DEVELOPMENT OF ACCELERATOR AND BRAKE PEDAL POSITION COMFORT ABILITY BASE ON MALAYSIAN POPULATION

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FACULTY OF ENGINEERING
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DEVELOPMENT OF ACCELERATOR AND BRAKE PEDAL POSITION COMFORT ABILITY BASE ON MALAYSIAN POPULATION

ABSTRACT

Pedal errors mention to the situation when the driver falsely presses the wrong pedal or does not press the pedal at all. A negative outcome of pedal misapplications is a sudden acceleration event, which has been related with crashes. The goal of this dissertation is to identify the factors influencing pedal misapplication through models of driver's foot movements. Data from 10 subjects were collected by conducting two studies: A parking lot study, and high way study. There were different foot movement seen that could be classified as a direct hit, hesitation, getting out of study scene or doing pedal error. Within the pedal errors, three different sub-categories were seen: wrong pedal, both pedal and miss (no pedal). Using a repeated Logitech Model, pedal errors were indicated to be associated with age-related, situational and experience-based factors. Investigation of the foot movement on a high way study indicated that high speed maneuvers were more likely related with errors as drivers had their foot on the accelerator pedal more often than Brake taking is as a part of game. Further investigation on Parking lot experiment using several Pedal distances and doing functional principal components analysis indicates that the largest contribution to pedal errors were seen in pressing both pedals. Upon summarizing the data, it is observed that highest contributing pedal distance is the smallest one among all 5 levels of pedal distances. This study concludes that 11cm distance is the most suitable as per international Standard and Favorable for Malaysian Population.

PEMBANGUNAN PENYELENGGARAAN DAN BRAKE PEDAL POSISI KEMUDAHAN KEMUDAHAN DALAM PENDUDUK MALAYSIA

ABSTRAK

Kesalahan pedal menyebutkan keadaan apabila pemandu secara palsu menekan pedal yang salah atau tidak menekan pedal sama sekali. Hasil negatif daripada salah penggunaan pedal adalah peristiwa percepatan secara tiba-tiba, yang berkaitan dengan kemalangan. Matlamat disertasi ini adalah untuk mengenal pasti faktor-faktor yang mempengaruhi salah penggunaan pedal melalui model pergerakan kaki pemandu. Data dari 10 subjek dikumpulkan dengan menjalankan dua kajian: Kajian tempat letak kereta, dan kajian cara yang tinggi. Ada pergerakan kaki yang berbeza yang dapat diklasifikasikan sebagai hit langsung, ragu-ragu, keluar dari adegan belajar atau melakukan kesalahan pedal. Dalam kesilapan pedal, tiga subkategori yang berbeza dilihat: pedal yang salah, kedua-dua pedal dan terlepas (tidak pedal). Menggunakan Model Logitech yang berulang, kesilapan pedal ditunjukkan untuk dikaitkan dengan faktor yang berkaitan dengan usia, keadaan dan pengalaman berasaskan faktor. Siasatan pergerakan kaki dengan cara yang tinggi menunjukkan bahawa gerakan kelajuan tinggi lebih mungkin berkaitan dengan kesilapan kerana pemandu kaki mereka pada pedal pemecut lebih kerap daripada mengambil Brake adalah sebagai sebahagian daripada permainan. Penyiasatan lanjut mengenai eksperimen Parking menggunakan beberapa jarak Pedal dan melakukan analisa komponen utama berfungsi menunjukkan bahawa sumbangan terbesar kepada kesalahan pedal dilihat dalam menekan kedua pedal. Apabila meringkaskan data, diperhatikan bahawa jarak pedal yang menyumbang tertinggi adalah yang terkecil di antara semua 5 tahap jarak pedal. Kajian ini menyimpulkan bahawa jarak 11cm adalah yang paling sesuai seperti Standard antarabangsa dan Baik untuk Penduduk Malaysia.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF GRAPHS

CHAPTER 1: INTRODUCTION

1.1 Background study

Since the beginning, there has been a lot of improvement in Cars Designs to increase the comfortability, efficiency and performance. Over the past two decades, Ergonomics has played an important role in improving the cars for the added Safety along with comfortable journey. A lot of research is being conducted on improving the safety levels by studying the factors that cause driving issues in which Pedal Misapplication is considered a vital factor to cause Accidents. This study is about highlighting all Pedal based factors by utilizing Anthropometric Data and getting safest pedal distance for Malaysian Population

We have seen that in every car there are two important two constant and important parts:

1. Accelerator pedal to increase and control the speed and produced power of engine by depressing the accelerator usually with driver's foot
2. Brake pedal to control the speed of car and to stop the car in require time with pedal depression by driver's foot

1.2 Problem Statement

Pedal misapplication is a driver error wherein the driver presses the accelerator when braking is intended which causes crash or incident. Pedal error accidents are a frequent occurrence due several factors in which among them is the design of the pedal position and situation of operation. As in most cases, standards may have not specifically considered the Malaysian population thus making the understanding of this issue is important (Richard, 2010). Cars gone wild: the major contributor to unintended acceleration in automobiles is pedal error) in guiding pedal location in vehicle design.

1.3 Project Objective:

People's characteristics like weight, height, feet size which is related to the height of human being (for the person with 180 cm height the shoe size is 40 but for the person with 160 cm

is 34) in different countries are different but international car manufacturers sell their productions with the standard sizes

In this study going to suggest a horizontal distance between accelerator and brake pedal based on Malaysian population to improve the comfort ability for drivers.

1) To determine / identify of seat distance and anthropometric dimensions on pedal positioning.
2) To investigate the influence of Pedal position on pedal misapplication.

1.4 Scope of project:

Study and research about this case has never done in real condition due to of high expenses and also danger of crash or incident that threaten and might be happened to the subjects during the experiments. To make is useful, This Study is conducted on driving simulator (Logitech G27) which considered effective for most of the Subjects (Survey). Several subjects and their different anthropometric characteristics evidently shows that it can be useful in understanding the factors of Pedal Misapplications and suitable design improvement for Malaysian Population.

1.5 Research Questions

There are four research questions for this research. It is of interest to study drivers' pedal reply classification (direct hit, hesitation, corrected trajectory and pedal error) and the factors related with those classifications.

A practical principal components analysis is helpful to visualize the major contributions to pedal errors and to detect the common patterns related with pedal applications. Investigation of the situational context is further tested using a naturalistic study, which included additional variables related with the driving sequence also other drivers' features.

As different foot behaviors were seen for emergency braking event, the fourth research question summarizes and quantifies the drivers' reply towards emergency events.

Research question 1:

Do different traffic signal cues affect foot behavior?

Video data from a driving simulator will be utilized to investigate pedal application sorts (direct hit, hesitation, corrected trajectory and pedal errors).

The prime hypothesis is that the sort of pedal application sorts will be affected by the driver and situational factors.

Different foot behaviors will be detected and modeled using statistical models with repeated measures.

The outcomes are explained in Chapter 3.

Research question 2:

What changes exist in drivers' foot-to-pedal behavior?

The objective is to evaluate the most common movements for pressing the pedal(s). This question is investigated using information from a simulated environment where the changes in drivers' foot trajectories towards the pedal can be catch. Practical principal components analysis is used to detect where the most change happens for the various pedal application types. The outcomes are explained in Chapter 4.

Research question 3:

Does foot behavior vary in terms of context and driver features?

This research question is addressed with data gathered on-road using the driver's own vehicle.

Foot placement on the pedal(s) and the pedal application sorts are summarized from the recorded videos. Similar strategies of categorizing pedal applications (as introduced in RQ1) are applied, and then a random forest is used to anticipate the pedal application categories given the larger number of characteristics that were obtained in a naturalistic setting.

A mixed logit model was then used to anticipate foot placements.

Research question 4:

How do drivers reply to emergency events?

Previous researches have indicated differences in drivers' behavior in normal driving and emergency situations.

