A DEVELOPMENT OF DRIVING MODEL AND DRIVING BEHAVIOR ANALYSIS BY USING DRIVING SIMULATOR

CHANOKNUN HLOWNGRAM

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ADVISOR

ASSISTANT PROFESSOR DR. MANOP PHANKOKKRUAD

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENT FOR THE DEGREE OF

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TITLE: A DEVELOPMENT OF DRIVING MODEL AND DRIVING BEHAVIOR ANALYSIS BY USING DRIVING SIMULATOR

BY

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บทคัดย่อ

ปริญญานิพนธ์นี้มีวัตถุประสงค์เพื่อพัฒนาแบบจำลองการขับรถเพื่อการตรวจสอบและวิเคราะห์พฤติกรรมการขับรถ โดยใช้แบบจำลองการขับรถ OpenDS ในการทดสอบ รวมถึงรวบรวมข้อมูลระหว่างการขับรถ โดยใช้ข้อมูลพฤติกรรมการขับรถที่แตกต่างกันของผู้ร่วมทดสอบจำนวน 30 ชุด จากผู้ร่วมการทดสอบ 10 คน โดยแบ่งการทดลองการขับขี่ออกเป็น 3 เส้นทาง ในการวิเคราะห์ข้อมูลพฤติกรรมการขับรถได้ใช้สมการและโปรแกรมวิเคราะห์เชิงของสถิติ โดยจัดพฤติกรรมการขับรถของผู้ร่วมทดสอบออกเป็นกลุ่ม ผลลัพธ์ที่ได้จากแบบจำลองการขับรถจะอยู่ในรูปของกราฟแสดงความสัมพันธ์และกลุ่มซึ่งแสดงระดับของผู้ขับขี่

Project Title	A Development of Driving Model and Driving Behavior Analysis by Using Driving Simulator
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Degree	Bachelor of Science
Program	Information Technology
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Advisor	Assistant Professor Dr. Manop Phankokkruad

ABSTRACT

This study aimed to develop the driving model for validate and analyze driving behavior by using OpenDS driving simulator for driving experiment and data collection. The safety driving measures in this model was defined by others research for the first safety criterion. In this experiment we use 10 participants to collect diverse driving data from different directions in three level to input into driving model. In driving model will analyze driving behavior by using equation and statistics calculation to find the new safety measurements suitable for each level and to classify driver into group following their own driving behavior by grading driver into A, B, C, D or F. The result from driving model was presented in graph of relation and the grade of driver.

ACKNOWLEDGEMENT

I am extremely thankful to Assistant Professor Dr. Manop Phankokkruad, for provide me infrastructural facilities to work in and their expert guidance, without with this work would not have been possible. I would like to thanks the family who assisted me with project. My thanks and appreciations also go to my classmates in developing the project and to the people who have willingly helped me out with their abilities.

Chanoknun Hlowngram

Patitta Klinhom

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Technology is growing up fast and not likely to stop. In Thailand everybody seriously concerned about security in life especially transportation security because many people are killed and injured in road accidents every year. Although there have been campaigns or trainings about driving safety, accident prevention and traffic rules from many organizations to improve driver knowledge and road safety. Even though the number of road accidents are increasing all the time because the driver do not always respect all the traffic rules. For all these reasons many organization begin using technology to improve security in transportation on the road. For example, public van was already using Vehicle Tracking System including GPS (Global position System) and RFID (Radio Frequency Identification) to management many functions such as public van tracking ,used for identify the current location, and speed control , in case of the driver using over speed according to standard. The system will warning the operators and the driver for intended to prevent the accident. However, most accidents occur by driver bad behavior and bad driving manner.

From the fact about this problem motivated us to develop the driving model and driving behavior analysis. This model intended to study examine and analyze the driving behavior for classify driver into five groups (Excellent, Good, Satisfactory, Unsatisfactory, and Bad). The information from this model may be used for build the system that can improving driving skills, driving behavior and driving manner to reduce road accidents rate.

This work studying about driving basic, driving principles and driving behavior for analysis driving behavior and present the outcomes in graph and level of driver.

1.2 Objectives

1. To study driving behavior for develop driving model.
2. To analyze driving behavior accuracy and precision.
3. To develop driving model for evaluate the accuracy of driver.

4. To validate driving behavior for indicate level of driver.

1.3 Scope of Operations

This project focuses on the analysis of driving behavior within this scope of operation as follows

1. Driving data collected by using driving simulator.
2. Design driving behavior model which provides accurate analysis of driving behavior.
3. Using R programing in term of statistics.
4. Develop driving behavior model which provides accurate analysis of driving behavior.
5. The driving behavior model can indicate good or misbehavior.
6. The driving behavior model can create accuracy graph or chart of relations between parameters and parameters.
7. The results of driving model will present in graph of relation and level of driver.

1.4 Procedures and Operations

In this project we began with planning the procedures and operations as follows

1. Define the scope of work.
2. Feasibility study by analysis of the possibility to complete project successfully.
3. Research literature review.
4. Study driving behavior.
5. Study R language.
6. Develop algorithm within the scope of work.
7. Evaluate the result.

1.5 Expected Outcomes

1. To develop the driving behavior model in effectively way.
2. Result of model able to use as the information that can improving driving skills.
3. The results of a driving model can use to accurately detect misbehavior of driver.

CHAPTER 2

BACKGROUND

This chapter presents article related information and review of the research about driving behavior for development of driving model and analysis.

2.1 Driving Basics

Before the driver begin to drive, it's essential that driver need to know the general basic knowledge of driving and what they have to do every time they are driving a car. Be it how to prepare their mental and physical, how to check their vehicle or understand driving rules and regulations.

2.1.1 Driver

Physical condition is one of the most important things that make a car accident occurred. The driver should avoid driving when their emotional or physical heaths are not ready such as drowsiness or hangover because that impair your ability to make decision and your driving performance. So every time before begin to drive, the driver should be aware about their current mental and physical health.

2.1.2 Vehicle

The vehicle have to check before start because the one of car accident caused of the vehicle not be ready. BE-WAGON is a principle for check the vehicle before start. It was set up to make the driver easy to check their vehicle.

1. Check a brake (B) which are level and condition of brake fluid, level and condition of oil clutch, brake fluid and oil clutch leak, and handbrake.
2. Check electricity system € which are the acid level in the battery, battery, total light vehicle, horn, and windshield wiper.
3. Check water system (W) which are the water level in the radiator and reserve tank, the radiator hose, and belt.
4. Check an air (A) which are the depth of the tread, tire wear, tire pressure, and date tire production.

5. Check to gasoline system (G) which are the leak of fuel at various points, air filter condition, and black exhaust smoke.
6. Check the oils (O) which are oil level, power steering fluid level, automatic transmission fluid level, and oil leak.
7. Check a noise (N) which are unusual sounds, weather engine mounting, and muffler condition.

2.1.2.1 Steering Wheel

The rotation of steering wheel is very important because the steering wheel use for control the direction of vehicle. Somebody hold the steering wheel with one hand. When the tire exploded while running at high speed, the car will be out of control that may make the driver and passenger fall in dangerous situation. For safety, the driver should to hold the steering wheel with two hands, hold it firmly and natural, don't put the arm on the door while driving, and don't hold a steering wheel with one hand while driving.

2.1.2.2 Type of rotation the steering wheel

1. Hand Over Hand: For vehicles without power steering and no air bag. The most drivers use hand over hand because easy to train.
2. Fixed Hand: For maneuver to solve the immediate problems.
3. Pull and Push: For vehicles that use power steering and have an air bag.

Pull and push the steering wheel is the best to control the car. By the rotation, put your hands on the steering wheel. Don't leave hand from the steering wheel. Pull and push balance with left and right hand. The advantages are ready to all emergencies because their hands on the steering wheel, to turn better and smoother, and hands not interrupt when the air bag ready.

2.1.2.3 Stopping Distances

$$\text{Stopping Distances} = \text{Thinking distance} + \text{Braking distance} \tag{2.1}$$

Where "Thinking distance" is the foot move from accelerator to touch the brakes, "Breaking distance" is the starting brakes until the vehicle stops, and "Stopping distances" depending on vehicle speed, load, braking performance, tires, road conditions, and the response to the brakes.

2.1.3 Driving Behavior

The driver respect the rules are the basic for being a good driver. So, driver have to avoid driving behavior that affect to accident, overtaking another car in a no overtaking area, driving very close to another car, racing on highway, driving over speed limit, not use the light before stopping or turning, low-speed driving in the right lane, not control emotions while driving, and failing to comply with traffic signs. The driver could be driving situations, be courteous of driving to driver and another person.

2.2 Driving Principles

Although driving is complex, there are many ways to make the driving easier. One way to simplify it is to learn how to find and use all metrics, control, and other devices on the car. Another way is to follow the simple step by step process for operating a vehicle.

The driver is required to prepare for the forthcoming all situations. Start to wipe clean on the windows, lock all of the doors, adjust the seat to the right, adjust the wing mirror and the rear view mirror, don't forget to wear a seat belt, pull the handbrake, into gear N is neutral or P is parking, clutch pedal, and cranked engine, check gauges and lights again, and ready to start a trip.

After the car has started, the drive will become more complicated. The driver must be able to move seamlessly through the car traffic. To do so, they must learn how to live on land, change lanes, make various turns, back up, and park.

2.2.1 Driving ahead: Adjustable a steering wheel, it is necessary to follow the path of any channel.

2.2.2 Braking control: To bring the car to a stop – and often slow down –the driver must apply the brakes. Coming to the point that people often use steady pressure to the brake pedals. They had a slightly reduced pressure for a fraction of a second to stop with that. Then the driver reapplies pressure to stop the car and to make it stop. Learn when to start a brake that takes time and practice.

2.2.3 Right turns: The driver should begin their turn to enter the intersection. They should turn the car into the lane closest to the traffic in that direction.

2.2.4 Left turns: Turn left and drove a cross into the path of traffic coming from the right and shift traffic to the right. Because turn left is less dangerous than turn right. Also, turn left often have to change the sharper the right people.

2.2.5 Lane changes: Before changing lanes, drivers should check the rearview mirror for traffic approaching. Drivers should make sure that the car is not in the blind spot by glancing over their shoulder. Directional signs should be used to indicate the change.

All driving behavior must be safety to main topic. Safe Driving is the most important goal for the drive each time. To prepare both the car and driver is very important, if you have to check the availability of your car before you leave, it reduced accidents by up to 30%. For the driver's own car, if you have to prepare travel plans and enough rest, it reduced accidents by up to 40 percent. If you hear or smell something that wrong, parking quickly, shutdown, and check out what's wrong, don't continue driving. Avoid accelerating sharply or sudden braking unnecessarily, and strictly follow traffic rules.

2.3 Traffic Rules

Traffic rules do serve a purpose, they help to protect life and property. Most often the work of deception and enforcement of traffic rules is the responsibility of state and local governments. These are the rules that apply to specific conditions. Because these conditions are not the same everywhere, the rules vary from place to place. Example, most states have regulations permitting left turns on a red light. But some people like to open only at intersections marked with a special sign. Other permits are open to all except those who separate rule out a signal that turns on red [1].

2.3.1 Light and noise of the car

Use the light by the law. A variety of vehicle must use their own unique sound, hooter for motorcycle and car, bell for horse drawn carriage and bicycle. Use sound only when necessary or accident prevention.

2.3.2 Speed

Driver have to drive with the speed laws. If turning or overtaking the driver have to reduce speed. If the road not good, the driver have to reduce speed. If a crossroads, overpass or circus, the driver should to reduces speed.

2.3.3 Traffic light and traffic signs

Driver have to follow traffic light and traffic signs correctly. Traffic light, red is stop, yellow is prepares to stop, and green is proceeds with caution [2].

Figure 2.1 Example of regulatory signs.

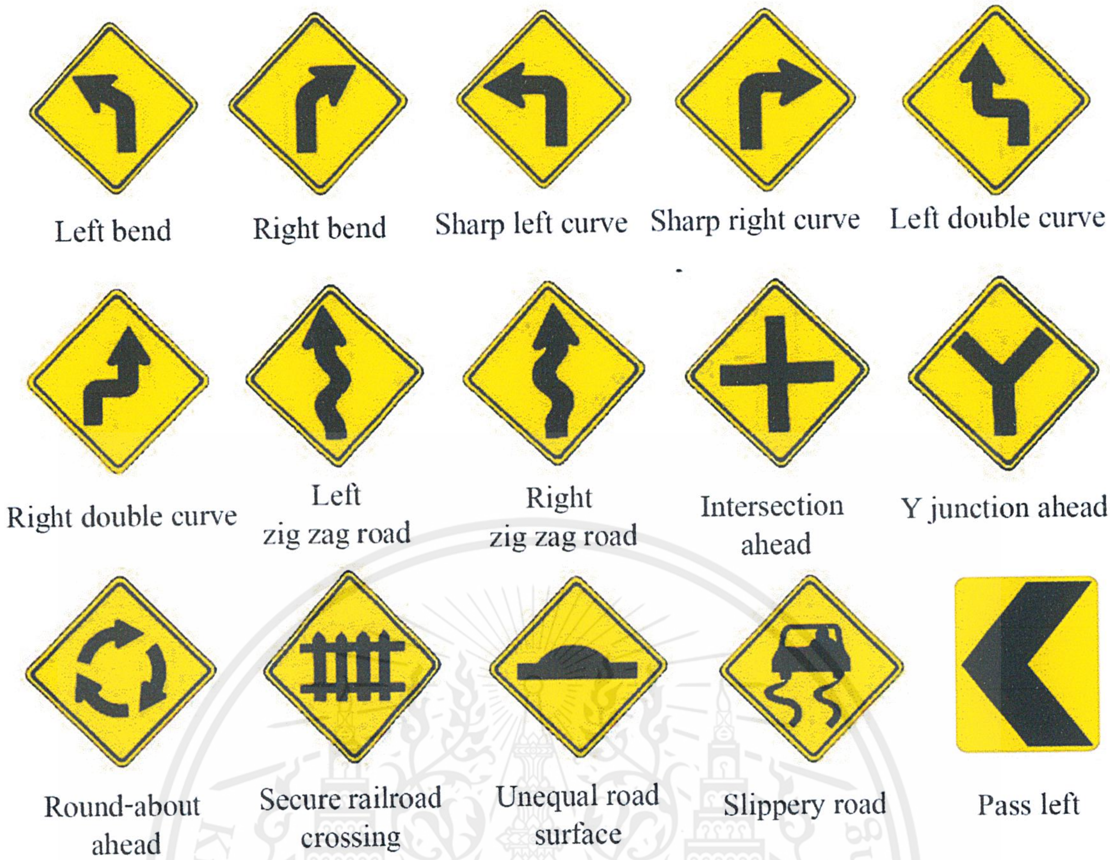


Figure 2.2 Example of traffic warning signs.

2.4 Driving Analysis

Driving analysis makes us know the driving behavior on the road, the excellent data for analysis is car data. Accidents caused by many factors. To example, driving too fast, driving across of lane, overtake another vehicle in an emergency, violators traffic rules, disable people, driving when vehicle was not ready, and so forth.

From these causes, driving behavior is the main cause of road accident, and many researches have discussed the causes of accident, which used to analyze driving behavior as well. To example, driving at night, driving over speed limit that the laws stipulated a maximum of 90 km/h, not respecting a traffic light, driving after drinking alcohol, driving alone, driving after taking drugs, driving in bad weather, driving while using a mobile phone, not stopping at a stop sign, driving without helmet or seatbelt, driving more than two hours without resting, smoking while driving, eating while driving, listening to radio or changing radio station, changing compact disk while driving, passing in a no-pass zone, and so forth [3].

2.4.1 Driving analysis equation

Driving analysis need to use a many factor for analyze, each factors is the basic statistical equation.

2.4.1.1 Vehicle velocity

Vehicle velocity represented as v[t], and units kilometers per hour [km/h]. This information specified the maximum speed that can drives, the average speed, range of variation speed, which consistent with the unusual driving behavior.

Max amplitude [km/h]:

$$v[t]_{max} = \max(v[t]) \tag{2.2}$$

Mean value [km/h]:

$$\bar{v} = \frac{1}{N}\sum_{1}^{N} v[t] \tag{2.3}$$

Standard deviation [km/h]:

$$\sigma_v = \sqrt{\frac{1}{N}\sum_{1}^{N} (\bar{v}-v[t])^2} \tag{2.4}$$

Median value [km/h]:

$$\tilde{v}_{even} = \left(\frac{N}{2}+1\right)^{th} \text{ term} \tag{2.5}$$

where v[t] is vehicle velocity in time, $\bar{v}$ is mean of vehicle velocity, N is number of vehicle velocity, $\tilde{\sigma}$ is standard deviation of vehicle velocity, and $\tilde{v}_{even}$ is median value of vehicle velocity [4].

Normally, desired speed usually depends on road types and legal speed limit of road. Fields et al, presented the recommend speed in the range between 15 km/h (not too slow) and 85 km/h (not too fast).

2.4.1.2 Brake pedal

It is represented as b[t], which has a value of 0 when not press the pedal and 1 when press the pedal. The brake pedal specified safety of driving on the road. In addition, the brake pedal continually identify abnormalities that drive.

Braking frequency (times pedal pressed) [Hz]

$$bt = \frac{\#\ \text{time pedal pressed}}{\text{total time}} \tag{2.6}$$

where bt is braking time frequency when pressed [4].

2.4.1.3 Steering wheel angle movement

The steering wheel is fast changing may indicate that aggressive driving behavior.

Max amplitude (°/S):

$$\omega[t]max \tag{2.7}$$

Mean value (°/S):

$$\overline{\omega} \tag{2.8}$$

Standard deviation (°/S):

$$\sigma_{\omega} \tag{2.9}$$

Median value (°/S):

$$\widetilde{\omega}_{even} \tag{2.10}$$

where $\omega[t]max$ is maximum amplitude of steering wheel movement, $\overline{\omega}$ is mean value of steering wheel movement, σ_{ω} is standard deviation of steering wheel movement, and $\widetilde{\omega}_{even}$ is median value of steering wheel movement [4].

2.4.1.4 Acceleration and deceleration

The normal and maximum acceleration and deceleration range may differ depending on vehicle type. Gipps said the maximum acceleration is between 1.5-3.6 and normal acceleration is between 0.9-1.5, emergency deceleration is between 1.5-2.4 and normal deceleration is 0.9-1.5. The acceleration of the following car can calculate by

$$a = A \cdot \text{sign}(-R) \cdot e^{-S(1\ R)^2} \quad (2.11)$$

where R is the ratio between safety distance (d_s) and actual distance (d).

$$R = \begin{cases} \frac{d}{d_s}, & d > d_s \\ \frac{d_s}{d}, & d < d_s \end{cases} \quad (2.12)$$

A is maximum acceleration or deceleration

$$A = \begin{cases} \text{Max acceleration}, & d > d_s \\ \text{Max deceleration}, & d < d_s \end{cases} \quad (2.13)$$

S is the aggressiveness of the acceleration and deceleration changes always a positive value.

$$S = |R| \quad (2.14)$$

If $0 \leq S < 1$ make it smoother, and $1 \leq S < \infty$ make it less smoother.

2.4.1.5 Headways

Headway is distance between leader vehicle and following vehicle. The safe distance can calculate by

$$d_s = \frac{v_f^2}{a_f} + 2^{\Delta T} \quad (2.15)$$

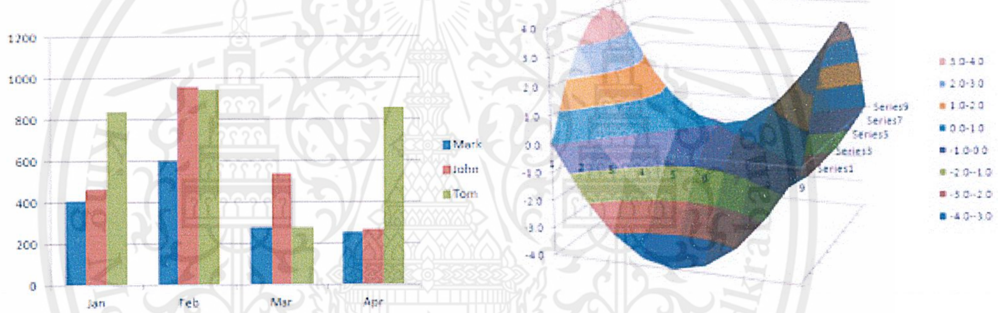
where a_f and v_f are the acceleration and speed of following vehicle and ΔT is the time step at which the status of the leader car obtained.

2.5 Data Analysis Tool

The analysis of big data or many data can use analysis tools for manage. Currently, there are many data analysis tools. The data analysis tools are wildly used among economist and researchers.

2.5.1 Microsoft Office Excel

Microsoft Excel forms part of Microsoft Office is a spreadsheet developed for Microsoft Windows, Mac OS X, and iOS. It features calculation, pivot tables, graphing tools, and a macro programming language called Visual Basic for Applications. Microsoft Excel organizes a numeric or text data in spreadsheets or workbooks. Viewing it in context helps to make more informed decisions. Microsoft Excel will perform complex analysis and summarizes data with previews of pivot-table options to compare them and select the one that tells the best of story. These programs recommend the charts and graphs that best illustrate a data patterns. Quickly preview options and pick those that present the most clearly of insights. However, Microsoft Excel have a problem of statistical tools about missing values and incorrectly [5].



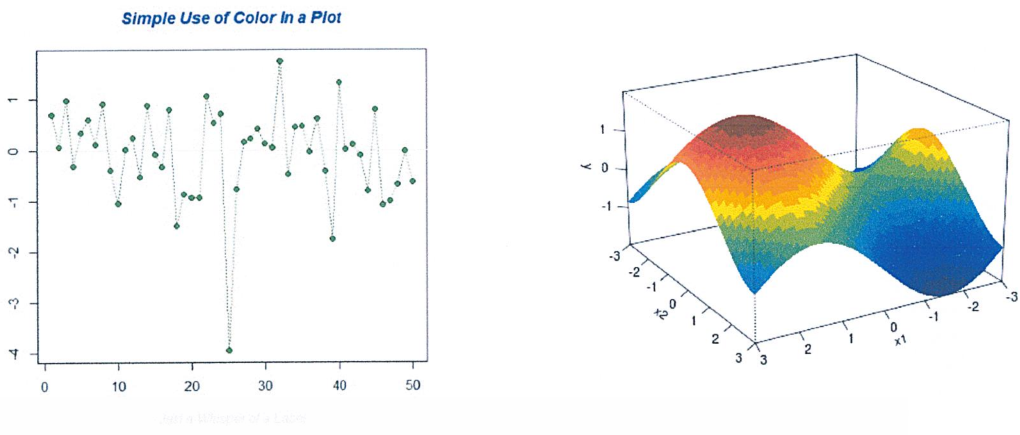
(a) (b)

Figure 2.3 An example of (a) 2D graph and (b) 3D graph in Microsoft Office Excel.

Source : https://stat21.wikispaces.com/2D+%26+3D+Modeling

2.5.2 R Programming

R programming is a language and software for statistical computing and graphics. R language is the most popular used in the groups of data miner and statistician for statistical and data analysis because R language quite good and inclusive in term of statistical and graphical techniques including linear and nonlinear modeling, time series analysis, clustering and so on. R programming is appropriate software for calculation, data manipulate and graphical including data handling, graphical facilities for data analysis and display. It's very simple and effective programming language which includes loops, conditionals, function that user-defined recursive and input/output facilities [7].



(a) (b)

Figure 2.4 Example of (a) 2D graph and (b) 3D graph in R.

Source : http://www.statmethods.net/graphs/scatterplot.html

In this project, we use R programming to analyze a driving data, and presented in number of driving performance and graph of driving behavior.

2.6 Driving Simulator

Driving simulator is driving by the simulator program without actually driving on the road and less risk. Driving simulator used for research, to monitor driver behavior, performance and entertainment. Many driving simulator are popularly to use, such as City Car Driving, Assetto Corsa, OpenDS, and etc.

2.6.1 City Car Driving

City Car Driving is a game of driving simulator, based on the Microsoft Windows platform, developed by Forward Development. The driver simulator game features two different maps, neither of which is based on particular streets or places throughout the world.

This program was established and widely popular. It has many features, such as realistic physics and realistic city. Users can be modify the game by adding more vehicles, choose the color of the cars and order in which they perform tasks in Career Mode, changing sounds and altering the way that other road users behave.

There are certain modifications that can mod things like the density of weather or the pedestrians that you see roaming the streets. In addition, users are also able to add different vehicles into the game so that they have more choices of vehicles when playing the game.

However, this program is limited. It has a license means can't to edit and modify this program and not for free [8].

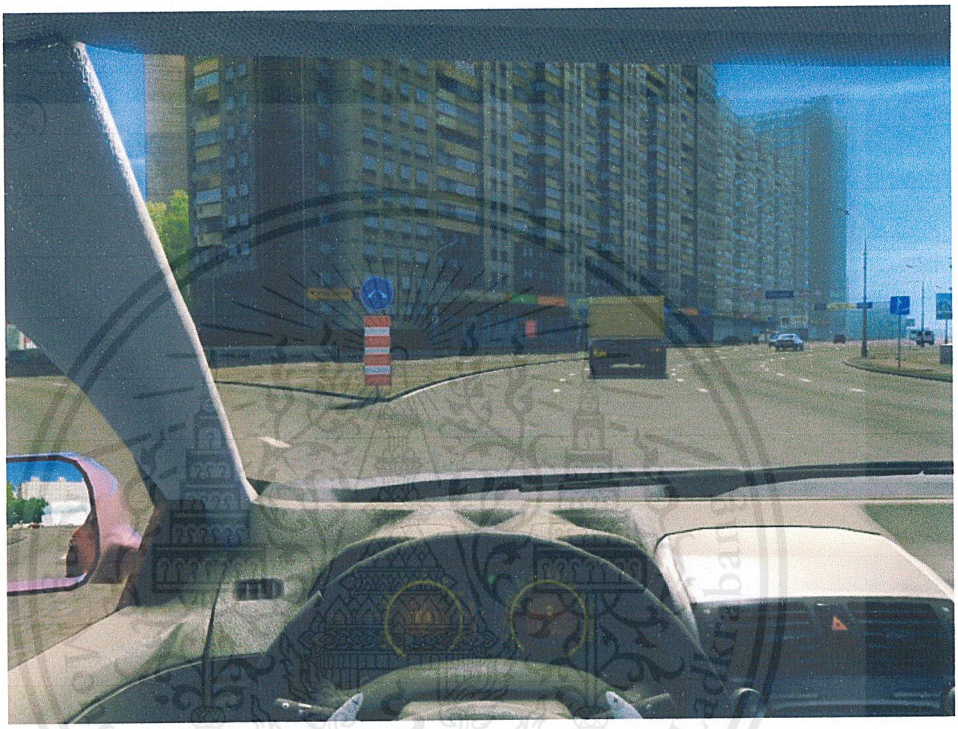


Figure 2.5 An example of City Car Driving's interface.

2.6.2 Assetto Corsa

Assetto Corsa is a simulator racing game designed with an emphasis on realistic racing experience with support for extensive customization and modification. Assetto Corsa is being designed to provide a very realistic driving experience, with single player and multiplayer options, officially licensed cars and tracks developed using Laser scan technology, and the highest level of accuracy possible in reproducing real world motor racing environments. Also, Assetto Corsa will allow for considerable customization and modification, in order to satisfy the expectations of professional racers or gamers who prefer to approach the driving experience more progressively, and hobbyists who just like to collect lots of cars and tracks.

Assetto Corsa was designed to support extensive modification and creation of additional cars and tracks by users themselves. A special WYSIWYG editor that is a system in which content onscreen during editing appears in a form closely corresponding to its appearance when printed or displayed as a finished product, bundled with the game, enables importing of 3D models and allows artists to assign properties and material shaders that are computer program used to shading to objects with an emphasis on ease of use. The editor exports a single game model file and does not allow opening of or addition of objects to, an already exported file. Assetto Corsa also supports addition of third party widgets and plugins written in Python, C++ and C# for interface enhancements and etc. Assetto Corsa has a license and not free. It is impossible to improve or modify the application code [9].

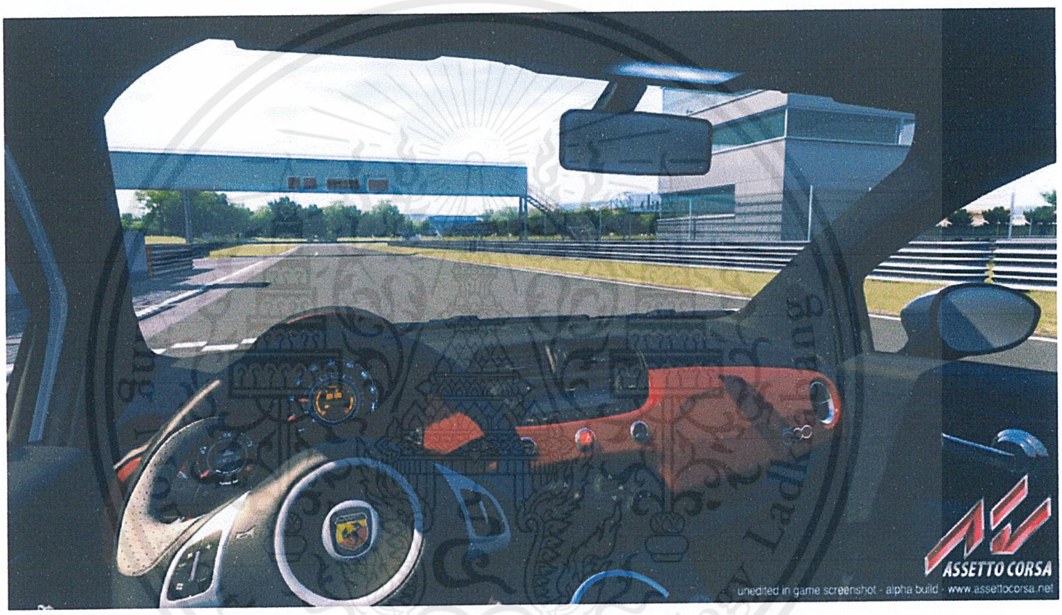


Figure 2.6 An example of Assetto Corsa's interface.

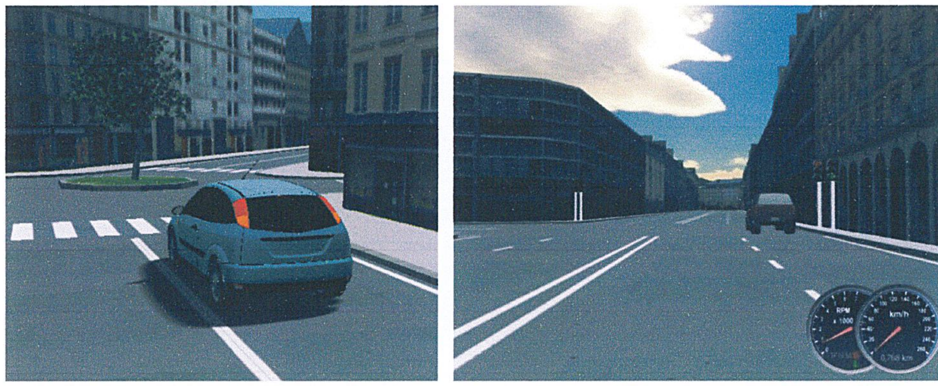
2.6.3 OpenDS

OpenDS is a free driving simulator program that aims for research. This program is written in Java language and based on the JmonkeyEngine framework, the scene graph based game engine that is mainly used for display and computational of physics. With the right hardware, although the city can be advanced at a high frame rate.

There is composed of three main parts, the driving task editor, the simulator and the driver analysis. First, on a graphics to driving task editor, this is not to be confused with the map editor, users can load a map format and place object to empty map, such as driving car, traffic lights, road signs, and vehicles. Moreover, car features and events will be discussed in the simulation run time, can be identified. After a driving task is finished, it can be store in XML format to allow for data replication components. The format will show the plan and attached to the physics engine for realistic.

