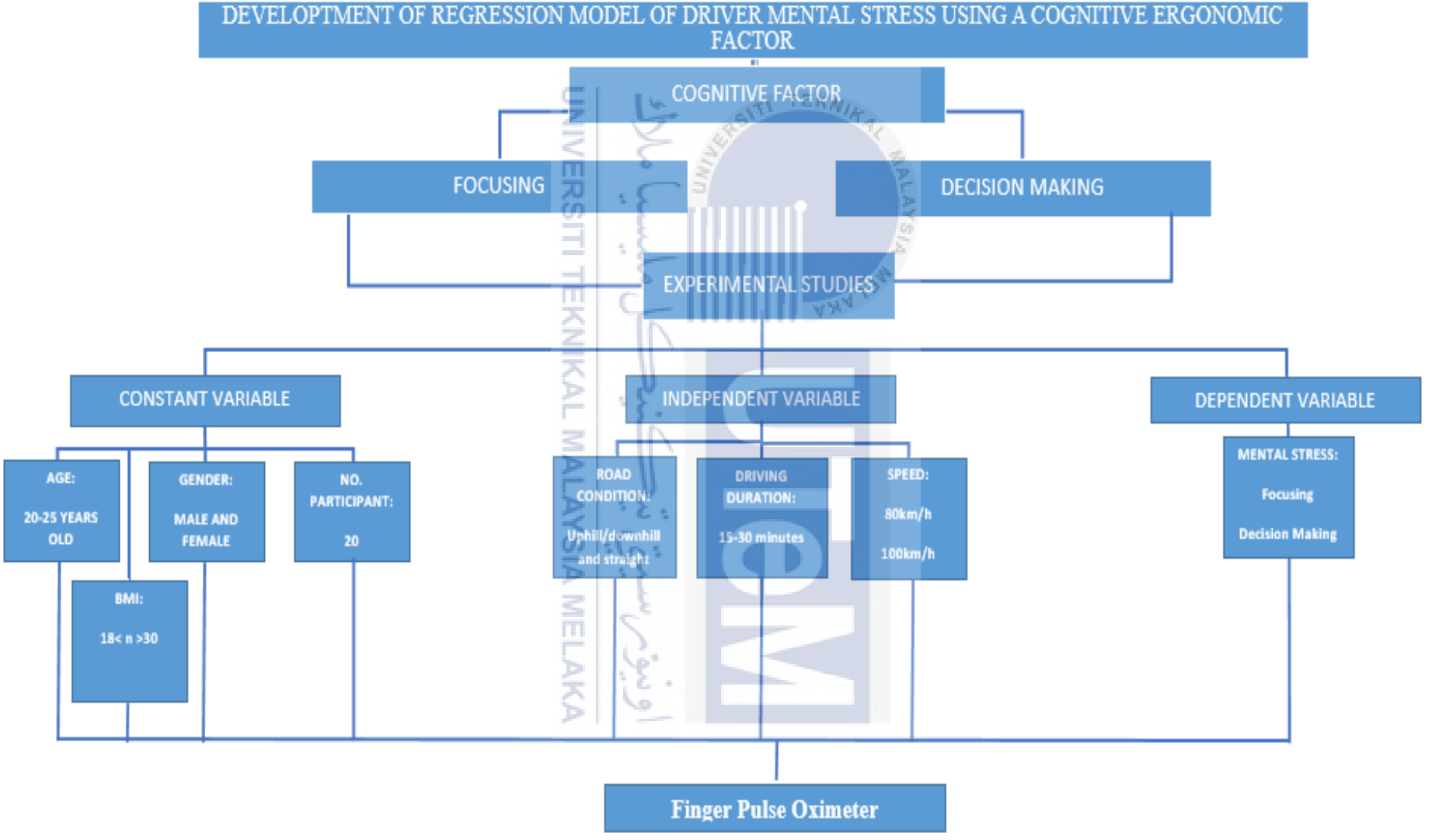
**Table 2.4.2.1**: Mental stress based on previous research

| Authors | Title | Findings |
|---|---|---|
| Munoz-Organero, M., & Corcoba-Magana, V. (2017) | Predicting Upcoming Values of Stress While Driving | Estimated stress levels could be used to adapt the driver's environment to minimize distractions in high cognitive demanding situations and to promote stress-friendly driving behaviors |

# CHAPTER 3

## METHODOLOGY

A methodology is a system that provides detailed explanations of the method and procedure used in this research while the experiment is being carried out. There are various ergonomic techniques that have been developed as a result of this experiment in order to meet the main goal of this project. This also include literature review from previous research need to analyse and understand. Next, run the project with respondent. Every type of road are using the same respondent to investigate which road more give fatigue on driver. Then, the data can be collected from the Pulse Oximeter, to read the value that produce from the heart rate. Next step is filtering the collected data and develop the equation using the Design Expert. The result will give the numerical answer to calculate the heart rate. Last but not least, validate the equation to make sure it can be used for further research and to help reduce the statistic of road crash that affected by human error.



### 3.1 Process Flow

This process flow is the procedure for this experiment. This flow chart gives the details step about this experiment.