The sample size available to address this question was properly small as these events are rare in the real world. Hence, summary statistics are created as an investigation of drivers reply to emergency situations within a driving simulator, in a parking scenario, and in a naturalistic environment and inferences are provided for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Pedal Misapplications Issue (Research Based)

Driver, environmental and vehicle factors have all been associated to pedal misapplications. Previous studies in this field have been carried out based on a review of the literature, key word searches in crash reporting databases, using a driving simulator.

The North Carolina State crash database and the National Motor Vehicle Crash Causation Survey (NMVCCS) have been previously investigated because they contain narratives of the incident and pedal error associated variables (Lococo et al., 2012; Schmidt, Young, Ayres, & Wong, 1997; Schmidt, Young, & Ayres, 1999). Other studies have employed driving simulator to control for several factors (such as distraction, startled events, etc.) (Ivancic & Hesketh, 2000; Kimura & Shinohara, 2012). These simulator studies have been utilized in conjunction with video recordings of the drivers' foot movements (McCall & Trivedi, 2007; Tran, Doshi, & Trivedi, 2011).

2.2 Driver Factors

Some of the following Factors that are associated with the Person behind the Steering are

2.2.1 Age and sex

Studies have indicated a relationship between crashes related with unintended acceleration and drivers' age. Kimura and Shinohara (2012) indicated that older drivers (mean age 66.2 yrs old) are more probably to commit a pedal error when compared to younger drivers (mean age 21.4 yrs old). Lococo et al (2012) explored the factors related with pedal misapplications.

2.2.2 Body position and size

Head and body position also driver size may affect the drivers' ability to spatially position their foot on unseen pedals. Moving the eyes or head can create large systematic biases in the targeted direction of the foot (Lococo et al., 2012).

The bias could be large enough causing to missing or pedal errors. Thus, pedal misapplications were more probably to occur when driver rotated the body to see the rear of the vehicle during a backing maneuver.

Most vehicle seats are designed to fit 95% of drivers, but shorter drivers may not fit as well into the car seat (Hill & Boyle, 2006). Therefore, the probability of being involved in pedal error crashes is even larger for shorter females with smaller feet (Lococo et al., 2012) considering they have to stretch using their toes, and usually need to pick their foot up to move between pedals.

2.2.3 Startled or panic

Pedal misapplications could occur during ordered driving cycle, but might be more probably to happen when drivers are startled or panic. They recognize the sudden stimulus as life threatening, requiring an instant solution (Schmidt, 1989). There might be a speed-accuracy trade off (Schmidt & Young, 1997): the probability of a pedal error raised when the driver was forced to reply more rapidly. About 20% to 60% of pedal misapplication crashes in the police report database were expressed as startled or in panic (Lococo et al.,2012).

2.2.4 Cognitive defects

During sudden events, drivers need to examine the environmental cues and identify the need to process and plan a respond and subsequently execute an action. Over time, this becomes a skill-based task but in certain situations, it still needs drivers to make immediate judgments

and decisions on unknown events. When facing sudden events, different drivers might plan and accomplish different decisions, which might or might not avoid the collision. Such capabilities to reply to unexpected and sudden events were proved to be associated to a person's cognitive function (Belanger, Gagnon, & Yamin, 2010). Cognitive impairment might also cause pedal errors that result in crashes or unintended acceleration.

2.2.5 Pedal Design and Engineering Issues

Human Errors play a large role in unintended acceleration incidents, vehicle design and engineering issues might rise the possibility of pressing the wrong pedal(s) (Collins, Evans, & Hughes, 2014).

According to Pollard and Sussman (1989), the Probabilities of pedal errors rises due to the following characteristics of the vehicle pedal design:

1. Relative close lateral spacing between accelerator and brake increase the chances of pressing both pedals in feedback
2. Relative Larger spacing between accelerator and brake increase the chances of pressing no pedals in feedback

Many researchers mention that the way drivers position themselves in the seat and how they locate the pedals can be related with pedal errors. In an unfamiliar vehicle, there may be a disturbance to the driver's postural set orientation.

2.2.6 Foot Behavior

The pedal application is a skill-based motion accomplished in an unlimited space with no visual target and no feedback until first pedal depression. Two important cues when operating the pedal are the pedal positioning and the "feel" (Pollard & Sussman, 1989). The direction and curvature of motion are critical and the feedback from touching the pedal (pressure,

texture, shape or contour) is important for identifying pedal and foot placement. In the case of operating a pedal, the leg movement can be viewed as two degrees of freedom with free hip and knee joints.

2.3 Summary

This chapter presented an overview of unintended acceleration. Pedal error refers to the foot behavior that the driver pressed the wrong pedal or failed to press the correct pedal, and appear to be related with many unintended acceleration crashes.

However pedal misapplications are considered rare events; the consequences can be severe. Previous studies indicated that factors related with pedal errors include the driver, driving tasks, vehicle design and engineering issues, and the surrounding environment.

The experimental design will be analyzed in the next chapter and the following chapters present the data analysis.

CHAPTER 3: METHODOLOGY

3.1 Experimental Design

Previous studies indicate that pedal misapplications can be seen for various driving tasks (while driving forward, back or parking). Hence, a comprehensive set of studies was accomplished to investigate pedal application for various tasks. Differences in drivers were gained using standard demographic information also a battery of cognitive function tests and anthropometric measurements. The study is divided into two parts:

(1) A controlled study using a lab-based driving simulator and an instrumented vehicle in a parking lot;

(2) A naturalistic driving study to observe drivers' real world driving behavior from the recorded videos during the experiments.

3.1.1 Apparatus

The Driving Simulator Device that was used for this study was Logitech G27 driving simulator including automatic shifting gears, brake and accelerator pedals and steering wheel. The game application is city car driving in which multiple options of car, color, playing area and conditions can be selected.

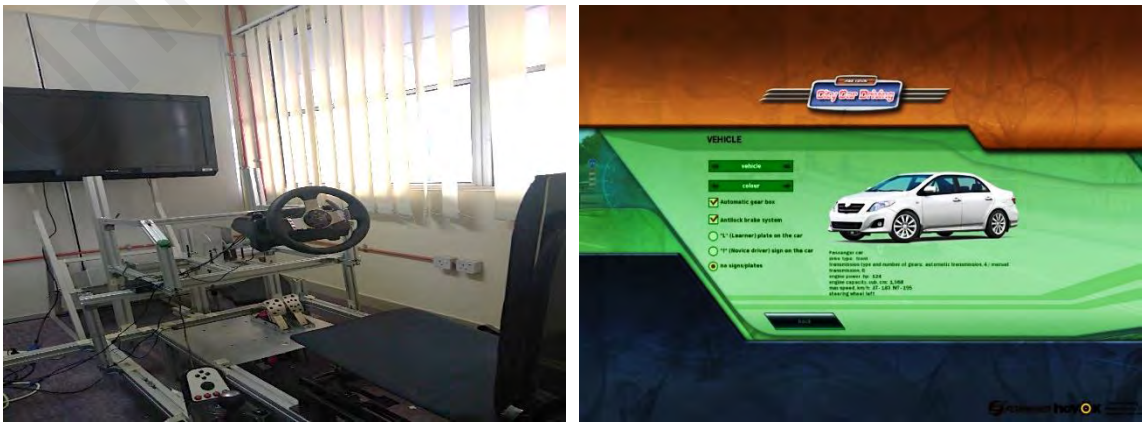


Fig 3.1 Driving Simulator Equipment with Application

The game that was used for these experiments was City Car Driving 1.5.0 Toyota Corolla.

Experiments had two parts,

1. Test and a hybrid simulator garage bay secured in a stationary position
2. Driving high way test with Free flow traffic

A 30" screen was installed in front of the steering wheel for subjects to monitor the experiments during their driving, on which the driving scenario will be projected.

A Logitech C920 webcam HD PRO was installed in front of the pedals to monitor the foot movements of subjects and was connected to a laptop for monitoring.