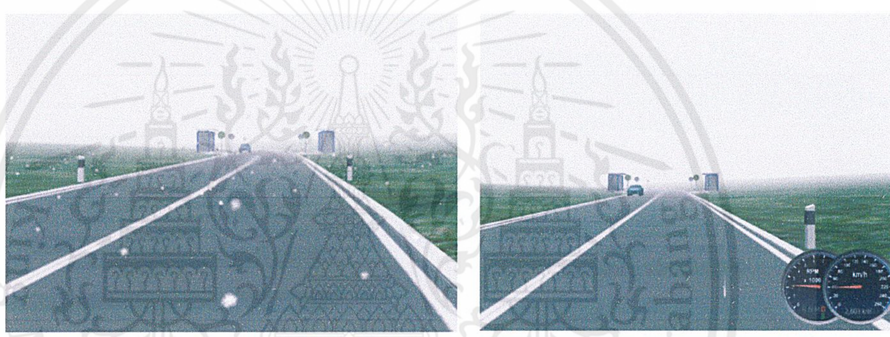
Nowadays, the main feature of simulator implementation is different to control traffic lights. Example, red-green on the way, interactive external control, pre-defined cycle, simulation of traffic on the road, different weather, and a realistic engine and transmission format, that can be used to calculate the fuel consumption of the current state of pedal power needed to overcome rolling resistance, inertia, and energy to potential, as well as friction within the engine. In addition, the incident which has been defined in driving task can under the given condition, such as the positioning of the drive, let objects to appear/disappear, move a vehicles, perform measurement, play audio, and more. A reaction data that saved in this way can be seen as a bar chart integrated reporting module with Jasper and exported to text or PDF format.

The last main part of OpenDS is the driver analysis, this can be used to visualize the data recorded during the drive several times per second, such as positions, speed, direction, and pedal state. This will allow investigators to create a simulated environment that certainly drives from earlier in order to analyze the state of the car in position. In addition, the route driven car can be compared to a pre-defined rules followed in order to calculate the deviation, this can be considered as a measure of performance driving. In order to facilitate realistic simulation, OpenDS not only provides an interface for game controllers. However, you can also interface for connection to a real cars, this enables the model to feature the car that like steering angle and pedal states, and to keep the device in a car in the simulation. To enhance the driving experience, OpenDS support multiple screens which can be used for 180-degree projection.



(a) (b)

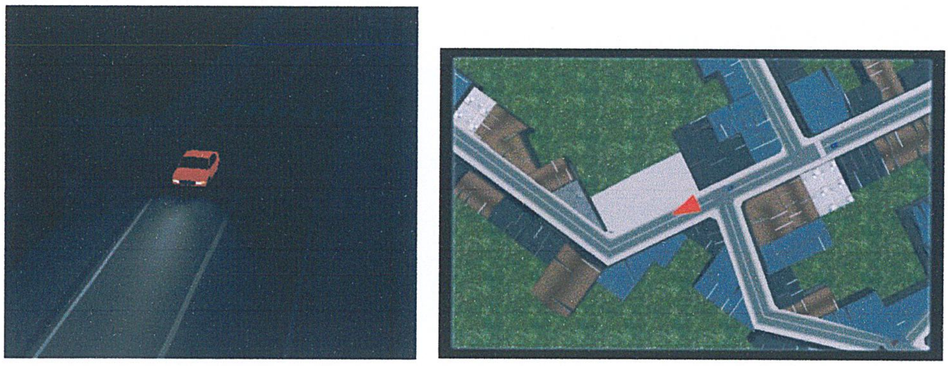
Figure 2.7 An example of, (a) realistic engine and **(b)** realistic traffic lights in OpenDS.



(a) (b)

Figure 2.8 An example of various weather conditions, (a) snowy, and (b) rainy in OpenDS.

Figure 2.9 Rearview mirror, speedometer is available in OpenDS.



(M) (b)

Figure 2.10 An example of, (a) light for vehicles, and (b) outside camera view in OpenDS.

Support Features in OpenDS, interface for interpreting commands from the steering wheel of a real car. Support for game controllers, example, gear, steering wheel, and pedals. Oculus rift support, and the screen multiplayer allows up to 360-degree projection [10].

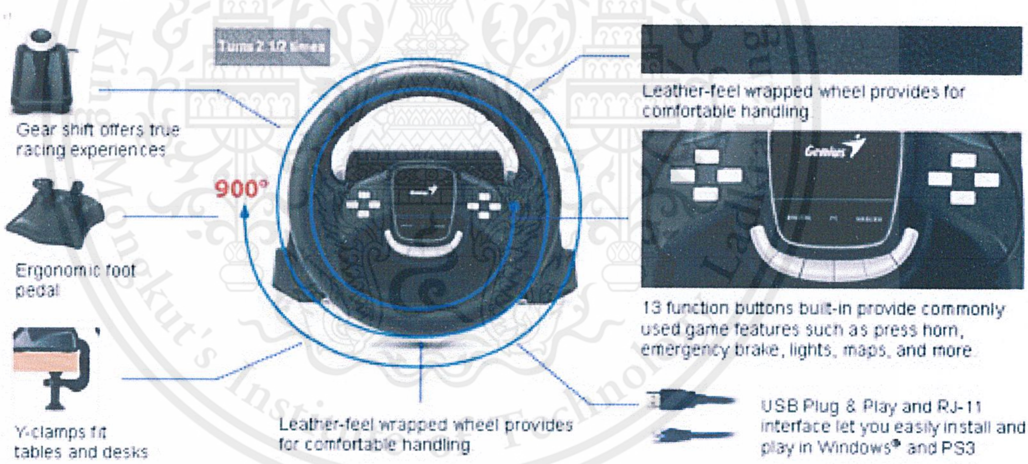


Figure 2.11 Example of feature a steering wheel

From the study, OpenDS have a many feature to simulate data. Therefore, we decided to use OpenDS Driving simulator in driving experiment include steering wheel and foot pedal.

2.7 Literature Review

2.7.1 Driving Behavior Analysis

Chiyomi et al [11], investigated about impact of driving context on stochastic driver behavior model. Their driver behavior model divided into two sections. The first section is behavior prediction and the second is driving context recognition. In behavior prediction part is about the prediction of the pedal-operation behavior of a driver focused on many factors such as car speed. In context recognition part is about recognize context conditions of car-following activity focused on driver's states, type of roads and traffic redundancy . They used a dirichlet process mixture modeling framework to keep away from model selection and misappropriate problems. From experiment they found that their models had better if the model predict driving behavior without a secondary task . Moreover, the models cloud predict driving behavior on main roads better than on local roads, and prediction of the driving behavior in medium traffic was worse than in low traffic.

Alexandre et al [12], examined crash avoidance behaviors between older and middle-aged drivers in six challenging events completed on two different driving simulator platforms. They used driving simulation for simulated driving conditions and driving events include surrounding environments. They made the original course in order to divided it into six road sections, each allowing the inclusion of any of the six challenging events as follow overtaking, Overtaking with shoulder, Right incursion, Left incursion, Sudden brake, Sudden brake with shoulder. Simulated environment during a 25 min accommodating and training session tackling five driving maneuvers of increasing complexity: (1) speed maintenance; (2) steering; (3) braking; and (4) turning. In analysis phase they executed using SPSS. The same analyses were performed separately for the two simulator platforms. Preliminary analyses indicated that the sequence of the challenging events. The first series of analyses examined the number of crash according to age. They found that older drivers were more likely to crash during events requiring rapid and simultaneous activation of vehicle controls on both platforms. Middle-aged drivers showed increased crash risk in events emphasizing braking.

Jing Zhao et al [13], studied how drivers respond to exit-lanes for left-turn intersections with a series of driving simulator experiments. They divided participant into two groups. One group is trained to use the exit-lanes for left-turn while the other group is not. They used driving simulator to study driver behavior at exit-lanes for left-turn intersections which is examining driver responses under different traffic conditions, signage, and other design factors without posing any risk to drivers for evaluate the performance of the sign and marking schemes and examine reaction of the left-turn drivers to the exit-lanes for left-turn intersection. They used the simulator experiment to collected data such as red-light violations, mixed-usage- area utilization, travel speed and wrong-way violations. From the results of the experiment they found it is difficult for participants to comprehend the special operation procedure of the exit-lanes for left-turn intersection if having no training or previous experience and One of the greatest safety concerns with exit-lanes for left-turn intersection is the possibility of red-light violations at the pre-signal.

Xiaohua Zhao et al [14], developed an eco-driving feedback system based on a driving simulator to support eco-driving training which provide both dynamic and static feedback to improve drivers' eco-driving behavior. Aim to develop a more comprehensive eco-driving system to support drivers training and provide both the static evaluation report and dynamic feedback. They estimated driving behavior with respect to saving fuel and reducing emissions and help drivers learn how to drive more environment-friendly. In support system they defined five types of non-eco-driving behavior including quick accelerate, rapid decelerate, engine revolutions at a high level, too fast or unstable speed on freeways and idling for a longer time. In Eco-driving behavior estimation and feedback they used the standard eco-driving behavior referred to the common rules of eco-driving and combining with the relationship between driving parameters such as speed and acceleration. In the experiment they intended to test 3 times (1) Normal test (normal), (2) Test with static feedback (static) and (3) Test with dynamic feedback (dynamic). Based on the second by second driving parameters such as speed and acceleration collected and the fuel/emissions calculation methods, the CO2 emissions and fuel consumption after each driving were obtained, and then the effectiveness of this eco-driving support system on reducing CO2 emissions and saving fuel using was analyzed. Thus, the eco-driving support system was verified to be an acceptable to reduce vehicle emissions and saving fuel consumption. Moreover, drivers' eco-driving behavior would be further improved with experience in this developed eco-driving support system.

Alessandro CALV et al [15], presented different of modeling speed between night and day environments. The analysis aim to the driver speed behavior while the model simulating in night and day along different of tangent-curve configurations in order to find and propose new relations between different of speed parameters over a sample of geometries under different visible conditions by using the driving simulator for improve road safety performance. They designed stability is assessed relation to the magnitude of reduction in speed between complete design elements using ΔV85. Criterion decides a design "good" if the differential magnitude in 85th percentile operating speeds from a method tangent to a curve (ΔV85) was less than 10 km/h; a design was "fair" if V85 was between 10 km/h and 20 km/h; and a design was "poor" if V85 was more than 20 km/h. The system was widely validated and used to evaluate driving performance in terms of speed, vehicle velocity and trajectory under different road environments and driving conditions. They recorded all driving performance parameters such as speed, breaking and position. They found that new relations between different of speed parameters was proposed that could be used by street engineers for evaluating the safety level of new road infrastructure or the performance of existing street treatments and measures. In addition, this driving simulator study had focused the difference between nightlight and daylight driving condition resulting in different relation purposed for the two conditions of visibility.

Jian Sun et al [16], developed, implemented, and validated an experimental platform that integrated a traffic simulator with multiple driving simulators. To validate the performance of traffic simulator with multiple driving simulators, 27 drivers were recruited to attend the lane changing experiments at a recurring on-ramp bottleneck and left-turn experiments at a two-phase signalized intersection. The experiment data come from two parts. One part is collected by questionnaires and is used to analyze validation of the integrated traffic simulator with multiple driving simulators platform, and the others are output by the traffic simulator with multiple driving simulators platform. The data they collected such as vehicle position coordinates (x, y), lane number, the simulation step and speed. In experiment procedure, the 12 drivers are randomly divided into four groups. In each group, when one driver controls the left-turn vehicle, another two drivers control the vehicles in the reversed direction. Each group conducts the experiment 15 times. The vehicles' trajectories in the scene are output by the traffic simulator with multiple driving simulators. The position, speed and other information needed from the vehicles can then be extracted from the original data. From the results of analysis they found the traffic simulator with multiple driving simulators not only allows conducting more accurate, controlled and versatile driving behavior experiments but can also be used to test special driving behaviors or multi-vehicle interactions under more realistic traffic flow environments.

2.7.2 Road Safety

Jabon et al [17], presented a system for tracking driver facial features aims to enhance the predictive accuracy of driver-assistance systems. They identified key facial features at various pre-accident intervals and used them to predicted minor and major accidents. They used facial expression videos and data from driving simulator log in data analysis procedure. Their dataset consist of extracting key facial features and head movements. They calculated averages, standard deviations, maximums, minimums, velocities, and ranges for each of the Neven outputs and for the vehicle outputs such as wheel angle, throttle, braking outputs, and speed. For some important facial characteristics, such as mouth-openness levels and eyes for predicting minor and major accidents from unsafe driving behavior. In their experiment, participants' faces are recorded with two Logitech Web cameras. The videos are compressed to AVI format in real time using the technologies that can captured the facial movements. They recorded the simulator while driving activity that was a steering wheel angle, data log file listing road conditions, car speed, lane tracking, braking information, longitudinal acceleration (feet/second2), and type and number of accidents.

Yutao et al [18], was developed and validated Go/No-Go Simulator Driving Task (G/NG-SDT) with objective assessments of driver risk related traits. Based on the above discussion, the proposed protocol and assessments. Aim to explore the decision-making and behavioral patterns of drivers. They designated driving task include a variety of driving situations and identify risky decisions in driving task for the behavioral assessments. In the behavioral assessments part they divided into high-risk drivers and low-risk drivers depending on the total number of Go decisions made. The performances of the simulator task included violations, crashes, and completion time. Referring to the previous studies involving behavioral assessments. Safety margin and longitudinal and lateral controls were recorded to quantify behavioral patterns. The assessment of safety margin , including minimum distance and minimum TTC (distance/relative velocity), were calculated over the segment from 150 m before to 100 m after the conflict point in each dilemma scene. The longitudinal controls were measured by average velocity, variance of velocity, percentage of gas, and brake pedals (from 0- no pressure, to 100%-full depth). From their study they found that Drivers with more Go decisions in G/NG-SDT also showed higher risk tendency on the road and in other related instruments, and demonstrated distinguishable behavioral patterns.

Mrinal et al [19], presented a visual analysis based driving behavior monitoring system to characterized driving behavior focus on rush driving detection. They used a single wide angle camera for detected surrounding environment and obstacle around the car including visual analysis other driver behavior. They propose a visual-analysis-based driving behavior monitoring system. The visual analysis includes the acceleration, lane- changing, and distance-maintaining behavior. To enhance traffic safety, making road accident and congestion free. The factors they use in their rash driving estimation algorithm such as fast sideway , forward acceleration , frequent lane change, drive close to car or people in front behavior are computed by using visual analysis techniques.

Lynn Meuleners et al [20], validated a laboratory-based driving simulator in measuring on-road driving performance by type and mean driving errors. Aim to assess whether driving performance in the UC-win/Road driving simulator was comparable to on-road driving performance on specific driving tasks. They combining the UC-win/Road with a driving simulator for created driving situations under a variety of environments including driving scenario which can reproduce a wide range of driving conditions such as bright sunlight, snow, rain and night. They recorded driving errors on the road and in the driving simulator were compared using paired samples t-tests. They found no difference between mean driving errors made in the simulator compared to on-road for the total number of errors, indicating relative validity of the simulator. However, there were significant differences between correct speed behaviors, gap selection, indicating and maintenance of lane position in the simulator and on road. It would also be useful to examine the validity of the simulator for assessing hazard perception and to develop a simulator assessment that could determine safe and unsafe drivers.

Masami et al [21], presented a modeling framework, and complicated phenomena in merging sections. The model is described on latent class model (LCM) and consist of multiple driving mode including with drivers attentions for maneuvering cars. Their model aim to analyze and reproduce a variety of driving behaviors even in merging sections. The model consist of three driving mode estimated into car-following, free driving and emergency-deceleration for merging sections. They used driving simulator (DS) for collected data and get parameters. All parameters estimated by vehicle trajectory data from driving experiments in order to analyze the effect in term of safety. In the driving simulator experiment the driver travelling on the main lane of the expressway. They set the scenarios when the driver drive arrive at the merging point other vehicle will merges into main lane but before the driver reaching the merging point the data that notifies the driver run along the main lane of the approaching merging vehicle to driver. The information was provided by two types of devices. The first device is Vehicle Tracking Information Board (VTIB) and second is Conventional Character Information Board (CCIB). Both information board notify the driver when a merging car passes the point on the merging lane to approach. The difference between Vehicle Tracking Information Board (VTIB) and Conventional Character Information Board (CCIB) is CCIB inform the driver by showing the word "approaching merging vehicle" but VTIB notify by continuous LED board with a flashing pictogram of car. All driver were required to drive the road with the information form VTIB and CCIB for collector the data. The used maximizing the likelihood function with a heuristic method composed of simulate annealing (SA) and down-hill simplex method (DSM) for analyze the effect of VTIB and CCIB including estimated and predicted driver driving behavior with driving mode and the relation between driving-mode and surrounding environment.

Ghulam H. Bham et al [22], presented driving simulator validation for the study of driver behavior in work zones. They collected data by using Driving Simulator (DS) for use in validation of a simulator. The work zones data were collected about 22 miles (3.54 km). simulator have a rural four-lane divided highway with a wide median, tubular markers on the center lane marking and have many signs on both side of highway road. They recorded videos during driving experiment for obtained the speeds of vehicles by using a video detection system to captured and processed the recorded video. The video detection identified vehicles and extract their speed by using image recognition and used the Global Positioning System (GPS) to collected vehicle position in real time. In their experiment all participants have to do pre-experiment and post-experiment questionnaires before test driving. The questionnaires evaluated the driver about alertness, eligibility and driving experience. In term of validating driving simulator they used Statistical tests (t-tests) and Error tests for compare the average speed profile on the highway road from the driving simulator. They divided the validation into two parts qualitative validation and quantitative validation. Qualitative validation was carried out to test if the driver behavior in driving simulator was similar to that in the real world but quantitative validation was carried out to evaluate the absolute validation of the driving simulator.

CHAPTER 3

SYSTEM ANALYSIS AND DESIGN

This chapter describe about problems of driving which is a result of not good driving behavior, data structure, procedure of this paper and driving behavior design.

3.1 State of problems

Nearly 50 million people injured and disable worldwide in road accident in addition nearly 1.3 million are die each year that means on average 3,287 deaths a day. Statistics from website livescience.com indicated that Thailand is rank second country often have road accident in the world with 44 deaths per 100,000 people. There are several reasons why fatal road traffic accidents occurred. The cause of road accidents can divided into two terms. First is caused by human error such as drowsiness, do not respect the traffic rules, not good driving habits and so forth. Second is caused by surrounding environment such as road type, weather conditions and so forth. However the most frequent fatal road accidents are caused by human error involved in driver's safe or unsafe driving behaviors. Whether they are due to do not respect for traffic rules and regulations, reckless driving, poor driving skills or lack of good driving behaviors. Good or not good driving behavior becomes a one of the leading causes of road traffic accidents if driver always drive with unsafe driving behavior such as overtaking or lane changing in dangerous situation, drive over speed limit, ignoring traffic signs and so forth it's becomes misbehavior that caused a hazardous road traffic accident eventually.

3.2 Problem analysis

From the road traffic accident study we found human error in term of misbehavior is the majority of the leading cause of road accident. While you are driving on the road it's easy to assessed other drivers who have safe or unsafe driving behaviors but it's difficult to observed and assessed their own driving habits. Therefore, we began to study the factor of the cause of road accident. The factors of problem and examples of errors are shown in Table 3.1

Table 3.1 List of problem factors and examples of errors.

Problem Factors	Possible Situations
Speed	- speed too fast - speed over limit - speed too slow
Distance	- tailgate
Lane and passing	- not using turn traffic signal - cutting other car off - signal too late - overtaking - dangerous lane change
Traffic lights	- driving at red light - accelerating through yellow light
Traffic signs	- ignoring traffic signs
Road	- wrong lane - merging improperly
Brake	- braking too early - braking too late - suddenly breaking - frequently breaking

This study aims to solve this problem therefore we develop the driving model and a driving behavior analysis for validate and analyze driving behavior.

3.3 Driving model design

The proposed of driving model is an analyze and evaluate driving behavior. We use data output from OpenDs driving simulator to input into the driving model for analysis combined with R programming technique in term of statistical analysis.

The results of driving analysis model can be divided into two parts, first is the driving behavior analysis which consists of speed behavior analysis, brake pedal behavior analysis and so forth. Second is the result of prediction which can classify the driver following there driving skill.

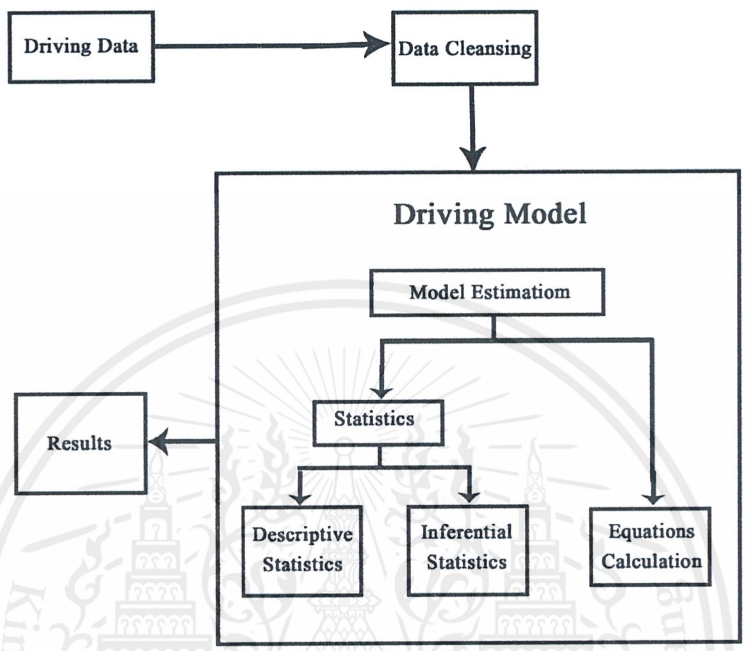


Figure 3.1 Data structure of driving model design.

Figure 3.1 show overview of driving model structure design involving procedure and how driving model works.

3.4 Implementation

3.4.1 Data collection

In field data collection we found the best three ways to gathering driving data about. The first way is collecting data by driving on real roads in real situation but this way seems to lack a driver's security on critical situation because we can't control surrounding environment. For example, others car may make us fall in dangerous situation that may put the driver in harm's way and so forth. The second way is creating a data generator application for generate road driving data. This way to be more safety than driving on real roads however the data we get is unrealistic data because it's not the real data gathering from human being. The last way of data collection is using driving simulator to simulate driving situation and surrounding environment. Driving simulator is the best choice to avoid critical situations that may make the driver at risk furthermore in term of data quality, the driving data we get from the simulator is very similar to realistic data gathering from real roads driving. So we decided that we'd better if use the driving simulator to collected driving data. So in this work the data were collected by using the OpenDS driving simulator to imitate driving in virtual driving environment and to get the parameters.

3.4.1.1 Preparation driving simulator

Before install an OpenDs driving simulator it's essential to installed Java Runtime Environment (JRE) version7 or higher and Java Development Kid (JDK) version 1.7 or higher already. In OpenDs's folder downloaded contains sources and already built version of OpenDs including library files needed to run OpenDs driving simulator.

We modified appropriate road and circumstance for driving experiment as a virtual reality. The example of simulator scene in experiment are shown in figure 3.2

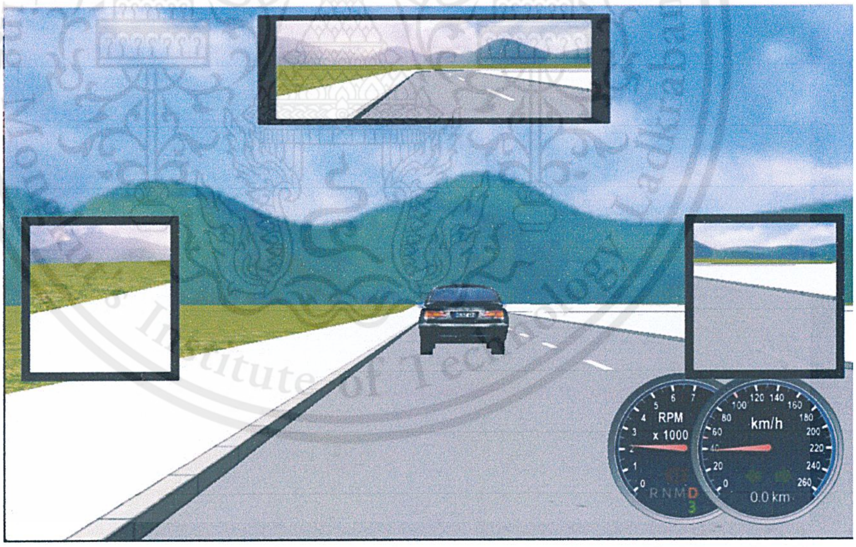


Figure 3.2 The example of simulator scene from driver's view showing leader car with rear view mirror, side view mirror, speed meter and RPM meter.

In this experiment we divided into three driving route according to difficulty. Each driving route are shown in figure 3.3, 3.4, and 3.5

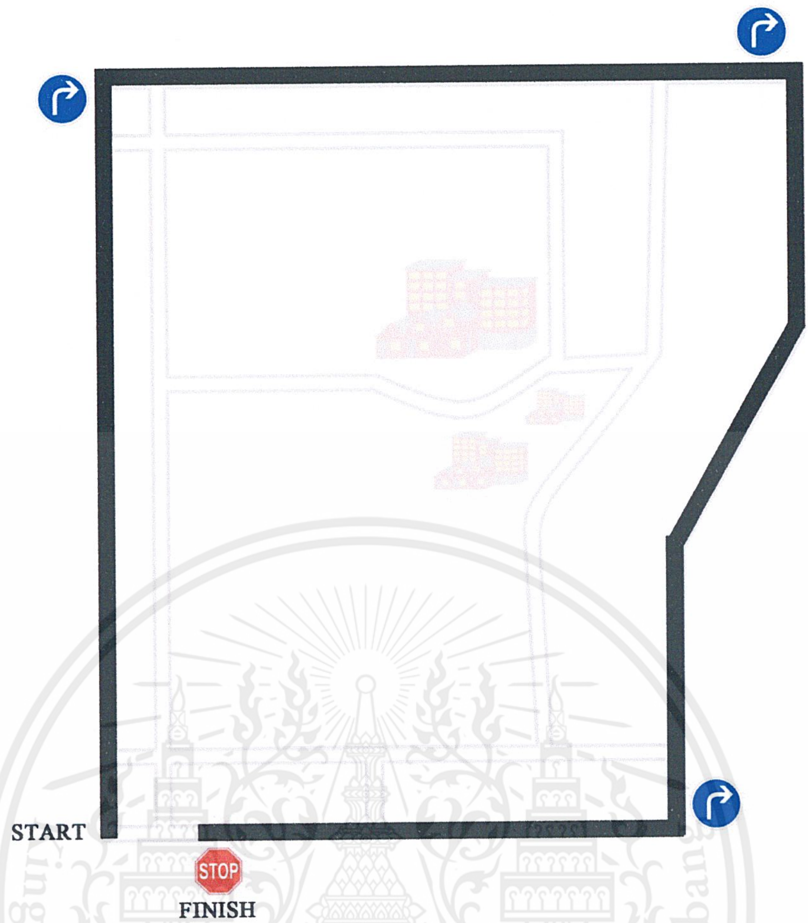


Figure 3.3 Easy level navigation showing with direction signs.

The easy level navigation is suitable for beginner driver because this level presenting a few difficulties driving direction with 3 turning points within approximately 8 kilometers.

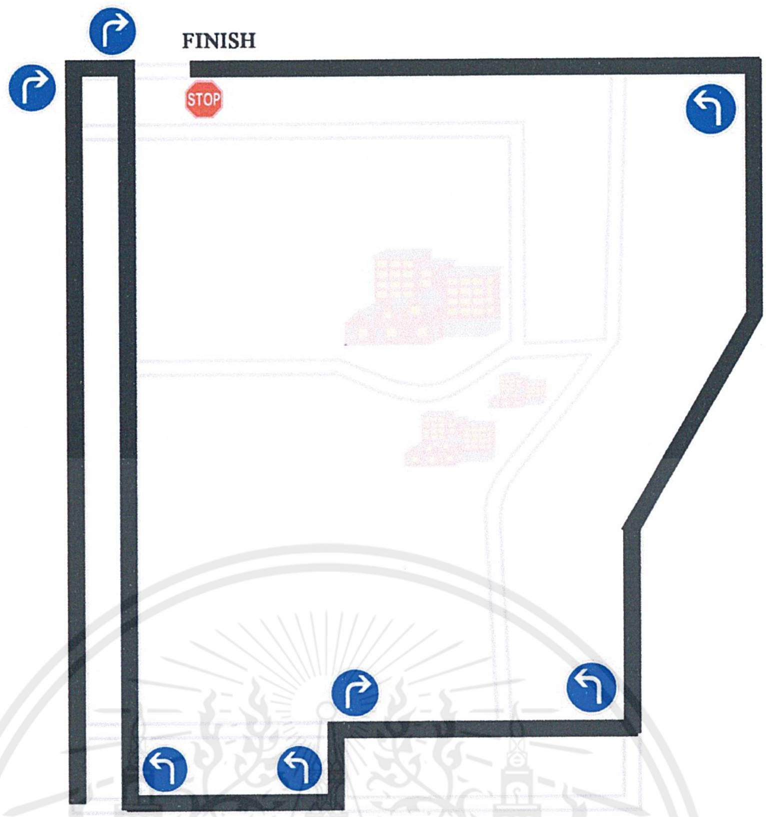


Figure 3.4 Medium level navigation showing with direction signs.

The medium level navigation is suitable for general average driver because the direction of this level quite a bit more complex than easy level. This level presenting an intermediate difficulties of driving direction with 7 turning points within approximately 9 kilometers with 7 T intersection, 2 intersections but have no traffic light.

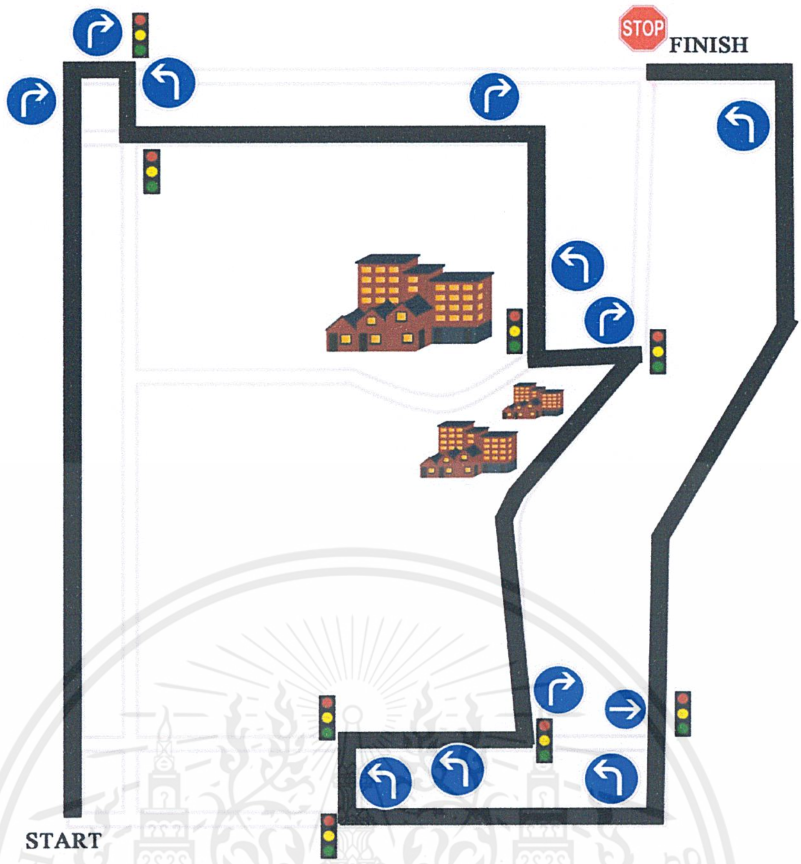


Figure 3.5 Difficulty level navigation showing with direction signs and traffic light.