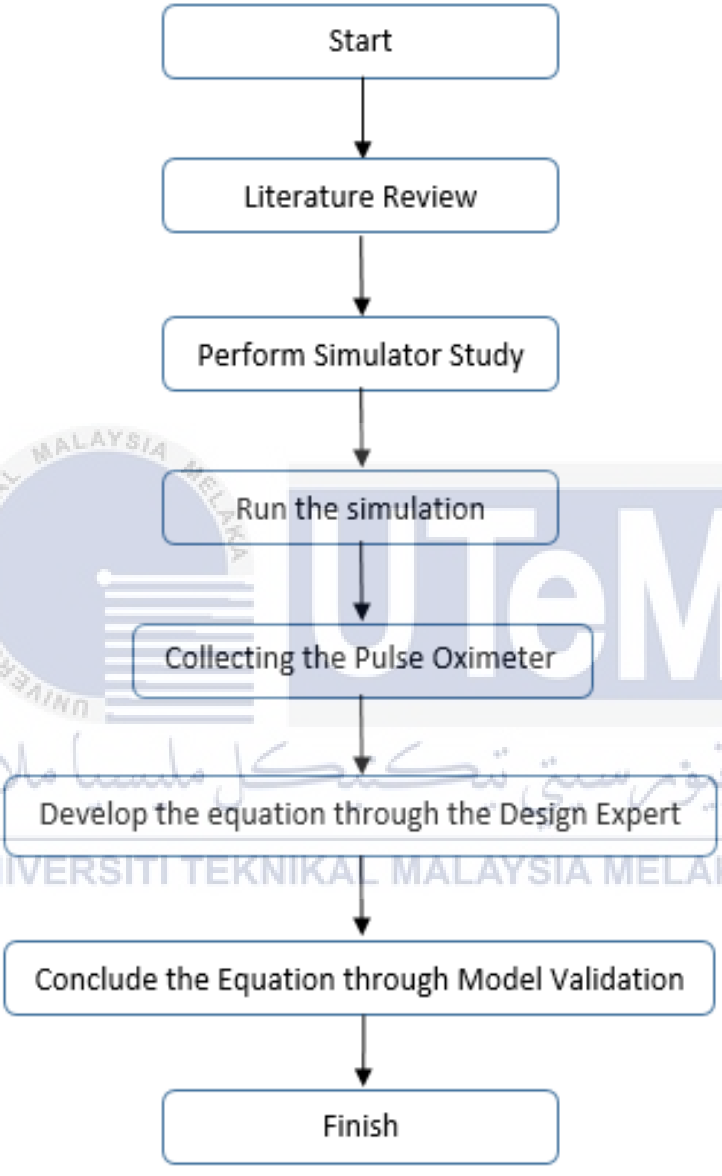





Figure 3.1a: The Experiment Flow Chart

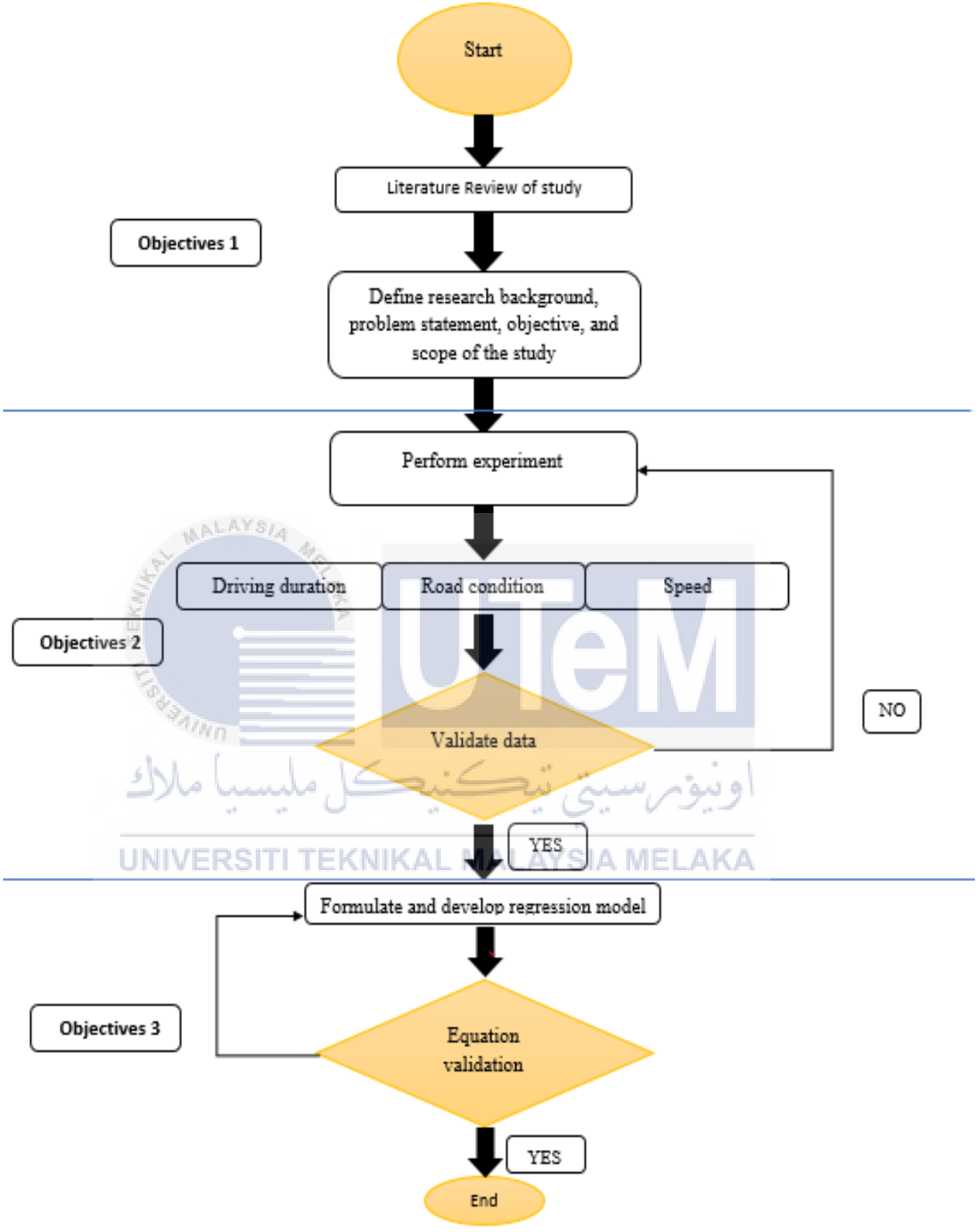



Figure 4.1b: The Flow Chart of the Experiment Based on the Objective

## 3.2 Previous Study (Literature Review)

This research is based on the previous study that conducted by other researcher. The aim for this process is to analyze and understanding the method used for this experiment. This also can gain the knowledge and information to use the proper method and procedure to avoid from the mistake. This process has been referred previous article that related to this research by using Google Scholar, and Mendeley.

