DESIGN AND FABRICATE ROLLOVER WARNING DEVICE WITH IOT MONITORING SYSTEM FOR COMMERCIAL VEHICLE

ADAM LUQMAN BIN AZMI

B092010259

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

2024

FACULTY OF TECHNOLOGY AND MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BACHELOR DEGREE PROJECT SUPERVISOR DECLARATION FORM

BACHELOR DEGREE PROJECT 1 [ ] **BACHELOR DEGREE PROJECT 2** [/]

SEMESTER 1 **SESSION** 2024 / 2025

A. DETAILS OF STUDENT *(to be completed by student)*

Name : Adam Luqman Bin Azmi

Program : BMKA **Matric No. :** B092110366 **Phone No. :**

Title : DESIGN AND FABRICATE ROLLOVER WARNING DEVICE WITH IOT MONITORING SYSTEM FOR COMMERCIAL VEHICLE

B. CHECKLIST *(to be completed by student, choose only 1)*

BACHELOR DEGREE PROJECT 1 *(Please tick (/) if completed)*

Project Proposal [/] E-log book [/]

BACHELOR DEGREE PROJECT 2 *(Please tick (/) if completed)*

Full report [/] E-log book [/] Technical paper [/]

Student's Signature :

Date : 7 January 2025

C. CERTIFICATION BY SUPERVISOR *(to be completed by student, choose only 1)*

Comments: The student final year report is ready to be examined.

[/] I hereby certified that the student completed all the documents as stated in Part B and recommended for evaluation

[ ] Not recommended for evaluation

Supervisor's Signature
And Stamp IR. TS. DR. MOHAMAD HAFIZ BIN HARUN
Pensyarah Kanan
Fakulti Teknologi Dan Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka (UTeM)

Date : 9 January 2025

REMINDER:
Kindly submit the completed form to the PSM (JTK) FTKM Committee

Faculty of Technology Mechanical and Engineering

DESIGN AND FABRICATE ROLLOVER WARNING DEVICE WITH IOT MONITORING SYSTEM FOR COMMERCIAL VEHICLE

Adam Luqman Bin Azmi

Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

2025

DESIGN AND FABRICATE ROLLOVER WARNING DEVICE WITH IOT MONITORING SYSTEM FOR COMMERCIAL VEHICLE

ADAM LUQMAN BIN AZMI

A thesis submitted
in fulfillment of the requirements for the Degree of
Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2025

DECLARATION

This thesis entitled "Design and Fabricate Rollover Warning Device with IOT Monitoring System for Commercial Vehicle" is the result of my research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : *ADAM LUQMAN BIN AZMI*

Date : 3/1/2025

APPROVAL

I hereby declare that I have checked this thesis and from my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature : ....

Supervisor Name : *Ir.Ts.Dr. Mohamad Hafiz Bin Harun*

Date : 9/1/2025

DEDICATION

I would like to thank Allah for the Almighty, my creator, my pillar of strength, and my source of inspiration, knowledge, and understanding. He gives me strength throughout this program and on His wings only I have soared.

I would also like to dedicate this to my family, especially to my parents who encouraged me all the way, instilled in me a desire to learn, prayed a lot for my success, and made sacrifices so I could have a successful future.

Also, to dedicate to my supervisor Ir. Ts. Dr. Mohamad Hafiz bin Harun, and his colleagues who have assisted me during the academic path. May the blessing of Allah be with them now and always "Aamiin Ya Robbal Alamin"

ABSTRACT

Nowadays, there are always been heard commercial vehicle involved in accident and the mainly caused by namely rollovers of lightweight trucks. There is higher rate of fatal and death rate compared to other types of crashes which rollover events resulting impact on both drivers and passengers. Several factor that contributes to the rollover events, leading to the fatal physical injuries and death. The main objective of this project is to develop a device called Rollover Warning Device (RWD) has been built for commercial vehicles that suit on those that which have much larger center of gravity height-to-track width ratio. This developed system eventually gathers all the information related to movement of the vehicle and evaluates its current capacity and load to stay stable using the rollover index algorithm created. The rollover index algorithm used in a rear-wheel drive (RWD) system determines the rollover index value by using the load transfer ratio (LTR). The block model parameters for the rollover index solution are observed by using MATLAB. All the information and index will be simulated in MATLAB/Simulink and determined to analyze the steering motion performed with different velocities. Odenthal rollover index have been improvise and shown in Truck Sim driving simulator and MATLAB/Simulink software. To make it succeed, modelling steering step maneuver at any different velocities and loads are applied using the Hardware-in-the-loop (HIL) simulation approach. The result produced shown that the improvised Odenthal rollover index algorithm provides a 12.3% of improvement in Time-To-Warn (TTW) for the driver to be aware of the situation. By that reason, it will allow Time-To-Respond (TTR) for the driver to carefully and efficiently carry out the counter action. The application of upgraded Odenthal rollover index algorithm much

more success to overcome rollover events by enhancing a dependable warning system. Rollover Warning Device (RWD) also equipped with IoT support which will inform and notify any desired party whenever rollover events might to occur. This support will be very useful to allow any currier company to observe and monitor the truck driver for the safety purpose. For IoT support, the notification must be shown as soon as possible for the monitoring and data collection.