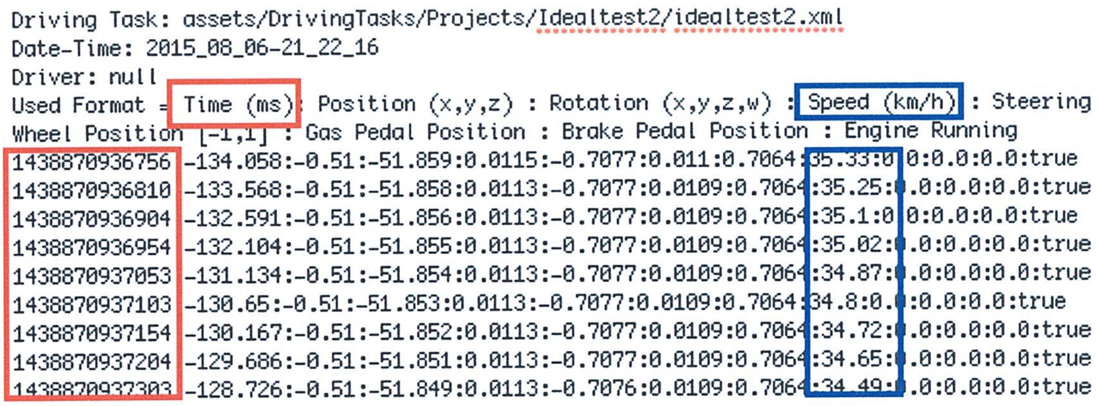
The difficulty level navigation is suitable experienced driver because this direction of this level is the most complex route, have traffic light and drive through the village. This level presenting a high difficulties of driving direction with 11 turning points within approximately 10 kilometers with 7 T intersection, 1 intersection and traffic light in every cross sections.

3.4.1.2 Participants

Ten volunteers were recruited for do driving simulator experiment among student in university according to the following characteristics: have experience with the driving simulator and must have a driver license. We did driving experiment for 10 times in each driving level route from 10 participants to collected diverse driving data from three driving directions.

3.4.1.3 Data structure

In current study we recorded the simulator's data and exported data output in text file formats. The simulator's data output consist of time (ms), car position (x,y,z), car speed (km/h), steering wheel position [-1,1], gas pedal position and engine running.



```
Driving Task: assets/DrivingTasks/Projects/Idealtest2/idealtest2.xml
Date-Time: 2015_08_06-21_22_16
Driver: null
Used Format = Time (ms) : Position (x,y,z) : Rotation (x,y,z,w) : Speed (km/h) : Steering
Wheel Position [-1,1] : Gas Pedal Position : Brake Pedal Position : Engine Running
1438870936756 -134.058:-0.51:-51.859:0.0115:-0.7077:0.011:0.7064:35.33:0 0:0.0:0.0:true
1438870936810 -133.568:-0.51:-51.858:0.0113:-0.7077:0.0109:0.7064:35.25: .0:0.0:0.0:true
1438870936904 -132.591:-0.51:-51.856:0.0113:-0.7077:0.0109:0.7064:35.1:0 0:0.0:0.0:true
1438870936954 -132.104:-0.51:-51.855:0.0113:-0.7077:0.0109:0.7064:35.02: .0:0.0:0.0:true
1438870937053 -131.134:-0.51:-51.854:0.0113:-0.7077:0.0109:0.7064:34.87: .0:0.0:0.0:true
1438870937103 -130.65:-0.51:-51.853:0.0113:-0.7077:0.0109:0.7064:34.8:0. :0.0:0.0:true
1438870937154 -130.167:-0.51:-51.852:0.0113:-0.7077:0.0109:0.7064:34.72: .0:0.0:0.0:true
1438870937204 -129.686:-0.51:-51.851:0.0113:-0.7077:0.0109:0.7064:34.65: .0:0.0:0.0:true
1438870937303 -128.726:-0.51:-51.849:0.0113:-0.7076:0.0109:0.7064:34.49: .0:0.0:0.0:true
```

Figure 3.6 An example of simulator's data output.

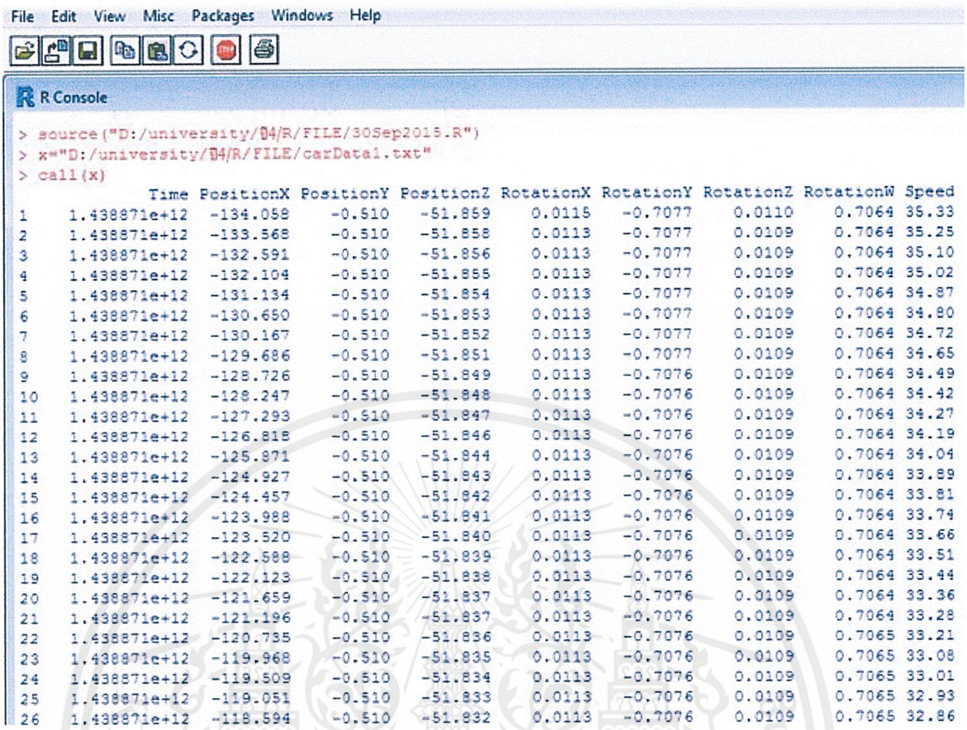
The simulator's data output consist of time (ms) , car position (x,y,z), Rotation (x,y,z,w) , car speed (km/h) , steering wheel position [-1,1] , gas pedal position , Brake pedal position and engine running .The data acquired from driving simulator and descriptions are shown in Table 3.2.

Table 3.2 Data acquired from driving simulator and descriptions.

Data Inputs	Descriptions
Time (ms)	Recorded time from start driving until finish
Position (x,y,z)	Car location identified by x,y,z-axis
Rotation (x,y,z,w)	The action of rotating about a car
Speed (km/hr)	The rate of car is able to move
Steering Wheel Position [-1,1]	The angle of rotating about a steering wheel
Gas Pedal Position	The value obtained from tread on gas pedal (acceleration)
Brake Pedal Position	The value obtained from tread on Brake pedal
Engine Running	Switch on or switch off an engine

3.4.2 Data cleansing

Data acquired from OpenDs driving simulator is inappropriate data to input into driving model. Data file need to correcting and removing something before import into driving behavior model. We have to removed header of text file and split attribute in column clearly. Moreover, time exported from OpenDs driving simulator is unix timestamp it's absolutely necessary to convert timestamp to normally date and time.




```
> source("D:/university/□4/R/FILE/30Sep2015.R")
> x="D:/university/□4/R/FILE/carData1.txt"
> call(x)
```

	Time	PositionX	PositionY	PositionZ	RotationX	RotationY	RotationZ	RotationW	Speed
1	1.438871e+12	-134.058	-0.510	-51.859	0.0115	-0.7077	0.0110	0.7064	35.33
2	1.438871e+12	-133.568	-0.510	-51.858	0.0113	-0.7077	0.0109	0.7064	35.25
3	1.438871e+12	-132.591	-0.510	-51.856	0.0113	-0.7077	0.0109	0.7064	35.10
4	1.438871e+12	-132.104	-0.510	-51.855	0.0113	-0.7077	0.0109	0.7064	35.02
5	1.438871e+12	-131.134	-0.510	-51.854	0.0113	-0.7077	0.0109	0.7064	34.87
6	1.438871e+12	-130.650	-0.510	-51.853	0.0113	-0.7077	0.0109	0.7064	34.80
7	1.438871e+12	-130.167	-0.510	-51.852	0.0113	-0.7077	0.0109	0.7064	34.72
8	1.438871e+12	-129.686	-0.510	-51.851	0.0113	-0.7077	0.0109	0.7064	34.65
9	1.438871e+12	-128.726	-0.510	-51.849	0.0113	-0.7076	0.0109	0.7064	34.49
10	1.438871e+12	-128.247	-0.510	-51.848	0.0113	-0.7076	0.0109	0.7064	34.42
11	1.438871e+12	-127.293	-0.510	-51.847	0.0113	-0.7076	0.0109	0.7064	34.27
12	1.438871e+12	-126.818	-0.510	-51.846	0.0113	-0.7076	0.0109	0.7064	34.19
13	1.438871e+12	-125.871	-0.510	-51.844	0.0113	-0.7076	0.0109	0.7064	34.04
14	1.438871e+12	-124.927	-0.510	-51.843	0.0113	-0.7076	0.0109	0.7064	33.89
15	1.438871e+12	-124.457	-0.510	-51.842	0.0113	-0.7076	0.0109	0.7064	33.81
16	1.438871e+12	-123.988	-0.510	-51.841	0.0113	-0.7076	0.0109	0.7064	33.74
17	1.438871e+12	-123.520	-0.510	-51.840	0.0113	-0.7076	0.0109	0.7064	33.66
18	1.438871e+12	-122.588	-0.510	-51.839	0.0113	-0.7076	0.0109	0.7064	33.51
19	1.438871e+12	-122.123	-0.510	-51.838	0.0113	-0.7076	0.0109	0.7064	33.44
20	1.438871e+12	-121.659	-0.510	-51.837	0.0113	-0.7076	0.0109	0.7064	33.36
21	1.438871e+12	-121.196	-0.510	-51.837	0.0113	-0.7076	0.0109	0.7064	33.28
22	1.438871e+12	-120.735	-0.510	-51.836	0.0113	-0.7076	0.0109	0.7065	33.21
23	1.438871e+12	-119.968	-0.510	-51.835	0.0113	-0.7076	0.0109	0.7065	33.08
24	1.438871e+12	-119.509	-0.510	-51.834	0.0113	-0.7076	0.0109	0.7065	33.01
25	1.438871e+12	-119.051	-0.510	-51.833	0.0113	-0.7076	0.0109	0.7065	32.93
26	1.438871e+12	-118.594	-0.510	-51.832	0.0113	-0.7076	0.0109	0.7065	32.86

Figure 3.7 Simulator's data after cleansing process in R.

3.4.3 Model estimation

Driving model estimation process considering time(ms), speed(km/hr), steering wheel position [-1,1] and brake pedal position. Estimation process is divided into two parts; driving measures, and statistics.

3.4.3.1 Driving measures

1. Speed

Speed is the rate of change of the car position able to move per time unit used for describe how fast a car is moving. Fildes et al, said the driver who drive at the speed below 15 km/h is the slow driver and the driver who drive at the speed over 85 km/h is the fast driver. So, we can conclude the safe speed or recommend speed should between 15 km/h and 85 km/h [23]

$$v=\frac{d}{t} \tag{3.1}$$

where v is speed, d is distance traveled , and t is time.

$$v_{av} = \frac{\Delta d}{\Delta t} \tag{3.2}$$

where v_{av} is average speed, Δd is total distance traveled, and Δt is total time.

2. Acceleration

Acceleration is the rate of increase of the car speed per unit of time. The acceleration value is always positive and the positive value means the car will speed up. Gipp et al, assumed the appropriate acceleration is between 0.9 m/s^2 and 1.5 m/s^2. The acceleration can estimate by equation

$$a = \frac{v}{t} \tag{3.3}$$

where v is speed or velocity and t is time.

3. Deceleration

Deceleration is the rate of decrease of the car speed per unit of time. The deceleration value is always negative and the negative value means the car will slow down. Gipp et al, assumed the appropriate deceleration is between -0.9 m/s^2 and -1.5 m/s^2. The higher deceleration value than -1.6 may be indicated for sudden deceleration or sudden breaking. The deceleration is the negative value of equation 2.18 [24].

4. Headway

Head way is the interval between two cars. So, safe headway is the safe interval between following car and leading car. Vogel et al, said the acceptable safety interval of headway is between 1.5 second and 2.5 second. The headway estimated with equation

$$Headway = \frac{L_0}{V_f} \tag{3.4}$$

where L_0 is the distance between following and leading car, and V_f is the speed of following car [25].

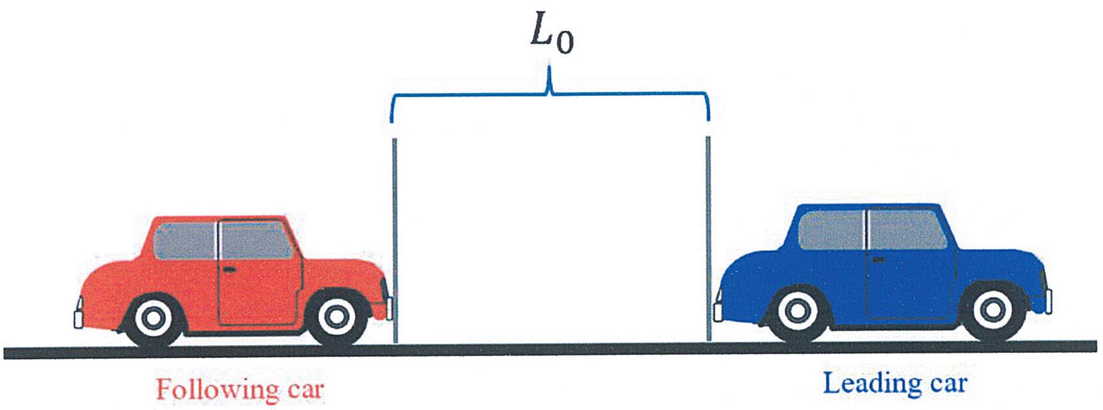


Figure 3.8 The following and leading car.

5. Aggressiveness of acceleration and deceleration changes (S)

The aggressiveness of acceleration and deceleration changes is the hostile or violent behavior of driver in speed up or slow down their vehicle. S can estimate by equation

$$S = |R| \tag{3.5}$$

where R is ratio between safety distance and actual travelled distance.

R can estimate by equation

$$R = \begin{cases} \frac{d}{d_s} & d > d_s \\ \frac{d_s}{d} & d < d_s \end{cases} \tag{3.6}$$

where d is actual travelled distance, and d_s is safety distance. Safety distance can calculate by

$$d_s = \frac{v^2}{a^2} + 2^{\Delta T} \tag{3.7}$$

where V is speed or velocity, a is acceleration or deceleration, and ΔT is the time at which the status of leader car is obtained.

Carillo et al, said the appropriate value of S is between 0 and 1 which represent smoother acceleration or deceleration changes [26].

6. Braking distance

Braking distance is the travelled distance when the driver decided to slow or stop a car moving. The safe brake distance is an approximate distance a car need to move after the brakes are applied. The safe brake distance can estimate by equation

$$v = \sqrt{u^2 + 2ax_s} \tag{3.8}$$

where V is the final speed of a car after the brake are not applied, u is the initial speed of a car after the brake are applied, a is the acceleration of a car, and x_s is the safety travelled distance.

From all equations and criterions can conclude the results as shown in Table 3.3

Table 3.3 Safe driving measures and formulation.

Factor	Formula	Safety Measures
Velocity	$v = \frac{d}{t}$ $v_{av} = \frac{\sum v}{N}$	15 ≥ recommend ≥ 85 depend on speed limit
Acceleration	$a = \frac{v}{t}$	0.9 ≥ recommend≥ 1.5
Deceleration	$-a = \frac{v}{t}$	-1.5 ≥ recommend≥ -0.9
Headway	$Headway = \frac{L_0}{V_f}$	1.5-2.5 s
Aggressiveness of the acceleration and deceleration changes (S)	$S = \lvert R \rvert$ $R = \begin{cases} \frac{d}{d_s} & d > d_s \\ \frac{d_s}{d} & d < d_s \end{cases}$ $d_s = \frac{v^2}{a^2} + 2^{\Delta T}$	$0 \leq S < 1$ make it smoother
Safe brake distance	$v = \sqrt{u^2 + 2ax_s}$	$X_S \leq X < \infty$

3.4.3.2 Statistics

In this study model we've decided to using R language programing for analysis all parameters and produce a graph of relation among parameter value.

a. Descriptive Statistics

Descriptive Statistics are used for analyze data in many different ways for instance, mean speed can be used to identify the speed over a specific period of time or standard deviation of speed can be used to identify high changes of velocity which may relate to misbehavior.

b. Area calculation of radar chart

The area of the radar chart is obtained by summing the area of triangles formed between two adjacent indicators [27].

$$area = \frac{\overline{AB} * \overline{AC} * \sin A}{2} \tag{3.9}$$

c. Mean value calculation

The mean is the average of all data value can calculate with summing all data value and divide the sum by total data count.

$$\overline{X} = \frac{\sum x}{n} \tag{3.10}$$

where $\bar{x}$ is mean value, $\sum x$ is sum of all data values, and n is number of data.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter discusses about the result of driving behavior model includes the driving behavior analysis and the classification of driver.

4.1 Model estimation results

Before doing experiments we have to set up steering wheel and both pedals for work with openDs driving simulator.

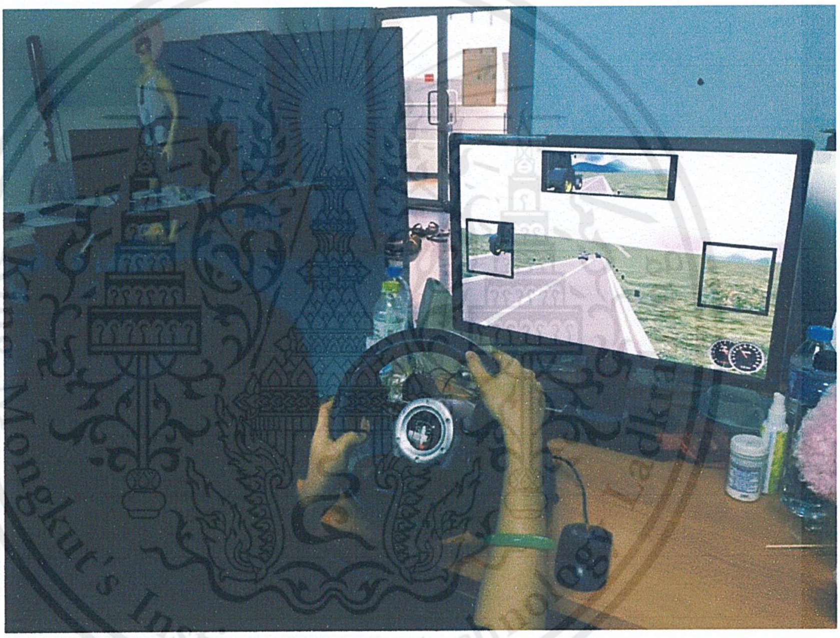


Figure 4.1 Driving simulator experiment by student in university.

The figure 4.1 show the picture while driving experiment by one of participant in easy level direction with steering wheel controller, gas pedal and brake pedal.

4.1.1 The result of first participant

The result of first participant using for validate the diving safety measurements of driving model. The data of first participant analyzed by driving model are shown in Table 4.1 and their own driving performance graph are shown in figure 4.1

Table 4.1 An example of driving simulator data.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Break Distance (m)	Safe Break Distance (m)	Aggressiveness of Acceleration Change
0	0	0.01	0	639.4			
1	0	0.01	0	1025.82			
2	0.49	1.79	1.78	7.81			
3	3.42	10.52	8.73	1.62			
4	9.16	20.65	10.13	0.93			
5 ↕ 30	684.94	141.97	2.71	-0.48			
31	725.13	144.57	2.6	-0.52			
32	766.10	147.39	2.82	-0.56			
33 ↕ 35	807.75	149.82	2.43	-0.61	41.07	63.44	1.55
36	931.13	147.73	0.01				
37	972.79	149.9	2.17				
38	1015.11	152.18	2.28				
39	1057.92	153.99	1.81				
40 ↕ 45	1324.23	162.91	1.15				
46	1369.82	163.98	1.07				
47 ↕ 49	1415.65	164.85	0.87		21.27	147.29	6.92

Table 4.1 An example of driving simulator data (cont.).

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Break Distance (m)	Safe Break Distance (m)	Aggressiveness of Acceleration Change
50 ↕ 53	1494.69	79.25	2.74		36.61	434.90	11.88
54	1572.27	70.18	5.87				
55	1593.67	76.97	6.79				
56	1616.45	81.96	4.99				
57 ↕ 59	1640.04	84.84	2.88		21.25	29.48	1.39
60 ↕ 68	1705.65	80.81	4.36		45.53	3921.14	86.12
69 . . . 313	1775.49 . . . 5027.03	7.43 . . . 0.24	0.52 . . . -30.73		. . . 17.31	. . . 119.20	. . . 6.89

The results of driving behavior presented by graph of relation with minimum and maximum acceptable measures graph with the area of each. The radar chart of first participant are shown in the figure 4.2

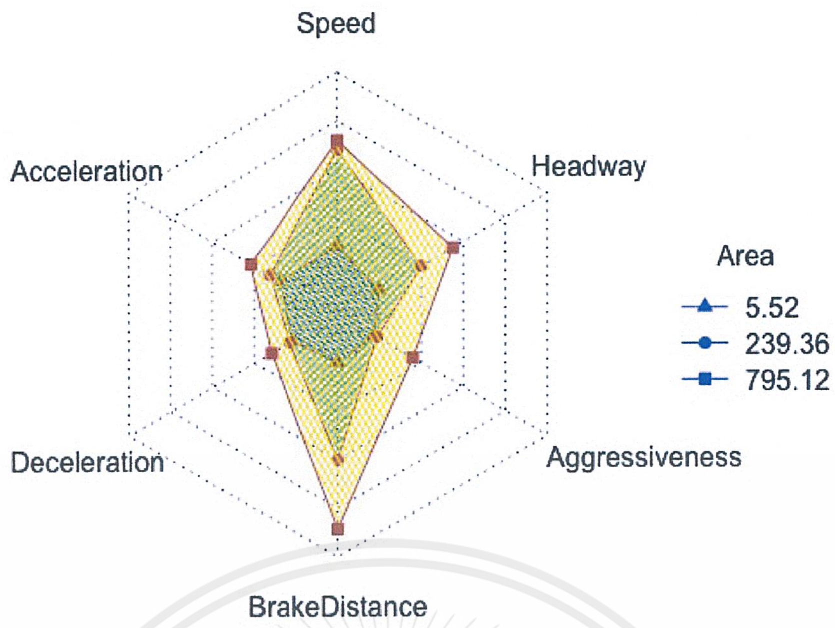


Figure 4.2 The radar chart of first participant.

The graph line with triangle symbol shows the minimum acceptable graph, the graph line with circle symbol shows the maximum acceptable measures graph and the graph line with square symbol shows driver performance graph from their own driving data.

As seen in figure 4.2, the driver performance chart is out of maximum acceptable graph in every factor axis.

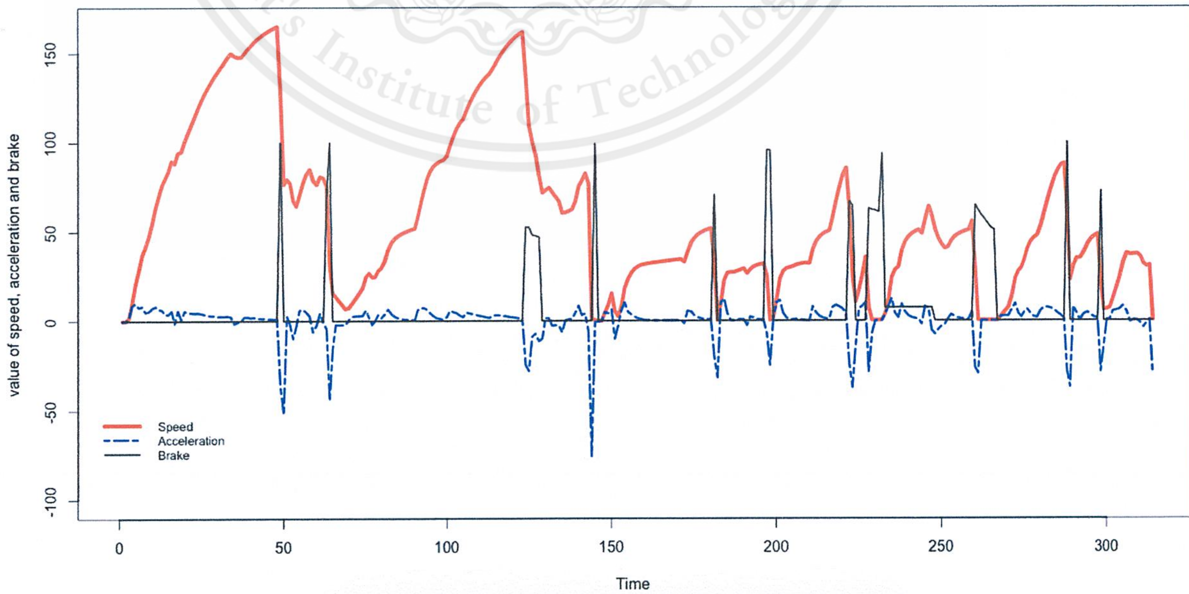


Figure 4.3 The comparison of speed, acceleration and brake behavior.

This graph shows the relationship of speed, acceleration and brake behavior. From this graph we can see the relationship between speed line and acceleration line when the acceleration line increase or decrease the speed line will change in the same way and another relationship is the relationship between speed and brake when the brake are applied the speed will decrease.

4.1.2 The result of sample participants

The result of sample participant using for identify the new safety driving measures suitable for each level route. The summary of driving data from 10 participants in each driving level direction are shown in table 4.2, 4.3, and 4.4

Table 4.2 The summary driving data of each participant when driving in easy level direction.

Driver No.	Time (Sec)	Distance[1] (m)	Speed (m/s)	Acc[2] (m/s^2)	Dec[3] (m/s^2)	Headway[4] (time)	Brake[5] (time)	Unsafe brake[6] (time)	Aggressive[7]
1	358	9178.56	91.97	2.55	-5.85	14	14	12	15.03
2	335	8095.81	86.67	1.86	-5.01	29	11	11	9.79
3	396	8438.33	76.46	1.41	-2.64	16	11	11	7.04
4	406	8404.41	74.27	1.23	-2.78	24	10	10	8.02
5	371	8054.76	77.88	1.58	-2.94	21	11	11	7.14
6	382	8136.38	76.42	2.32	-2.91	28	14	14	16.22
7	376	8050.41	76.81	2.25	-2.92	14	13	13	6.41
8	374	8181.29	78.48	2.29	-3.84	14	15	15	13.49
9	388	8344.40	77.16	2.27	-2.92	16	16	15	8.56
10	353	8170.33	83.02	2.57	-3.32	14	14	12	7.30
$\bar{X}$	373.9	8305.47	79.91	2.03	-3.51	19	12.9	12.4	9.9

[1]Traveled Distance, [2]Acceleration, [3]Deceleration, [4]Unsafe headway, [5]Brake Time, [6]Unsafe brake distance, and [7]Aggressiveness of Acceleration Change

Table 4.2 shows the summary driving data of each participant in term of time, traveled distance, speed, acceleration, deceleration, unsafe headway, brake time, unsafe brake distance and aggressiveness of acceleration changes when driving in easy level direction and the last row of table shows average value of each factor from 10 participants in this level direction. The average value will bring to define the new measures suitable for this level of direction.

Table 4.3 The summary driving data of each participant when driving in medium level direction.

Driver No.	Time (Sec)	Distance[1] (m)	Speed (m/s)	Acc[2] (m/s^2)	Dec[3] (m/s^2)	Headway[4] (time)	Brake[5] (time)	Unsafe brake[6] (time)	Aggressive[7]
1	430	9950.53	83.05	3.06	-5.56	17	20	18	23.86
2	451	9786.23	77.88	2.64	-4.31	16	17	15	50.53
3	459	10295.15	80.51	3.17	-3.74	17	16	14	8.32
4	469	10793.4	82.61	2.79	-3.37	20	18	16	61.79
5	471	10841.09	82.62	2.87	-3.39	18	14	14	9.41
6	470	10740.88	82.03	2.98	-3.13	18	17	17	28.50
7	435	10604.77	87.49	3.29	-3.58	17	20	19	23.89
8	454	10907.98	86.23	3.52	-3.41	19	17	17	13.59
9	441	10661.09	86.76	3.78	-4.92	17	18	18	15.45
10	454	10720.9	84.76	3.55	-4.33	18	20	19	13.49
$\bar{X}$	**453.4**	**10530.2**	**83.39**	**3.17**	**-3.97**	**17.7**	**17.7**	**16.7**	**24.88**

[1]Traveled Distance, [2]Acceleration, [3]Deceleration, [4]Unsafe headway, [5]Brake Time, [6]Unsafe brake distance, and [7]Aggressiveness of Acceleration Change

Table 4.3 shows the summary driving data of each participant in term of time, traveled distance, speed, acceleration, deceleration, unsafe headway, brake time, unsafe brake distance and aggressiveness of acceleration changes when driving in medium level direction and the last row of table shows average value of each factor from 10 participants in this level direction. The average value will bring to define the new measures suitable for this level of direction.

Table 4.4 The summary driving data of each participant when driving in difficulty level direction.

Driver No.	Time (Sec)	Distance[1] (m)	Speed (m/s)	Acc[2] (m/s^2)	Dec[3] (m/s^2)	Headway[4] (time)	Brake[5] (time)	Unsafe brake[6] (time)	Aggressive[7]
1	470	10295.5	78.63	3.58	-6.28	17	23	18	60.32
2	476	10065.32	75.91	3.82	-5.52	17	25	22	17.14
3	531	10259.43	69.37	3.58	-4.04	17	27	27	23.55
4	510	10094.65	71.06	3.99	-5.44	16	31	30	8.58
5	502	10405.89	74.42	3.57	-5.02	18	32	28	8.68
6	478	10306.81	77.40	3.88	-5.54	17	27	23	14.44
7	501	10354.39	74.19	3.63	-4.18	18	24	23	49.19
8	520	10309.95	71.18	3.38	-3.24	17	27	25	22.59
9	487	10362.41	76.38	3.86	-5.99	18	29	29	29.57
10	477	10156.81	76.44	4.11	-5.27	17	24	23	13.36
$\bar{X}$	**495.2**	**10261.12**	**74.49**	**3.74**	**-5.052**	**17.2**	**26.9**	**24.8**	**24.742**

[1]Traveled Distance, [2]Acceleration, [3]Deceleration, [4]Unsafe headway, [5]Brake Time, [6]Unsafe brake distance, and [7]Aggressiveness of Acceleration Change

Table 4.4 shows the summary driving data of each participant in term of time, traveled distance, speed, acceleration, deceleration, unsafe headway, brake time, unsafe brake distance and aggressiveness of acceleration changes when driving in difficulty level direction and the last row of table shows average value of each factor from 10 participants in this level direction. The average value will bring to define the new measures suitable for this level of direction.

4.1.3 The summary and analysis of an experiment results

We can summarize the new measurement appropriate for each level direction from the experiment results by using an average, minimum and maximum of each factor. The new suitable measurements are shown in Table 4.5, 4.6, and 4.7

Table 4.5 New measurements appropriate for easy level direction.