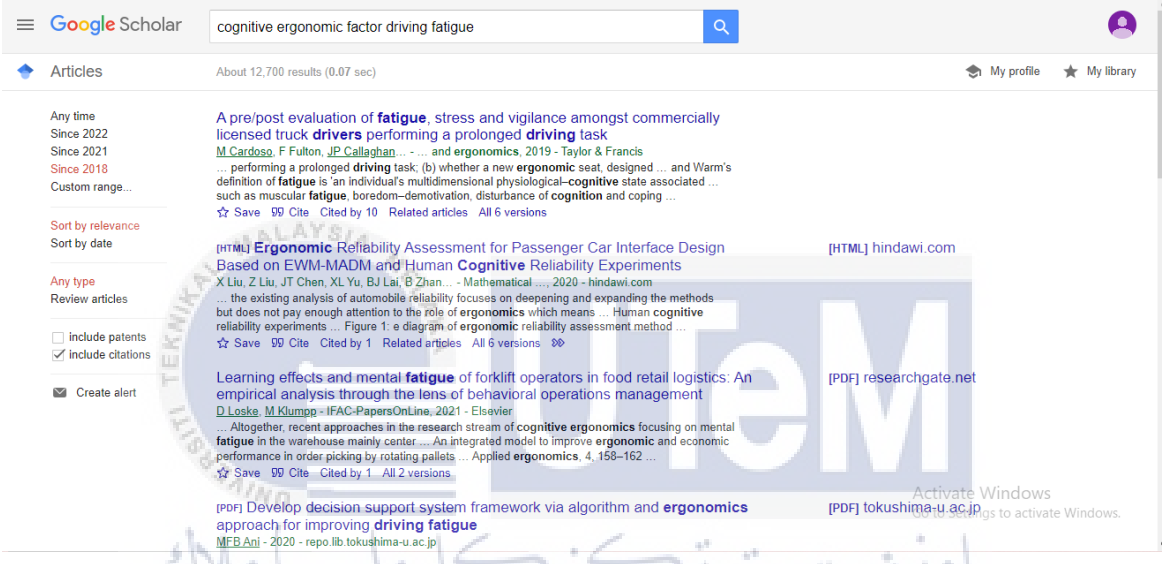



Figure 3.2a: Google scholar website



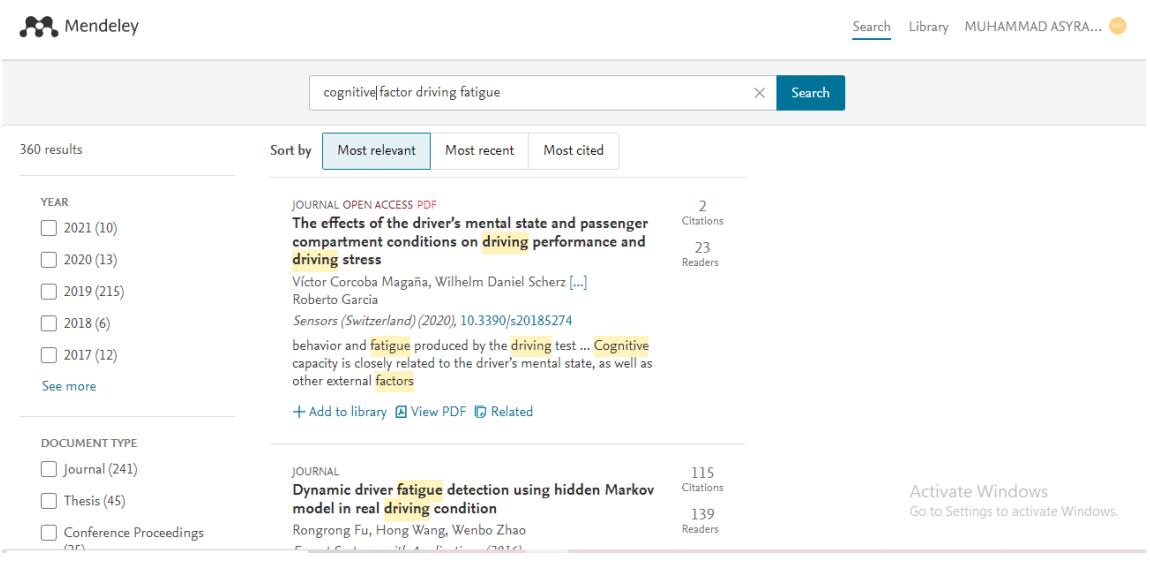



Figure 3.2b: Mendeley website

### 3.3 Blood Pressure Monitor

For this experiment, Blood Pressure Device is the electronic device that are used before run the experiment. A blood pressure is a device that records the Systolic (SYS) and Diastolic (DIA) reading. According to the American Heart Association (AHA), for a normal reading, the SYS pressure number should be between 90 and less than 120, while the DIA pressure number should be between 60 and less than 80.


Figure3.3a: Blood Pressure Monitor Device

**Blood Pressure Stages**

| Blood Pressure Category | Systolic mm Hg (upper #) | | Diastolic mm Hg (lower #) |
|---|---|---|---|
| Low blood pressure (Hypotension) | less than 80 | or | less than 60 |
| Normal | 80-120 | and | 60-80 |
| Prehypertension | 120-139 | or | 80-89 |
| High Blood Pressure (Hypertension Stage 1) | 140-159 | or | 90-99 |
| High Blood Pressure (Hypertension Stage 2) | 160 or higher | or | 100 or higher |
| High Blood Pressure Crisis (Seek Emergency Care) | higher than 180 | or | higher than 110 |

Figure 3.3b: Blood Pressure Stages

### 3.4 Pulse Oximeter

For this experiment, Pulse Oximeter device is the electronic device that are used while run the experiment. The optimal oxygen saturation ranges from 96% to 98%, while the appropriate heart rate is from 50% to 90% (bpm).


Figure 3.4a: Pulse oximeter device

| Observation | Oxygen saturation (SpO2) % | Pulse rate (bpm) | Temp (°C) |
|---|---|---|---|
| Normal readings | 96% or more | 40-100 | 36.5-37.5 |
| Acceptable to continue home monitoring | 95% | 101-109 | 38 |
| Seek advice from your GP | 93-94% | 110-130 | 38.1-39 |
| Need urgent medical advice – call 999 | 92% or less | 131 or more | 39 or more |

Figure 3.4b: Pulse oximeter reading

## 3.5 The Analysis of Output Data

### 3.5.1 The Design Expert

The Design Expert is a software that analyze the collected data and will produce the regression analysis. Regression model is the mathematical model that formulate the data to form an equation. The aim is to calculate the input parameter and the output in numerical value. In this experiment, regression model is used to detect driving fatigue that effected focusing and decision making by observation on selected parameter as the input. The output will give the numerical form that related to achieving objective for this research which is reduce the number of accidents in Malaysia.