ABSTRAK

Pada masa kini, negara sering dihebohkan dengan kenderaan komersial yang terlibat dalam kemalangan dan terutamanya disebabkan oleh terbaliknya kenderaan komersial. Terdapat kadar kematian dan kematian yang lebih tinggi berbanding dengan jenis kemalangan lain yang peristiwa terbalik mengakibatkan kesan kepada pemandu dan penumpang. Beberapa faktor yang menyumbang kepada peristiwa kenderaan terbalik, yang membawa kepada kecederaan fizikal yang membawa maut dan kematian. Objektif utama projek ini adalah untuk membangunkan peranti yang dipanggil *Rollover Warning Device* (RWD) yang telah dibina untuk kenderaan komersial yang sesuai dengan mereka yang mempunyai pusat graviti yang lebih besar nisbah ketinggian-ke-trek dengan lebar. Sistem yang dibangunkan ini akhirnya mengumpulkan semua maklumat yang berkaitan dengan pergerakan kenderaan dan menilai kapasiti dan muatan semasanya untuk kekal stabil menggunakan algoritma indeks pusing ganti yang dicipta. Algoritma indeks kenderaan terbalik yang digunakan dalam sistem pacuan roda belakang (RWD) menentukan nilai indeks pusing ganti dengan menggunakan nisbah pemindahan beban (LTR). Parameter model blok untuk penyelesaian indeks peralihan diperhatikan dengan menggunakan MATLAB. Semua maklumat dan indeks akan disimulasikan dalam MATLAB/Simulink dan ditentukan untuk menganalisis gerakan stereng yang dilakukan dengan halaju yang berbeza. Indeks peralihan Odenthal telah diubahsuai dan ditunjukkan dalam simulator pemanduan Truck Sim dan perisian MATLAB/Simulink. Untuk menjayakannya, pemodelan manuver langkah stereng pada mana-mana halaju dan beban yang berbeza digunakan menggunakan pendekatan simulasi Hardware-In-the-Loop (HIL). Keputusan yang dihasilkan menunjukkan bahawa algoritma indeks peralihan Odenthal yang telah diubahsuai memberikan 12.3% peningkatan dalam Masa-Untuk-Amaran (TTW) untuk pemandu menyedari situasi tersebut. Oleh sebab itu, ia akan membolehkan Masa-Untuk-Tindak Balas (TTR) untuk pemandu berhati-hati dan cekap menjalankan tindakan balas. Penerapan algoritma indeks peralihan Odenthal yang dinaik taraf lebih berjaya untuk mengatasi peristiwa peralihan dengan mempertingkatkan sistem amaran yang boleh dipercayai. Peranti Amaran Kenderaan Terbalik(RWD) juga dilengkapi dengan sokongan IoT yang akan memaklumkan dan memberitahu mana-mana pihak yang dikehendaki apabila peristiwa peralihan mungkin berlaku. Sokongan ini akan sangat berguna untuk membolehkan mana-mana syarikat kurier memerhati

dan memantau pemandu trak untuk tujuan keselamatan. Untuk sokongan IoT, notifikasi mestilah ditunjukkan secepat mungkin untuk pemantauan dan pengumpulan data.

ACKNOWLEDGEMENTS

The text begins with an invocation to Allah, the Most Forgiving and Most Merciful of all.

Initially, I express my gratitude and admiration to Allah the Supreme Being, who is responsible for my existence and sustenance, for all the blessings bestowed upon me throughout my lifetime. The purpose of this message is to express gratitude towards Universiti Teknikal Malaysia, Melaka (UTeM) for furnishing the research platform. Gratitude is expressed towards the Malaysian Ministry of Higher Education (MOHE) for providing financial aid.

The author expresses their utmost gratitude towards their primary supervisor, Ir.Ts.Dr. Mohamad Hafiz Bin Harun, affiliated with Universiti Teknikal Malaysia, Melaka (UTeM), for providing unwavering support, invaluable guidance, and a source of motivation throughout their work. The subject's ability to offer valuable guidance and insights with great patience will be forever memorialized.

I would like to express my heartfelt gratitude to my esteemed father, Azmi Bin Jantan, for his unwavering encouragement and steadfast support throughout my various pursuits. His financial assistance has also been instrumental in my endeavors. I would like to express my gratitude to my dear companions for their unwavering assistance, affection, and supplications. Ultimately, gratitude is extended to all those who offered aid, encouragement, and motivation in facilitating the initiation of my research.

TABLE OF CONTENT

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBEREVIATIONS

a	-	Distance from front tire to center
a_y	-	Lateral acceleration
$a_{y,2}$	-	Lateral acceleration of the body only
b	-	Distance from rear tire to center
c	-	Damping coefficient
C_{sf}	-	Front damper coefficient
C_{sr}	-	Rear damper coefficient
$F_{Z,L}$	-	Left vertical tire force
$F_{Z,R}$	-	Right vertical tire force
g	-	Gravitational acceleration
h	-	Height of CoG
h_R	-	Roll center height
I_x	-	Moment of inertia of roll axis
I_{xx}	-	Roll inertia
K	-	Steer gradient
k	-	Spring stiffness
K_{sf}	-	Front spring stiffness
K_{sr}	-	Rear spring stiffness
K_t	-	Tire stiffness
Ka	-	Coefficient of body lateral acceleration
Kr	-	Coefficient of roll angle
L	-	Wheelbase
m	-	Total mass
m_2	-	Body mass
M_s	-	Sprung mass
M_u	-	Unsprung mass
T or t or l_w	-	Track Width
v	-	Velocity
φ	-	Roll angle

$\dot{\phi}$	-	Roll rate
$\ddot{\phi}$	-	roll acceleration
δ	-	Steering angle

3D	-	3-dimension
ADAS	-	Advanced Driver Assistance Systems
AI	-	artificial intelligence
AIDS	-	acquired immunodeficiency syndrome
ARM	-	Advanced RISC Machine
CDC	-	Centers for Disease Control and Prevention
CoG	-	center of gravity
CPU	-	central processing unit
EMI	-	electromagnetic interference
ESP	-	Espressif System
EWD	-	Early Warning Devices
FMCSA	-	Federal Motor Carrier Safety Administration
HIL	-	Hardware-in-the-Loop
HIV	-	human immunodeficiency virus
HTTP	-	Hypertext Transfer Protocol
IoT	-	Internet of Things
I/O	-	input/output
LED	-	Light-Emitting Diode
LTR	-	Load Transfer Ratio
MIL	-	Model-in-the-Loop