Fig 3.2 Logitech C920 Camera

And TV was connected to a computer PC to run and control the game and also monitoring the game for subject in the computer's screen for the analyzer and shoot the videos from subject's feet performances. Laptop and computer's screen placed beside of each other for shooting operations and for this case we used a GoPro HERO3^{+}

Fig 3.3 GoPro HERO 3 Camera

A camera was installed to record and achieve video data of foot movements on the pedals and also recording the game which was conducted by subjects at the same time and date acquisition was started from starting the simulator system until the end of experiments.

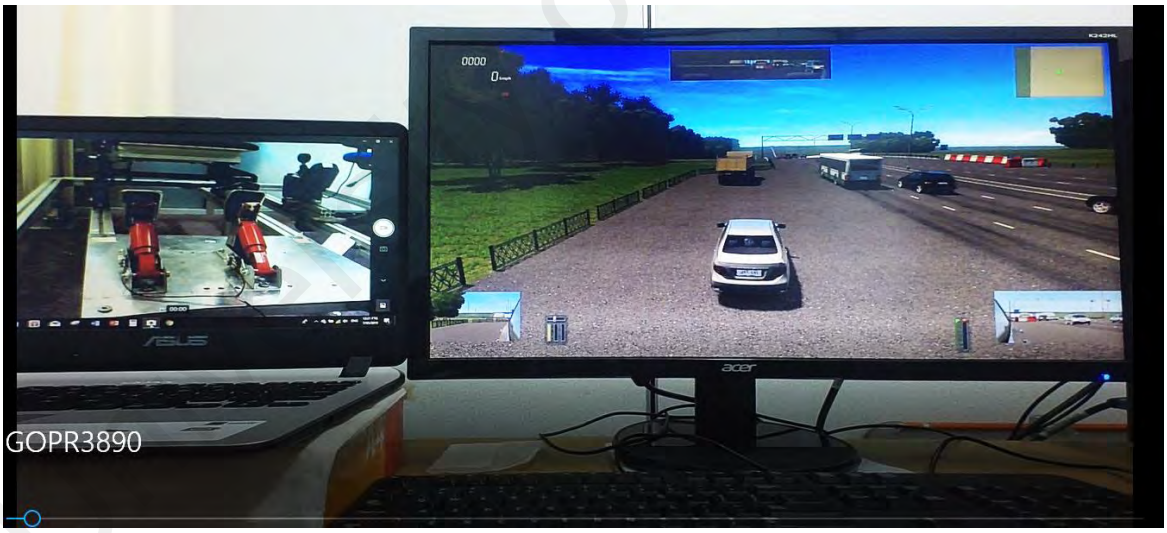


Fig 3.4 Camera Recording by GoPro Hero 3

3.1.2 Additional Measurements

- ❖ Brake pedal: Measure length, height, width
- ❖ Accelerator pedal: Measure length, height, width

- ❖ Horizontal Separation (edge to edge): Measure from the left edge of the accelerator to the right edge of the brake
- ❖ Horizontal Separation (center to center): Measure from the center of the accelerator to the center of the brake.

3.1.3 Experimental Procedures

After arriving, each subject was given an informed consent form and administered a questionnaire. Then they were invited to get into the driving simulator and were asked to position themselves comfortably, just as they normally would to drive.

Figure 3.5 Subjects on Simulator

subjects make the driving seat position comfortable based on their heights. There was a 5-minute practice driving to help them get familiar with the driving simulator and the scenario. At the same time, we recorded several aspects of the seated position the driver used within the vehicle during the simulator drive: the position of the seat on the seat-track, seatback angle, and steering wheel tilt angle (the driver will be asked to leave this as they were when they exit the vehicle). At this point, anthropometric measurements were taken.

Elements of stature and body size would affect drivers seated positions and their reach/use of the pedals.

3.1.4 Simulator Driving Procedure

Drivers were asked to respond and select the right pedal based on traffic signals and driving situations as rapidly and accurately as possible in different gaps between accelerator and brake pedals.

And also if drivers faced with green traffic light, they should press the accelerator pedal and if they faced with amber traffic light they should not press any of the pedals and if they encountered the red traffic light then they should apply the brake pedal and stop the car.

3.1.4.1 Highway Study

subjects were asked to drive in highway condition with high level of traffic jam as rapidly and accurately as possible and in different distances between both pedals to find a suitable horizontal distance between accelerator and brake pedal which it need to be Fit for 95% Malaysian population. Based on the latest published statistics in 2018 the moderate height for Malaysian male is 168Cm and for the female is 156 Cm.

For this case experiments were performed by our subjects in five different gaps but in the same driving situation to observe and analyze this issue and also find a suitable gap for 95%, other 5% would be outlier, the people who are taller than 168 cm and shorter than 156 cm.

3.1.4.2 Parking Lot (Garage bay) Study

During the second part of the controlled study, we used the same driving simulator G27 Logitech and in setting we changed the configuration part of City Car Driving game 1.5.0 version and selected a passenger car at garage bay test. At the beginning of the study, the vehicle was properly positioned and parked in the starting position for the parking lot

scenario. All other instrumentation that we employed for high way test remained for new passenger vehicle to perform this experiment, including the automatic shifting gearbox and also our cameras and laptop and continued to function in the driving scenario that is conducted in the outdoor of garage bay.

The driving scenarios took place outside in a portion of a closed parking lot (Figure 5) that have been designed to examine phases of pedal use in low speed maneuvers associated with parking (both pulling in and backing out).

The parking lot scenario consisted Four Sub-Phases:

1) (Front View Camera): Entre into the Parking Area by moving Forward (Point A to B), Bringing up reverse to Point C
2) (Front View Camera) Move Forward (Point C to A), moving reverse to point B and turning into the parking lot, Point C
3) (Back View Camera): Moving Reverse from Parking Area (Point C to B), Moving forward to Point A, Bringing Reverse into Parking Area again, Point C
4) (Back View Camera) Move Forward (Point C to B), moving reverse to point A and turning into the parking lot, Point C

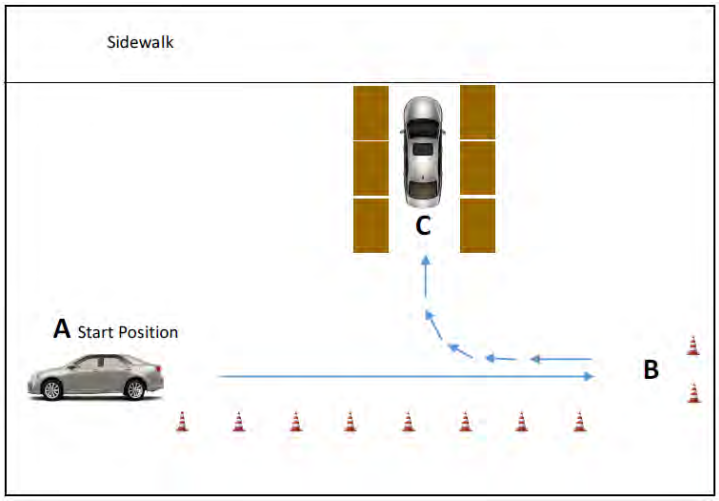


Figure 3.6 Parking Lot Activity

3.2 Performing Experiment: Impact of Pedal Distance on Pedal Miss Application (Activity Based Data)

For all the subjects we have adjusted the Seats to pedal distance at the comfortable position (Knee Angle: 110^{o}-120^{o}) and performed experiment in which above mentioned parking lot study is performed at all pedal distances.

In order to perform, the experimental setup is designed such that all activities are closely monitored using GoPro Video Recording. Each and Every subject performed same activities. After getting information about right seat distance, we have performed this experiment to analyze the Types of Pedal Miss Application and its reasons.