	Speed (m/s)	Acceleration (m/s^2)	Deceleration (m/s^2)	Headway (s)	Brake Distance (times)	Aggressive
Min	74.27	1.23	-5.85	0.21	10	6.41
Max	91.97	2.57	-2.64	4.38	15	16.22
Mean	79.91	2.03	-3.51	2.3	12.4	9.9

Table 4.5 shows new suitable measurements suitable for easy level direction with minimum acceptable value, maximum acceptable value and average acceptable value in speed, acceleration, deceleration, headway, and brake distance and aggressive of acceleration and deceleration changes factor.

Table 4.6 New measurements appropriate for medium level direction.

	Speed (m/s)	Acceleration (m/s^2)	Deceleration (m/s^2)	Headway (s)	Brake Distance (times)	Aggressive
Min	77.88	2.64	-5.56	0.53	14	8.32
Max	87.49	3.78	-3.13	7.32	19	61.79
Mean	83.39	3.165	-3.97	3.96	16.7	24.88

Table 4.6 shows new suitable measurements suitable for medium level direction with minimum acceptable value, maximum acceptable value and average acceptable value in speed, acceleration, deceleration, headway, and brake distance and aggressive of acceleration and deceleration changes factor.

Table 4.7 New measurements appropriate for difficulty level direction.

	Speed (m/s)	Acceleration (m/s^2)	Deceleration (m/s^2)	Headway (s)	Brake Distance (times)	Aggressive
Min	69.37	3.38	-6.28	0.69	18	8.58
Max	78.63	4.11	-3.24	8.09	30	60.32
Mean	75.17	3.725	-5.36	4.39	24	19.87

Table 4.7 shows new suitable measurements suitable for easy level direction with minimum acceptable value, maximum acceptable value and average acceptable value in speed, acceleration, deceleration, headway, and brake distance and aggressive of acceleration and deceleration changes factor.

4.2 Classification of driver

In driver classification process the driver will be divided into five groups (A,B,C,D,F) following their own driving performance. All groups and group description are shown in table 4.8

Table 4.8 The groups of driving model and description in term of driver classification.

Classification of Driver	
Grades	Descriptions
A	Excellent driving behavior
B	Good driving behavior
C	Satisfactory driving behavior
D	Unsatisfactory driving behavior
F	Bad driving behavior

The acceptable range of each group are calculated by using the difference area between maximum acceptable graph area and minimum acceptable graph area compare with the area of driver performance graph.

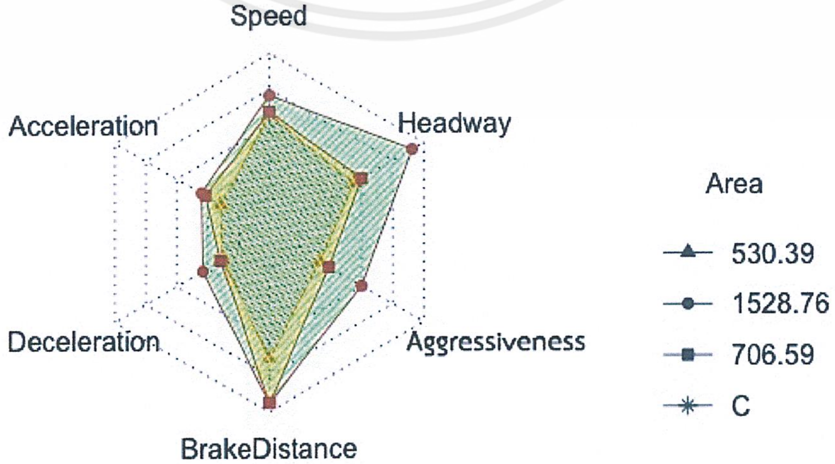


Figure 4.4 An example of radar chart with driving grade.

Figure 4.4 shows the example of driver performance graph with minimum acceptable, maximum acceptable, area of each graph and the result of driving grade.

As seen from figure 4.4 we can be concluded that this C.

Table 4.9 The driving grade of 10 participants in different level of direction.

Driver No.	Level of Direction		
	Easy	Medium	Difficulty
1	A	C	B
2	C	A	C
3	D	D	C
4	B	D	D
5	B	D	D
6	C	B	C
7	D	B	B
8	C	C	C
9	C	C	A
10	D	C	C

Table 4.9 show the driving grade of 10 participants in different level of direction. As seen from the table in easy level direction from 10 participants have only one driver got an A grade, 2 driver got a B grade, 4 driver got a C grade and 3 driver got a D Grade.

In medium level direction from 10 participants have only one driver got an A grade, 2 driver got a B grade, 4 driver got a C grade and 3 driver got a D Grade.

In difficulty level direction from 10 participants have only one driver got an A grade, 2 driver got a B grade, 5 driver got a C grade and 2 driver got a D Grade.

4.3 Model validation

From the experiment, we can conclude the new measures suitable for each level direction from the average of minimum and maximum acceptable values of each factor. In model validation process, we perform a simple validation to assess that the new measures can work effectively or unbelievable by calculate the standard deviation (SD) between the new measures from experiment and the measures have been accepted in general. Diomidis H. stamatis, said the excellent acceptable standard deviation is between 10 and 30 percent of mean value [28]. In this validation, we used the measures have been accepted in general as a mean value. So, the acceptable standard deviation is between 10 and 30 percent of each standard measures. The standard deviation of each minimum and maximum value between new measures and standard measures in each level of direction excluding safe brake distance because this factor has no fixed value. The suitable value of safe brake distance has to calculate time to time when the brake pedal are applied and depend on current speed. The standard deviation of each minimum and maximum value are shown in Table 4.10

Table 4.10 The standard deviation of each minimum and maximum value between new measures and standard measures in each level of direction.

	Easy		Medium		Difficulty	
	Min	Max	Min	Max	Min	Max
Speed	6.97	59.27	2.49	62.88	-8.86	54.37
Acceleration	0.33	1.07	1.74	2.28	2.48	2.61
Deceleration	-4.35	-1.74	-4.06	-2.23	-4.78	-2.34
Headway	-1.29	1.88	-0.97	4.82	-0.81	-11.46
Aggressiveness	6.41	15.22	8.32	60.79	8.58	59.32

Table 4.11 The 30% of each standard measures.

	Min (10% of standard measures)	Max (30% of standard measures)
Speed	1.5	25.5
Acceleration	0.09	0.45
Deceleration	-0.15	-0.27
Headway	0.15	0.75
Aggressiveness	0	0.3

As seen from Table 4.10 and Table 4.11, more than 50% of standard deviation have a value more than 30% or value less than 10% of standard measures. So, we can conclude that this new measures considered unreasonable.

CHAPTER 5

CONCLUSION

We began this project with found scope of work and studied project feasibility by analysis of the ability to complete a project successfully. After we decided that this project have high possibility to success. We began to study about the factors of the leading cause of road accidents such as driving too fast or too slow, safe or unsafe braking distance and good or not good driving behavior by following traffic sign such as speed limit on difference road types and the meaning of them.

We analyzed driving behavior by study on safe driving factors from many others research to find out about the relationship between factor and the best way to analyzing parameter. We find formula to transform the parameter we got from OpenDS driving simulator to suitable form for use to calculate safety driving measurement.

We developed the driving behavior model by using OpenDS driving simulator to collect driving data. We design three level of direction including easy level direction, medium level direction and difficult level direction. Then we modified road and surrounding environment to appropriate driving experiment of each level.

We did driving experiment and analyze driving data. We analyze all results from experiment by R programing in term of descriptive statistics and conclude our new measurement suitable for each driving level direction. Finally, we grading driver by using the differences of area between new minimum acceptable measures chart and maximum acceptable measures chart.

The purpose of this project is study and develop driving model for analysis safe or unsafe driving behavior. The only limitation of this work is unrealistic data because we decided to use driving simulator in data collection process but the simulator offer less realistic driving environment. So, the driving data we get from driving simulator is quite unbelievable. This is the reason why our new measures unreasonable.

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Appendix

Appendix A

Car data from driving simulator

1. Car data of easy level direction

Table A-1 Car data simulator of driver No.1 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	1.42	5.09	5.08	2.70			
3	5.43	14.44	9.35	1.14			
4	11.91	23.3	8.86	0.79			
5	21.02	32.77	9.47	0.61			
6	31.87	39.03	6.26	0.53			
7	44.34	44.87	5.84	0.47			
8	58.58	51.22	6.35	0.41			
9	74.98	59.01	7.79	0.34			
10	93.39	66.19	7.18	0.29			
11	113.58	72.65	6.46	0.24			
12	135.74	79.71	7.06	0.18			
13	159.66	86.03	6.32	0.14			
14	184.96	91.01	4.98	0.09			
15	211.74	96.34	5.33	0.06			
16 ↕ 18	290.67	91.97	-2.22	-0.05	25.57	57.89	2.26
19	316.26	92.06	0.09	-0.09			
20	342.65	94.9	2.84	-0.12			

Table A-1 Car data simulator of driver No.1 easy level direction (cont.).

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
21	369.74	97.47	2.57	-0.16			
22	397.46	99.7	2.23	-0.19			
23	425.79	101.9	2.2	-0.23			
24	454.71	104.06	2.16	-0.26			
25	484.23	106.17	2.11	-0.30			
26	514.34	108.32	2.15	-0.33			
27	545.01	110.32	2	-0.37			
28	576.19	112.18	1.86	-0.41			
29	607.73	113.42	1.24	-0.45			
30	639.55	114.45	1.03	-0.48			
31	671.65	115.48	1.03	-0.52			
32 . . . 358	9178.56	0.01	-0.22		132.78	4975.55	37.47

Table A-2 Car data simulator of driver No.2 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1 ↕ 5	18.73	25.13	3.52	0.82			
6	26.88	29.32	4.19	0.75			
7	36.26	33.74	4.42	0.69			
8 ↕ 63	1256.02	96.98	0.17				
64 ↕ 68	1385.44	89.59	-1.41		76.06	235.73	3.09
69 ↕ 82	1654.46	49.65	-2.02		194.28	1101.78	5.67
83	1668.37	50.03	0.38				
84	1682.56	51.04	1.01				
85	1697.03	52.07	1.03				
86	1711.84	53.25	1.18				
87	1727.01	54.6	1.35				
88 . . . 335	8095.81	33.63	-15.3		188.57	4711.08	24.98

Table A-3 Car data simulator of driver No.3 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.03	0.09	0.08	156.84			
3	2.03	7.2	7.11	2.42			
4	7.22	18.67	11.47	1.06			
5	14.78	27.19	8.52	0.79			
6	24.90	36.42	9.23	0.62			
7	36.51	41.75	5.33	0.56			
8	49.65	47.26	5.51	0.49			
9	64.46	53.29	6.03	0.44			
10 ↕ 18	272.88	104.28	4.61	0			
19	303.0617	108.56	4.28	-0.04087			
20 ↕ 38	751.45	67.69	-0.08		388.35	799.39	2.06
39 ↕ 45	886.73	70.91	0.47				
46 . . . 396	8438.33	0.28	-10.55		224.63	4333.86	19.29

Table A-4 Car data simulator of driver No.4 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.37	1.32	1.31	10.62			
3 ↕ 9	19.04	16.92	3.96	2.12			
10 ↕ 37	427.31	75.72	0.05				
38 ↕ 43	551.76	72.42	-0.43		40.39	147.82	3.66
44 ↕ 60	950.53	96.65	1.17				
61 ↕ 69	1176.11	82.48	-1.91		171.79	798.39	4.65
70 ↕ 74	1293.23	85.7	0.71				
75 . . . 406	8404.41	0.34	-19.47		462.73	5145.47	11.12

Table A-5 Car data simulator of driver No.5 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.01	0.05	0.04	282.37			
3	0.86	3.06	3.01	5.79			
4	3.54	9.64	6.58	2.16			
5	8.43	17.57	7.93	1.33			
6 ↕ 14	120.92	66.59	5.62	0.40			
15 ↕ 28	460.65	97.94	0.95	-0.14			
29	487.93	98.13	0.19	-0.18			
30 ↕ 33	594.85	94.47	-0.33	-0.33	52.62	187.06	3.56
34 ↕ 39	746.63	87.25	-0.74		99.32	703.65	7.08
40 . . . 371	8054.76	0.2	-19.46		431.43	2819.84	6.54

Table A-6 Car data simulator of driver No.6 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.08	0.07	128.23			
2	0.77	2.76	2.68	5.04			
3	3.42	9.55	6.79	1.78			
4	8.52	18.33	8.78	1.06			
5	15.24	24.17	5.84	0.89			
6 ↕ 13	130.37	75.28	6.97	0.27			
14 ↕ 25	354.17	55.72	-0.93	0.08	179.38	608.60	3.39
26 ↕ 40	649.04	87.94	2.7				
41	674.24	90.63	2.69				
42	700.14	93.18	2.55				
43 ↕ 58	1098.74	78.01	-0.51		290.10	1476.85	5.09
59 . . . 382	8136.38	0.01	-0.31		333.22	3714.98	11.145

Table A-7 Car data simulator of driver No.7 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.21	0.76	0.75	18.50			
3	2.69	8.93	8.17	1.93			
4	8.29	20.12	11.19	0.97			
5 ↕ 15	210.39	101.95	5.74	0.06			
16	240.07	106.77	4.82	0.01			
17	270.60	109.8	3.03	-0.03			
18 ↕ 23	439.38	93.68	-1.91	-0.28	108.1615	265.67	2.45
24	465.45	93.76	0.08	-0.32			
25 ↕ 41	941. 48	104.81	0.43				
42 ↕ 56	1299.54	70.11	-1.27		300.01	1817.98	6.06
57 . . . 376	8050.41	0.26	-19.55		171.53	1155.30	6.74

Table A-8 Car data simulator of driver No.8 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.49	1.76	1.75	7.95			
3	3.55	11.01	9.25	1.54			
4	9.58	21.71	10.7	0.88			
5	18.19	30.95	9.24	0.67			
6	28.85	38.36	7.41	0.56			
7 ↕ 29	680.55	136.4	1.85	-0.52			
30 ↕ 37	908.68	53.45	-1.82		153.29	149.94	9.78
38 ↕ 44	1017.18	53.92	-0.34		30.07	70.66	2.35
45	1032.48	55.03	1.11				
46	1048.11	56.22	1.19				
47 . . . 374	8181.29	0.05	-1.06		450.14	1949.79	4.33

Table A-9 Car data simulator of driver No.9 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0	0.01	0	1412.16			
3	1.39	5	4.99	3.52			
4	5.08	13.26	8.26	1.54			
5 ↕ 17	219.14	95.23	5.8	0.12			
18	247.06	100.42	5.19	0.07			
19	276.19	104.78	4.36	0.03			
20 ↕ 28	503.68	78.68	-2.18	-0.32	170.18	548.24	3.22
29	525.66	79.06	0.38	-0.35			
30	547.92	80.09	1.03	-0.37			
31	570.50	81.22	1.13	-0.39			
32	593.36	82.23	1.01	-0.42			
33	616.51	83.27	1.04	-0.45			
34 ↕ 47	922.37	67.88	-0.86		210.97	2376.67	11.27
48 . . . 388	8344.40	0.05	-5.61		523.06	2205.56	4.22

Table A-10 Car data simulator of driver No.10 easy level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	1.98	7.11	7.1	1.91			
3	7.13	18.54	11.43	0.86			
4	14.64	27	8.46	0.66			
5	24.72	36.26	9.26	0.52			
6	36.41	42.06	5.8	0.46			
7	49.91	48.55	6.49	0.40			
8	65.12	54.71	6.16	0.35			
9	82.25	61.65	6.94	0.29			
10 ↕ 20	374.05	119.08	4.03	-0.17			
21	408.15	122.63	3.55	-0.21			
22	443.18	126.04	3.41	-0.25			
23	479.07	129.08	3.04	-0.29			
24 ↕ 42	991.21	80.96	-0.16		440.78	757.91	1.72
43	1013.87	81.5	0.54				
44	1036.95	83.01	1.51				
45 . . . 353	8170.33	37.18	-6.25		229.59	908.34	3.96

2. Car data of medium level direction

Table A-11 Car data simulator of driver No.1 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.05	0.04	205.16			
2	1.59	5.71	5.66	2.39			
3 ↕ 14	173.04	85.3	5.22	0.15			
15 ↕ 17	196.91	85.86	0.56	0.11	22.72	86.47	3.81
18	220.21	83.84	-2.02	0.08			
19	242.94	81.73	-2.11	0.056			
20	311.58	82.75	0.52	-0.04			
21	334.76	83.38	0.63	-0.07			
22	358.09	83.95	0.57	-0.09			
23 ↕ 42	924.51	121.2	1.88				
43 ↕ 63	1468.93	68.36	-0.17		476.11	15734.32	33.05
64 . . . 426	9950.53	0.01	0		238.90	14897.26	62.36

Table A-12 Car data simulator of driver No.2 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.91	3.28	3.27	4.23			
3	3.99	11.09	7.81	1.52			
4	9.70	20.53	9.44	0.93			
5	17.33	27.44	6.91	0.76			
6	27.044	34.94	7.5	0.63			
7	38.19	40.13	5.19	0.56			
8	50.65	44.78	4.65	0.52			
9	64.77	50.8	6.02	0.46			
10 20	329.99	112.15	4.39	-0.07			
21	362.27	116.14	3.99	-0.11			
22	395.60	119.9	3.76	-0.15			
23	429.78	122.95	3.05	-0.19			
24 ↕ 38	862.91	88.91	-1.36		365.07	1547.43	4.24
39 . . . 451	9786.23	26.65	-31.6		264.02	3190.57	12.08

Table A-13 Car data simulator of driver No.3 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.37	1.35	1.34	10.38			
3	2.79	8.71	7.36	1.98			
4	7.68	17.57	8.86	1.12			
5	14.51	24.58	7.01	0.88			
6	23.35	31.78	7.2	0.73			
7	33.89	37.94	6.16	0.63			
8	45.71	42.48	4.54	0.58			
9	58.99	47.82	5.34	0.52			
10	73.89	53.57	5.75	0.46			
11 ↕ 25	478.76	126.61	2.99	-0.24			
26	514.74	129.44	2.83	-0.28			
27	551.44	132	2.56	-0.32			
28	588.83	134.51	2.51	-0.37			
29	626.92	136.98	2.47	-0.41			
30 ↕ 50	1276.56	79.12	-1.06		451.56	1403.99	3.11
51 . . . 459	10295.15	0.04	-2.93		233.27	2795.47	11.98

Table A-14 Car data simulator of driver No.4 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0	0.01	0	1412.16			
3	0.01	0.03	0.02	599.45			
4	1.12	3.99	3.96	5.39			
5	4.19	11.04	7.05	2.22			
6 ↕ 15	128.67	69.18	5.16	0.41			
16	149.4	74.58	5.4	0.36			
17	171.59	79.83	5.25	0.31			
18	195.33	85.39	5.56	0.25			
19	220.49	90.53	5.14	0.20			
20	247.03	95.42	4.89	0.16			
21 ↕ 29	470.36	83.86	-0.11	-0.15	169.45	358.31	2.11
30 . . . 469	10793.4	0	-0.04		271.78	1714.08	6.31

Table A-15 Car data simulator of driver No.5 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.41	1.49	1.48	9.40			
3	2.22	6.49	5	2.68			
4	4.45	8.02	1.53	2.57			
5	8.09	13.11	5.09	1.789			
6	14.01	21.27	8.16	1.21			
7	21.78	27.97	6.7	0.98			
8	31.52	35.04	7.07	0.81			
9	42.48674	39.44	4.4	0.74			
10	54.52414	43.3	3.86	0.69			
11 ↕ 25	411.19	117.93	3.88	-0.096			
26	444.94	121.39	3.46	-0.14			
27	479.57	124.58	3.19	-0.18			
28	515.06	127.63	3.05	-0.22			
29	551.06	129.51	1.88	-0.27			
30 ↕ 44	1029.78	94.1	-0.78		294.92	1004.33	3.41
45 . . . 471	10841.09	0.37	-31.49		499.88	1702.22	3.41

Table A-16 Car data simulator of driver No.6 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0	0.01	0	1412.16			
3	1.12	4.01	4	4.41			
4	4.32	11.52	7.51	1.79			
5	9.84	19.85	8.33	1.16			
6	17.12	26.18	6.33	0.95			
7	26.29	33.02	6.84	0.79			
8	36.98	38.44	5.42	0.70			
9	48.81	42.55	4.11	0.65			
10	62.04	47.6	5.05	0.58			
11	76.78	53	5.4	0.52			
12	93.22	59.16	6.16	0.45			
13	111.42	65.44	6.28	0.39			
14	131.07	70.71	5.27	0.34			
15 ↕ 40	1022.53	154.33	1.72				
41 ↕ 54	1521.32	101.21	-2.07		413.33	1921.75	4.65
55 . . . 470	10740.88	0.01	-0.31		263.27	1566.91	5.95

Table A-17 Car data simulator of driver No.7 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.58	2.08	2.07	6.71			
3	3.14	9.23	7.15	1.85			
4	8.19	18.17	8.94	1.08			
5	14.97	24.37	6.2	0.88			
6 ↕ 15	169.22	80.28	5.55	0.22			
16 ↕ 40	1058.18	155.76	1.53				
41 ↕ 57	1606.52	89.6	-0.67		461.88	2135.95	4.62
58 ↕ 85	2070.01	34.1	-1.88		413.22	15190.58	36.76
86 . . . 435	10604.77	0.25	-14.62		510.12	1392.85	2.73

Table A-18 Car data simulator of driver No.8 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.16	0.59	0.58	23.86			
3	2.05	6.77	6.18	2.57			
4	6.22	15.01	8.24	1.34			
5	12.32	21.93	6.92	1.02			
6	19.68	26.49	4.56	0.91			
7	28.29	30.97	4.48	0.83			
8	38.07	35.18	4.21	0.76			
9 ↕ 20	263.05	96.49	5.11	0.11			
21 ↕ 23	344.64	96.09	-1.73	-0.01	26.71	96.39	3.61
24 ↕ 30	556.65	119.94	3.35	-0.27			
31 ↕ 52	1190.34	76.33	-1.64		456.50	6535.87	14.32
53 . . . 454	10907.98	0	-0.3		400.21	3905.17	9.76

Table A-19 Car data simulator of driver No.9 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0	0.01	0	1412.16			
3	1.36	4.89	4.88	3.60			
4	5.01	13.11	8.22	1.56			
5	10.92	21.26	8.15	1.07			
6 ↕ 20	286.14	102.62	4.17	0.04			
21	315.68	106.26	3.64	-0.01			
22	346.34	110.27	4.01	-0.04			
23	378.07	114.13	3.86	-0.09			
24	410.82	117.81	3.68	-0.13			
25	444.53	121.28	3.47	-0.17			
26	479.09	124.31	3.03	-0.21			
27	514.46	127.24	2.93	-0.25			
28	550.56	129.85	2.61	-0.29			
29	587.33	132.26	2.41	-0.34			
30 . . . 441	10661.09	0.2	-23.57		257.34	1328.96	5.16

Table A-20 Car data simulator of driver No.10 medium level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.62	2.23	2.22	6.26			
3	3.24	9.41	7.18	1.82			
4	8.22	17.94	8.53	1.09			
5	14.89	23.99	6.05	0.89			
6	23.55	31.14	7.15	0.74			
7	33.95	37.42	6.28	0.64			
8	45.39	41.13	3.71	0.60			
9	58.16	45.95	4.82	0.54			
10 ↕ 20	294.11	101.38	4.21	0.02			
21	323.44	105.5	4.12	-0.02			
22	353.82	109.3	3.8	-0.06			
23	385.29	113.2	3.9	-0.10			
24	417.75	116.73	3.53	-0.15			
25	451.18	120.27	3.54	-0.19			
26 ↕ 38	833.06	92.54	-1.21		313.67	1770.94	5.65
39 . . . 453	10720.9	0.01	0		121.36	1400.41	11.54

3. Car data of difficulty level direction

Table A-21 Car data simulator of driver No.1 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	1.21	1.2	8.48			
2	2.25	8.09	6.88	1.67			
3	6.76	16.21	8.12	0.99			
4	13.08	22.75	6.54	0.80			
5	21.24	29.34	6.59	0.68			
6	31.20	35.85	6.51	0.58			
7	42.39	40.23	4.38	0.54			
8	54.79	44.62	4.39	0.49			
9	68.59	49.66	5.04	0.45			
10 ↕ 20	319.09	105.81	4.11	-0.05			
21	349.62	109.83	4.02	-0.09			
22	381.18	113.5	3.67	-0.13			
23	413.71	117.01	3.51	-0.17			
24	447.21	120.52	3.51	-0.21			
25 ↕ 35	785.76	97.88	-1.12		234.87	784.99	3.34
36 . . . 470	10295.5	0.01	-0.21		8.67	307.24	35.45

Table A-22 Car data simulator of driver No.2 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	4.14	4.13	2.48			
2	3.25	11.68	7.54	1.13			
3	9.01	20.7	9.02	0.75			
4	16.47	26.86	6.16	0.64			
5	25.93	34.05	7.19	0.54			
6 ↕ 20	344.58	110.81	3.99	-0.11			
21	376.45	114.65	3.84	-0.15			
22	409.33	118.26	3.61	-0.19			
23 ↕ 25	509.00	118.61	-0.39	-0.32	32.97	24.13	1.37
26	542.24	119.58	0.97	-0.37			
27	575.86	120.93	1.35	-0.41			
28	609.88	122.36	1.43	-0.45			
29 ↕ 34	802.48	105.12	-3.84		123.69	879.29	7.11
35 . . . 476	10065.32	0.22	-13.52		85.79	9907.35	115.48

Table A-23 Car data simulator of driver No.3 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	1.39	4.99	4.98	2.75			
3	4.93	12.73	7.74	1.31			
4	10.71	20.79	8.06	0.91			
5	18.20	26.97	6.18	0.77			
6	27.69	34.15	7.18	0.64			
7	38.51	38.89	4.74	0.58			
8	50.56	43.34	4.45	0.54			
9	63.96	48.2	4.86	0.49			
10 ↕ 20	312.19	105.44	3.89	-0.03			
21	342.63	109.47	4.03	-0.07			
22	374.15	113.36	3.89	-0.11			
23	406.64	116.88	3.52	-0.15			
24	440.11	120.41	3.53	-0.19			
25 ↕ 44	955.15	70.76	-2.02		447.71	1244.76	2.78
45 . . . 531	10259.43	0.24	-19.84		33.08	3710.62	112.16

Table A-24 Car data simulator of driver No.4 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	1.74	6.27	6.26	2.18			
3	6.04	15.46	9.19	1.05			
4	12.49	23.19	7.73	0.79			
5	21.01	30.65	7.46	0.65			
6	31.46	37.58	6.93	0.55			
7	43.22	42.31	4.73	0.51			
8	56.54	47.93	5.62	0.45			
9	71.66	54.37	6.44	0.39			
10 ↕ 25	514.01	128	2.29	-0.31			
26	549.86	128.94	0.94	-0.36			
27 ↕ 29	657.61	128.79	-0.2	-0.49	35.80	30.33	1.18
30 . . . 510	10094.65	20.58	-7.14		135.31	740.61	5.47

Table A-25 Car data simulator of driver No.5 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.55	1.99	1.98	7.019			
3	2.97	8.71	6.72	1.97			
4	7.71	17.03	8.32	1.16			
5	14.24	23.48	6.45	0.93			
6	22.74	30.58	7.1	0.76			
7	32.97	36.79	6.21	0.66			
8	44.29	40.73	3.94	0.6			
9	56.85	45.2	4.47	0.56			
10 ↕ 20	293.60	102.18	3.94	0.02			
21	323.09	106.06	3.88	-0.02			
22 ↕ 26	468.15	101.08	-1.43	-0.23	85.59	303.49	3.55
27 . . . 501	10405.8	0.01	-0.3		23.72	805.51	33.95

Table A-26 Car data simulator of driver No.6 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	1.99	1.98	5.15			
2	2.54	9.12	7.13	1.47			
3	7.42	17.57	8.45	0.91			
4	14.15	24.22	6.65	0.74			
5	22.77	30.99	6.77	0.63			
6 ↕ 15	192.29	85.66	5.24	0.13			
16	217.46	90.5	4.84	0.08			
17	244.05	95.67	5.17	0.04			
18	271.88	100.11	4.44	0.03			
19	300.87	104.25	4.14	-0.04			
20 ↕ 40	1097.91	157.45	1.38				
41	1141.95	158.42	0.97				
42	1186.11	158.85	0.43				
43 ↕ 47	1350.79	66.06	-15.87		76.99	4124.01	53.56
48 . . . 478	10306.81	11.64	-19.53		42.34	737.02	17.41

Table A-27 Car data simulator of driver No.7 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.12	0.11	85.49			
2	1.66	5.96	5.84	2.29			
3	5.39	13.43	7.47	1.23			
4	11.31	21.31	7.88	0.87			
5	18.99	27.62	6.31	0.74			
6 ↕ 15	177.10	80.79	5.25	0.19			
16	201.10	86.34	5.55	0.14			
17	226.53	91.44	5.1	0.09			
18	253.29	96.27	4.83	0.06			
19	281.19	100.39	4.12	0.02			
20 ↕ 30	652.21	135.21	2.23	-0.44			
31 ↕ 44	1088.76	90.99	-1.22		360.15	264920.8	735.59
45 . . . 501	10354.39	9.38	-8.4		44.96	260.68	5.79

Table A-28 Car data simulator of driver No.8 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.8	0.79	12.82			
2	1.97	7.08	6.28	1.92			
3	6.10	14.87	7.79	1.09			
4	12.35	22.49	7.62	0.82			
5	20.43	29.04	6.55	0.69			
6 ↕ 20	319.93	106.59	4.09	-0.05			
21 ↕ 32	627.39	80.52	-1.81	-0.55	248.94	569.49	2.29
33	650.06	81.52	1	-0.57			
34	673.11	82.92	1.4				
35	696.53	84.22	1.3				
36	720.32	85.58	1.36				
37	744.48	86.91	1.33				
38 ↕ 42	860.17	79.22	-2.01		67.74	258.71	3.82
43 . . . 520	10309.95	0.2	-2.7		9.89	4216.32	425.91

Table A-29 Car data simulator of driver No.9 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	0.01	0	1025.82			
2	0.18	0.64	0.63	21.99			
3	2.19	7.26	6.62	2.39			
4	6.39	15.1	7.84	1.33			
5	12.53	22.06	6.96	1.01			
6 ↕ 15	159.89	77.28	5.2	0.26			
16	182.92	82.85	5.57	0.21			
17	207.49	88.36	5.51	0.16			
18	233.44	93.37	5.01	0.12			
19	260.68	97.97	4.6	0.07			
20 ↕ 35	821.92	144.68	2				
36	862.67	146.6	1.92				
37 ↕ 59	1584.46	87.55	-0.45		639.69	3809.79	5.95
60 . . . 487	10362.41	22.5	-4.74		171.72	676.78	3.94

Table A-30 Car data simulator of driver No.10 difficulty level direction.