### 3.5.2 Analysis of various, data and statistical using Design Expert

ANOVA tests the hypothesis for two or more populations with identical means. Using Examination of Variance, a mathematical model describing the link between psychophysical and biomechanical components in fatigue state is derived from an analysis of the data obtained by the Design Expert software (ANOVA). The ANOVA test is used to assess whether or not the hypothesis is accepted or rejected. The obtained data for ANOVA must have a regularly distributed population with the same variance for each matrix number.

# CHAPTER 4
## RESULT AND DISCUSSION

This chapter discussed the results of several experiments that were carried out during the course of the study. Several subchapters describe each step in the process about result of driver fatigue based on several dependent and independent variable. Based on the objective of this study, this chapter divides the main findings into three main parts:

1) To investigate the driving fatigue based on heart rate with different condition of the road (uphill/downhill and straight road).
2) To analyse the data of the heart rate that cause driving stress with different condition of the road (uphill/ downhill and straight road).
3) To develop and validate the regression models using Design Expert System based on the heart rate with different condition of the road (uphill/downhill and straight road).



The findings were summarized and concluded at the end of this chapter. In addition, this chapter provides advice and solutions for reducing the incidence of road accidents, especially in high-risk locations, among Malaysian drivers.

### 4.1 Literature Review in Determining the Variable

As the primary objective of this part is to comprehend the current situation of driving fatigue among male and female drivers in Malaysia, a number of publications have been thoroughly reviewed. This article was written by previous scholars and is based on their research. Equally important, this phase guarantees that the prior knowledge is accurate and relevant to the experiment. This guarantees that the entire experiment stays on course and does not divert from its intended objective, making the experiment more concentrated and

limiting the external noise that can affect the final results. Several journal were read throughout this period, and a foundational understanding was developed as a result. Initially, the primary concept of fatigue. Fatigue is defined as the condition of being too tired to perform at one's maximum potential. On the basis of this concept, the experiment's variables are chosen**.**

### 4.2 Run the Experiment and Collect Data

#### 4.2.1 The Data Collected

Objective 2 are achieved after all the data of the measurement of heart was recorded in Table 4.2.1. The table shows the data that used in formulating the regression modelling for the heart rate of the subjects. In this study, sixty-eight experimental runs were carried out with five factors were studied as the input parameters; driving speed, driving duration, BMI, gender and road condition. While heart rate as the output response in this experimental runs.

| Run | Driving Speed (km/h) | Driving Duration (min) | BMI (kg/m) | Gender | Road Condition | Heart Rate (bpm) |
|---|---|---|---|---|---|---|
| 1 | 90.00 | 15.00 | 18.50 | Male | Straight | 90 |
| 2 | 90.00 | 22.50 | 27.50 | Male | Uphill/Downhill | 108 |
| 3 | 90.00 | 22.50 | 27.50 | Male | Straight | 100 |
| 4 | 100.00 | 30.00 | 27.50 | Male | Straight | 113 |
| 5 | 80.00 | 22.50 | 30.00 | Male | Uphill/Downhill | 110 |
| 6 | 100.00 | 15.00 | 27.50 | Female | Uphill/Downhill | 114 |
| 7 | 100.00 | 15.00 | 27.50 | Male | Uphill/Downhill | 107 |
| 8 | 80.00 | 30.00 | 27.50 | Male | Uphill/Downhill | 109 |
| 9 | 100.00 | 30.00 | 27.50 | Female | Straight | 120 |
| 10 | 80.00 | 22.50 | 18.50 | Female | Uphill/Downhill | 101 |
| 11 | 80.00 | 15.00 | 27.50 | Male | Uphill/Downhill | 94 |
| 12 | 90.00 | 22.50 | 27.50 | Male | Straight | 102 |
| 13 | 90.00 | 30.00 | 18.50 | Female | Straight | 112 |
| 14 | 100.00 | 30.00 | 27.50 | Male | Uphill/Downhill | 121 |
| 15 | 100.00 | 22.50 | 18.50 | Male | Straight | 103 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | 80.00 | 22.50 | 30.00 | Female | Uphill/Downhill | 115 |
| 17 | 80.00 | 30.00 | 27.50 | Female | Straight | 110 |
| 18 | 90.00 | 22.50 | 27.50 | Female | Straight | 111 |
| 19 | 80.00 | 15.00 | 27.50 | Female | Straight | 95 |
| 20 | 90.00 | 22.50 | 27.50 | Female | Uphill/Downhill | 114 |
| 21 | 90.00 | 22.50 | 27.50 | Female | Straight | 109 |
| 22 | 90.00 | 15.00 | 30.00 | Male | Straight | 102 |
| 23 | 100.00 | 15.00 | 27.50 | Female | Straight | 112 |
| 24 | 80.00 | 22.50 | 18.50 | Female | Straight | 96 |
| 25 | 90.00 | 30.00 | 18.50 | Male | Uphill/Downhill | 110 |
| 26 | 90.00 | 22.50 | 27.50 | Female | Uphill/Downhill | 116 |
| 27 | 100.00 | 22.50 | 18.50 | Male | Uphill/Downhill | 108 |
| 28 | 90.00 | 30.00 | 18.50 | Female | Uphill/Downhill | 117 |
| 29 | 90.00 | 15.00 | 30.00 | Female | Uphill/Downhill | 118 |
| 30 | 80.00 | 30.00 | 27.50 | Female | Uphill/Downhill | 118 |
| 31 | 100.00 | 15.00 | 27.50 | Male | Straight | 101 |
| 32 | 90.00 | 22.50 | 27.50 | Male | Straight | 103 |
| 33 | 100.00 | 22.50 | 30.00 | Female | Straight | 122 |
| 34 | 100.00 | 22.50 | 18.50 | Female | Straight | 107 |
| 35 | 90.00 | 22.50 | 27.50 | Male | Uphill/Downhill | 109 |
| 36 | 100.00 | 22.50 | 30.00 | Male | Uphill/Downhill | 123 |
| 37 | 100.00 | 22.50 | 30.00 | Female | Uphill/Downhill | 127 |
| 38 | 80.00 | 30.00 | 27.50 | Male | Straight | 105 |
| 39 | 90.00 | 15.00 | 18.50 | Female | Uphill/Downhill | 104 |
| 40 | 90.00 | 15.00 | 30.00 | Male | Uphill/Downhill | 110 |
| 41 | 100.00 | 22.50 | 30.00 | Male | Straight | 118 |
| 42 | 80.00 | 15.00 | 27.50 | Male | Straight | 92 |
| 43 | 90.00 | 22.50 | 27.50 | Male | Uphill/Downhill | 111 |
| 44 | 90.00 | 22.50 | 27.50 | Male | Uphill/Downhill | 112 |
| 45 | 80.00 | 22.50 | 18.50 | Male | Uphill/Downhill | 95 |
| 46 | 80.00 | 15.00 | 27.50 | Female | Uphill/Downhill | 103 |
| 47 | 90.00 | 15.00 | 18.50 | Female | Straight | 97 |
| 48 | 100.00 | 22.50 | 18.50 | Female | Uphill/Downhill | 116 |
| 49 | 80.00 | 22.50 | 30.00 | Female | Straight | 111 |
| 50 | 90.00 | 22.50 | 27.50 | Female | Uphill/Downhill | 118 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 51 | 90.00 | 22.50 | 27.50 | Female | Straight | 110 |
| 52 | 90.00 | 30.00 | 30.00 | Female | Uphill/Downhill | 126 |
| 53 | 90.00 | 30.00 | 30.00 | Male | Uphill/Downhill | 120 |
| 54 | 90.00 | 22.50 | 27.50 | Male | Straight | 107 |
| 55 | 100.00 | 30.00 | 27.50 | Female | Uphill/Downhill | 125 |
| 56 | 90.00 | 22.50 | 27.50 | Male | Uphill/Downhill | 109 |
| 57 | 90.00 | 30.00 | 30.00 | Female | Straight | 121 |
| 58 | 80.00 | 22.50 | 18.50 | Male | Straight | 93 |
| 59 | 90.00 | 15.00 | 18.50 | Male | Uphill/Downhill | 97 |
| 60 | 90.00 | 30.00 | 18.50 | Male | Straight | 105 |
| 61 | 90.00 | 30.00 | 30.00 | Male | Straight | 116 |
| 62 | 90.00 | 22.50 | 27.50 | Female | Straight | 106 |
| 63 | 80.00 | 22.50 | 30.00 | Male | Straight | 102 |
| 64 | 90.00 | 22.50 | 27.50 | Female | Uphill/Downhill | 117 |
| 65 | 90.00 | 22.50 | 27.50 | Male | Straight | 105 |
| 66 | 90.00 | 15.00 | 30.00 | Female | Straight | 105 |
| 67 | 90.00 | 22.50 | 27.50 | Female | Uphill/Downhill | 119 |
| 68 | 90.00 | 22.50 | 27.50 | Female | Straight | 108 |