3.2.1 Experiment Briefing:

Every subject is thoroughly briefed about the tools and gadgets to rightly perform the Simulation Experiment. Briefing is done as

- Pressing up the Right Central Red Button on Steering Wheel to Fasten Seat Belt
- Pressing up the Left Bottom Red Button on Steering Wheel to Pullout Hand Brake
- After Pressing the Brake pedal while gear is Neutral, keep on Pressing the Right Bottom Red Button to Start the Car.
- All Signs of Seat Belt, Double Indicator, Speedometer and Gear Transmission can be seen on the Monitor.
- Gear Transmission is Automatic and easily adoptable.
- All experiments will be performed with Shoes.
- 02 Cameras will be recording your motion activities to analyze later.

- You have to perform this activity within the White Marking, if you cross the line, you need to redo/continue the activity until it's complete.
- You will have sufficient time to get yourself familiar with all features to enhance comfortability for experiment.
- For each and every activity, your reaction time will be recorded
- You are supposed to perform some activities on 05 Different Levels of Pedal Distances.
- You will be distracted throughout the Activity to increase the chances of mistake.
- There will be a survey in the end to access your feelings about PMA.

3.2.2 Types of Activities:

1. As explained before, parking in the Garage, in which subject is supposed to Park the Car in Closed loop four Times Back and Forth, in two different types of Views (Front & Back). There is no Restriction of Damaging Poles (It isn't the part of Experiment) but every subject is advised to use Accelerator as much as possible. This Activity is performed 05 times at all levels.

Figure 3.7 Activity 01 Parking Lot

2. Free Driving on a highway, in this activity Driver is advised not to Crash the car and achieving the maximum speed. This activity is performed 01 Times at a certain level for each subject.

Figure 3.8 Activity 02 Highway

3.2.3 Distraction during Experiment:

Following types of distraction is used while performing activity

- Frequent Horns (Quite Loud)
- Double Indicators
- Casual Talking and Asking Questions

3.2.4 Pedal Distance Levels:

In each car, universally the Distance between Pedals (Accelerator & Break) is 11cm, in order to check its validity, we have performed this experiment at 05 different levels.

Table 3.1 Pedal Distance Levels

Level	Distance
1	3 cm
2	5 cm
3	7 cm
4	11 cm
5	15 cm

Figure 3.9 Pedal Distance Applications

3.2.5 Reaction Time of Subjects:

Total time taken by a subject to complete the Activity. This reaction time plays an important role in making the right decision in case of emergency and Data is evaluated in terms of Reaction Time and Experience in Driving.

3.2.6 Types of PMAs:

03 Main Types of Pedal Miss Applications considered while performing Experiment

1. Pressing a Wrong Pedal:
2. Pressing Both Pedals
3. Pressing No Pedal

If someone crosses the line, we will be analyzing the Possible PMA involved in it too. In highway the Number of Crashes also helpful in Understanding the PMA in Unconscious State of Mind.

The Distractions during Experiments increases the Chances of doing Misapplication.

3.3 Standards (Society of Automotive Engineers)

- J4004: Positioning the H Point Design Tool - Seating Reference point and seat track length. We have used this standard to get the right position for Seat Adjustment and Seat to pedal distance for all Subjects.
- PL52 (SAE Internationals Standards) Pedal Distance Offset – We have used this standard to change pedal distance for all subjects in Experiment.

3.4 Survey: -

A short survey is conducted to access the experience of each subject and to compare the Survey Record with Observed Data, to see if they have made any mistake unconsciously. This Survey clarifies the Risk of making mistake that Driver usually ignore.

We have questioned relevant details about experiments in which they might have done a mistake, if Yes, then how much. The data of Personal Details like Height and Age is also calculated, in the end, Which Pedal Distance has much better experience.

Table 3.2 Survey Questions for all subjects

No.	Survey Questions
1	What is Your Height?
2	How Old are you?
3	Do you have any Disorder/Mental disease?
4	How similar was the driving with simulator with the real driving condition?
5	Did you push the wrong pedal?
6	Did you push brake and gas pedals simultaneously?
7	Has anything ever occurred confusing you to the sense that you did not know which pedal to push?
8	How comfortable (was the driving experience) when the distance between accelerator and brake was 3 cm?
9	How comfortable (was the driving experience) when the distance between accelerator and brake was 5 cm?
10	How comfortable (was the driving experience) when the distance between accelerator and brake was 7 cm?
11	How comfortable (was the driving experience) when the distance between accelerator and brake was 11 cm?
12	How comfortable (was the driving experience) when the distance between accelerator and brake was 15 cm?
13	Which pedal separation size you were quietly comfortable and dominated to the driving conditions?
14	Did Interfaring in terms of auditory and visual signs during driving caused you to commit misapplication?

No.	A	B	C	D	E
1	Less than 162.5		More than 162.5		
2	Less than 30		More than 30		
3	Yes		No		
4	30%	50%	70%	More than 80%	
5	Once	Twice	More than 3 times	None	
6	Once	Twice	More than 3 times	None	
7	Once	Twice	More than 3 times	None	
8	Quite Good	Made Mistake Once	Two Times	More than 3 Times	
9	Quite Good	Made Mistake Once	Two Times	More than 3 Times	
10	Quite Good	Made Mistake Once	Two Times	More than 3 Times	
11	Quite Good	Made Mistake Once	Two Times	More than 3 Times	
12	Quite Good	Made Mistake Once	Two Times	More than 3 Times	
13	3	5	7	11	15
14	No	Once	Two Times	More than 2 Times	

CHAPTER 4: RESULTS

4.1 Experiment: Impact of Pedal Distance on Pedal Miss Application (Activity Based Data)

There are so many different types of results have been induced from this experiment which clearly shows which Pedal Distance Level is Recommended and Which types of Pedal Misapplication is Performed Mostly.

4.1.1 EXPERIMENTAL DATA

Table 4.1 Impact of Pedal Distance on Pedal Miss Application

No.	Height (cm)	Foot Width (cm)	Exp .1 (Suitable Level)	Driving Experience (Years)	Pedal Distance (Parking)	Pressing Wrong Pedal	Pressing Both	Pressing None	Reation Time (Minutes)	Crossing Area/Crash
1	150	9.144	74.09	1	3	2	6	1	8.35	3
					5	0	2	0	6.35	1
					7	0	0	1	7.42	2
					11	0	0	0	6.07	2
					15	0	0	0	7.38	2
					Highway-5	9	1	2	4.4	5
2	159	9.652	78.41	0.1	3	2	2	1	11.2	1
					5	0	1	2	8.16	2
					7	3	0	0	8.25	0
					11	0	0	1	7.5	1
					15	1	0	0	8.09	0
					Highway -3	28	2	2	7.02	20
3	159.2	9.652	78.49	5	3	0	8	0	4.43	2
					5	0	3	0	3.41	1
					7	1	0	0	2.45	1
					11	0	0	0	2.22	0
					15	1	0	0	4.07	1
					Highway-5	8	0	1	2.54	5
4	167.5	10.41	82.34	2	3	0	5	0	4.07	0
					5	1	3	0	4.3	1
					7	0	0	1	3.35	1
					11	0	0	0	3.19	0
					15	0	0	0	4.1	0
					Highway-15	20	0	2	5.51	15
5	170	9.906	83.51	3	3	0	4	0	4.39	0
					5	1	1	0	3.53	1
					7	3	0	0	4.2	3
					11	0	0	0	3.45	0
					15	0	0	0	2.13	0
					Highway-5	12	0	0	5.56	8