MORI	-	Modified Odenthal Rollover Index
MIROS	-	Malaysian Institute of Road Safety Research
MQTT	-	MQ Telemetry Transport
NHTSA	-	National Highway Traffic Safety Administration.
PSO	-	Particle Swarm Optimization
RAR	-	Rearward Amplification Ratio
RC	-	Remote Control
RI	-	rollover index
RMP		Royal Malaysian Police
RSF	-	Roll Safety Factor
IDE	-	Integrated Development Environment
SUV	-	Sport Utility Vehicle
SPI	-	Serial Peripheral Interface
SRT	-	Static Rollover Threshold
SSF	-	Static Stability Factor
SIL	-	Software-in-the-Loop
SSC	-	Step Steer Cornering
SoC	-	System-on-Chip
TTW	-	Time-To-Warn
TTR	-	Time-To-Respond
USB	-	Universal Serial Bus
VIL	-	Vehicle-In-the-Loop

CHAPTER 1

INTRODUCTION

1.1 Background

Due to grown of technology, there are only certain part that had been emphasized in enhancing vehicle safety around the globe. Based on that fact, the accident rate that happen still increasing and based on observation made by The National Centre for Injury Prevention and Control, part of the Centers for Disease Control and Prevention stated that there are 1.35 million individuals have been death cause by vehicle accident globally. In 2022 alone, 42795 people die from fatal vehicle accident and report said that there are estimation more than 3700 accident that involving vehicles, motorbikes, buses, lorries and pedestrian. Besides that, accidents will also resulting permanent disability to the victim. Until 2023, there are 2.35 million suffer in injuries and permanent disability which is much more concerning that half of that number involved children and adolescents. Currently, fatalities resulting from accidents surpass those caused by HIV/AIDS. In Europe, vehicle accidents already claim more than 50,000 fatalities and 150,000 injuries reported.

In Malaysia, there are total of 6,080 deaths due to accidents were recorded throughout the year 2023 throughout the country and referring from Senior Director of the Enforcement Division of the Road Transport Department Datuk Lokman Jamaan, there are average almost 17-18 of deaths happened every day cause by fatal vehicles accident in 2023. Besides that, Royal Malaysian Police (RMP) stated that there are Bukit Aman confirmed 598635 road accident cases nationwide for the period from January 1 to December 30 in Kosmos Newspaper.

After that, Malaysian Institute of Road Safety Research (MIROS) reported that there are over 34,747 traffic accident that involving heavy vehicles. (MIROS) also stated that head-on and rear-end incidents cases were highest reported which is 32.8% and 28.4% from total accidents rate and average pattern of accident shown 51% happen in daylight and 49% happen at nighttime. 55.1% of accidents occur during nighttime cause by low efficiency of lighting which causing low visibility for the driver. The transport minister of Malaysia, Anthony Loke, said that the overload vehicles may be factor for the heavy vehicles or trucks involved with the accident. Overload vehicles also will the stability of the vehicles which can cause it to loss control or worst rollover. Studies have been done to examine the contributing factor to the fatal incidents for heavy vehicles was the rollover event.

The most common incidents that involving rollover was lateral vehicle which happened when a vehicle is sliding sideways and tires hit the curb. Heavy commercial vehicles will face higher risk to rollover which have more heavy weight, large in size, and higher center of mass compare to other vehicles. As known, economic development had been affected by any road accidents that involve heavy loaded commercial vehicles that carry goods and also rollover incidents might threaten the lives of others road user and property. Road accidents involving commercial vehicle rollovers have a significant impact on economic development, people's lives and property.

To low down any risk for the vehicles undergo rollover motion, warning system devices must be used to allow the driver been warned much earlier for applying counter measure to upcoming rollover event. The devices will assist the driver to perform any corrective counter measure such as applying braking and adjusting steering angle within proper time to stabilize the vehicles. Besides, rollover may happen when there are time delay for the warning signal has been too late to develop braking force for the commercial vehicles that have greater forward inertia force due to heavy load. The devices will be valued by the effectiveness of warning system to warn the driver at the accurate early timing. Whereas other safety measure has going through such a significant improvement, rollover warning devices should be emphasized due to rollover event continue to be most of fatal accident on our road.

1.2 Problem Statement

Whenever the vehicles undergo control loses, it may cause to rollover veers to sideway or up-front. The magnitude of the collision will determine number of times when the vehicle rolls before stopping. Studies conducted by (Large Truck and Bus Crash Facts, 2015) inform that 12.3% from truck incident that involve fatality were cause by rollover event and 9.9% were contributed to injury crashes. Not to overlooked, heavy commercial driver also might suffer severe injuries due to rollover as reported by National Highway Traffic Safety Administration (NHTSA). In addition, from 2011 to 2015, 58% from total injuries by heavy commercial vehicles driver cause by rollover. In Malaysia, at the first 6 weeks in 2022, there are 19,888 road accident involving commercial vehicles and some of it cause by rollover as reported by Department of Road Transport. All of these numbers and percentages was totally concerning due to number of injuries and death reported.

Vehicles rollover events are much more complicated compared to other type of accident which is harder to identify the main cause of it. Usually, any vehicles accident might be cause and influenced by three primary factors: the driver condition (sleepy, exhausted, and health issue), driving environment (road condition, weather, and degree of vision) and the vehicle condition (such as tire condition and lack of maintenance before continue to road trip). As stated by National Traffic Safety Administration (NHTSA) and Federal Motor Carrier Safety Administration (FMCSA), there are more that 56 percent of commercial vehicles rollover incident happened on a straight roadway.