Table 4.2.1: Experimental runs and results of HR, bpm



## 4.3 Determination of Appropriate Polynomial Equation to Represent Regression Model

By using Design Expert 8.0.6 software, the determination of appropriate polynomial equations to represent the regression model for the Heart Rate was done by carrying out sequential model sum of squares (SMSS) and lack of fit test as shown in Table 4.3(a) and Table 4.3(b) respectively. Both analyses suggested the relationship between factors and output response can be model using a Quadratic equation.

| Source | Sum of square | DF | Mean square | F value | Prob>F | |
|---|---|---|---|---|---|---|
| Mean | 8.118E+005 | 1 | 8.118E+005 | | | |
| Linear | 4770.81 | 5 | 954.16 | 151.52 | < 0.0001 | |
| 2FI | 26.05 | 10 | 2.61 | 0.37 | 0.9534 | |
| Quadratic | 179.89 | 3 | 59.96 | 15.93 | < 0.0001 | Suggested |
| Cubic | 60.78 | 18 | 3.38 | 0.85 | 0.6384 | Aliased |
| Residual | 123.71 | 31 | 3.99 | | | |
| Total | 8.170E+005 | 68 | 12014.68 | | | |

Table 4.3(a): Sequential Model Sum of Squares

| Source | Sum of Squares | DF | Mean Square | F Value | Prob > F | |
|---|---|---|---|---|---|---|
| Linear | 2.51 | 0.9244 | 0.9183 | 0.9090 | 469.70 | |
| 2FI | 2.65 | 0.9294 | 0.9090 | 0.8762 | 639.09 | |
| Quadratic | 1.94 | 0.9643 | 0.9511 | 0.9318 | 351.97 | Suggested |
| Cubic | 2.00 | 0.9760 | 0.9482 | 0.8708 | 666.91 | Aliased |
| Linear | 2.51 | 0.9244 | 0.9183 | 0.9090 | 469.70 | |

Table 4.3(b): Lack of Fit Tests



### 4.3.1 ANOVA for Response Surface Quadratic Model

Table 6 represents the ANOVA analysis of the linear model. The Model F-value of 73.43 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. The accuracy of this model is also supported by the lack of fit analysis as the “Lack of Fit F-value” of 0.8 implies the lack of fit is not significant relative to the pure error.

| Source | Sum of Square | Degree of Freedom | Mean Square | F-Value | P-Value | |
|---|---|---|---|---|---|---|
| **Model** | 4976.74 | 18 | 276.49 | 73.43 | <0.0001 | significant |
| **A** | 978.38 | 1 | 978.38 | 256.85 | <0.0001 | |
| **B** | 1226.65 | 1 | 1226.65 | 325.79 | <0.0001 | |
| **C** | 1188.28 | 1 | 1188.28 | 315.60 | <0.0001 | |
| **D** | 564.07 | 1 | 564.07 | 150.03 | <0.0001 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **E** | 546.07 | 1 | 546.07 | 145.03 | <0.0001 | |
| **$A^2$** | 6.06 | 1 | 6.06 | 1.61 | 0.2104 | |
| **$B^2$** | 2.87 | 1 | 2.87 | 0.76 | 0.3872 | |
| **$C^2$** | 175.26 | 1 | 175.26 | 46.55 | <0.0001 | |
| **AB** | 10.56 | 1 | 10.56 | 2.81 | 0.1003 | |
| **AC** | 0.043 | 1 | 0.043 | 0.012 | 0.9149 | |
| **AD** | 0.000 | 1 | 0.000 | 0.000 | 1.000 | |
| **AE** | 0.50 | 1 | 0.50 | 0.13 | 0.7171 | |
| **BC** | 3.71 | 1 | 3.71 | 0.99 | 0.3258 | |
| **BD** | 0.78 | 1 | 0.78 | 0.21 | 0.6507 | |
| **BE** | 2.53 | 1 | 2.53 | 0.67 | 0.4162 | |
| **CD** | 0.083 | 1 | 0.083 | 0.022 | 0.8825 | |
| **CE** | 1.96 | 1 | 1.96 | 0.52 | 0.4743 | |
| **DE** | 5.88 | 1 | 5.88 | 1.56 | 0.2173 | |
| **Residual** | 184.49 | 49 | 3.77 | | | |
| **Lack of Fit** | 114.89 | 33 | 3.48 | 0.80 | 0.7149 | not significant |
| **Pure Error** | 69.60 | 16 | 4.35 | | | |
| **Cor Total** | 5161.24 | 67 | | | | |

Table 4.3.1: Analysis of variance table



The value of p-value less than 0.1 indicate model terms are significant. In this case, driving speed, driving duration, BMI, gender and type of road are significant influencing factors of the resultant heart rate. In all parameter, BMI is more significant than other parameter.