Table 4.1 Impact of Pedal Distance on Pedal Miss Application

No.	Height (cm)	Foot Width (cm)	Exp .1 (Suitable Level)	Driving Experience (Years)	Pedal Distance (Parking)	Pressing Wrong Pedal	Pressing Both	Pressing None	Reation Time (Minutes)	Crossing Area/Crash
6	173	9.906	84.67	4	3	2	3	0	5.21	2
					5	2	0	0	3.02	2
					7	1	0	0	2.34	1
					11	0	0	0	2.19	0
					15	2	0	0	2.33	2
					Highway-7	13	0	2	3.49	9
7	173	10.16	84.67	1.5	3	0	3	2	2.53	2
					5	0	4	1	2.57	1
					7	0	1	1	5.11	1
					11	1	0	0	3.03	0
					15	0	0	0	3.06	0
					Highway-7	16	0	0	4.36	0
8	175	10.416	86.08	2.5	3	1	1	3	3.32	1
					5	0	0	0	1.35	0
					7	0	0	2	3.21	2
					11	0	0	2	2.49	2
					15	0	0	4	5.06	4
					Highway -3	28	1	1	5.25	20
9	180.5	10.668	88.63	6	3	1	5	0	4	1
					5	0	0	1	3.28	1
					7	0	0	0	3.09	0
					11	0	0	0	2.46	0
					15	0	0	0	2.42	0
					Highway -11	16	0	3	4.45	12
10	183.5	10.416	89.58	8	3	1	3	0	4.39	1
					5	3	0	0	3.5	3
					7	0	0	0	2.12	0
					11	3	0	0	3.27	3
					15	1	0	0	2.37	1
					Highway -11	18	0	2	5.35	14

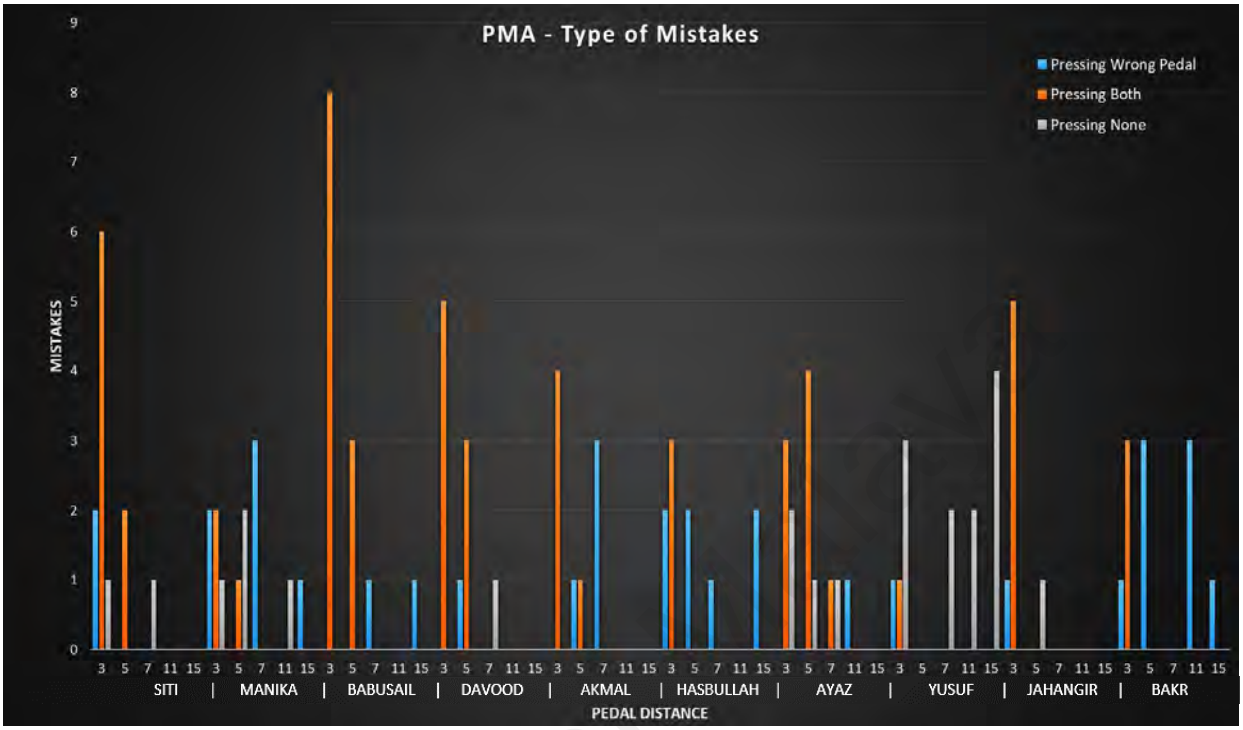
4.1.2 Pedal Misapplications – All Distances (Type of Mistakes)

Initially the Data of every type of misapplication for all subjects is analyzed. Data from Table 3.4 is collected. Bar Chart is helpful in understanding the Pedal Mistakes of Each and Every subject. All pedal distances are taken in cm.

Table 4.2 PMA – Types of Mistakes

Participant Name	Pedal Distance (Parking)	Pressing Wrong Pedal	Pressing Both	Pressing None	Participant Name	Pedal Distance (Parking)	Pressing Wrong Pedal	Pressing Both	Pressing None
SITI	3	2	6	1	HASBULLAH	3	2	3	0
	5	0	2	0		5	2	0	0
	7	0	0	1		7	1	0	0
	11	0	0	0		11	0	0	0
	15	0	0	0		15	2	0	0
MANIKA	3	2	2	1	AYAZ	3	0	3	2
	5	0	1	2		5	0	4	1
	7	3	0	0		7	0	1	1
	11	0	0	1		11	1	0	0
	15	1	0	0		15	0	0	0
BABUSAIL	3	0	8	0	YUSUF	3	1	1	3
	5	0	3	0		5	0	0	0
	7	1	0	0		7	0	0	2
	11	0	0	0		11	0	0	2
	15	1	0	0		15	0	0	4
DAVOOD	3	0	5	0	JAHANGIR	3	1	5	0
	5	1	3	0		5	0	0	1
	7	0	0	1		7	0	0	0
	11	0	0	0		11	0	0	0
	15	0	0	0		15	0	0	0
AKMAL	3	0	4	0	BAKR	3	1	3	0
	5	1	1	0		5	3	0	0
	7	3	0	0		7	0	0	0
	11	0	0	0		11	3	0	0
	15	0	0	0		15	1	0	0

Graph 4.1 (Bar Chart) PMA – Types of Mistakes by All subjects



4.1.2.1 Analysis (Types of Mistakes): -

1. Highest Number of Mistakes are contributed by Pressing Both Pedals, for all subjects.
2. For all subject's level 1 & Level 2 is the most difficult one, most number of Mistakes are in this region.
3. Pressing none is taken as: when he pressed the Accelerator but forgot to apply brake on time leading to Game over Scenario (Getting Out of the Box Area). It is observed majorly by 1-2 subjects.

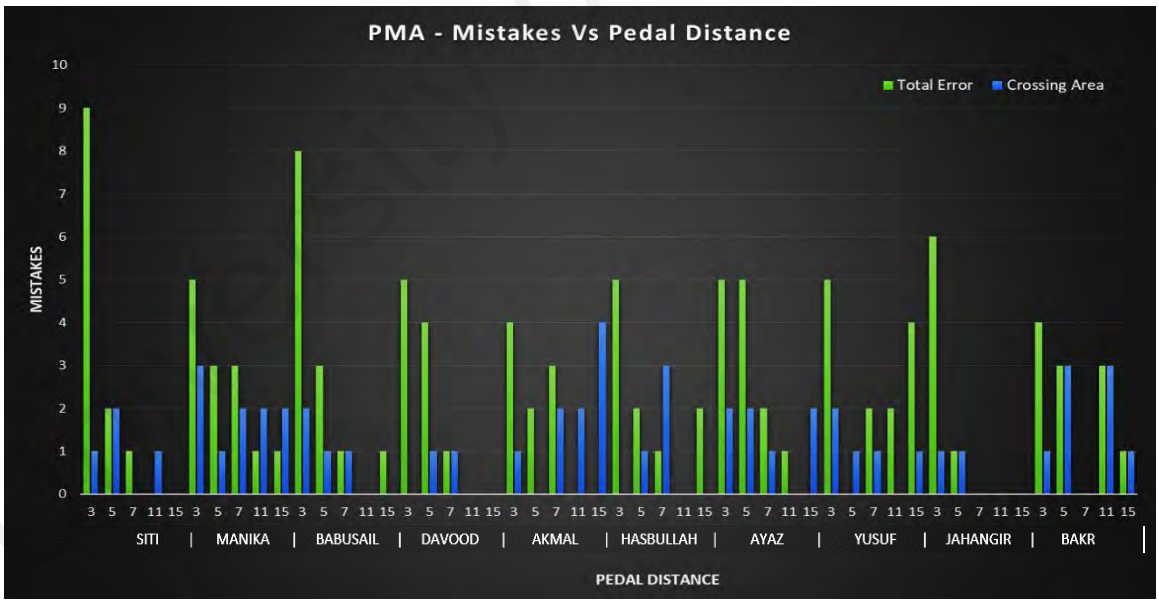
4.1.3 Pedal Misapplication - Total Errors by all subjects: -