Surprisingly, most commercial vehicles rollover tends to happen on dry road surface which cover up 93 percent from total rollover cases. But, 28 percent of commercial vehicles accident cause by excessive speeding. Besides that, (Rosenfeld, J. December 13,2016) stated that 66 percent of commercial vehicles rollover occur with the driver who have around ten years of driving experience. Most commercial vehicles rollover happened due to human error by negligent several safety precaution. Any miscalculating the degree of road bend, high velocity on curved roadways and sudden maneuvers can resulting in a rollover. Another several contributing factors to rollover events was vehicle type, load position, and the torsional stiffness of the trailer. Commercial vehicles, tractor-trailers, pickup trucks, passengers van, and Sport Utility Vehicle (SUV) likely vulnerable to rollover due to its higher structure.

After that, elevated center of gravity cause by unbalanced weight distribution on the upper part will decrease vehicle's equilibrium and steadiness. Another factor that may cause rollover to happen is connected to vehicles speed and acceleration. There are around 40 percent of rollover event that cause fatality involved high speed on curved road with additionally distracted while driving such as texting on cellphones, eating, and drinking cause disturb the concertation of the driver.

Based on previous evidence, it much more recommended to apply vehicle assistance technology to overcome several incidents that involving heavy loaded commercial vehicle such as rollover warning system. By installing this device, it will notify the driver and allow them to apply any counter maneuver to reposition the vehicle whenever needed. This system might also save the driver life which allow the them to get out the vehicles when its too late for any counter measure. This advanced rollover safety warning system will use much intelligent coding and algorithms to overcome the demand to warn the driver at appropriate timing and avoid any lagged to the system, latest microcontroller was used

After the device been installed, the warning system will indicate in form of light flashing and signal whenever the rollover threshold been detected. Besides, speaker or buzzer will also be used as an alternative if the driver does not aware of any flashing light signal to ensure that the driver will be notice at the warning indicator and perform corrective movements. As additional, devices will be connected to Internet of Things (IoT) which will notify the desire user about the incident or whenever the vehicles reach rollover threshold. With this, any company can monitor their driver for safety purpose and to take discipline action when they driving in dangerous condition. This advanced rollover systems will consider several criteria and factors such as velocity, mass, partially loaded, unloaded, vehicle stature, and vehicle configuration, to determine and fulfill the calculation for rollover index.

The vehicle rollover warning system will be more precise by adding several more data to get the exact timing for rollover determination threshold. The reading of the data will be enhanced by the using of latest microcontroller such as Arduino IDE, ESP 8266 and embedded with advance coding and algorithm. With steering angle and vehicle speed been set up as the input of the system, it will allow it to improve the warning indication much more accurate and time to respond will be much faster. To predict the probability of any commercial vehicles experiencing rollover, real-time algorithm is used.

1.3 Research Objective

The main goal of this research is to design, build, and improve a rollover warning system for commercial vehicles. The following are the specific objectives:

1. To design and modifies rollover warning devices for commercial vehicles.

2. To embedded the IoT system in Rollover Warning Device for commercial vehicles monitoring purposes.

1.4 Scope of Research

The scope of this research are as follows:

- The modified rollover index is combined in the microcontroller.
- The rollover warning device is developed using Matlab/Simulink, TruckSim and Blynk
- The IoT system is designed and developed as a monitoring system that receives, stores, and analyzes data that transmitted by microcontroller.
- Implement suitable apps notification for transmitting the collected sensor data to a central monitoring system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, there are it already been common to travel using any motor or engine powered vehicles and provides unparalleled level of mobility due to development of automobiles industry. This progress might result constant increasing in traffic as the number of vehicles. This is also encouraged by increasing of road and highway allowing people get to any destination much easier and reachable. By all of the statement, the distant traveled by vehicle increase worldwide, resulting the increasing number of road accident which might be caused by road condition and human error. As all industry growing up, there are many factories are opened to fulfill all the needs and there will be also many vehicles needed to transport all the goods from one place to another places. Reported road accident involving courier vehicles increases every day and there some cases involving rollover vehicle incidents.

2.2 Early Warning Device

There are many and various method that have been develops as prevention for rollover by researcher and engineers across the globe to overcome this problem. Limited time was a main problem face by them which for the activator begin to react effectively once the next transition phase start. This problem needs to be solved to allow the driver notice the warning of any possibilities and prediction of rollover to happen. Based on that reason, indication for warning system for rollover must be earlier crucially as it warned the driver before any tires lose traction from the road which is allow the prevention for vehicles from rollover.

2.3 Wired-controlled Auxiliary Braking

Vehicles with enhanced anti-rollover systems use body attitude sensing to initiate automatically controlled auxiliary braking. Regarding vehicle dynamics, the system makes use of sensors to track any vehicle's roll angle and lateral acceleration over time in order to detect circumstances that increase the likelihood of a rollover. An electro-hydraulic brake-by-wire actuation system is used by the system to apply differential braking to the front wheels when a critical condition. In turn, this creates a stabilizing moment that prevents the rollover and helps the driver keep control of the vehicles.

The main benefits of this system is it can prevents rollovers quite well, especially in higher vehicles, and it is quiet easy to install. However, in order to be properly reliable, it increases complexity and costs and is dependent on how accurate body-attitude detection algorithms. In essence, this technique offers a viable way to improve car stability and safety in scenarios where rollovers are likely.