Time (Sec)	Traveled Distance (m)	Speed (m/s)	Acceleration (m/s^2)	Headway (Sec)	Actual Brake Distance	Safe Brake Distance	Aggressiveness of Acceleration Change
1	0	1.08	1.07	9.49			
2	2.19	7.91	6.83	1.71			
3	6.79	16.52	8.61	0.97			
4	13.34	23.54	7.02	0.77			
5	21.74	30.24	6.7	0.65			
6	31.98	36.85	6.61	0.56			
7	43.39	41.05	4.2	0.52			
8	56.07	45.57	4.52	0.48			
9	70.26	51.05	5.48	0.42			
10	86.04	56.75	5.7	0.37			
11 ↕ 28	598.63	128.6	1.12	-0.40			
29 ↕ 43	1069.79	96.43	-2.02		399.05	8894.64	22.29
44 . . . 477	10156.81	52.55	-8.11		94.10	745.99	7.93

Graph of speed, acceleration and brake

1. Easy level direction

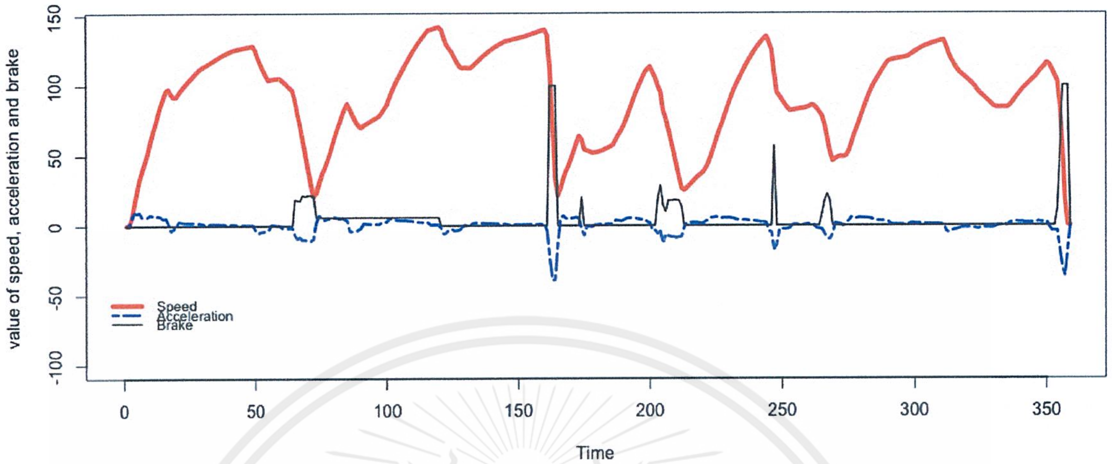

Figure A-1 graph of speed, acceleration and brake Driver No.1 easy level direction.

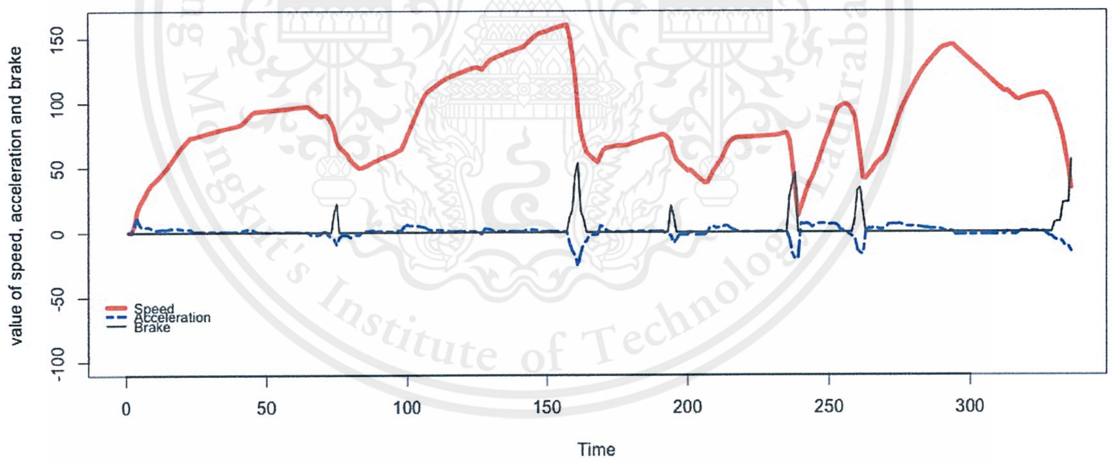

Figure A-2 graph of speed, acceleration and brake of driver No.2 easy level direction.

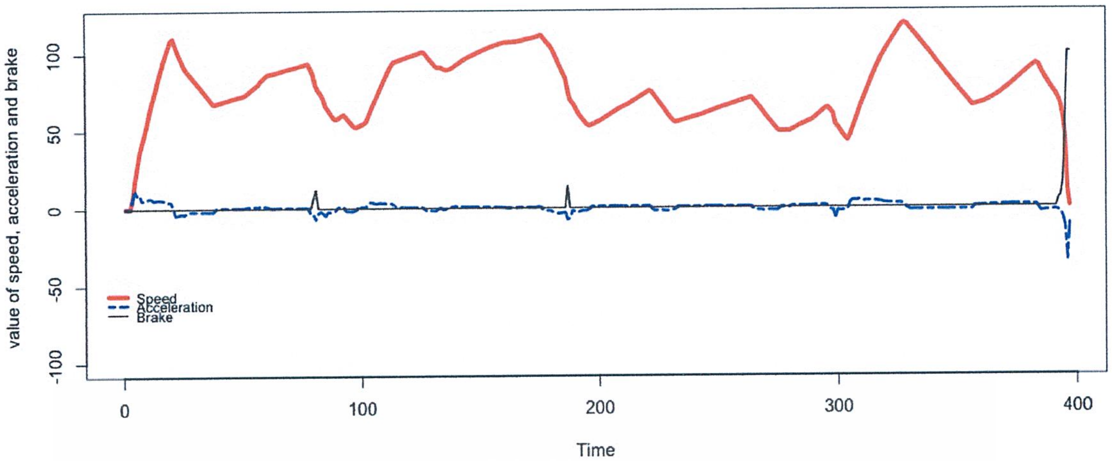

Figure A-3 graph of speed, acceleration and brake of driver No.3 easy level direction.

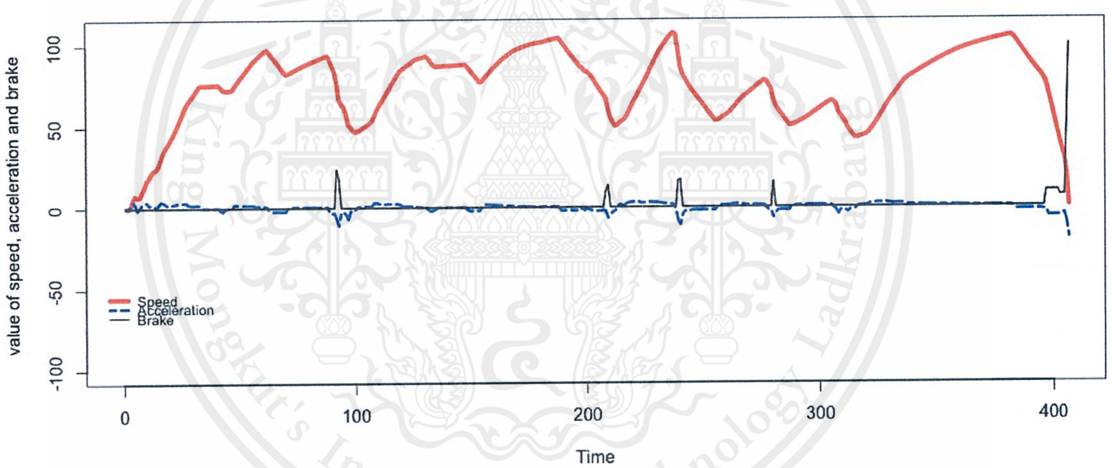

Figure A-4 graph of speed, acceleration and brake of driver No.4 easy level direction.

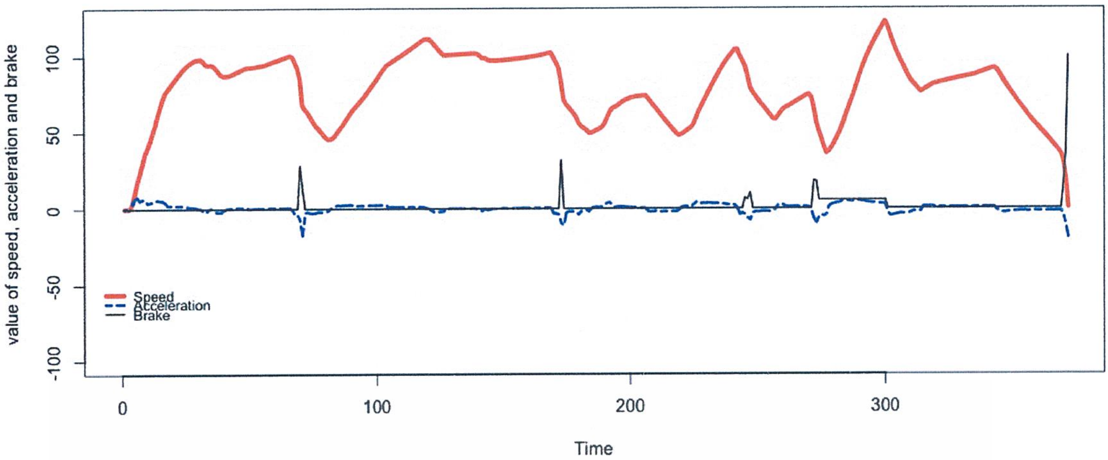

Figure A-5 graph of speed, acceleration and brake of driver No.5 easy level direction.

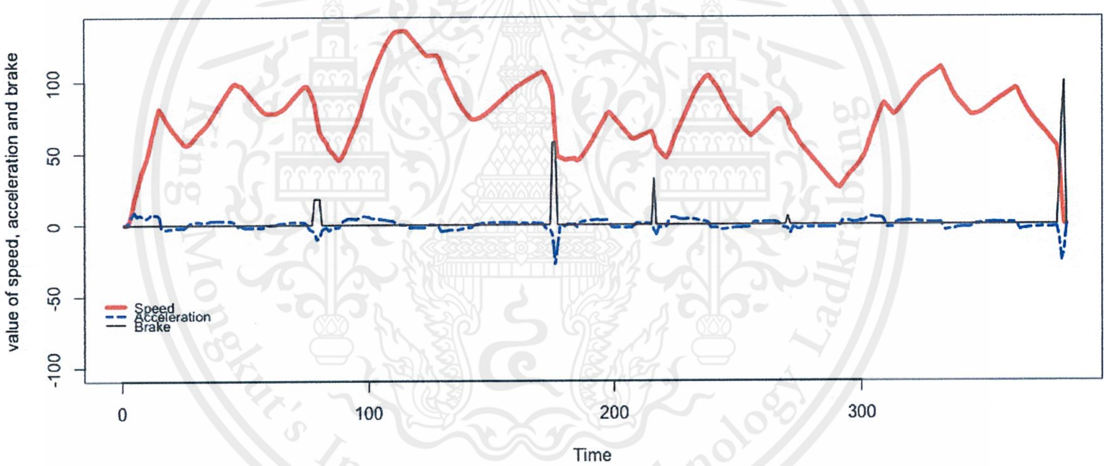

Figure A-6 graph of speed, acceleration and brake of driver No.6 easy level direction.

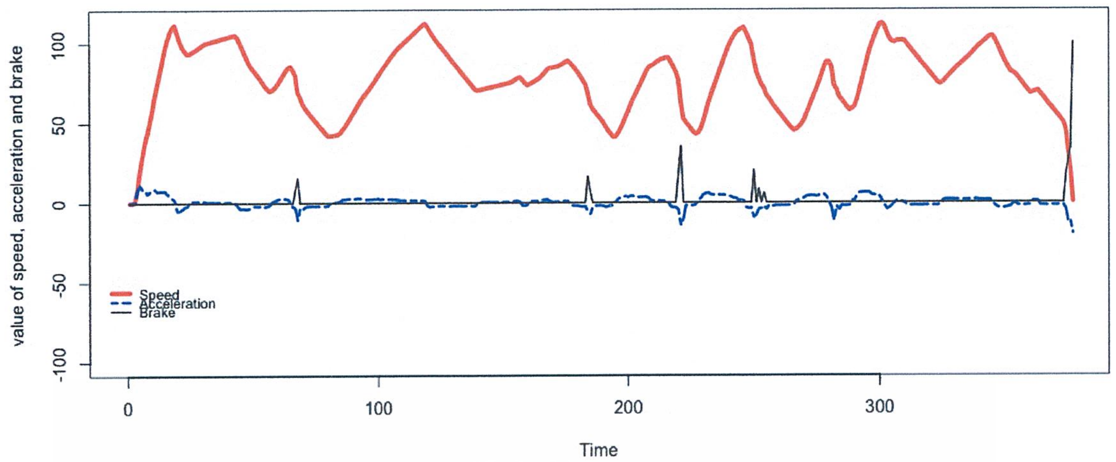

Figure A-7 graph of speed, acceleration and brake of driver No.7 easy level direction.

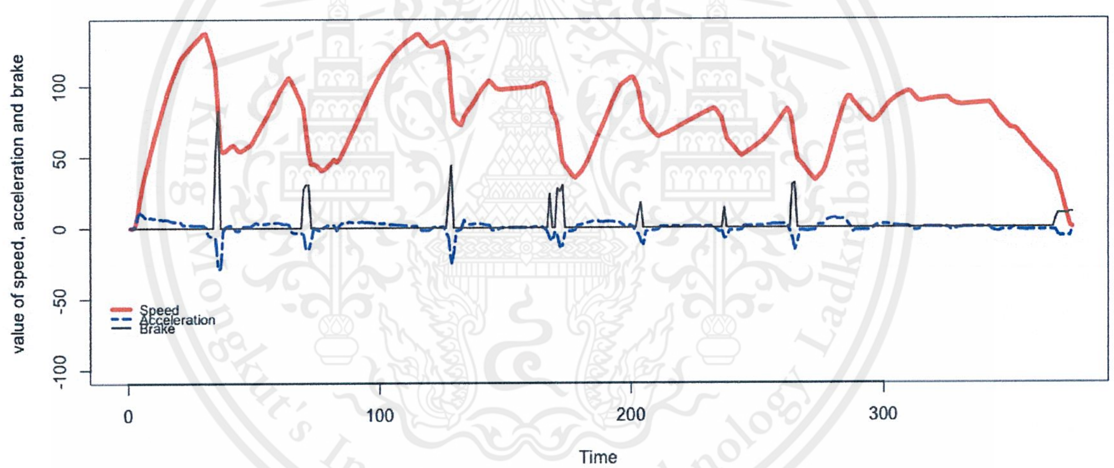

Figure A-8 graph of speed, acceleration and brake of driver No.8 easy level direction.

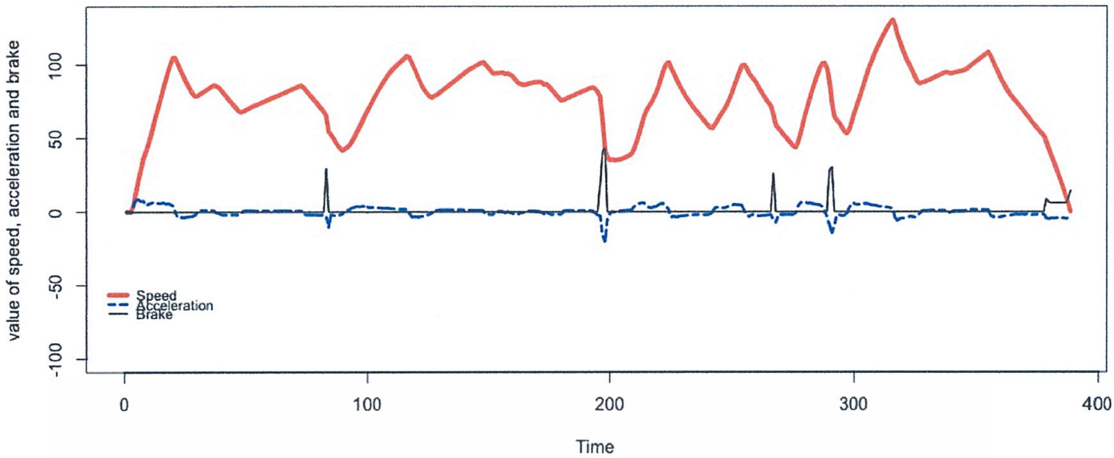

Figure A-9 graph of speed, acceleration and brake of driver No.9 easy level direction.

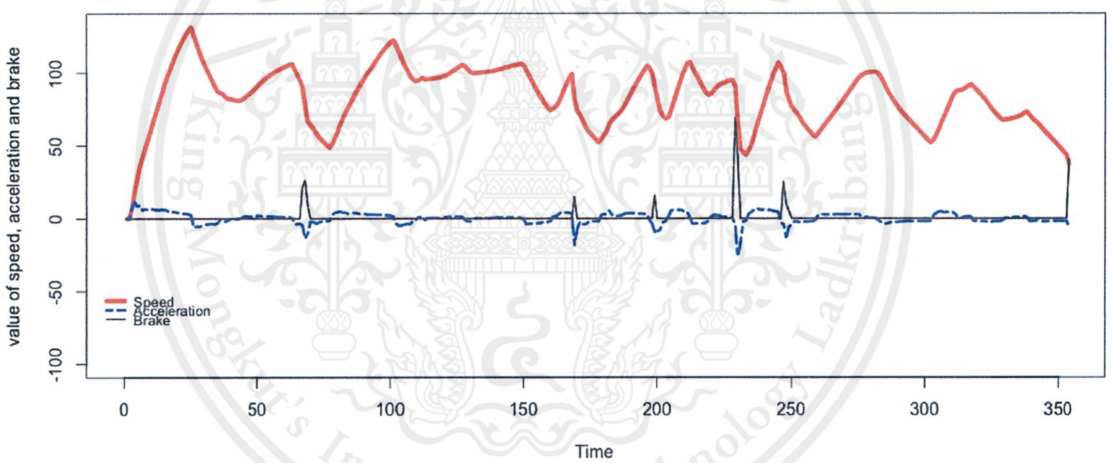

Figure A-10 graph of speed, acceleration and brake of driver No.10 easy level direction.

2. Medium level direction

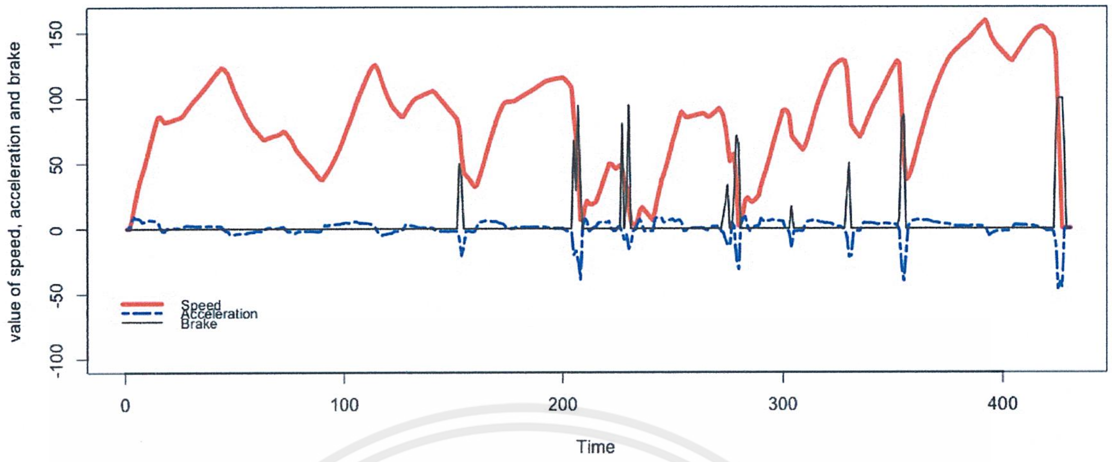

Figure A-11 graph of speed, acceleration and brake of driver No.1 medium level direction.

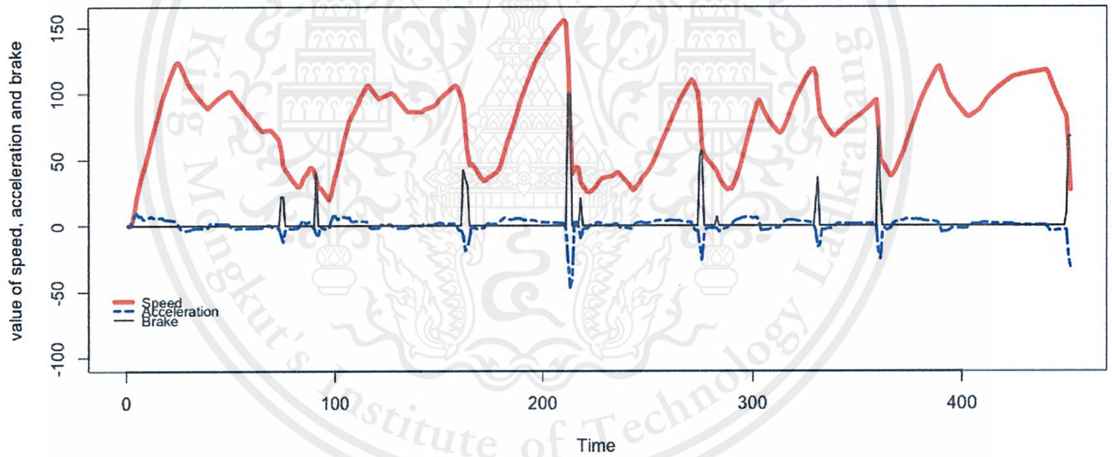

Figure A-12 graph of speed, acceleration and brake of driver No.2 medium level direction.

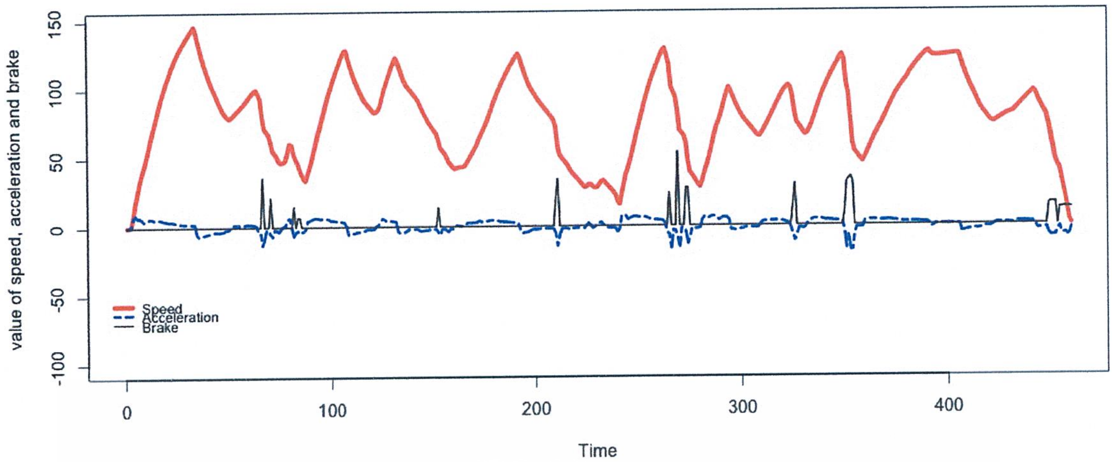

Figure A-13 graph of speed, acceleration and brake of driver No.3 medium level direction.

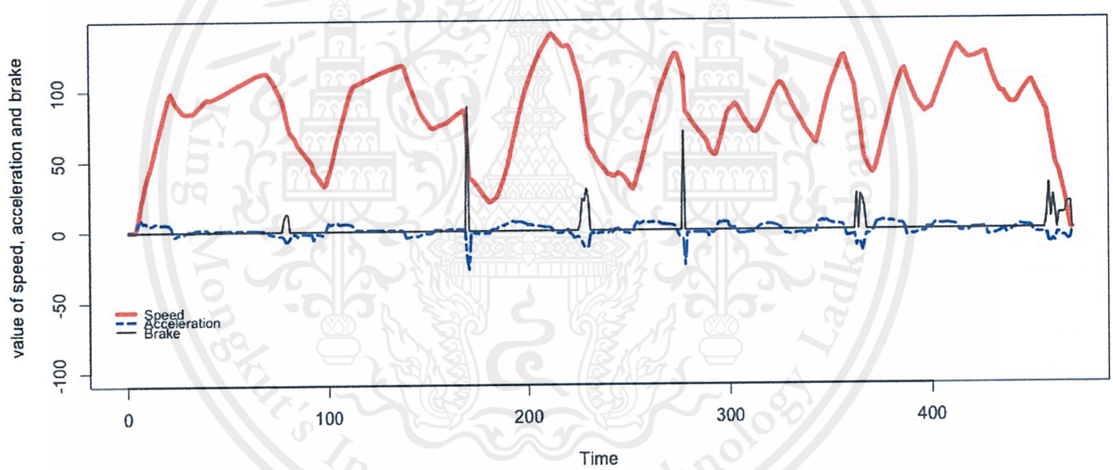

Figure A-14 graph of speed, acceleration and brake of driver No.4 medium level direction.

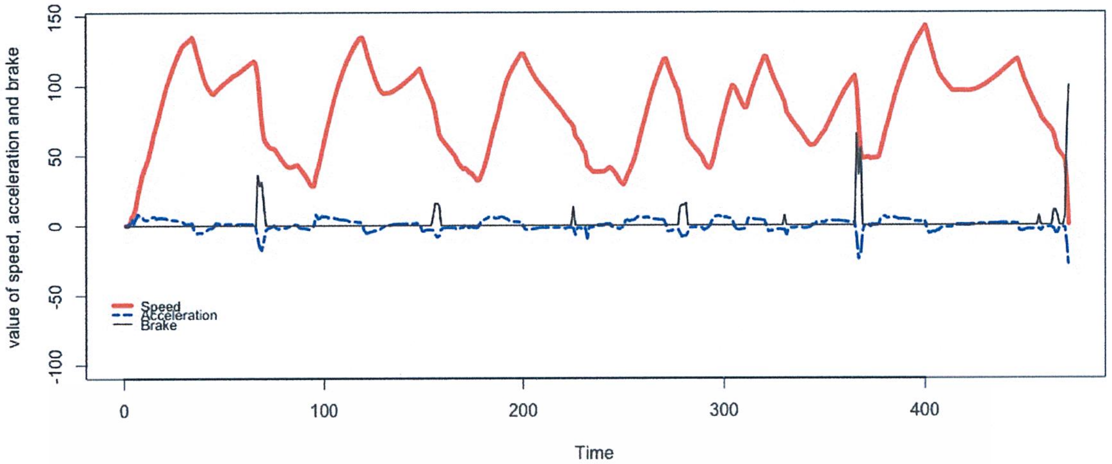

Figure A-15 graph of speed, acceleration and brake of driver No.5 medium level direction.

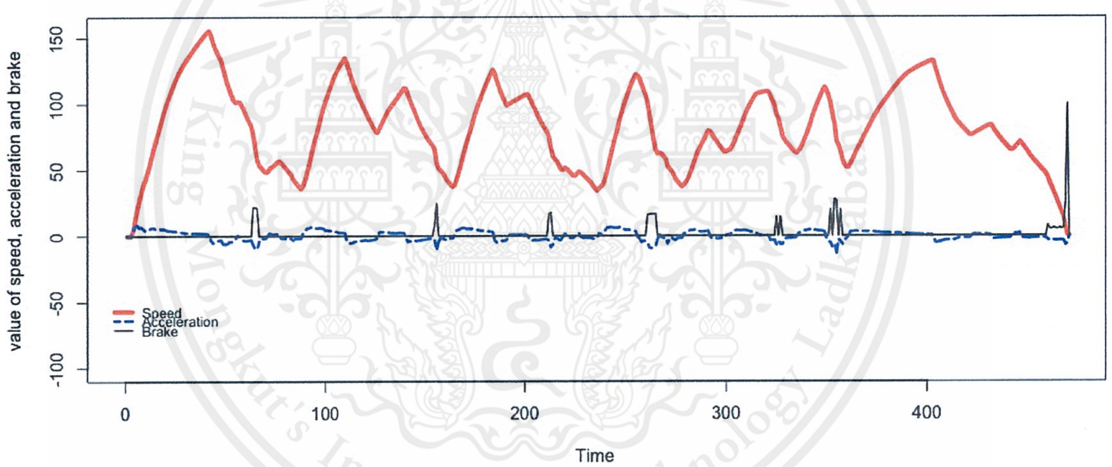

Figure A-16 graph of speed, acceleration and brake of driver No.6 medium level direction.

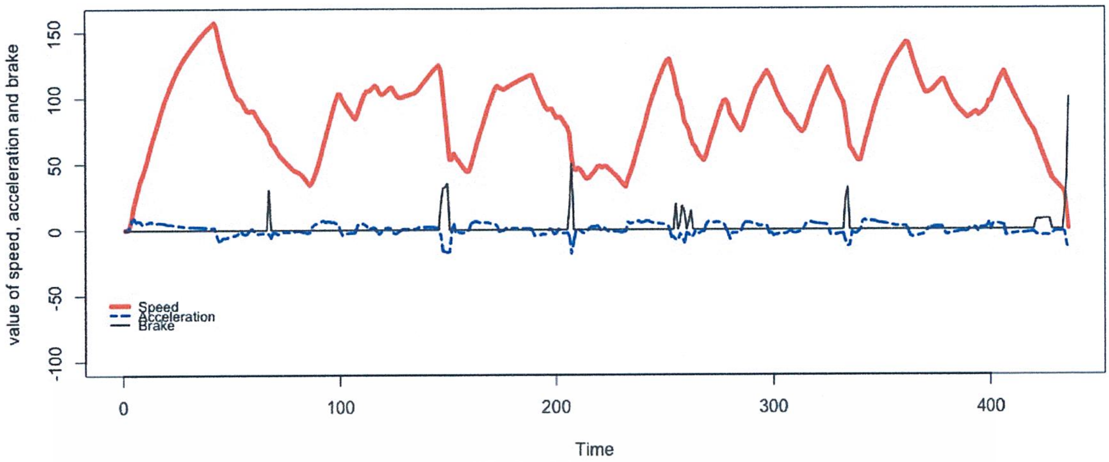

Figure A-17 graph of speed, acceleration and brake of driver No.7 medium level direction.

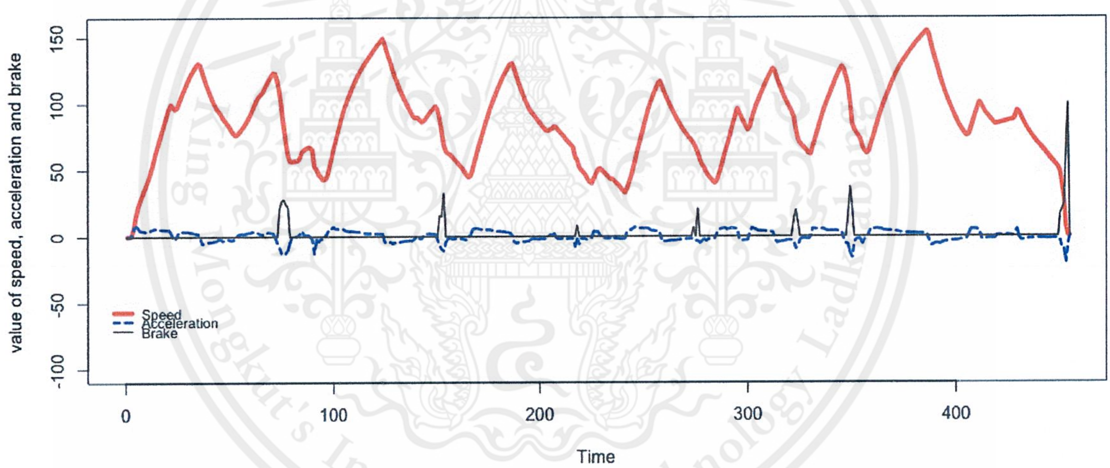

Figure A-18 graph of speed, acceleration and brake of driver No.8 medium level direction.