We have added up all types of Mistakes done by each subject to analyze who was uncomfortable at which Pedal Distance Level. This data also displays the number of times subjects has done game over Scenario (Crossed the Area).

Table 4.3 PMA - Total Mistakes by Each subject

Participant Name	Pedal Distance (Parking)	Total Error	Crossing Area	Participant Name	Pedal Distance (Parking)	Total Error	Crossing Area
SITI	3	9	1	HASBULLAH	3	5	0
	5	2	2		5	2	1
	7	1	0		7	1	3
	11	0	1		11	0	0
	15	0	0		15	2	0
MANIKA	3	5	3	AYAZ	3	5	2
	5	3	1		5	5	2
	7	3	2		7	2	1
	11	1	2		11	1	0
	15	1	2		15	0	2
BABUSAIL	3	8	2	YUSUF	3	5	2
	5	3	1		5	0	1
	7	1	1		7	2	1
	11	0	0		11	2	0
	15	1	0		15	4	1
DAVOOD	3	5	0	JAHANGIR	3	6	1
	5	4	1		5	1	1
	7	1	1		7	0	0
	11	0	0		11	0	0
	15	0	0		15	0	0
AKMAL	3	4	1	BAKR	3	4	1
	5	2	0		5	3	3
	7	3	2		7	0	0
	11	0	2		11	3	3
	15	0	4		15	1	1

Graph 4.2 (Bar Chart) PMA – Total Mistakes by Every subjects



4.1.3.1 Analysis (Total Errors): -

1. As discussed in Previous Chart, most errors are at the distance 3, 5, 7 in which 3cm is the highest contributor.

2. Crossing Area is done by most of the subjects at all levels.

3. Manika, Akmal and Yusuf weren't comfortable with the Parking Activity due to Highest number of Tries (In case of Failure, have to continue until its complete)

4.1.4 Pedal Misapplication – Reaction Time with Respect to Experience of subjects: -

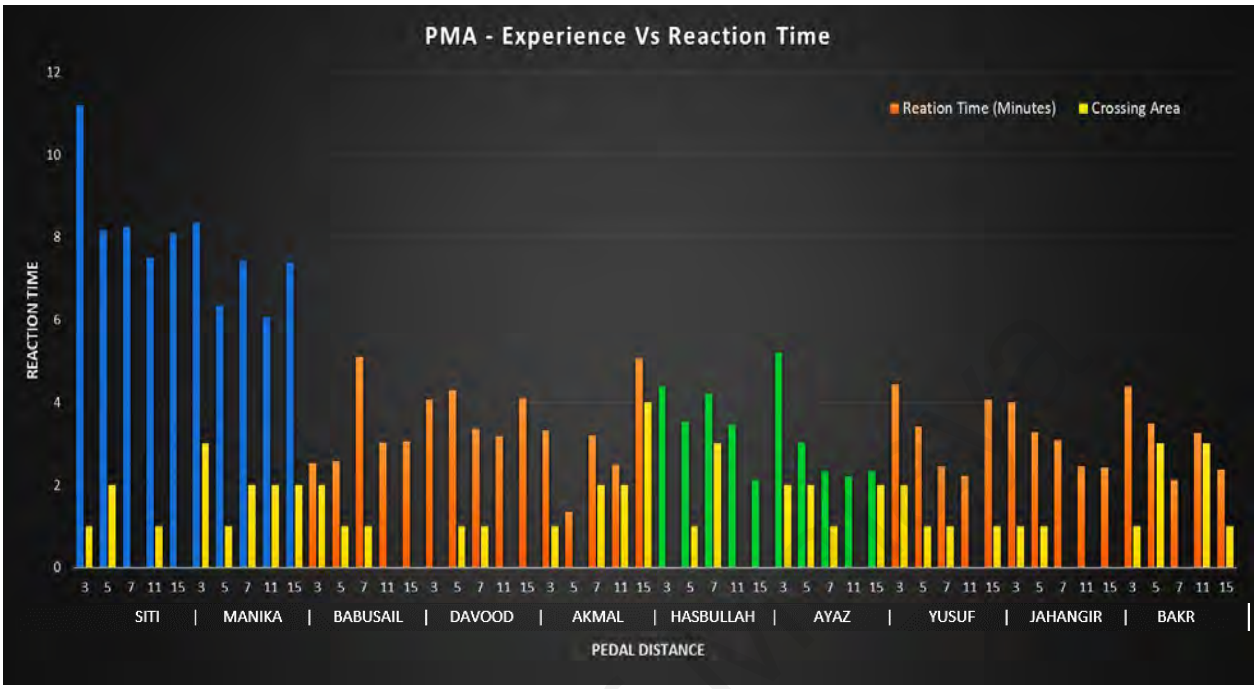
The following data shows the Reaction time of all subjects and compared with the Experience of everyone in Driving. This is helpful to get more idea about the comfortability towards performing experiment and how much they are distracted with environment and experimental conditions (Noise, Double Indicators and Asking Questions).

We have arranged all the Data in Ascending Order (Least to Highest Experience) and Transferred to Bar Chart to analyze it.

Table 4.4 PMA – Reaction time with respect to Experience

Participant Name	Driving Experience	Pedal Distance	Reation Time (Minutes)	Crossing Area	Participant Name	Driving Experience	Pedal Distance	Reation Time (Minutes)	Crossing Area
MANIKA	0.1	3	11.2	1	AKMAL	3	3	4.39	0
		5	8.16	2			5	3.53	1
		7	8.25	0			7	4.2	3
		11	7.5	1			11	3.45	0
		15	8.09	0			15	2.13	0
SITI	1	3	8.35	3	HASBULLAH	4	3	5.21	2
		5	6.35	1			5	3.02	2
		7	7.42	2			7	2.34	1
		11	6.07	2			11	2.19	0
		15	7.38	2			15	2.33	2
AYAZ	1.5	3	2.53	2	BABUSAIL	5	3	4.43	2
		5	2.57	1			5	3.41	1
		7	5.11	1			7	2.45	1
		11	3.03	0			11	2.22	0
		15	3.06	0			15	4.07	1
DAVOOD	2	3	4.07	0	JAHANGIR	6	3	4	1
		5	4.3	1			5	3.28	1
		7	3.35	1			7	3.09	0
		11	3.19	0			11	2.46	0
		15	4.1	0			15	2.42	0
YUSUF	2.5	3	3.32	1	BAKR	8	3	4.39	1
		5	1.35	0			5	3.5	3
		7	3.21	2			7	2.12	0
		11	2.49	2			11	3.27	3
		15	5.06	4			15	2.37	1

Graph 4.3 (Bar Chart) Reaction Time related to Experience



4.1.4.1 Analysis (Experience and Reaction Time): -

1. More the driver drives/perform the Activity, Less Reaction time is taken by him/her. Initial activities took more time than the last one.