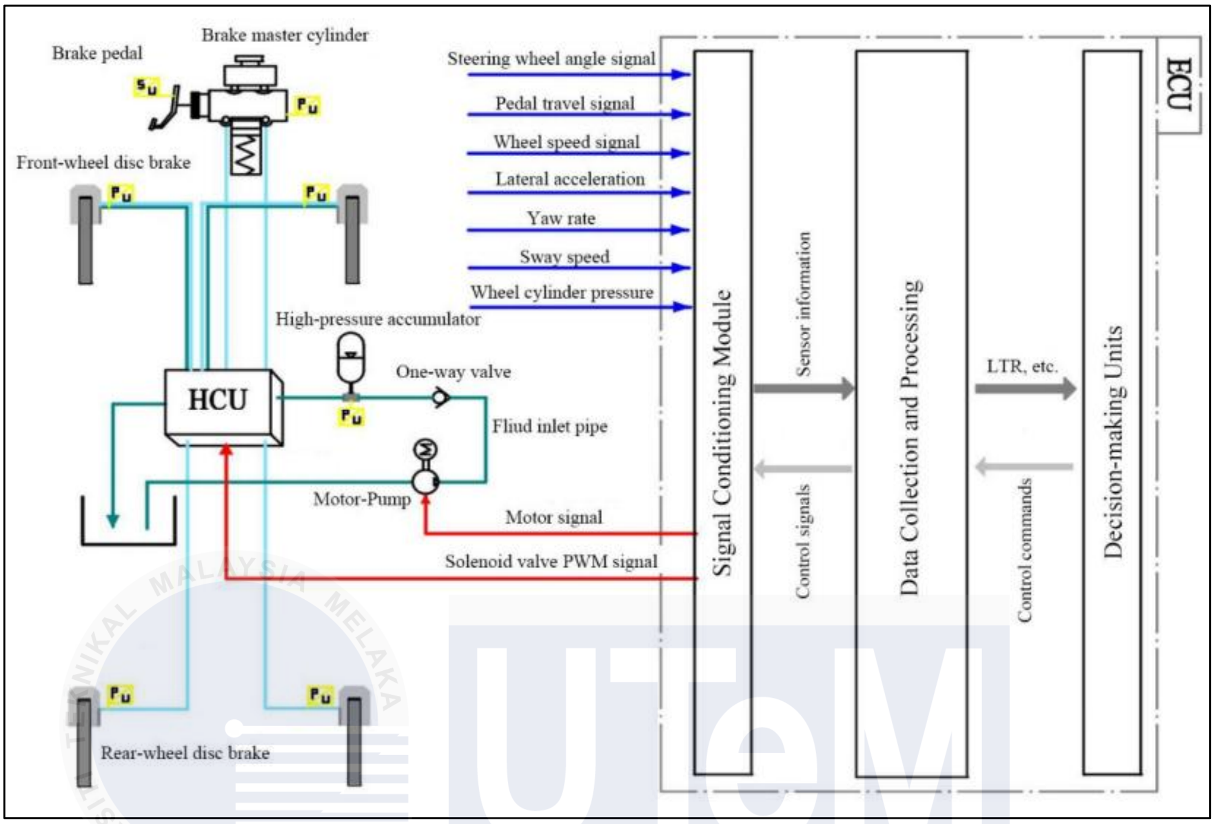


Figure 2.1: General drawing of the brake-by-wire system (Wang et al., 2023).

2.4 Intelligent Adjustment System

Another safety feature that improves seatbelt protection in the event of a collision is the early warning seatbelt intelligent adjustment system. It makes use of big data analysis technologies. In order to process a real time data, the system uses advanced big data processing techniques. A number of sensors are used to continuously monitor the vehicle's operating circumstances, including vehicles speed, seatbelt usage, and occupant information. The technology intelligently modifies the seatbelt's pretension and locking mechanisms based on the characteristics of the occupant and the actual driving conditions. By enhancing the seatbelt system's performance in real-time in comparison to conventional seatbelt systems, this early warning seatbelt intelligent adjustment system, in general, would represent a novel way toward enhancing vehicle safety.

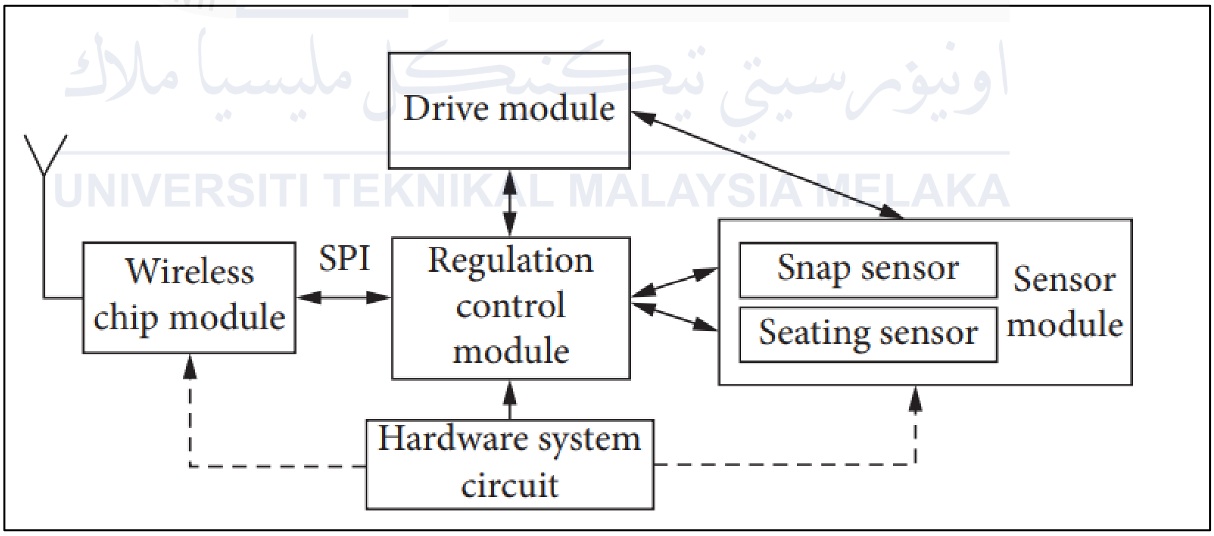


Figure 2.2: System hardware composition structure diagram (Zhou, 2020).