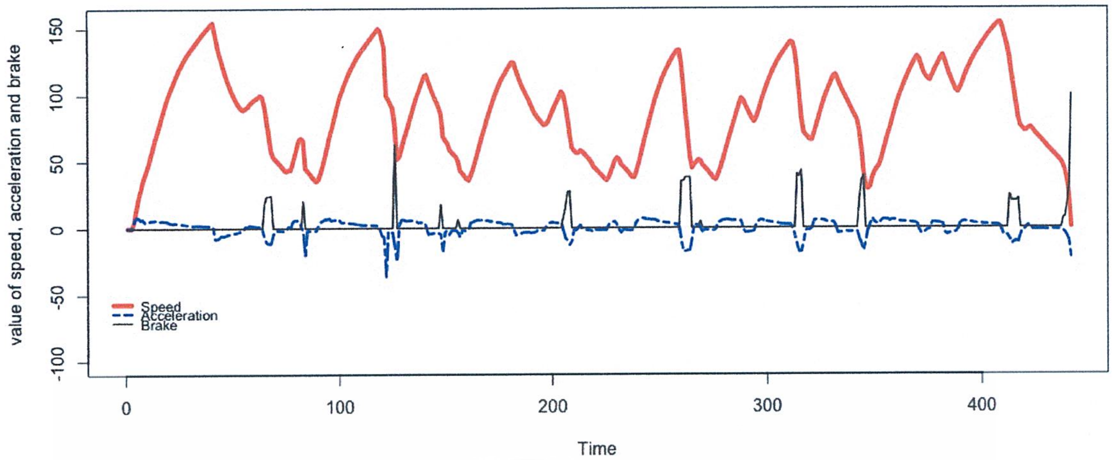

Figure A-19 graph of speed, acceleration and brake of driver No.9 medium level direction.

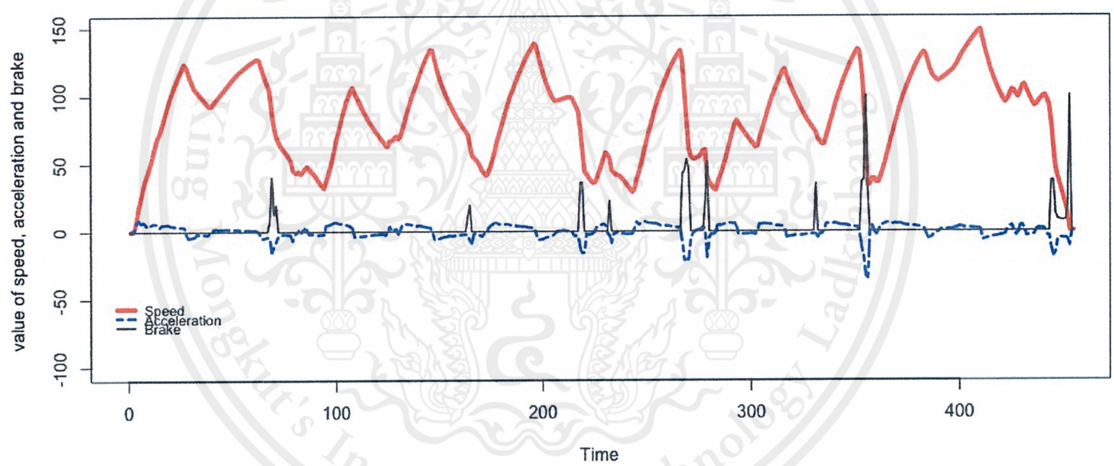

Figure A-20 graph of speed, acceleration and brake of driver No.10 medium level direction.

3. Difficulty level direction

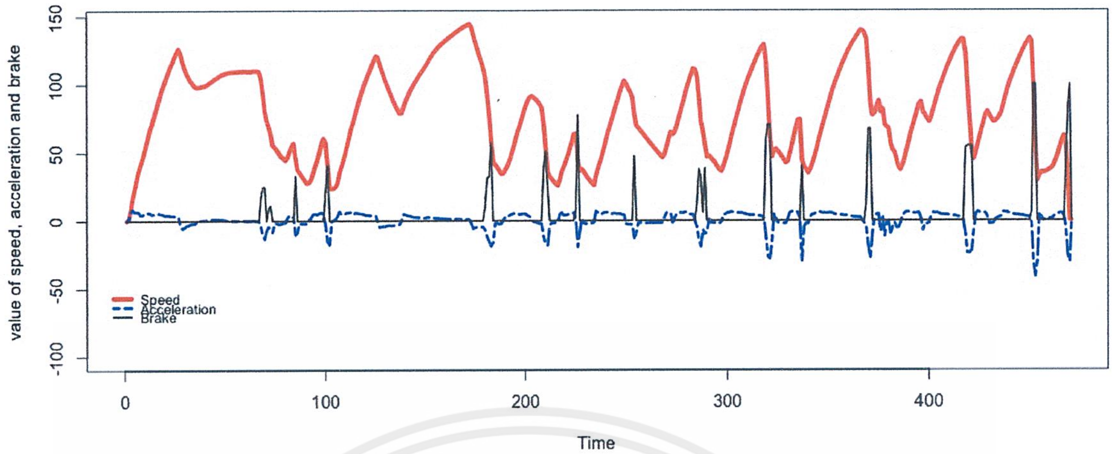

Figure A-21 graph of speed, acceleration and brake of driver No.1 difficulty level direction.

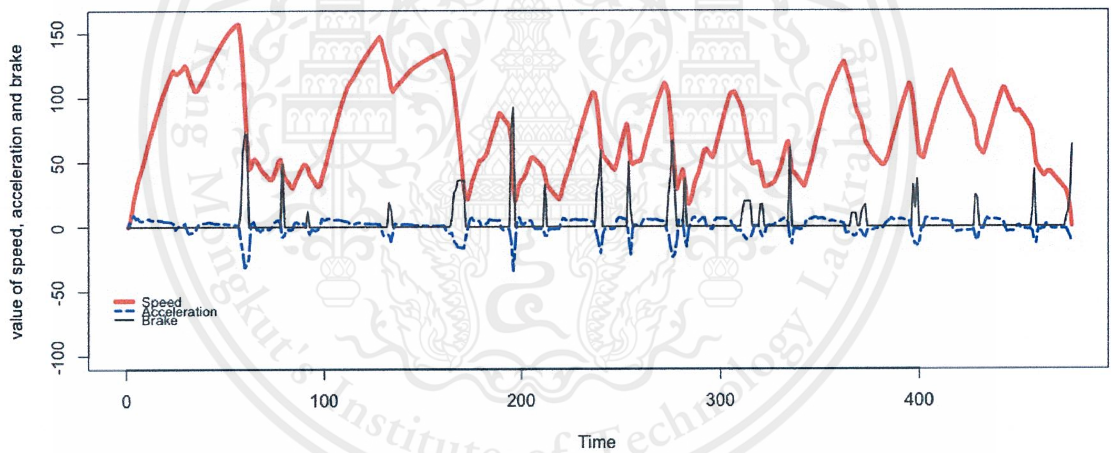

Figure A-22 graph of speed, acceleration and brake of driver No.2 difficulty level direction.

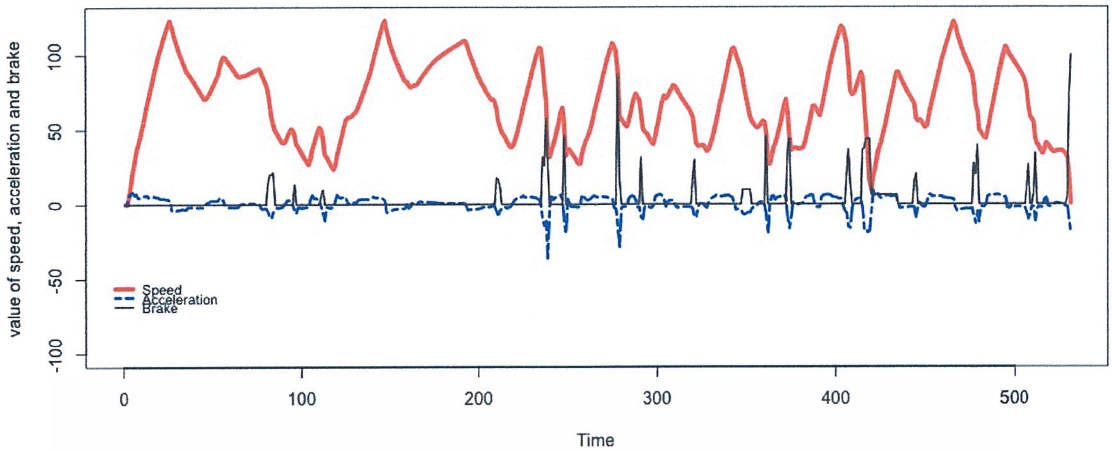

Figure A-23 graph of speed, acceleration and brake of driver No.3 difficulty level direction.

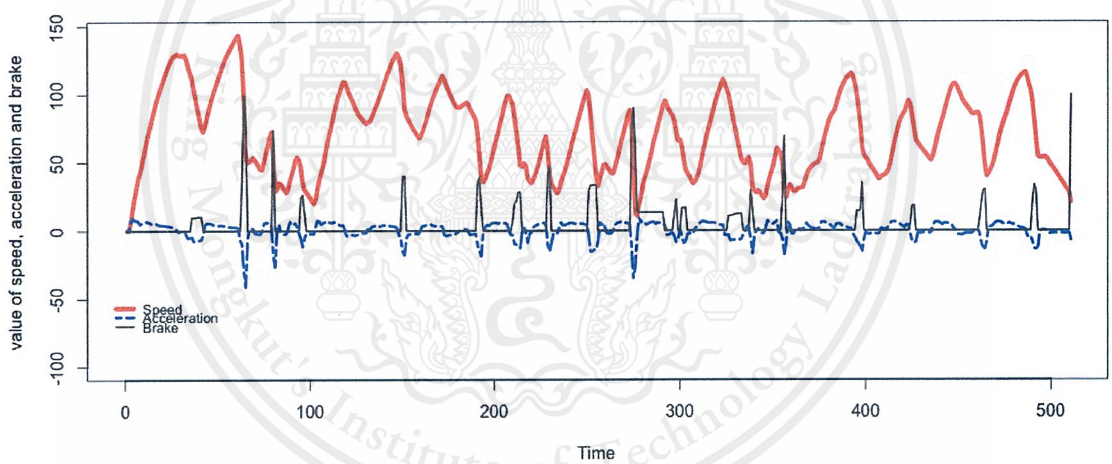

Figure A-24 graph of speed, acceleration and brake of driver No.4 difficulty level direction.

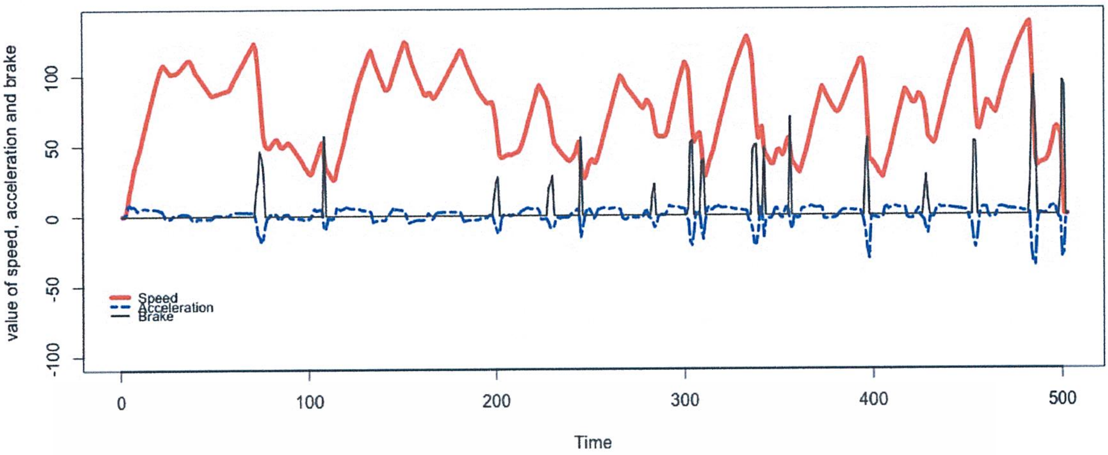

Figure A-25 graph of speed, acceleration and brake of driver No.5 difficulty level direction.

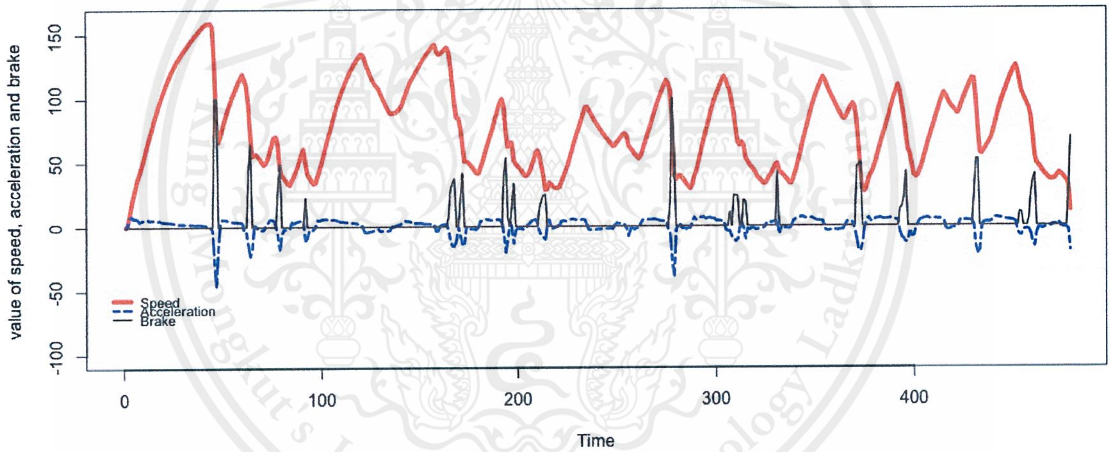

Figure A-26 graph of speed, acceleration and brake of driver No.6 difficulty level direction.

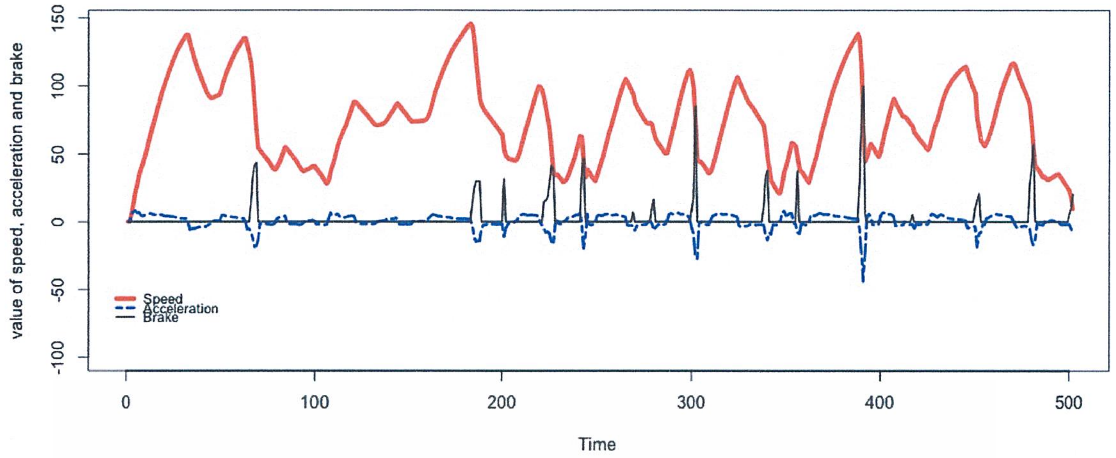

Figure A-27 graph of speed, acceleration and brake of driver No.7 difficulty level direction.

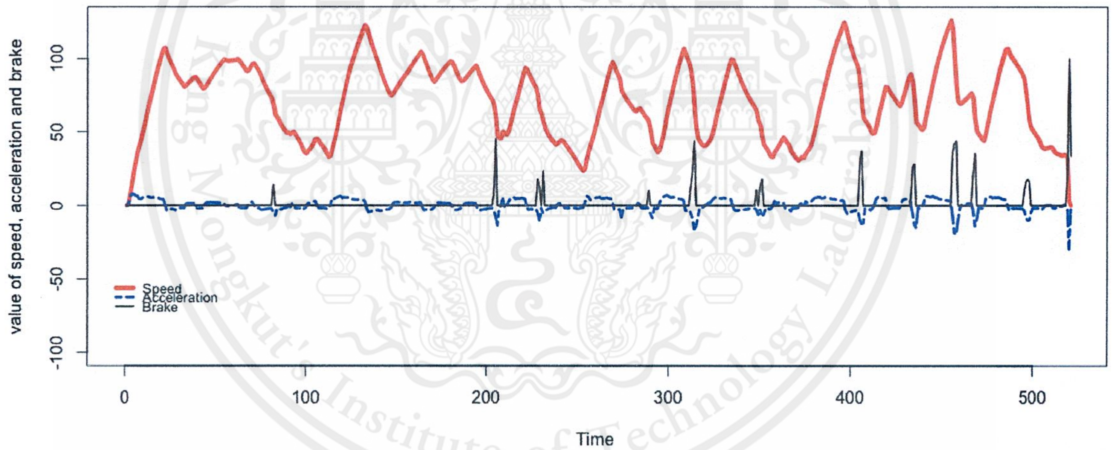

Figure A-28 graph of speed, acceleration and brake of driver No.8 difficulty level direction.

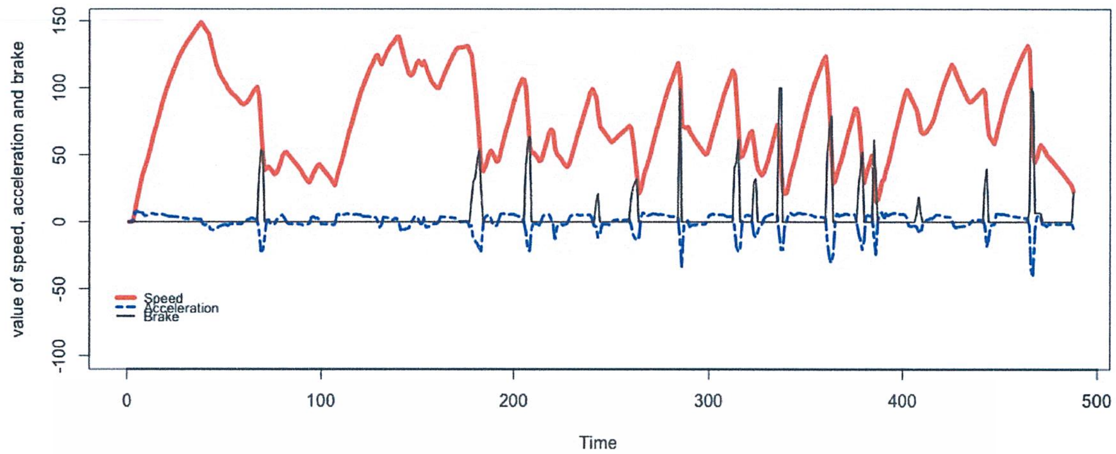

Figure A-29 graph of speed, acceleration and brake of driver No.9 difficulty level direction.

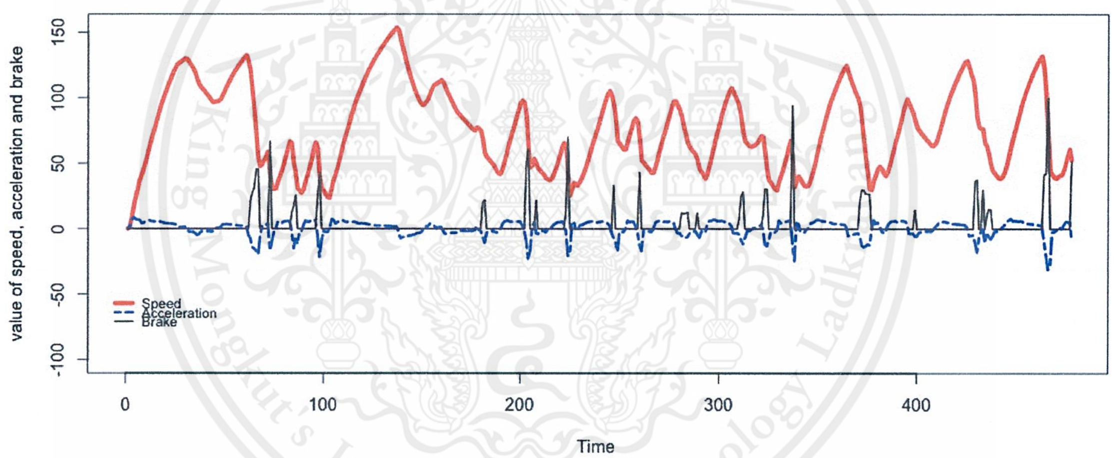

Figure A-30 graph of speed, acceleration and brake of driver No.10 difficulty level direction.

Radar Chart of car data from simulator

1. Easy level direction

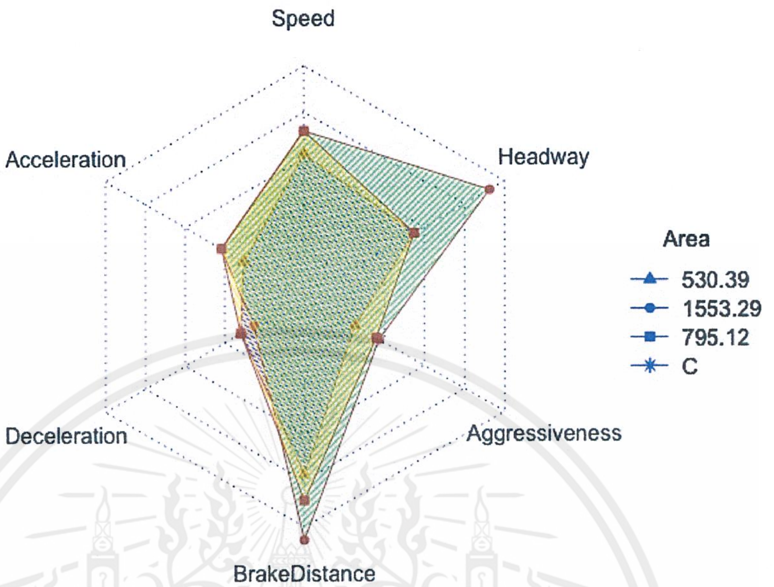

Figure A-31 Radar chart car data of driver No.1 in easy level direction.

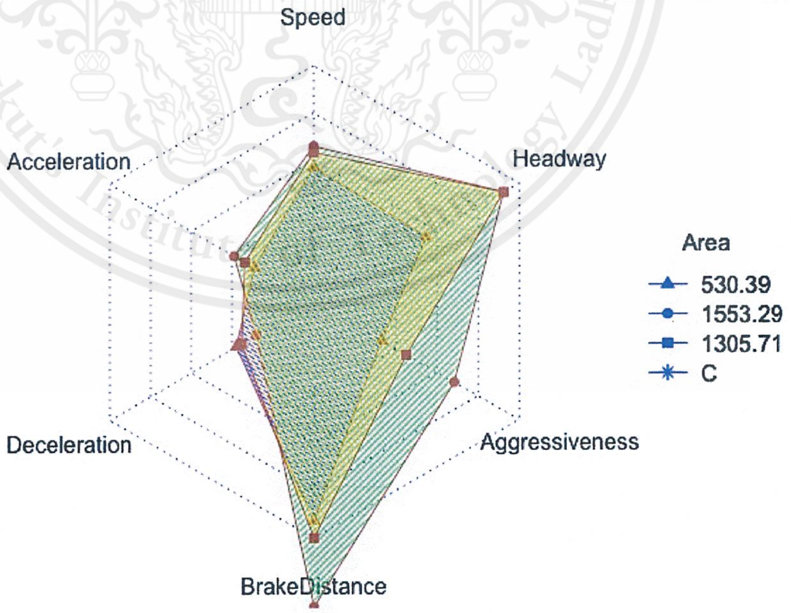

Figure A-32 Radar chart car data of driver No.2 in easy level direction.

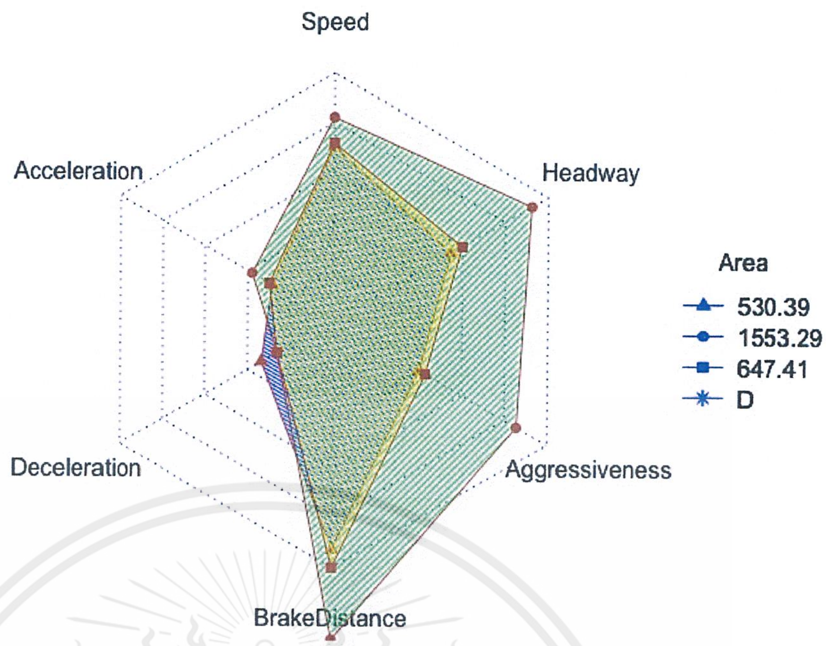

Figure A-33 Radar chart car data of driver No.3 in easy level direction.

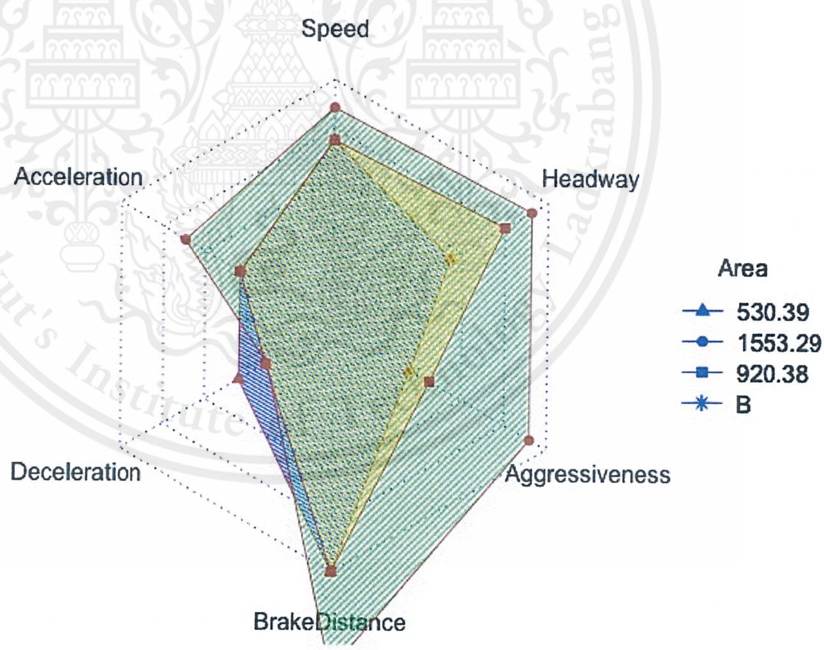

Figure A-34 Radar chart car data of driver No.4 in easy level direction.

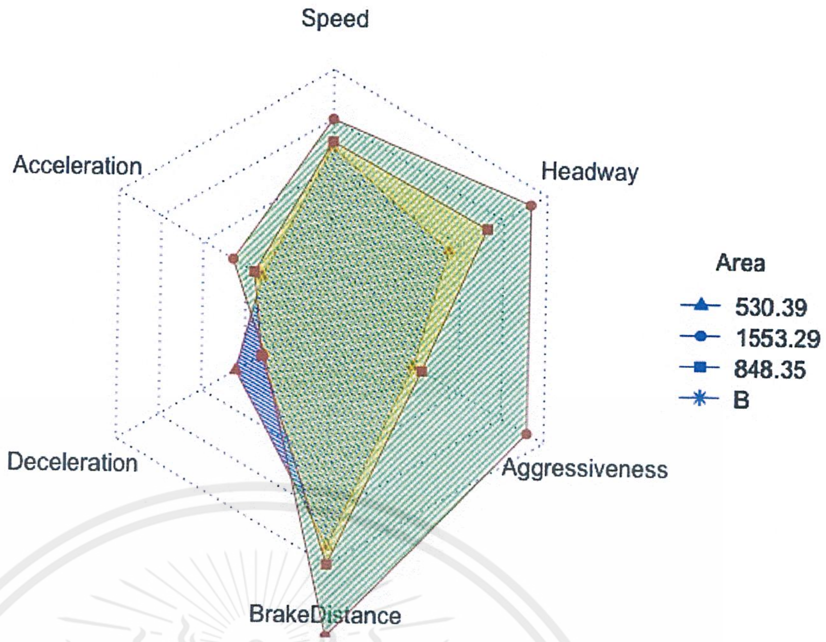

Figure A-35 Radar chart car data of driver No.5 in easy level direction.

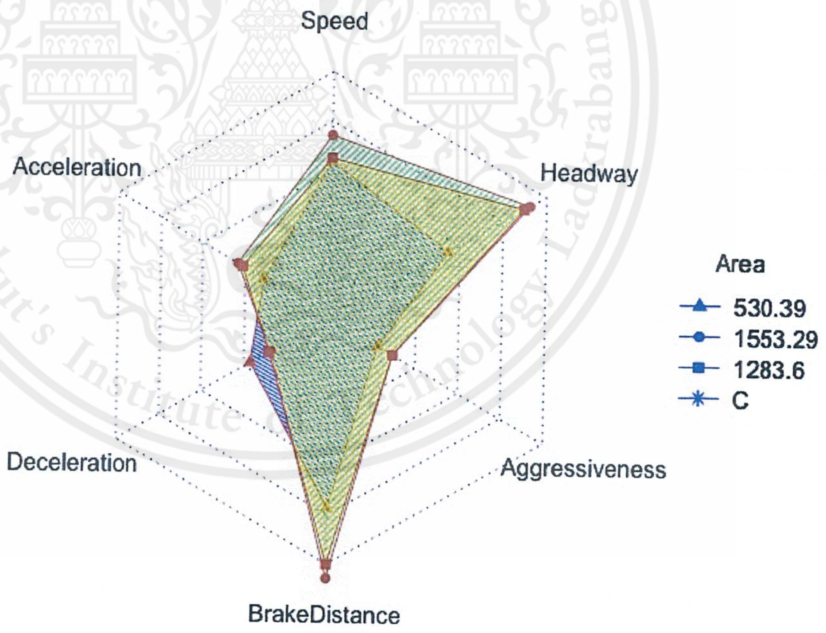

Figure A-36 Radar chart car data of driver No.6 in easy level direction.

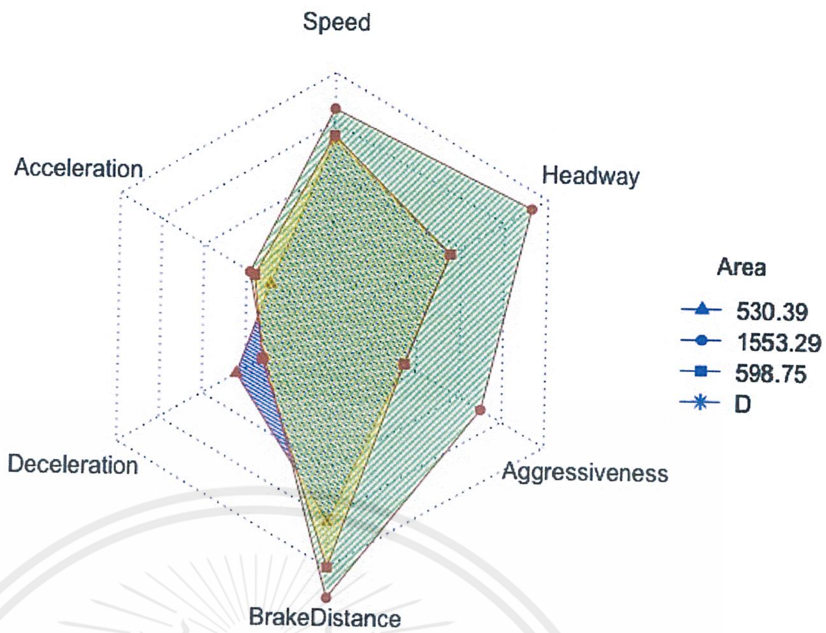

Figure A-37 Radar chart car data of driver No.7 in easy level direction.