### 4.3.2 Behaviour of HR in Response to Parameter

#### I. Driving Speed Graph

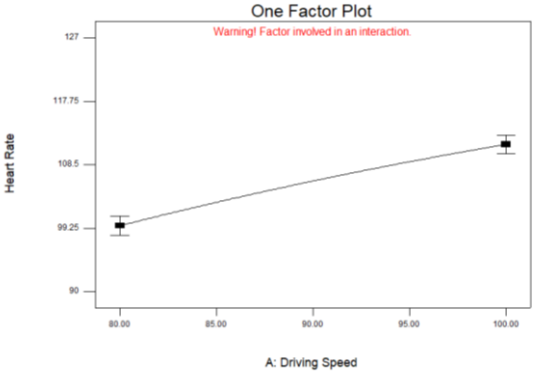



Figure 4.3.2a: Behaviour of HR in response to variation in driving speed

Figure 4.3.2(a) shows the driver heart rate increase when driving speed increase from 80 km/h to 100km/h. Due to this graph, driving at high speed need more focus and alert with any possibility while driving. Height alertness while drives can make stress drive (Gulian, E et al, 1989), that can makes heart rate increased.



#### II. Driving Duration Graph

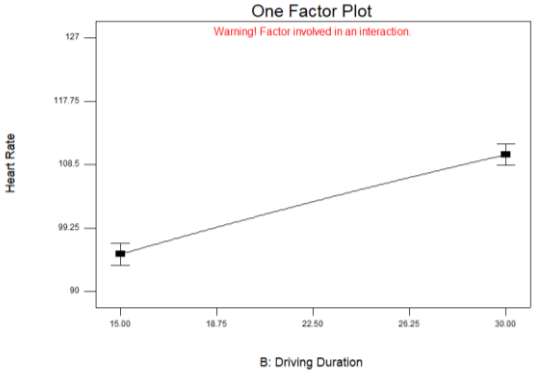



Figure 4.3.2b: Behaviour of HR in response to variation in driving duration

Based on figure 4.3.2(b), drive for long duration makes heart rate increase. Long drives are stressful. The effects of stress on respiration resemble shallow breathing.

Breathing shallowly raises blood pressure and heart rate. Both longer inhale and exhale breaths slow the heart rate and reduce blood pressure (Ku, J.-L. et al, 2017) driving for long hours elicits a stress response over an extended period of time.( Antoun, M. et al, 2017)

### III. **Body Mass Index (BMI) Graph**

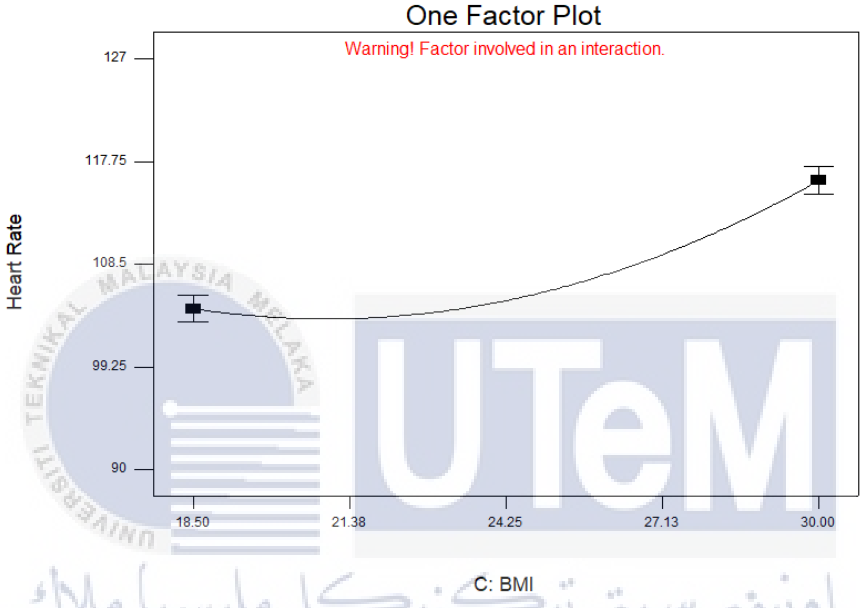



Figure 4.3.2c: Behaviour of HR in response to variation in BMI



Figure 4.3.2(c) shows obese BMI have higher heart rate than people with normal BMI. This related with previous research that Overweight and obese people have a higher metabolic rate and a lower body surface-to-weight ratio. Their heart rate is higher than normal weight person. (Yazdanirad, et al,2015)

## IV. Gender Graph

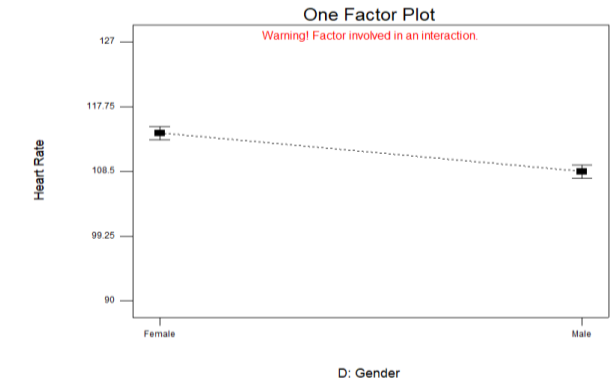



Figure 4.3.2d: Behaviour of HR in response to variation in gender

Figure 4.3.2(d) shows women have higher heart rate than man when drive. Women have a completely different hormonal system, which as a result causes them to react more emotionally and become more exhausted on an emotional level. The average heart rate for an adult man is 70 to 72 beats per minute, while the average heart rate for an adult woman is 78 to 82. This difference is because women hearts are smaller than men. (Prabhavathi, K. et al, 2014)