2.5 Real-Time Voice Alarms

The Real-Time Voice Alarms with the Collision Prevention Warning Detection System continuously monitors the environment around a vehicle using lidar, radar, and cameras. It quickly detects objects, pedestrians, or other possible hazards by evaluating sensor data, and it will instantly inform the driver by voice alerts. These alerts provide drivers with the necessary information to take immediate action to avoid collisions by applying any counter measure to overcome it. This instant warning function improves overall road safety by giving drivers the time to react.

However, the accuracy and consistency of the sensor data as well as the threat to detection and the algorithms are key components that determine how effective such a system would be. Relative to other vehicle safety technologies, the Collision Prevention Warning and Detection System with Real-Time Voice Alarms is a noteworthy advancement that can potentially prevent catastrophic collisions by raising driver awareness.

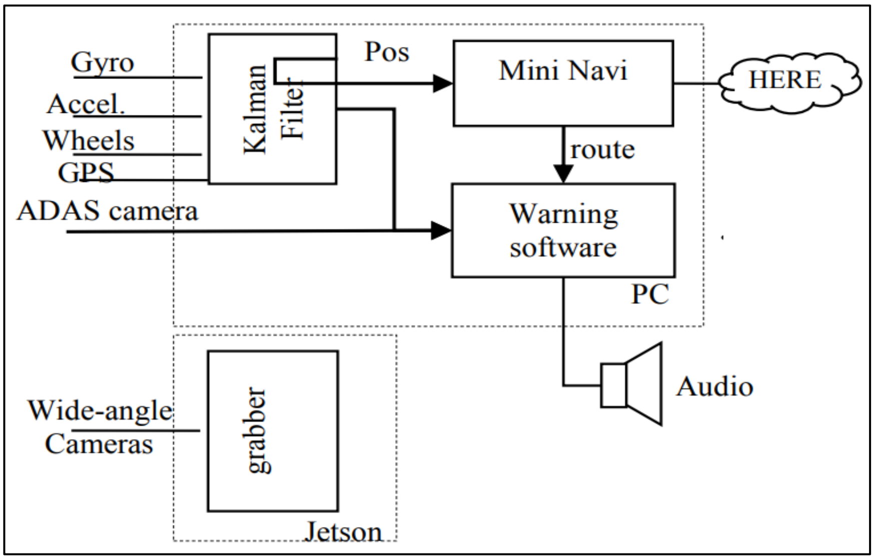


Figure 2.3: System Overview (Wolf, n.d.)

Besides that, in higher vehicles like commercial vehicles, trucks, SUVs, and vans, Early Warning Devices (EWDs) are essential safety equipment for identifying and avoid any rollover incidents. These cutting-edge systems constantly track the dynamics and motion of the car using a range of sensors, searching for signs of an approaching rollover scenario. Wire-controlled auxiliary braking systems, for instance, have the ability to recognize when there is too much lateral acceleration or body roll and will immediately apply differential brakes to help balance the car. Smart seatbelt adjustment systems use big data analysis to predict rollovers and enhance the locking and pretension of the seatbelt to improve occupant safety. While drivers are also be warned by real-time voice alerts of impending rollover hazards to grant them vital seconds to take corrective action. By addressing rollover concerns before they completely materialize, Electronic Warning Devices (EWDs) can intervene early to avoid accidents and save lives. These early warning systems are essential for higher-risk vehicle types as vehicle safety technology advances.

2.6 Rollover Index

Rollover often occur whenever the vehicle has loss control and swerve to its side or front then undergoing a rolling motion. It still under concern that many vehicles might loss control and has potential to rollover, either once or several times and it depends on the magnitude of the sideways acceleration which is equal or over 90 degrees. Other vehicle might undergo rollover event, but commercial trucks literally more vulnerable bear to its top-heavy loads and capacity. Besides, commercial trucks have greater center of gravity which will disturb its balance and stability.

Unfortunately, this learning will only focus on two contributes factor which is steering angle and longitudinal speed. To detect and predict any rollover that will occur, the rollover index (RI) will be very useful. The method is by estimate the roll angle and role rate of vehicle body depends on lateral acceleration and time taken for the tires to lift up from the ground. In order to install rollover control systems and successful crash prevention tactics, these indices use a variety of characteristics and dynamic models to determine the probability of rollover under various driving situations. Additionally, according to Shin et al. (2021; Zheng et al., 2023), they ensure real-time rollover detection, reduce parameter uncertainties, and give controllers enough response time to step in and prevent rollover events.

2.7 Types of Rollover Accidents

Severe rollover incidents can cause serious injury to persons and property as well as cause vehicles to tip over. The two primary categories are un-tripped and tripped. Around 95 percent of rollovers involving a single vehicle are caused by item tripping, such as loose dirt or guard rails. Un-tripped rollovers occur as a result of aggressive driving without the presence of outside tripping hazards. Rollovers can also result from factors like sidewind, ramp-like impediments, and sudden steering. Physical evidence analysis, vehicle inspection, and roll distance evaluation which differs in controlled tests and real-world situations are all part of the process of assessing rollover accidents. It is essential for road safety and the development of preventative tactics to comprehend the eight categories of rollover incidents.

'Trip-over' happen whenever the vehicle is suddenly stop suddenly and causes it to be overturned.