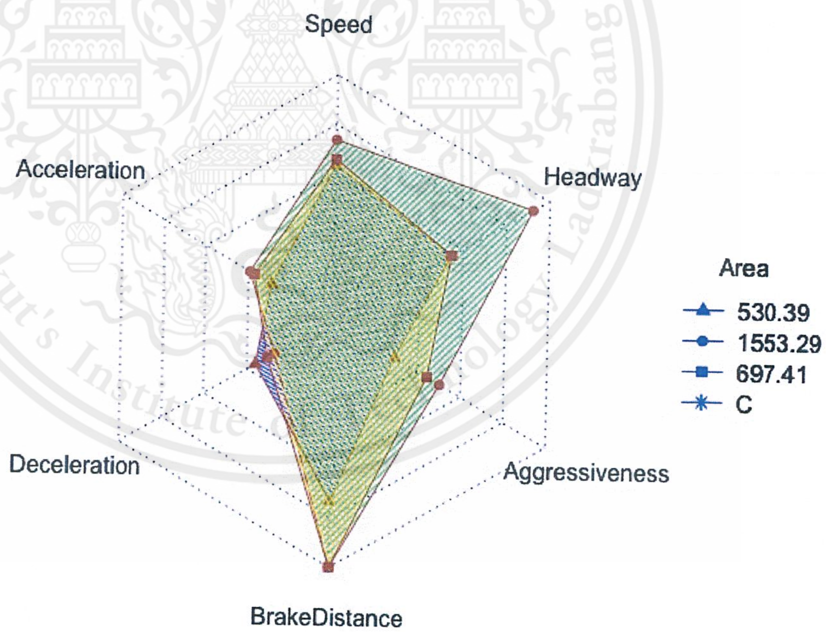

Figure A-38 Radar chart car data of driver No.8 in easy level direction.

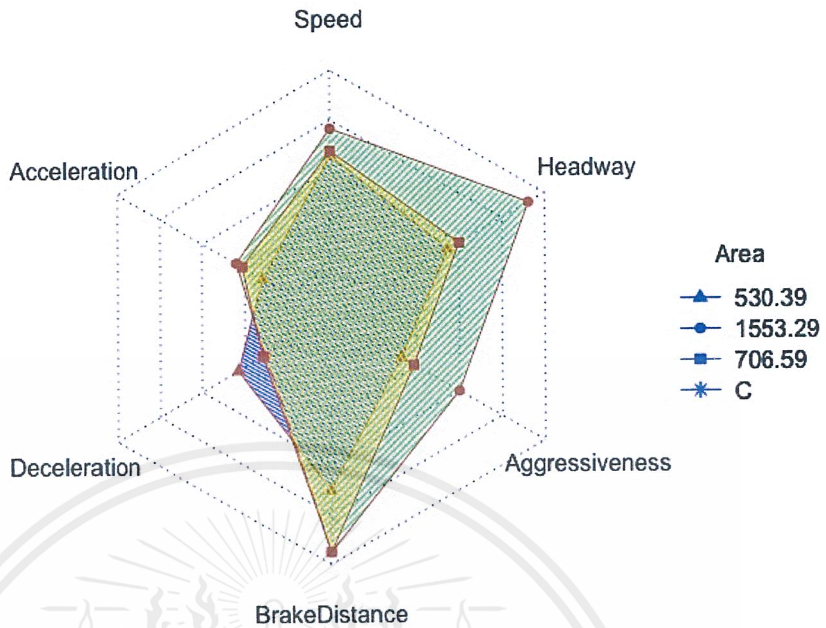

Figure A-39 Radar chart car data of driver No.9 in easy level direction.

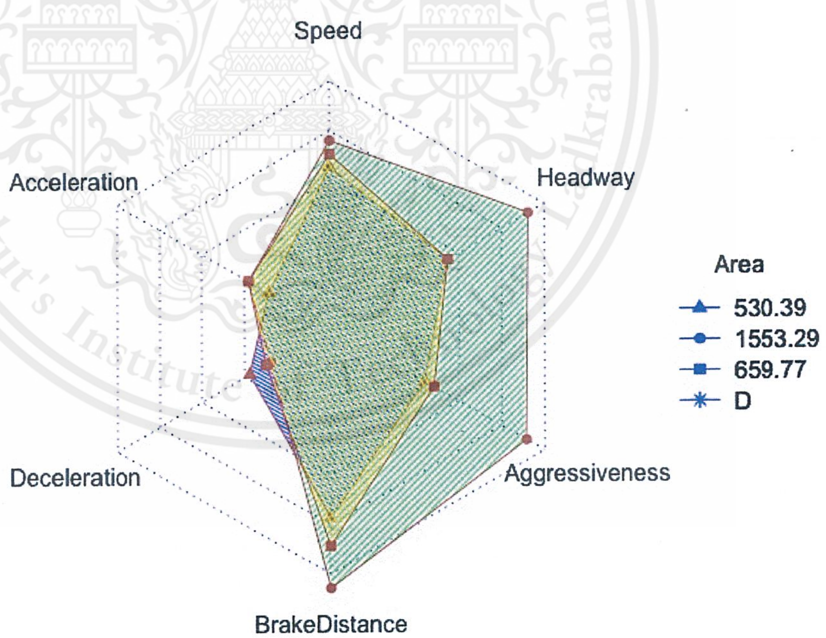

Figure A-40 Radar chart car data of driver No.10 in easy level direction.

2. Medium level direction

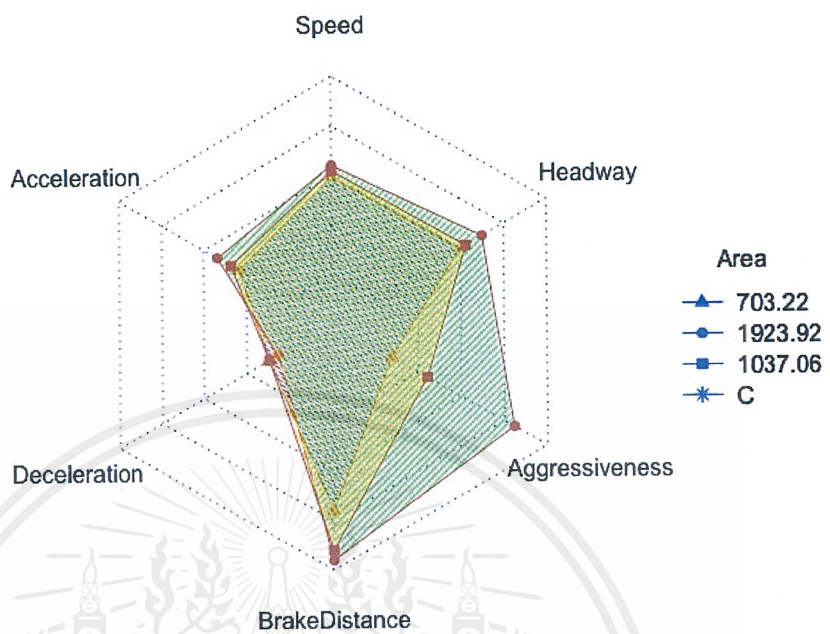

Figure A-41 Radar chart car data of driver No.1 in medium level direction.

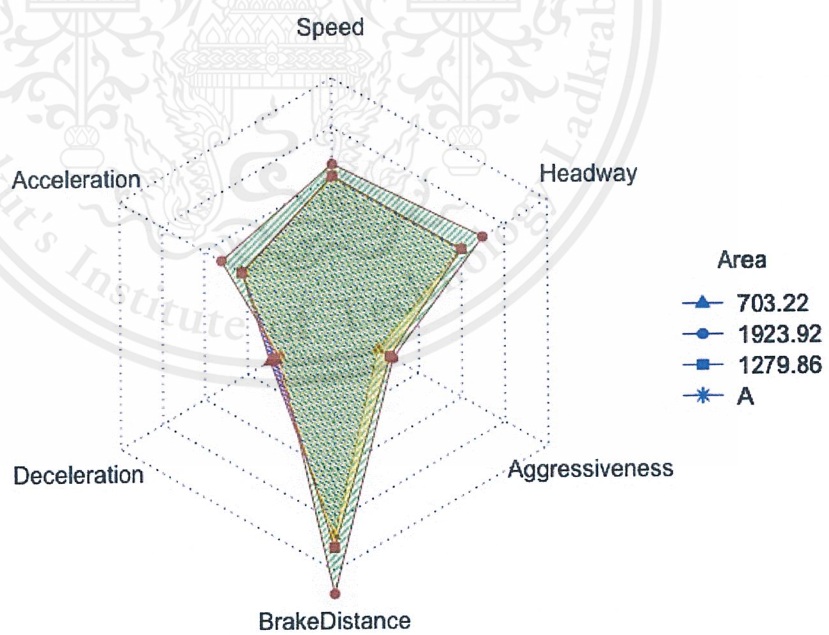

Figure A-42 Radar chart car data of driver No.2 in medium level direction.

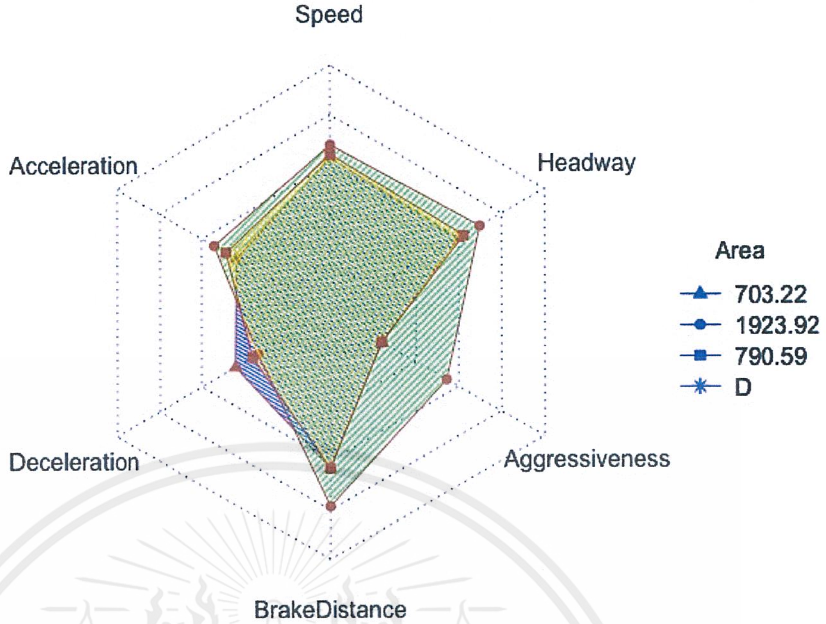

Figure A-43 Radar chart car data of driver No.3 in medium level direction.

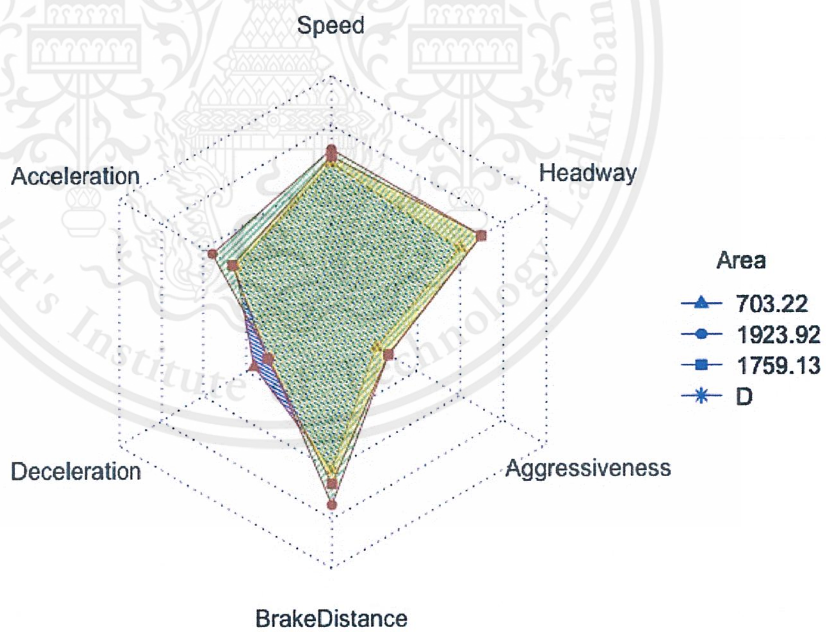

Figure A-44 Radar chart car data of driver No.4 in medium level direction.

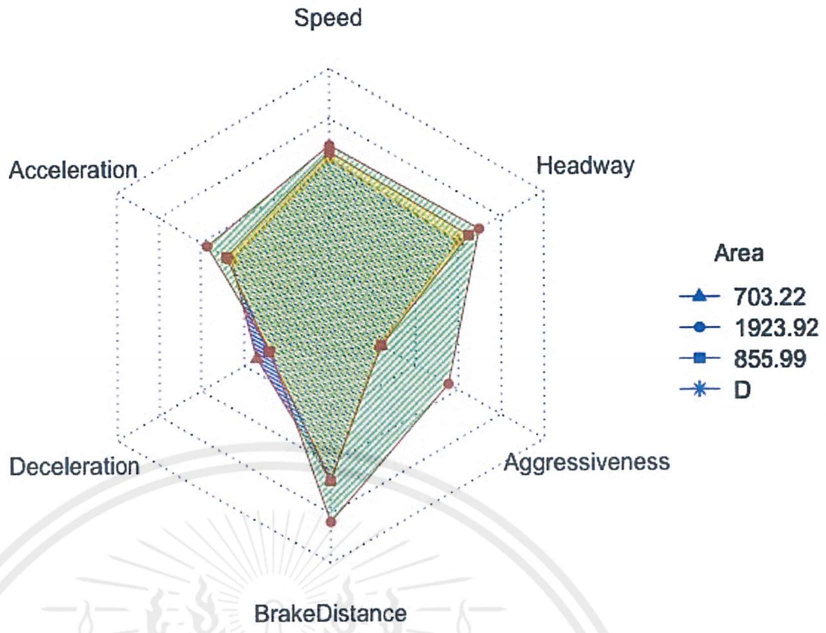

Figure A-45 Radar chart car data of driver No.5 in medium level direction.

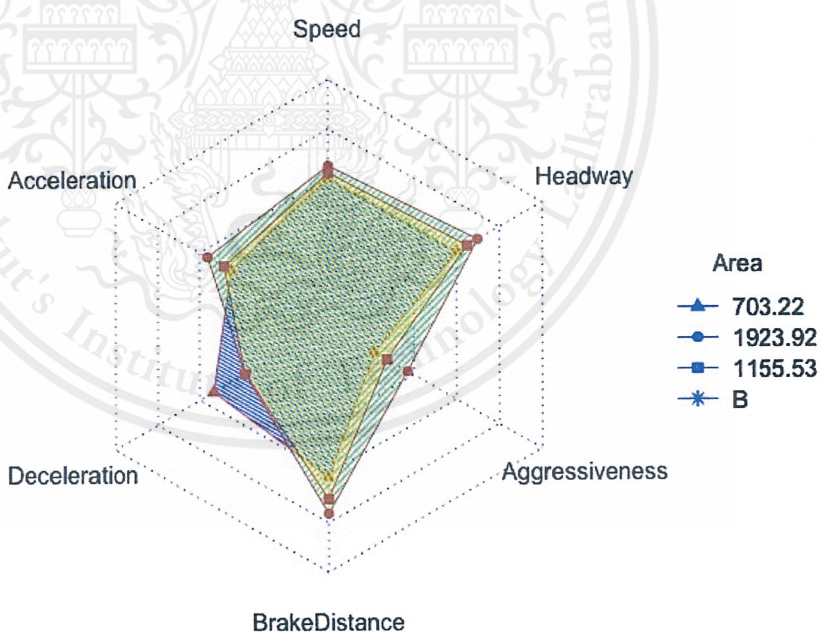

Figure A-46 Radar chart car data of driver No.6 in medium level direction.

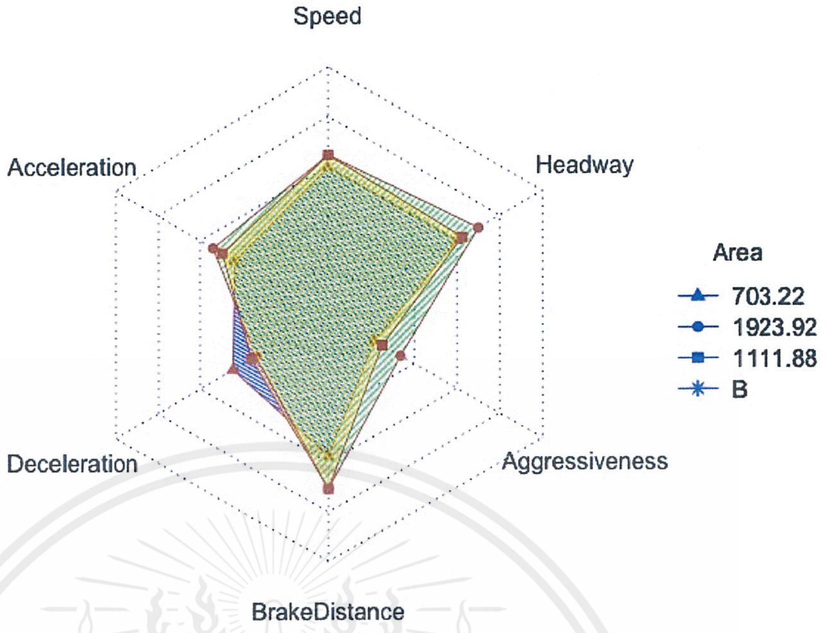

Figure A-47 Radar chart car data of driver No.7 in medium level direction.

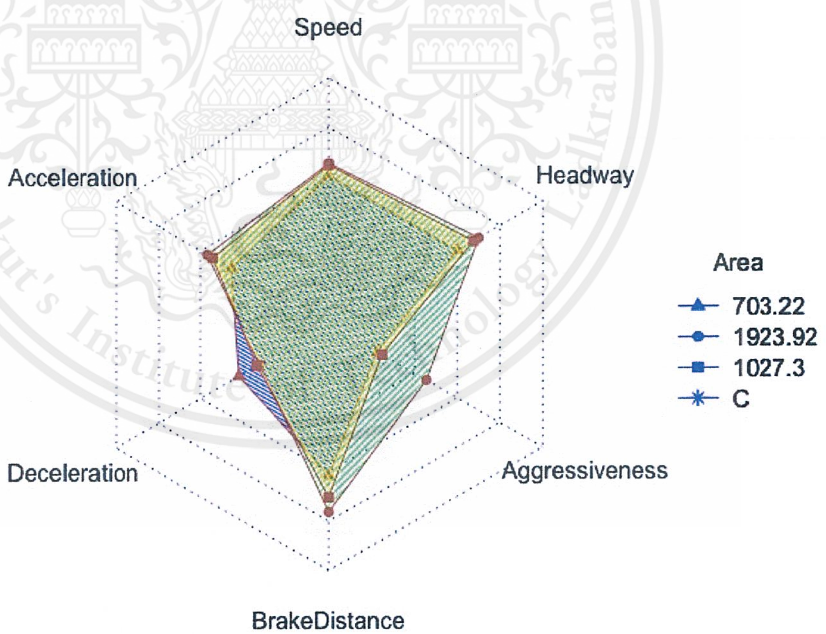

Figure A-48 Radar chart car data of driver No.8 in medium level direction.

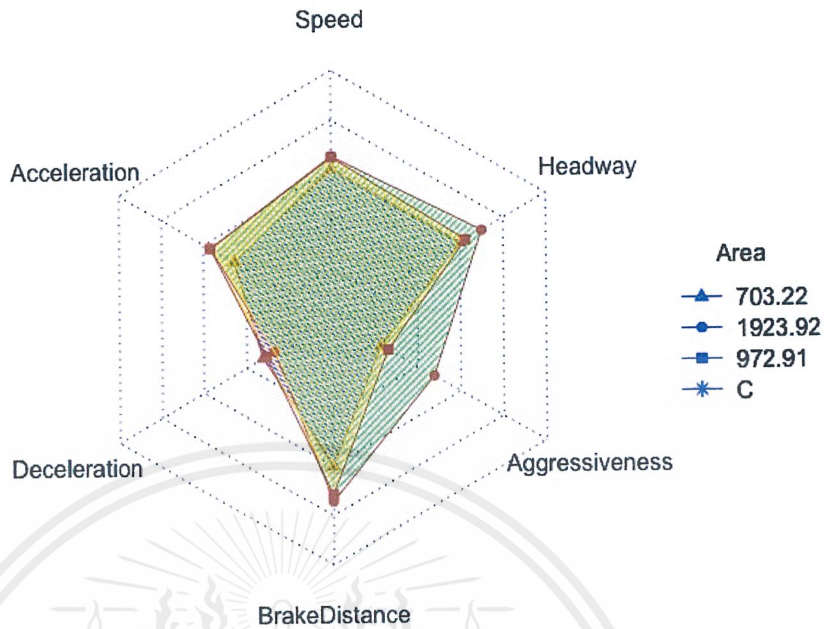

Figure A-49 Radar chart car data of driver No.9 in medium level direction.

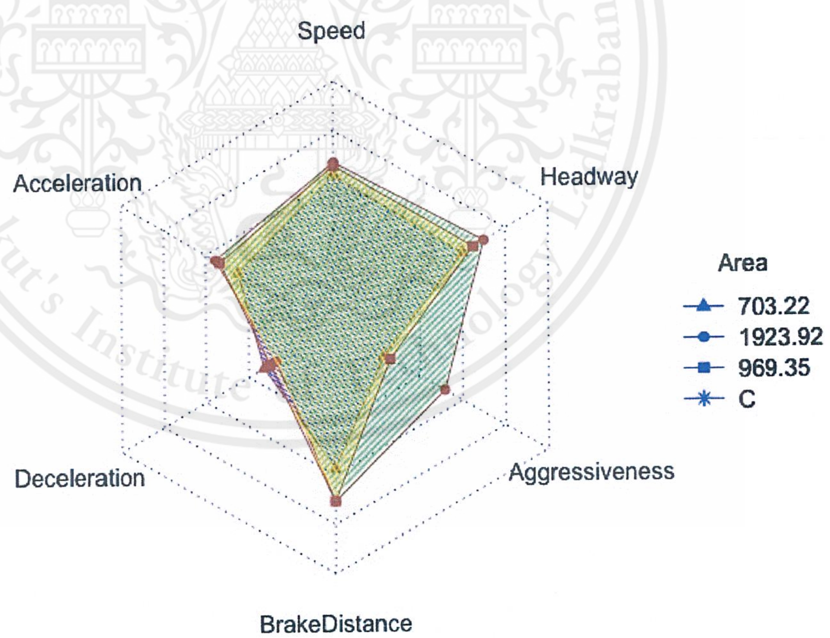

Figure A-50 Radar chart car data of driver No.10 in medium level direction.

3. Difficulty level direction

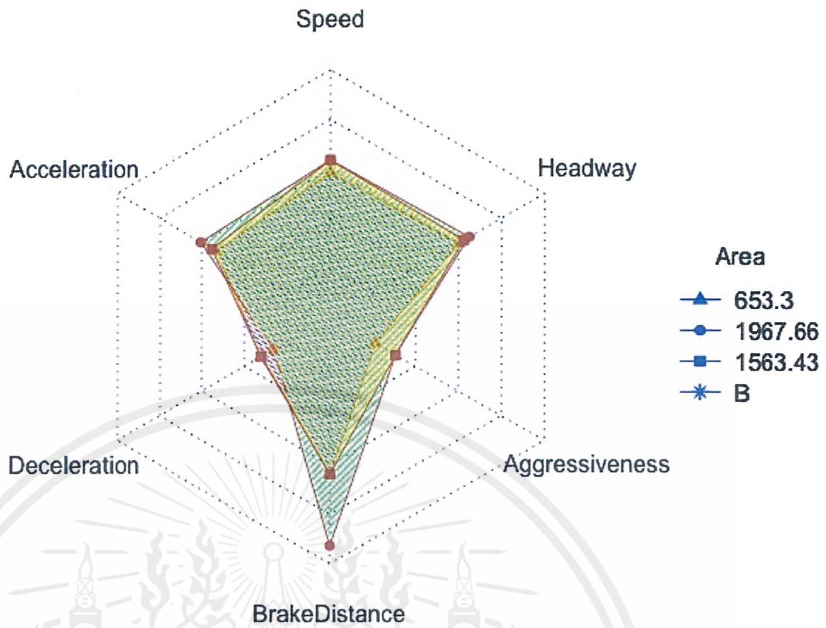

Figure A-51 Radar chart car data of driver No.1 in difficulty level direction.

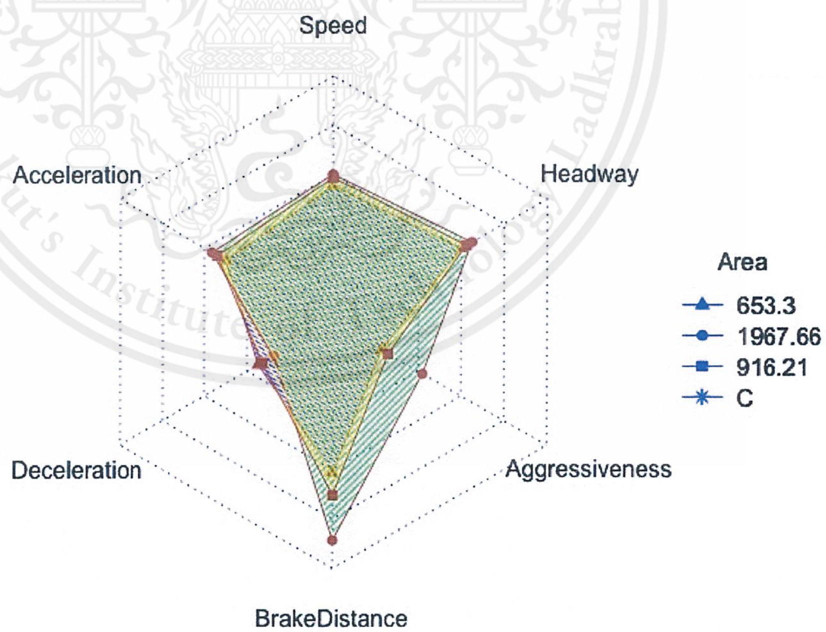

Figure A-52 Radar chart car data of driver No.2 in difficulty level direction.

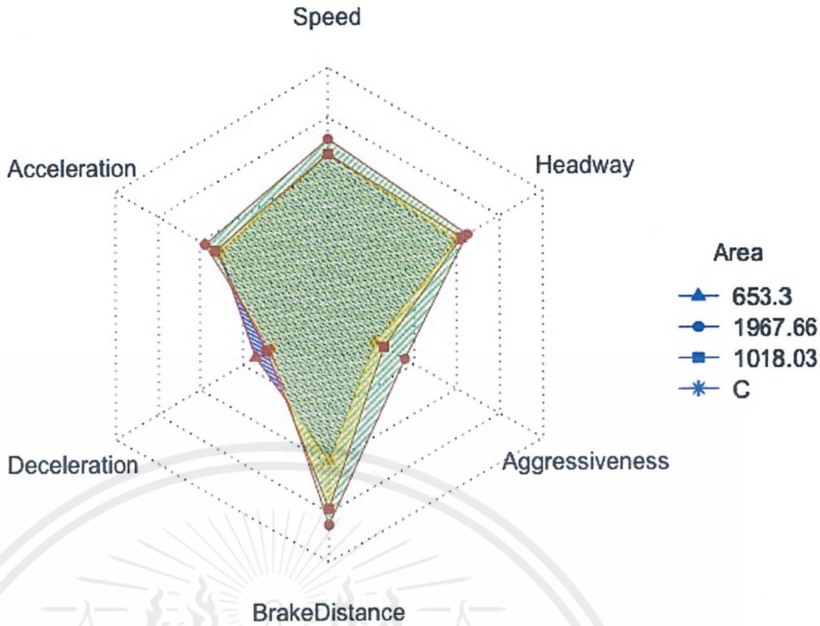

Figure A-53 Radar chart car data of driver No.3 in difficulty level direction.

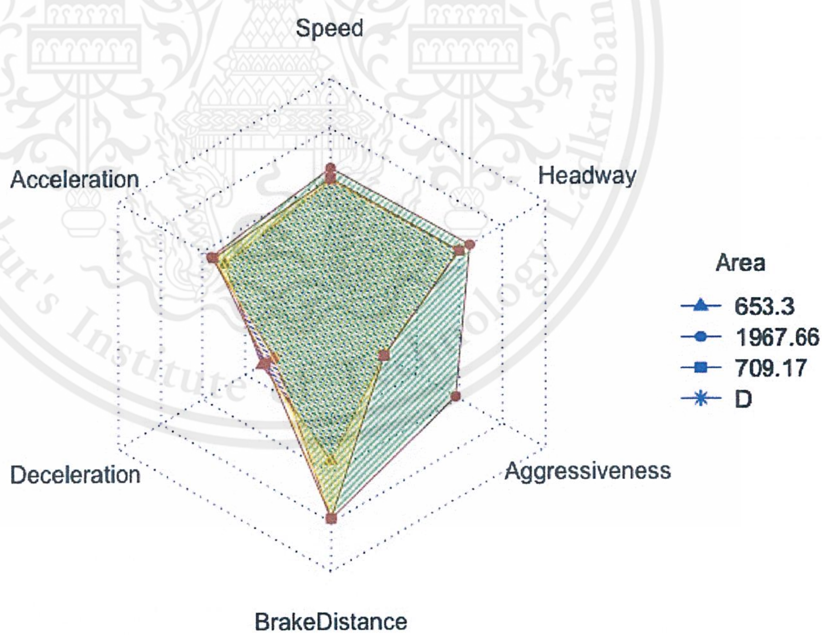

Figure A-54 Radar chart car data of driver No. in difficulty level direction.

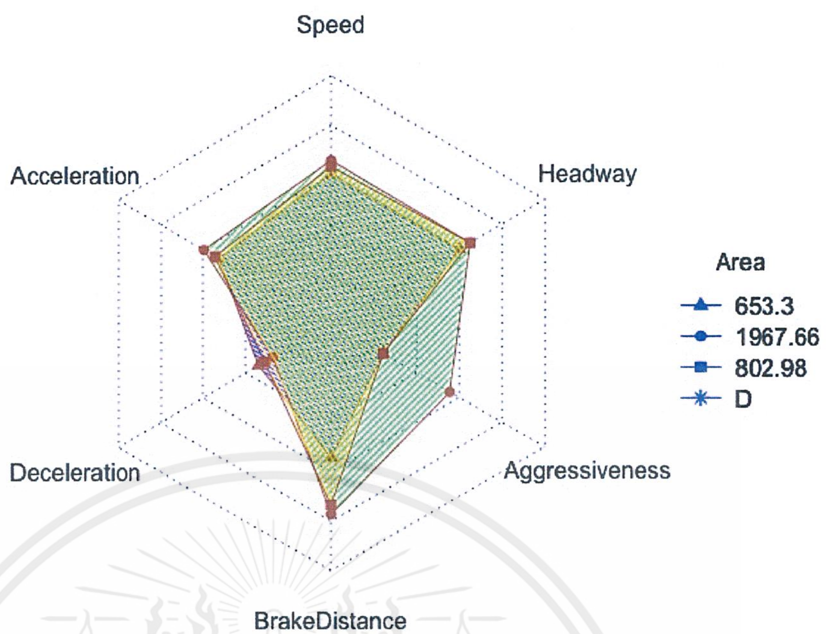

Figure A-55 Radar chart car data of driver No.5 in difficulty level direction.