## V. Type of Road Graph

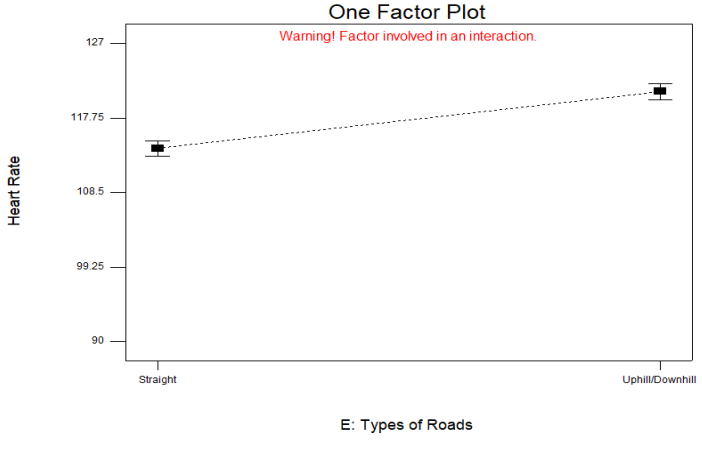



Figure 4.3.2e: Behaviour of HR in response to variation in type of road

Based figure 4.3.2(e), the heart rate increase when the driver drive with different road conditions. The result shows that the straight road produced the lowest heart rate. While the high heart rate happened when driving through uphill/downhills road which is 111.94 bpm of the female subjects. This happened due to the subjects cautious when turns at uphill/downhills road condition. (Deng, T. et al, 2019)

### 4.3.3 The Equation in Actual Terms

Based on surface response modeling the Quadratic polynomial equation developed to relate the input parameters to the heart rate is shown in Table 4.4.3. The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. This output has made the objective 3 achievable which is to develop and validate the regression models using Expert System based on the heart rate with different condition of the road.

#### 4.3.3.1 Final Equation in Terms of Coded Factors:

| | |
|---|---|
| **Heart Rate** | 104.75+5.89 * A+6.59 * B+6.09 * C-3.10 * D+3.05 * E-0.60 * $A^2$-0.41 * $B^2$+5.04 * $C^2$-0.81 * A * B-0.048 * A * C+0.000 * A * D+0.13 * A * E-0.45 * B * C+0.16 * B * D-0.28 * B * E+0.047 * C * D+0.23 * C * E-0.29 * D * E |

Table 4.3.3.1: Final Equation in Terms of Coded Factors

#### 4.3.3.2 Final Equation in Terms of Actual Factors:

| Type of Gender | Type of Roads | Heart Rate |
|---|---|---|
| Female | Straight | 15.82482 + 1.92054 × Driving Speed + 2.45271 × Driving Duration - 6.07148 × BMI - 6.00000E -003 × Driving $Speed^2$ - 7.33333E - 003 × Driving $Duration^2$ + 0.15243 × $BMI^2$ - 0.010833× Driving |

| | | |
|---|---|---|
| | | Speed × Driving Duration - 8.42991E - 004 × Driving Speed × BMI - 0.010389 × Driving Duration × BMI |
| Male | Straight | 8.87291 + 1.92054 × Driving Speed + 2.49438 × Driving Duration - 6.05505 × BMI - 6.00000E - 003 × Driving Speed$^2$ - 7.33333E - 003 × Driving Duration$^2$ + 0.15243 × BMI$^2$ - 0.010833 × Driving Speed × Driving Duration - 8.42991E - 004 × Driving Speed × BMI - 0.010389 × Driving Duration × BMI |
| Female | Up/down hills | 20.01715 + 1.94554 × Driving Speed + 2.37771 × Driving Duration - 5.99174 × BMI - 6.00000E - 003 × Driving Speed$^2$ - 7.33333E - 003 × Driving Duration$^2$ + 0.15243 × BMI$^2$ - 0.010833 × Driving Speed × Driving Duration - 8.42991E-004 × Driving Speed × BMI - 0.010389 × Driving Duration × BMI |
| Male | Up/down hills | 11.88876 + 1.94554 × Driving Speed + 2.41938 × Driving Duration - 5.97531 × BMI - 6.00000E - 003 × Driving Speed$^2$ - 7.33333E - 003 × Driving Duration$^2$ + 0.15243 × BMI$^2$ - 0.010833 × Driving Speed × Driving Duration - 8.42991E - 004 × Driving Speed × BMI-0.010389 × Driving Duration × BMI |

Table 4.3.3.2: Final Equation in Terms of Actual Factors

## 4.4 Regression Model Validation

The investigation continued with the validation of the regression model. This validation is undertaken to test whether the created response surface model can accurately predict heart rate activity. Using the point prediction function of the Design Expert software, three sets of process parameters were chosen for validation runs. The software calculates the predicted heart rate values together with their 90% prediction interval values. Besides, the residual error was calculated to determine the accuracy of the model.

| Input Parameter | | | | | Prediction (bpm) | 90% PI low (bpm) | 90% PI Hi (bpm) | Actual (bpm) | Error (%) |
|---|---|---|---|---|---|---|---|---|---|
| Driving Speed (km/h) | Driving Duration (min) | BMI (kg/m) | Gender | Type Of Road | | | | | |
| 80.00 | 30.00 | 27.50 | Female | straight | 109.84 | 105.37 | 114.49 | 110.00 | 0.16 |
| 100.00 | 22.50 | 18.50 | Female | Uphill/ downhills | 115.42 | 110.79 | 120.05 | 116.00 | 0.58 |
| 80.00 | 30.00 | 27.50 | Male | Straight | 104.59 | 100.12 | 109.24 | 105.00 | 0.41 |

## 4.5 Summary of the Result

The result obtained through the design expert software. Method that has been used in the software is Box-Behnken Design. Based on objective 1, the parameter has been found to choose the best parameter to run the experiment. The data from the Design Expert has been collected to achieve the objective 2. From the design expert data, the experiment has been run to validate the data. The validation is carried out to determine if the developed response surface model can predict the heart rate behavior was successfully performed to achieve objective 3.