2. We have observed a significant trend of decrease in Reaction Time for Experienced Drivers. Less Experienced Drivers took time to get familiar.

3. Blue bars show the Female subjects and Orange & Green bars show Male subjects. So Reaction time of all both female subjects was 50-60% more. Even the green bar subjects were unknown/randomly picked too but they didn't take significant time.

4.2 Highway Experiment: -

As explained above, Highway experiment was selected to perform free driving activity with Highest Speed and Less number of Crashes. We have got the data in terms of all types Pedal

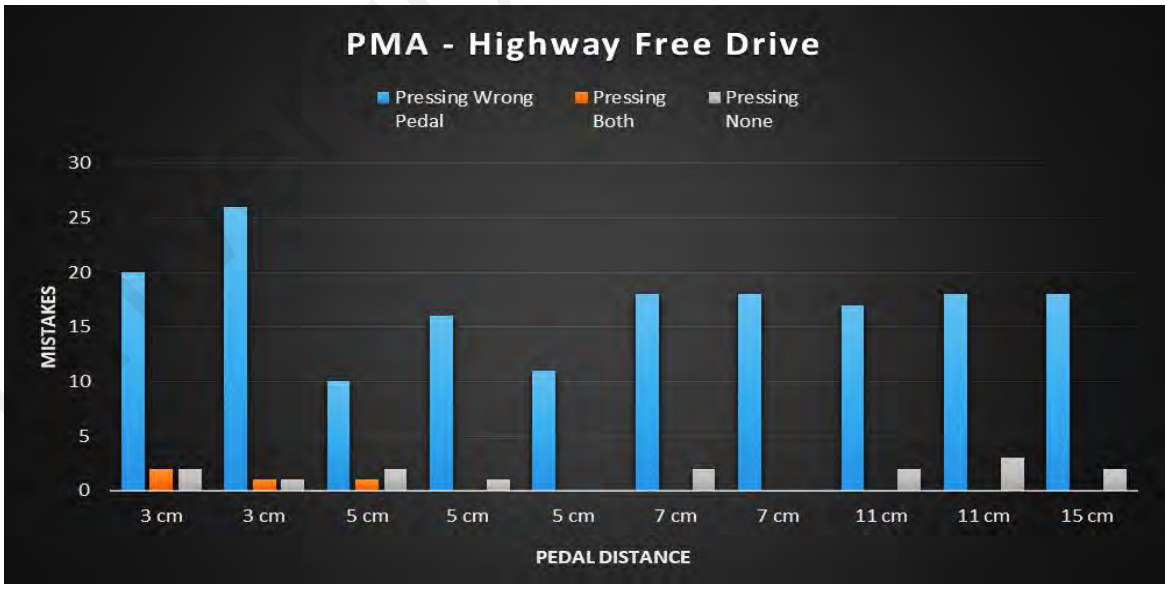
Missapplication, but it can't be recognized as useful because all subjects were taking it as a part of a game and crashing on Purpose.

As highway timings isn't fix so we have rounded off all mistakes to 5 Minutes to Increase its validity.

Table 4.5 Summarized Highway Observations

Participant Name	Pedal Distance	Pressing Wrong Pedal	Pressing Both	Pressing None
MANIKA	3 cm	20	2	2
YUSUF	3 cm	26	1	1
SITI	5 cm	10	1	2
BABUSAIL	5 cm	16	0	1
AKMAL	5 cm	11	0	0
HASBULLAH	7 cm	18	0	2
AYAZ	7 cm	18	0	0
BAKR	11 cm	17	0	2
JAHANGIR	11 cm	18	0	3
DAVOOD	15 cm	18	0	2

Graph 4.4 (Bar Chart) Highway Free Driving



As there is not significant pattern is observed and all of the subjects have crashed the vehicle multiple times by pressing wrong Pedal.

4.3 Survey: -

All data collected from 10 subjects are recorded in excel sheet and analyzed. Furthermore, the relevant information of Several Types of Pedal Misapplications are compared with the experimental data to idealize the concept of Survey Authenticity.

Table 4.6 Data Collected from Survey

Question	SITI	MANIKA	BABUSAIL	DAVOOD	AKMAL	HASBULLAH	AYAZ	YUSUF	JAHANGIR	BAKR
1	Less than 162.5	Less than 162.5	Less than 162.5	More than 162.5	More than 162.5	More than 162.5	More than 162.5	More than 162.5	More than 162.5	More than 162.5
2	More than 30	Less than 30	Less than 30	More than 30	Less than 30	Less than 30	Less than 30	More than 30	Less than 30	More than 30
3	No	No	No	No	No	No	No	No	No	No
4	50%	More than 80%	More than 80%	50%	More than 80%	50%	50%	More than 80%	50%	50%
5	More than 3 times	More than 3 times	None	More than 3 times	More than 3 times	Twice	More than 3 times	None	More than 3 times	Twice
6	More than 3 times	More than 3 times	None	More than 3 times	Once	More than 3 times	None	Twice	Twice	Twice
7	More than 3 times	More than 3 times	Once	More than 3 times	Once	More than 3 times	Once	None	None	More than 3 times
8	Two Times	Made Mistake Once	Quite Good	More than 3 Times	More than 3 Times	More than 3 Times	More than 3 Times	Quite Good	Two Times	Made Mistake Once
9	More than 3 Times	Made Mistake Once	Quite Good	More than 3 Times	Made Mistake Once	More than 3 Times	More than 3 Times	More than 3 Times	Quite Good	Quite Good
10	More than 3 Times	Quite Good	Quite Good	Quite Good	Made Mistake Once	Made Mistake Once	Two Times	Quite Good	Quite Good	Quite Good
11	More than 3 Times	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good
12	Two Times	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good	Quite Good
13	5	7	7	11	15	7	11	11	7	7
14	Two Times	More than 2 Times	No	Once	No	Two Times	Two Times	Once	No	Once

4.3.1 Survey (Analysis): -

We have summarized the survey to get the following outputs

- 03 subjects were less than average Malaysian Height (162.5 cm) while rest are more.
- 4 subjects are more than 30
- 6 subjects consider it average Resemblance to Actual Driving while rest of 4 consider it 80%
- Level of Comfortability is different for each pedal distance. Following table shows survey data.

Table 4.7 Comfortable Pedal (Survey Data)

L1-3cm	**0**
L2-5cm	**1**
L3-7cm	**5**
L4-11cm	**3**
L5-15cm	**1**

4.4 Survey Comparison with Observed Data: -

Considerable Difference in Survey and Observed Data in terms of all types of Misapplications.

4.4.1 Pressing Wrong Pedal: -

- 04 subjects pressed 01 Time, but they aren't sure.
- 06 subjects think that they have pressed more than 3 times but actually they didn't.
- 02 subjects think they haven't pressed wrong pedal but in reality, they did.

Figure 4.1 Data - Pressing Wrong Pedal

4.4.2 Pressing Both Pedal: -

- 03 subjects think they have pressed twice but in reality, more than 3 times.
- 02 subjects think haven't pressed both pedal anytime but actually they have done it more than 3 times. It shows their unconsciousness during experiment.

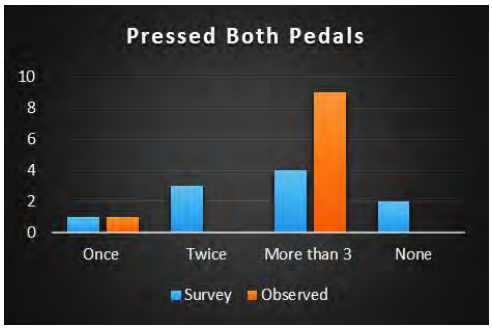


Figure 4.2 Data - Pressing Both Pedals

4.4.3 Pressing No Pedal: -

- 02 subjects think they haven't pressed any pedal once but, 04 of the subjects haven't.
- 01 subjects haven't pressed any pedal 2nd time but he cannot remember.
- 05 subjects think that they haven't done the mistake of pressing no pedal more than 3 times but in actual reading only 03 of them did this mistake
- 02 subjects unconsciously think they did a mistake but they didn't.