'Rollover' occurs when the vehicle trips over its side, resulting from the factors such as excessive speed, abrupted steering or striking object that cause the vehicles tripping

When a car suddenly stopped moving, it was said to have "**tripped over**," rolling onto its side or roof.

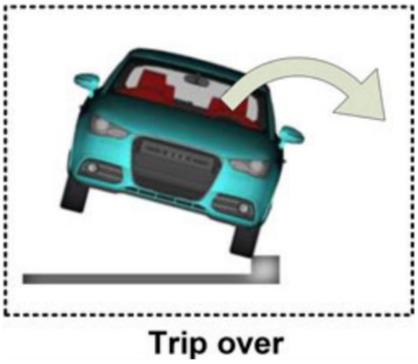


Figure 2.4 Vehicle illustration when trip-over (Seyedi et al., 2020)

The phenomena referred as "**Fall Over**" occurs when a vehicle is traveling on a sloping terrain, which causes the vehicle's center of gravity (CoG) to shift beyond the wheel and cause the vehicle to rollover.

Figure 2.5: Vehicle illustration when fall-over (Seyedi et al., 2020)

A "**Flip Over**" happened when there were barriers on the road, like something that resembled a ramp. This caused the vehicle to rotate on its longitudinal axis.

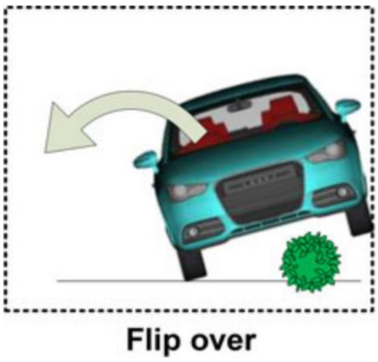


Figure 2.6: Vehicle illustration when flip-over (Seyedi et al., 2020)

'Bounce over' happens when the vehicle bounces off the stationary object that leads to rollover.

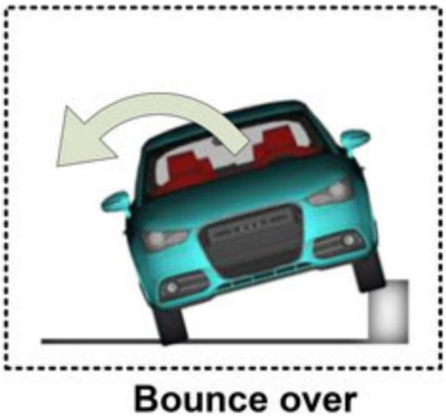


Figure 2.7: Vehicle illustration when bounce-over (Seyedi et al., 2020)

A "**turn over**" occurs when a vehicle makes a turn sharply, creating instability from an excessive amount of centrifugal force.

Figure 2.8: Vehicle illustration when turn-over (Seyedi et al., 2020)

A "**Collision Rollover**" is a phenomenon in which a vehicle rollover after colliding with another vehicle.

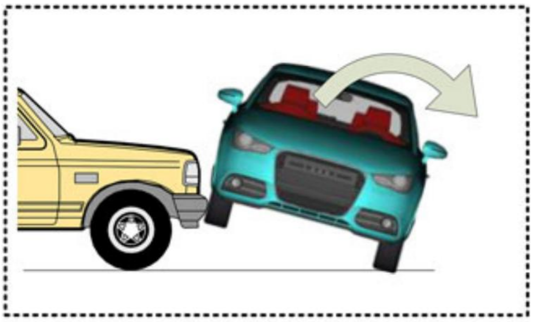


Figure 2.9: Vehicle illustration when collision with another vehicle is occurred (Seyedi et al., 2020)

When a vehicle rides up a guardrail or barrier that requires evaluation, this is known as a "**Climb Over**" incident.

Figure 2.10: Vehicle illustration when climb-over (Seyedi et al., 2020)

When a vehicle crashes into an object or obstruction, it enters a state known as "**End-Over-End**," where it rolls to its lateral axis.

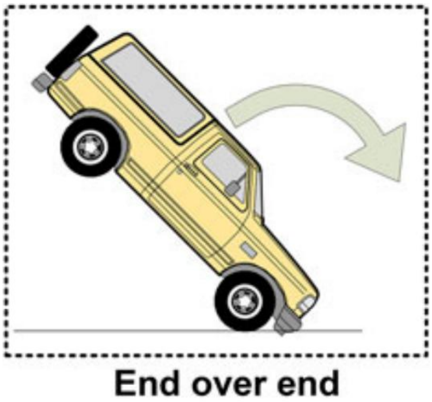


Figure 2.11: Vehicle illustration when end-over-end (Seyedi et al., 2020)

Among the 8 rollover types, this study will focus **'Turn Over'.**

2.8 Rollover Phase

Compared to frontal and side hits, which usually take less than 200 milliseconds, rollover crashes can involve multiple blows and last over a second, making them substantially more complex events. The path of a single vehicle rollover collision is shown in Figure 2.3.2. The three stages of traffic accidents which is pre-crash, crash, and post-crash and can be further divided into subcategories. It is possible to further divide the pre-crash phase into three smaller periods. Over the course of the typical driving subphase, the longitudinal velocity and the longitudinal axis of the vehicle align. Next, there is a significant change in the yaw rate and the vehicle loses stability. Present-day active rollover safety systems now attempt to halt the rollover.