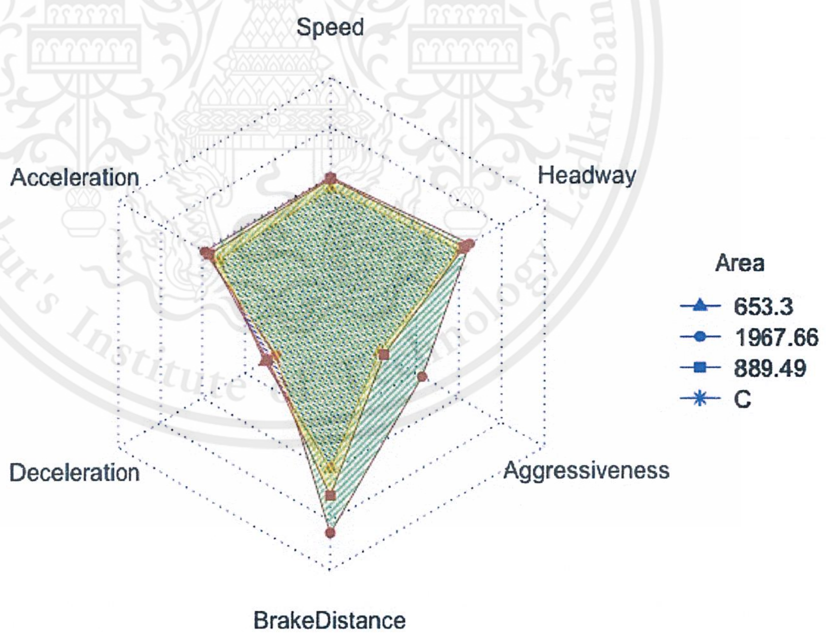

Figure A-56 Radar chart car data of driver No.6 in difficulty level direction.

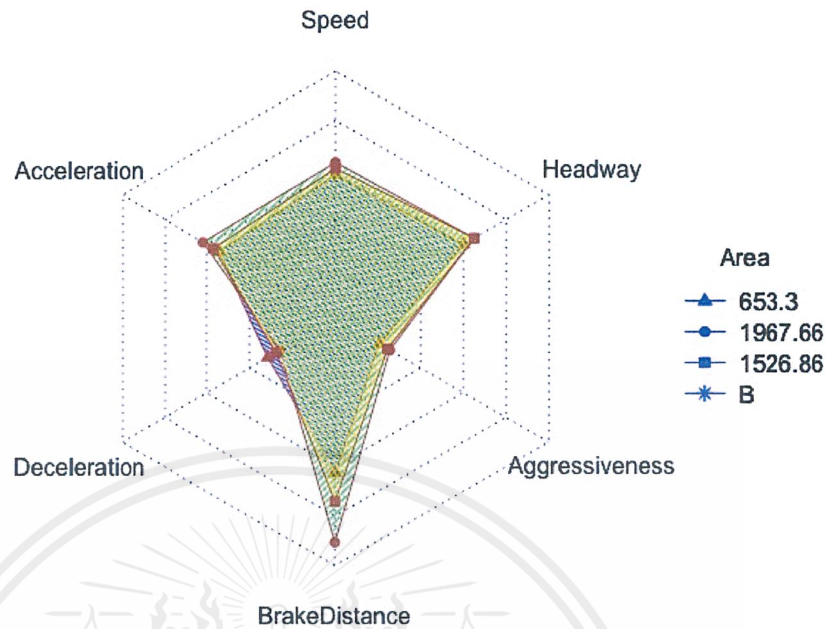

Figure A-57 Radar chart car data of driver No.7 in difficulty level direction.

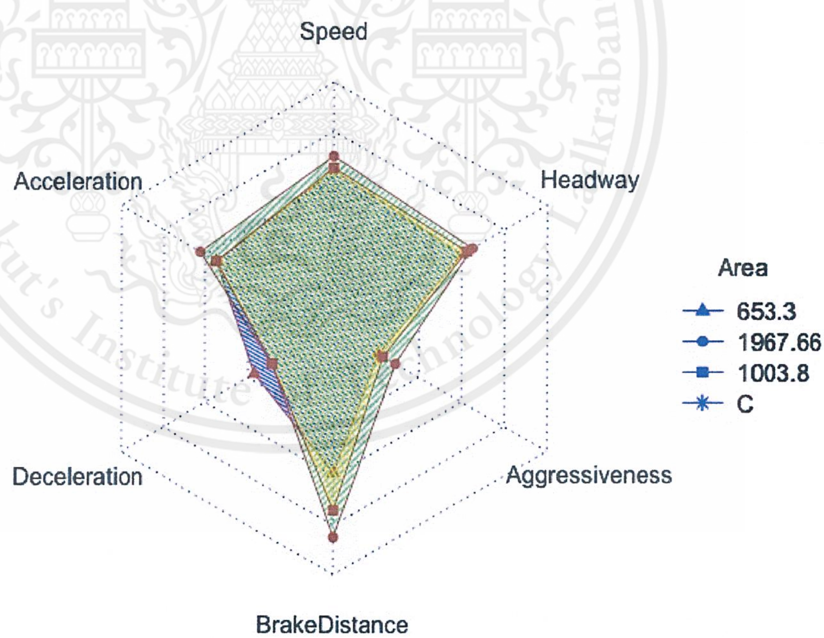

Figure A-58 Radar chart car data of driver No.8 in difficulty level direction.

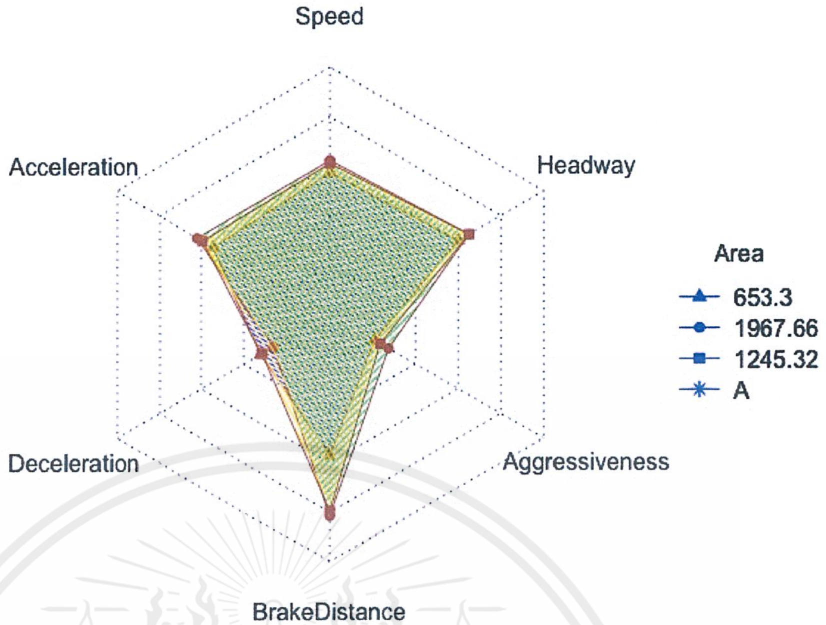

Figure A-59 Radar chart car data of driver No.9 in difficulty level direction.

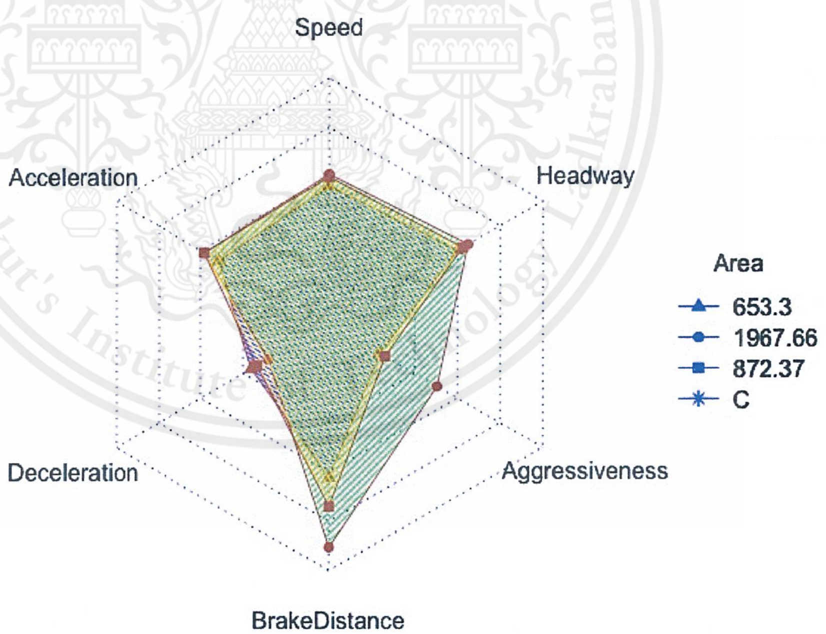

Figure A-60 Radar chart car data of driver No.10 in difficulty level direction.

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A DEVELOPMENT OF DRIVING MODEL AND DRIVING BEHAVIOR ANALYSIS BY USING DRIVING SIMULATOR

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ABSTRACT

This study aimed to develop the driving model for validate and analyze driving behavior by using OpenDS driving simulator for driving experiment and data collection. The safety driving measures in this model was defined by others research for the first safety criterion. In this experiment we use 10 participants to collect diverse driving data from different directions in three level to input into driving model. In driving model will analyze driving behavior by using equation and statistics calculation to find the new safety measurements suitable for each level and to classify driver into group following their own driving behavior by grading driver into A, B, C, D or F. The result from driving model was presented in graph of relation and the grade of driver.

Index Terms – Driving Behavior Analysis; Driving Model; Driving Simulator

1. INTRODUCTION

Technology is growing up fast and not likely to stop. In Thailand everybody seriously concerned about security in life especially transportation security because many people are killed and injured in road accidents every year. Although there have been campaigns or trainings about driving safety, accident prevention and traffic rules from many organizations to improve driver knowledge and road safety. Even though the number of road accidents are increasing all the time because the driver do not always respect all the traffic rules. For all these reasons many organization begin using technology to improve security in transportation on the road. For example, public van was already using Vehicle Tracking System including GPS (Global position System) and RFID (Radio Frequency Identification) to management many functions such as public van tracking, used for identify the current location, and speed control , in case of the driver using over speed according to standard. The system will warning the operators and the driver for intended to prevent the accident. However, most accidents occur by driver bad behavior and bad driving manner. From the fact about this problem motivated us to develop the driving model and driving behavior analysis. This model intended to study examine and analyze the driving behavior for classify driver into five groups (Excellent, Good, Satisfactory, Unsatisfactory, and Bad). The information from this model may be used for build the system that can improving driving skills, driving behavior and driving manner to reduce road accidents rate. This work studying about driving basic, driving principles and driving behavior for analysis driving behavior and present the outcomes in graph and level of driver.

2. METHODOLOGY

This section present article related information.

2.1 Driving Basics

2.1.1 Driver

Driving is one of the most useful skills. Before begin to drive, don't forget the driving is a special right, and the driver should to learn how to be a responsible driver before start the car. All of the rules and regulations of driving is very important. Physical conditions affect driving very much, drivers always prepared their body, mind, meditation, and don't drink alcohol before driving. Because the most accidents caused by the driver drinking before driving. The bodies have to take at least one hour to make one glass of alcohol wears off. If the driver drinks three glasses, they have to spend three hours for rest. The body need to rest up when the driver drinking, and someone hank because not rest enough.

2.1.2 Vehicle

The vehicles have to check before start because the one of car accident caused of the vehicle not be ready. Check a brake, electricity system, water system, air, gasoline system, oils, and noise are principles for check the vehicle before start. It was set up to make the driver easy to check their vehicle. The rotation of steering wheel is very important because the steering wheel for steering and maneuver while driving. When the tire exploded while running at high speed, the car will be losing out on the street that may make the driver and passenger fall in dangerous situation.

2.1.3 Driving behavior

The driver respect the rules are the basic for being a good driver. So, driver have to avoid driving behavior that affect to accident, overtaking another car in a no overtaking area, driving very close to another car, racing on highway, driving over speed limit, not use the light before stopping or turning, low-speed driving in the right lane, not control emotions while driving, and failing to comply with traffic signs. The driver could be driving situations, be courteous of driving to driver and another person.

2.2 Driving Principles

Although driving is complex, there are many ways to make the driving easier. One way to simplify it is to learn how to find and use all metrics, control, and other devices on the car. Another way is to follow the simple step by step process for operating a vehicle. The driver is required to prepare for the forthcoming all situations. After the car has started, the drive will become more complicated. The driver must be able to move seamlessly through the car traffic. Safe Driving is the most important goal for the drive each time. To prepare both the car and driver is very important, if you have to check the availability of your car before you leave, it reduced accidents by up to 30 percent. For the driver's own car, if you have to prepare travel plans and enough rest, it reduced accidents by up to 40 percent. If you hear or smell something that wrong, parking quickly, shutdown, and check out what's wrong, don't continue driving. Avoid accelerating sharply or sudden braking unnecessarily, and strictly follow traffic rules.

2.3 Traffic Rules

Traffic rules do serve a purpose, they help to protect life and property. Most often the work of deception and enforcement of traffic rules is the responsibility of state and local governments. These are the rules that apply to specific conditions. Because these conditions are not the same everywhere, the rules vary from place to place. Example, most states have regulations permitting left turns on a red light.

But some people like to open only at intersections marked with a special sign. Other permits are open to all except those who separate rule out a signal that turns on red [1].

2.4 Driving Analysis

Driving analysis makes us know the driving behavior on the road, the excellent data for analysis is car data. Accidents caused by many factors. To example, driving too fast, driving across of lane, overtake another vehicle in an emergency, violators traffic rules, disable people, driving when vehicle was not ready, and so forth. From these causes, driving behavior is the main cause of road accident, and many researches have discussed the causes of accident, which used to analyze driving behavior as well. To example, driving at night, driving over speed limit that the laws stipulated a maximum of 90 km/h, not respecting a traffic light, driving after drinking alcohol, driving alone, driving after taking drugs, driving in bad weather, driving while using a mobile phone, not stopping at a stop sign, driving without helmet or seatbelt, driving more than two hours without resting, smoking while driving, eating while driving, listening to radio or changing radio station, changing compact disk while driving, passing in a no-pass zone, and so forth [2].

2.5 Data Analysis Tool

2.5.1 R Programming

R programming is a language and software for statistical computing and graphics. R language is the most popular used in the groups of data miner and statistician for statistical and data analysis because R language quite good and inclusive in term of statistical and graphical techniques including linear and nonlinear modeling, time series analysis, clustering and so on[3]. R is appropriate software for calculation, data manipulate and graphical including data handling, graphical facilities for data analysis and display. It's very simple and effective programming language which includes loops, conditionals, function that user-defined recursive and input/output facilities [4].

2.6 Driving Simulator

2.6.1 OpenDS

OpenDS is a free driving simulator program that aims for research. This program is written in Java language and based on the JMonkeyEngine framework, the scene graph based game engine that is mainly used for display and computational of physics. With the right hardware, although the city can be advanced at a high frame rate. There is composed of three main parts, the driving task editor, the simulator and the driver analysis. The route driven car can be compared to a pre-defined rules followed in order to calculate the deviation, this can be considered as a measure of performance driving. In order to facilitate realistic simulation, OpenDS not only provides an interface for game controllers. However, you can also interface for connection to a real cars, this enables the model to feature the car that like steering angle and pedal states, and to keep the device in a car in the simulation. To enhance the driving experience, OpenDS support multiple screens which can be used for 180-degree projection [5].

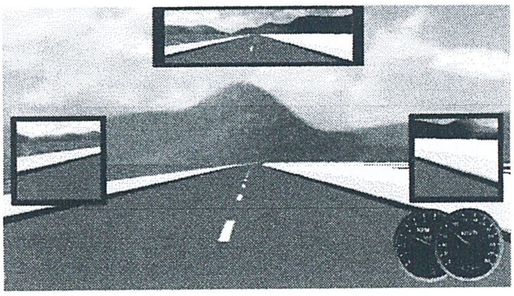

Figure 1 An example of simulator view.

3. IMPLEMENTATION

This section describe about problems of driving which is a result of not good driving behavior, data structure, procedure of this paper and driving behavior design.

3.1 Problem Definition

The most frequent fatal road accidents are caused by human error involved in driver's safe or unsafe driving behaviors. Whether they are due to do not respect for traffic rules and regulations, reckless driving, poor driving skills or lack of good driving behaviors. Good or not good driving behavior becomes a one of the leading causes of road traffic accidents if driver always drive with unsafe driving behavior such as overtaking or lane changing in dangerous situation, drive over speed limit, ignoring traffic signs and so forth it's becomes misbehavior that caused a hazardous road traffic accident eventually. From the road traffic accident study, human error in term of misbehavior is the majority of the leading cause of road accident. The factors of problem and examples of errors are shown in table 1.

Table 1 List of problem factors and examples of errors.

Problem Factors	Possible Situations
Speed	- speed too fast - speed over limit - speed too slow
Distance	- tailgate
Lane and passing	- not using turn traffic signal - cutting other car off - signal too late - overtaking - dangerous lane change
Traffic lights	- driving at red light - accelerating through yellow light
Traffic signs	- ignoring traffic signs
Road	- wrong lane - merging improperly
Brake	- braking too early - braking too late - suddenly breaking - frequently breaking

3.2 Driving Model Design

The proposed of driving model is analyze and evaluate driving behavior. In figure 2, use data output from OpenDs driving simulator to input into driving model for analysis combined with R programming technique in term of statistical analysis. The results of driving analysis model can divided into two parts, first is the driving behavior analysis which consists of speed behavior analysis, brake pedal behavior analysis and so forth. Second is the result of prediction which can classify the driver following there driving skill.

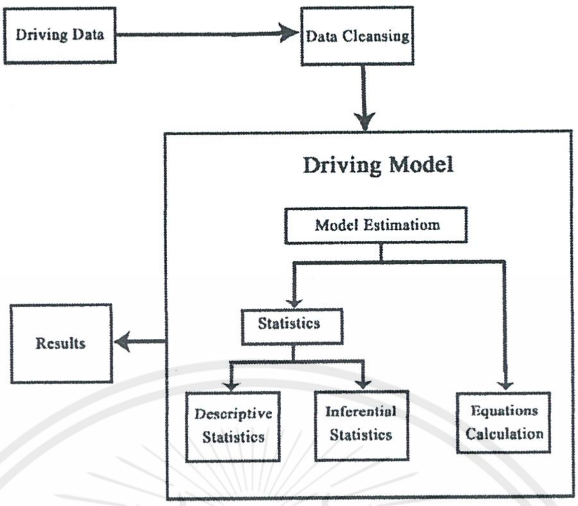

Figure 2 Data structure of driving model design

3.3 Data Collection and Data Cleansing

The data were collected by using the OpenDS driving simulator to imitate driving in virtual driving environment and to get the parameters. This project modified appropriate road and circumstance for driving experiment as a virtual reality and divided the experiment into three levels with different directions according to the difficulty. Ten volunteers were recruited for do driving simulator experiment among student in university according to the following characteristics: have experience with the driving simulator and must have a driver license. Driving experiment for 30 times from participants to collected diverse driving data from three maps in figure 3, figure 4, and figure 5.

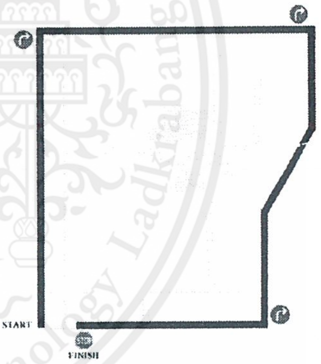

Figure 3 Easy level driving direction.

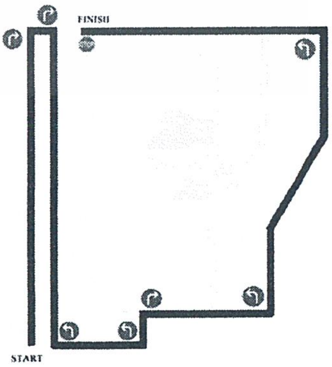

Figure 4 Medium level driving direction.

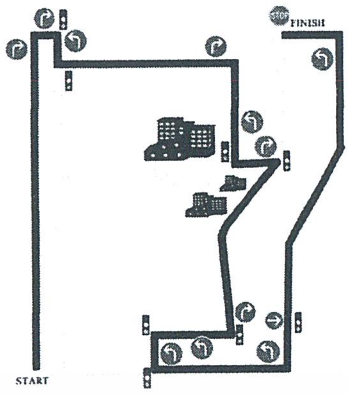

Figure 5 Difficulty level driving direction.

The simulator's data output consist of time, car position, Rotation, car speed, steering wheel position, gas pedal position , Brake pedal position and engine running. Data file need to correcting and removing something before import into driving behavior model. We have to removed header of text file and split attribute in column clearly. Moreover, time exported from OpenDs driving simulator is unix timestamp it's absolutely necessary to convert timestamp to normally date and time.

3.4 Model Estimation

Driving model estimation process considering time, speed, steering wheel position and brake pedal position. All parameters from OpenDs driving simulator are estimated by driving measures in speed, acceleration, deceleration, headway, Aggressiveness of acceleration and deceleration changes, and braking distance. Plot to radar chart and calculate area to grouping driver.

3.4.1 Driving measures

3.4.1.1 Speed

Speed is the rate of change of the car position able to move per time unit used for describe how fast a car is moving. The driver who drive at the speed below 15 km/h is the slow driver and the driver who drive at the speed over 85 km/h is the fast driver [6].

$$v=\frac{d}{t} \quad (1)$$

Where v is velocity or speed, and d is distance traveled and t is time.

3.4.1.2 Acceleration

Acceleration is the rate of increase of the car speed per unit of time. The acceleration value is always positive and the positive value means the car will speed up. The appropriate acceleration is between 0.9 m/s^2 and 1.5 m/s^2 [7].

$$a=\frac{v}{t} \quad (2)$$

Where v is speed or velocity and t is time.

3.4.1.3 Deceleration

Deceleration is the rate of decrease of the car speed per unit of time. The deceleration value is always negative and the negative value means the car will slow down. The appropriate deceleration is between -0.9 m/s2 and -1.5 m/s2. The higher deceleration value than -1.6 may be indicated for sudden deceleration or sudden breaking. The deceleration is the negative value of Acceleration equation [7].

3.4.1.4 Headway

Head way is the interval between two cars. So, safe headway is the safe interval between following car and leading car. The acceptable safety interval of headway is between 1.5 second and 2.5 second [8].

$$\text{Headway}=\frac{L_0}{V_f} \quad (3)$$

Where L_0 is the distance between following and leading car, and V_f is the speed of following car.

3.4.1.5 Aggressiveness of acceleration and deceleration changes (S)

The aggressiveness of acceleration and deceleration changes is the hostile or violent behavior of driver in speed up or slows down their vehicle. The appropriate value of S is between 0 and 1 which represent smoother acceleration or deceleration changes [9].

$$S=|R| \quad (4)$$

$$R=\begin{cases}\frac{d}{d_s} & d > d_s\\ \frac{d_s}{d} & d < d_s\end{cases} \quad (5)$$

$$d_s=\frac{v^2}{a^2}+2^{\Delta T} \quad (6)$$

Where R is ratio between safety distance and actual travelled distance, d is actual travelled distance, d_s is safety distance, V is speed or velocity, a is acceleration or deceleration, and ΔT is the time at which the status of leader car is obtained.

3.4.1.6 Braking distance

Braking distance is the travelled distance when the driver decided to slow or stop a car moving. The safe brake distance is an approximate distance a car needs to move after the brakes are applied .

$$v=\sqrt{u^2+2ax_s} \quad (7)$$

Where V is the final speed of a car after the brake are not applied, u is the initial speed of a car after the brake are applied, a is the acceleration of a car, and x_s is the safety travelled distance.

3.4.2 Area calculation of radar chart

The area of the radar chart is obtained by summing the area of triangles formed between two adjacent indicators [10].

$$area=\frac{\overline{AB}*\overline{AC}*\sin A}{2} \quad (8)$$

4. RESULTS AND DISCUSSION

This section discusses about the result of driving behavior model includes the driving behavior analysis and the classification of driver.

4.1 Model estimation results

4.1.1 The result of first participant

The graph line with triangle symbol shows the minimum acceptable graph, the graph line with circle symbol shows the maximum acceptable measures graph and the graph line with square symbol shows driver performance graph from their own driving data in figure7.

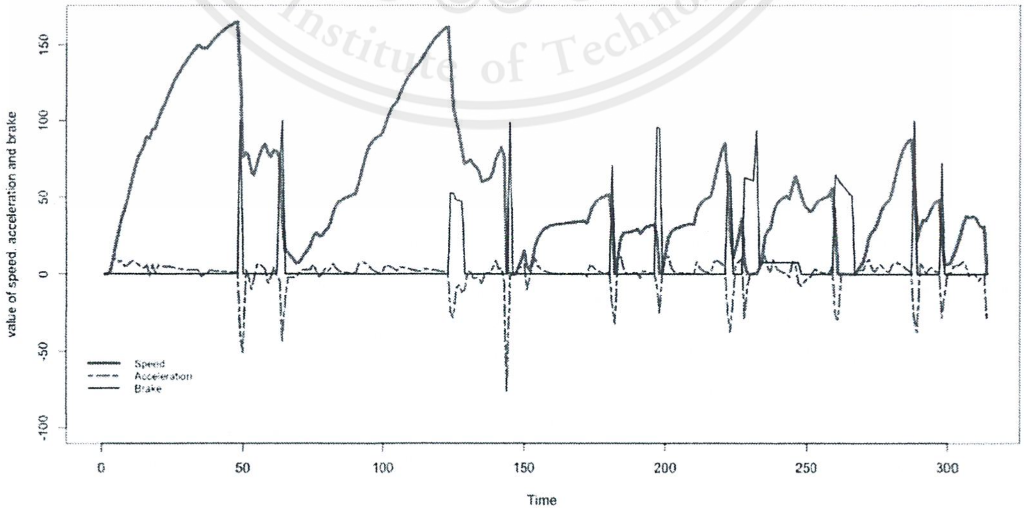

Figure 6 Graph of **relationship between speed, acceleration and brake**.

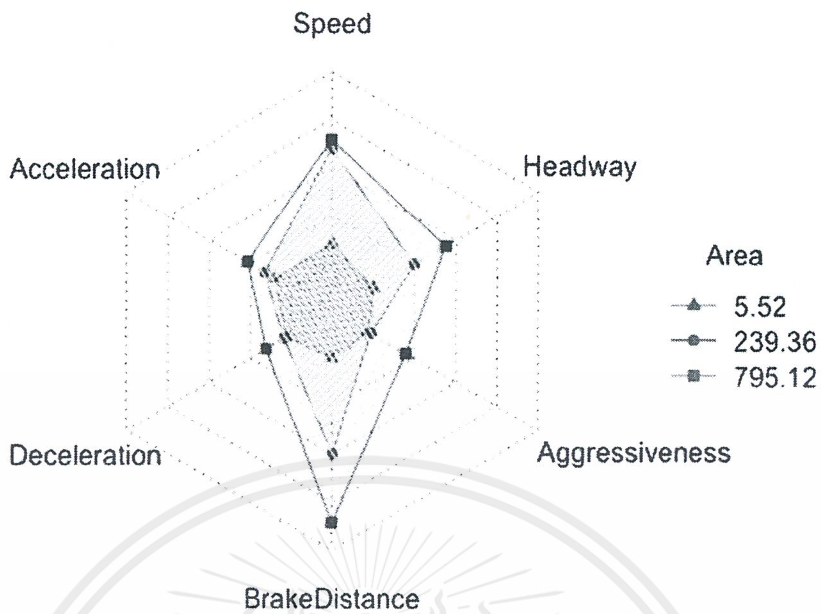

Figure 7 Radar chart of driving behavior.

4.1.2 The summary and analysis of experiment results

From the experiment results we can define a new measurement appropriate for each level direction in Table2, Table 3, and Table 4.

Table 2 New measurements appropriate for easy level direction.

	Speed	Acceleration	Deceleration	Headway	Brake Distance	Aggressive
Min	74.27	1.23	-5.85	14	10	6.41
Max	91.97	2.57	-2.64	29	15	16.22
Mean	79.914	2.033	-3.513	19	12.4	9.9

Table 3 New measurements appropriate for medium level direction.

	Speed	Acceleration	Deceleration	Headway	Brake Distance	Aggressive
Min	77.88	2.64	-5.56	16	14	8.32
Max	87.49	3.78	-3.13	20	19	61.79
Mean	83.39	3.165	-3.97	17.7	16.7	24.88

Table 4 New measurements appropriate for difficulty level direction.

	Speed	Acceleration	Deceleration	Headway	Brake Distance	Aggressive
Min	69.37	3.38	-6.28	16	18	8.58
Max	78.63	4.11	-3.24	18	30	60.32
Mean	75.17	3.725	-5.36	17	24	19.87

4.2 Classification of driver

In driver classification process were divided driver into five groups following their own driving performance in Table 5.

Table 5 The groups of driving model and description in term of driver classification.

Classification of Driver	
Results	Descriptions
A	Excellent driving behavior
B	Good driving behavior
C	Satisfactory driving behavior
D	Unsatisfactory driving behavior
F	Bad driving behavior

The acceptable range of each group are calculated by using the difference area between maximum acceptable graph area and minimum acceptable graph area compare with the area of driver performance graph.

4.3 Model validation

Diomidis H. stamatis, said the excellent acceptable standard deviation is between 10 and 30 percent of mean value [11]. In this validation, we used the measures have been accepted in general as a mean value. So, the acceptable standard deviation is between 10 and 30 percent of each standard measures. The standard deviation of each minimum and maximum value between new measures and standard measures in each level of direction excluding safe brake distance because this factor has no fixed value. The suitable value of safe brake distance has to calculate time to time when the brake pedal are applied and depend on current speed.

Table6 The standard deviation of each minimum and maximum value between new measures and standard measures in each level of direction.

	Easy		Medium		Difficulty	
	Min	Max	Min	Max	Min	Max
Speed	6.97	59.27	2.49	62.88	-8.86	54.37
Acceleration	0.33	1.07	1.74	2.28	2.48	2.61
Deceleration	-4.35	-1.74	-4.06	-2.23	-4.78	-2.34
Headway	-1.29	1.88	-0.97	4.82	-0.81	-11.5
Aggressiveness	6.41	15.22	8.32	60.79	8.58	59.32

5. CONCLUSION

We began this project with found scope of work and studied project feasibility by analysis of the ability to complete a project successfully. After we decided that this project has high possibility to success. We began to study about the factors of the leading cause of road accidents such as driving too fast or too slow, safe or unsafe braking distance and good or not good driving behavior by following traffic sign such as speed limit on difference road types and the meaning of them. We analyzed driving behavior by study on safe driving factors from many others research to find out about the relationship between factor and the best way to analyzing parameter. We find formula to transform the parameter we got from OpenDS driving simulator to suitable form for use to calculate safety driving measurement. We developed the driving behavior model by using OpenDS driving simulator to collect driving data. We design three level of direction including easy level direction, medium level direction and difficult level direction. Then we modified road and surrounding environment to appropriate driving experiment of each level. We did driving experiment and analyze driving data. We analyze all results from experiment by R programing in term of descriptive statistics and conclude our new measurement suitable for each driving level direction. Finally, we grading driver by using the differences of area between new minimum acceptable measures chart and maximum acceptable measures chart. The purpose of this project is study and develop driving model for analysis safe or unsafe driving behavior. The only limitation of this work is unrealistic data because we decided to use driving simulator in data collection process but the simulator offer less realistic driving environment. So, the driving data we get from driving simulator is quite unbelievable. This is the reason why our new measures unreasonable.

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