# CHAPTER 5
# CONCLUSION AND SUGGESTION

## 5.1 Introduction

Final chapter of this thesis present a complete conclusion of the research findings. Explanation about the results was made on research objective. Furthermore, the limitation of the study was also stated and the end of this chapter, the recommendation was given for the better in future research on this topic.

## 5.2 Research Summary



The summarization of this study was made by looking at the achievement of the research objective through the analysis of research findings. The methodology in this research is a finding the suitable parameter based on previous research related to driving fatigue. Besides, the respondent finding are based on the parameter.

First objective is to investigate the driving fatigue based on heart rate with different condition of the road (uphill/downhill and straight road). The second objective is to analyses the data of the heart rate that cause driving stress with different condition of the road (uphill/ downhill and straight road). For the last objective is to develop and validate the regression models using Design Expert System based on the heart rate with different condition of the road (uphill/downhill and straight road).

### 5.2.1 1st Objective achievement

Based on the first objective is to investigate the driving fatigue based on heart rate with different condition of the road (uphill/downhill and straight road). The parameter are selected after study several previous research. The five parameter which is driving duration, driving speed, BMI, gender and type of road is suitable to use in this experiment.

### 5.2.2 2nd Objective achievement

Based on second objective is to analyses the data of the heart rate that cause driving stress with different condition of the road (uphill/ downhill and straight road), By using Design Expert 8.0.6 software, the determination of appropriate polynomial equations to represent the regression model for the Heart Rate was done by carrying out sequential model sum of squares (SMSS) and lack of fit test. Both analyses suggested the relationship between factors and output response can be model using a Quadratic equation. The most significant parameter is BMI. Then the objective two is achieved.



### 5.2.3 3rd Objective achievement

Based on third objective is to develop and validate the regression models using Design Expert System based on the heart rate with different condition of the road (uphill/downhill and straight road). The validation is carried out to determine if the developed response surface model can predict the heart rate behavior was successfully performed. Then, the third objective is achieved.

## 5.3 Research Limitation

During the process of completing this research, there was a little limitation that has been faced which are;

I. Finding the respondent based on the parameter.
II. Finding suitable time to run based on respondent schedule and weather must be on sunny day.

## 5.4 Recommendations for Future Study

Continues process in the future enables an individual to gain more knowledge in a certain field as a learning process. Therefore, the recommendation for future research should be carried out to validate the findings which are:

I. Use EEG device to get more accurate data to detect fatigue driving
II. Finding more suitable parameter based on previous research and statistics road accident by Ministry of Transport Malaysia (MOT)



## 5.5 Summary

In conclusion, it is possible to assume that the researcher was effective in carrying out this investigation and that the research study was successful in achieving its goals. The intended respondents are not offering cooperation and are not completely participating, but the data was effectively gathered and analyses despite the fact that there are certain obstacles involved in the process of acquiring the data.

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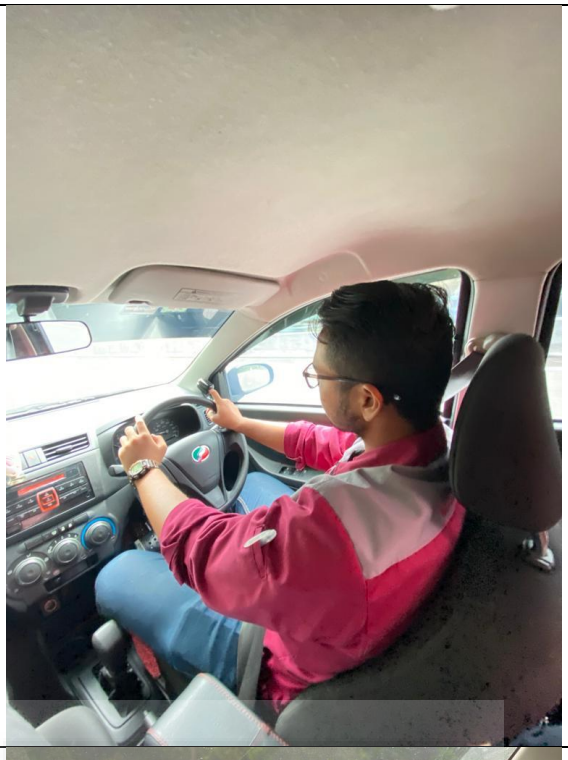
# APPENDIX 1

| PROJECT PLANNING PSM 1<br>*~Duration: 4 October 2021 to 12 January 2022~* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *List major activities involved in the proposed project. Indicate duration of each activity to the related week(s).* | | | | | | | | | | | | | | | |
| *Project Activities* | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 |
| Project Title Selection | | | | | | | | | | | | | | | |
| Determination of problem statement, objective, and scope | | | | | | | | | | | | | | | |
| Discussion on introduction | | | | | | | | | | | | | | | |
| Discussion on literature review | | | | | | | | | | | | | | | |
| Research of articles and journals | | | | | | | | | | | | | | | |
| Discussion on methodology | | | | | | | | | | | | | | | |
| Prepare draft report | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | |
| Submission of PSM 1 report | | | | | | | | | | | | | | | |

| TASK / WEEK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General briefing | | | | | | | | | | | | | | |
| Find journal and article according to the topic | | | | | | | | | | | | | | |
| Visit UTeM to distribute the questionnaire | | | | | | | | | | | | | | |
| Observation and collect data | | | | | | | | | | | | | | |
| Chapter 4: Result and discussion | | | | | | | | | | | | | | |
| Chapter 5: Conclusion | | | | | | | | | | | | | | |
| Submit technical report PSM 2 to Supervisor | | | | | | | | | | | | | | |
| Submission of Logbook to Supervisor | | | | | | | | | | | | | | |
| Preparation Presentation | | | | | | | | | | | | | | |
| Presentation PSM 2: Video Presentation | | | | | | | | | | | | | | |
| Final Report Checked by Supervisor | | | | | | | | | | | | | | |
| Submission of PSM 2 Report (Supervisor & Examiner) | | | | | | | | | | | | | | |

# APPENDIX 2

| Procedure | Example |
|---|---|
| • Some of the respondent to run the experiment and collect the data |   |
| • Respondent check the blood pressure before driving the car |  |

| | |
|---|---|
| • The respondent drives the car with the driving speed and driving duration based on the data from Design Expert |  |
| • The driving speed must be on 80km/h to 100km/h |  |

| | |
|---|---|
| • The heart rate data is collect after the respondent drives the car |  |