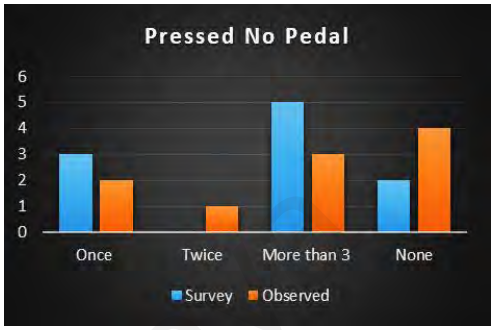


Figure 4.3 Data - Pressing No Pedal

4.5 Subjects Height's significance for Pedal Distance: -

We have recorded the Shoes Sizes (Length & Width) along with Height to understand the Minimum Distance Level for different subjects. Taller the Person is, more the Pedal Distance required to ensure least pedal misapplication.

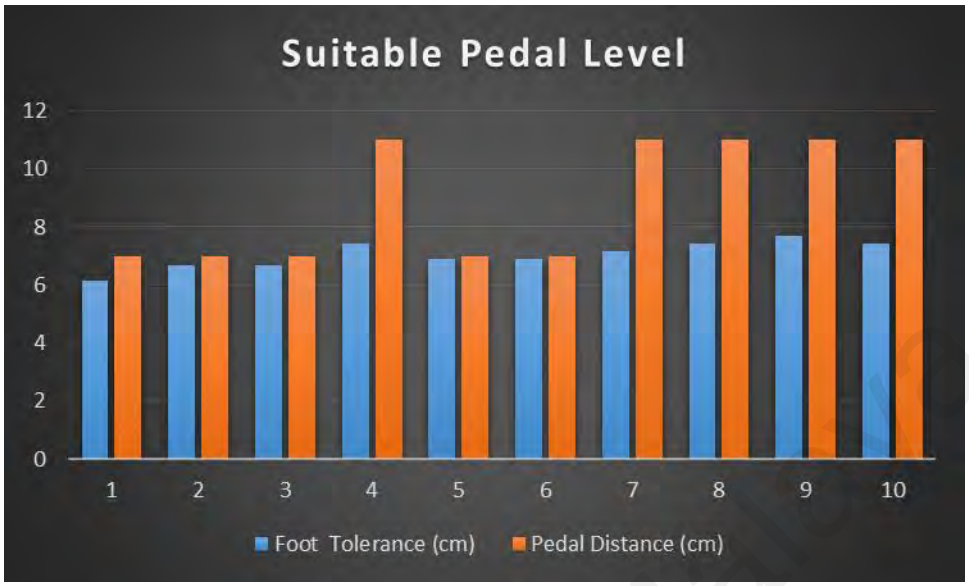
In this Experiment, all foot measurements are taken with Shoes (Requirement of Experiment) so there isn't any significant difference in width. The width of Accelerator and Brake Pedal is itself 7 cm each so there should be at least enough distance that the difference of Feet width to Pedal can be easily covered. We have taken the margin of 2cm on both Sides to increase the safety.

Following Data shows the Relevance of Height to Suitable Pedal Distance Level.

Table 4.8 Relation of Suitable Pedal Distance with Height

No.	Participant Name	Height (cm)	Foot Size (cm)	Foot Width	Pedal Distance
1	SITI	150	39	9.144	7
2	MANIKA	159	40	9.652	7
3	BABUSAIL	159.2	40	9.652	7
4	DAVOOD	167.5	42	10.41	11
5	AKMAL	170	42	9.906	7
6	HASBULLAH	173	42	9.906	7
7	AYAZ	173	42.5	10.16	11
8	YUSUF	175	43.5	10.416	11
9	JAHANGIR	180.5	44.5	10.668	11
10	BAKR	183.5	44	10.416	11

Graph 4.5 (Bar Chart) – Suitable Pedal Level for Different Heights



Following the Data and Number of Mistakes done at different levels, it is clearly visible that for all Malaysian Heights less than 160cm, Pedal Distance of 7cm is acceptable however increasing tolerance, safety and Following International Standards 11cm distance is adopted because of least chances of Errors.

CHAPTER 5: CONCLUSION

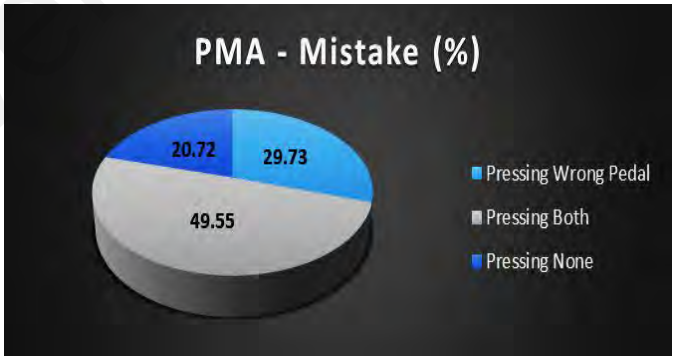
We have summarized all the data towards getting an understanding that Pedal Misapplication is so much important to increase the safety measures towards driving in different conditions. In this regard there are several points that has been addressed.

1. Most appropriate distance from Pedal to Seat is ensured by Knee angle between 110^{o}-120^{o} and it contributes towards the comfortability of Driver. Results shows that for taller people this angle variation is low thus reducing the risk of Doing Pedal Misapplication due to distance.
2. All types of mistakes are accumulated & investigated, shows the following types of Pedal Misapplication chances are the Highest.

Table 5.1 Total Pedal Misapplications Data

Data - PMA Mistakes Pie Chart		
PMA – Type	**PMA - Mistake**	**PMA - Mistake (%)**
Pressing Wrong Pedal	33	29.73
Pressing Both	55	49.55
Pressing None	23	20.72
Total	111	100.00

Graph 5.1 (Pie Chart) PMA – Mistakes (%)

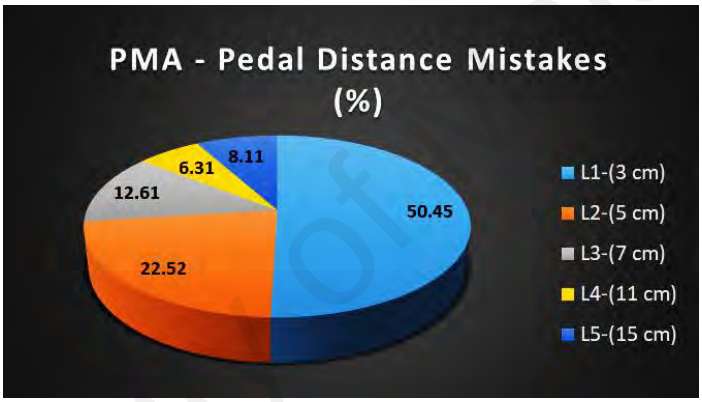


3. Total mistakes happened at all pedal distances to show which level is most risky while driving. Another Pie chart to understand the Most Risky and Comfortable Pedal Distances.

Table 5.2 Pedal Misapplication at Distances

Data - PMA Mistakes Due to Distance Pie Chart		
Pedal Distance	**PMA - Total Mistakes**	**PMA - Total Mistake (%)**
L1-(3 cm)	56	50.45
L2-(5 cm)	25	22.52
L3-(7 cm)	14	12.61
L4-(11 cm)	7	6.31
L5-(15 cm)	9	8.11
Total	111	100

Graph 5.2 (Pie Chart) PMA - Pedal Distance Mistakes (%)



As we have seen that 50% of the Mistakes done by subjects is by pressing both pedals. This study is helpful in understanding the safest zone in term of pedal distance reducing the risk to doing Pedal Misapplication to 7%.

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