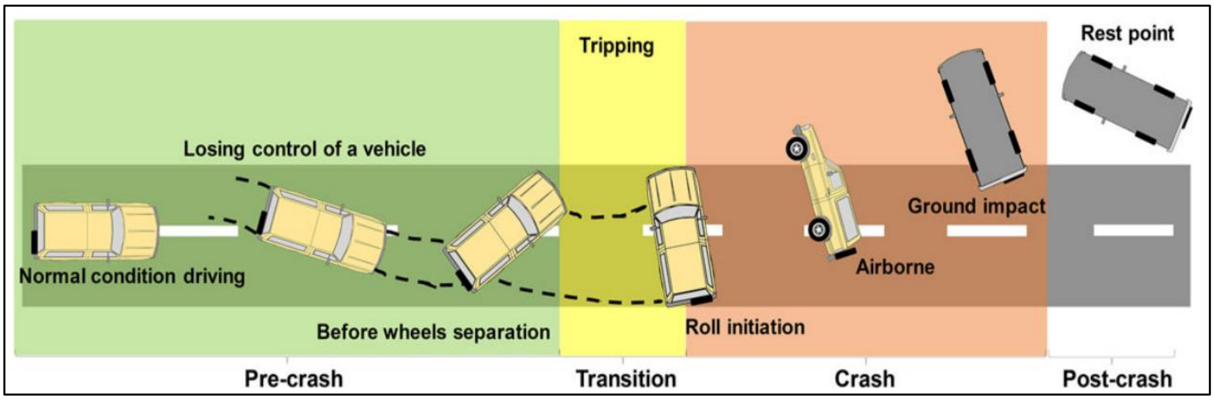


Figure 2.12: Rollover Crash Phase

2.9 Static Roll Instability

The Static Stability Factor (SSF) and the Static Rollover Threshold (SRT) are two measures of static roll instability for vehicles. Before beginning the rollover process, a commercial vehicle's maximum lateral inertial force is evaluated using the SRT, which is essential for establishing safe speeds when navigating curves (Moreno et al., 2020). However, the SSF is a gauge of rollover risk that depends on the vehicle's vertical and lateral location when cornering or avoiding (Guillermo Moreno Contreras et al., n.d.-a).

The Static Rollover Threshold (SRT) is a crucial metric for evaluating a vehicle's propensity to rollover on banked surfaces or during steady turns. SRT stands for the most lateral acceleration a vehicle can sustain before rolling over, and it is especially significant for big vehicles like large commercial vehicles and trucks. Assisting in guaranteeing better handling and design for larger vehicles, it measures a vehicle's static roll instability and provides information about its tendency to roll over. Studies done by (Czechowicz and Mavros, 2014) proposed that the Static Rollover Index (SRI) should be check again to involve suspension effects in the measurement.

The height of the vehicle's center of gravity and track width influence the Static Rollover Threshold (SRT), which is a direct correlation to a vehicle's stability. A wider track and a lower center of gravity are two ways to attain a greater SRT, which indicates more stability. On the other hand, a narrower track width is typically linked to a lower SRT and a higher centre of gravity, which raise the risk of rollover. Heavy commercial vehicles often strive for an SRT over 0.35-0.40g to provide steady handling. This acceleration is measured in units of gravitational acceleration (g). However, factors such as load conditions, operational requirements, and vehicle configuration can affect allowable SRT levels.

Based on the traditional analysis, a roll moment is the result of the lateral tire forces counteracting the lateral inertial force during a car's rotation. The usual load on the inner tire (Fz2) is zero at the rollover threshold condition. To calculate the value of SRT factor, Equation 2.3.3 can be use

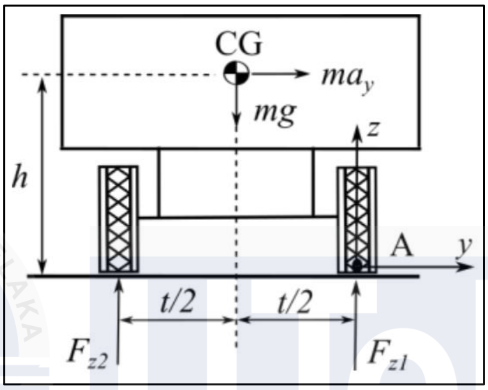


Figure 2.13: Rigid Vehicle Body (Moreno et al., 2018)

$$SRT = \frac{a_y}{g} = \frac{t/2}{h} \quad (1)$$

From the Equation (1), t is presented as the track width, h is the height center of gravity, while ay is the lateral acceleration, and g is the gravity. The placement of the vehicle's center of gravity, which is impacted by a number of vehicle characteristic such as weight distribution, suspension qualities, and load circumstances, determines the SRT.

One crucial statistic for evaluating any vehicles that in risk of rolling over was when escaping or cornering is the Static Stability Factor (SSF) (Guillermo Moreno Contreras et al., n.d.-b). This factor is calculated by dividing the lateral distance between the vehicle's wheels and the height of its center of mass above the ground plane by two.

The SSF can be stated mathematically as:

$$SSF = \frac{T}{2h} \tag{2}$$

The higher SSF value will contribute higher resistance for the rollover as it generates wider track width relate to the center of mass height which will increase static lateral stability.

Method of RI	Concept	Advantage	Disadvantage	Comment
Static Rollover Threshold (SRT)	Measures the maximum lateral acceleration a vehicle can withstand before initiating rollover.	Useful for assessing rollover risk, especially for large vehicles like trucks and tractor-trailers.	Depends on vehicle's center of gravity height and track width, which can vary with load conditions.	A key metric for evaluating a vehicle's static roll instability and ensuring adequate rollover stability, typically recommended to be above 0.35-0.40g for heavy commercial vehicles.
Static Stability Factor (SSF)	Measures the lateral distance between the wheels divided by twice the center of mass height above the ground.	Serves as a predictor of a vehicle's rollover propensity, especially for heavy vehicles with inherently lower stability characteristics.	Does not account for dynamic factors like suspension and load changes that can affect rollover risk.	An important concept in engineering education to help students understand the factors influencing vehicle stability and handling. Also relevant in aircraft design for ensuring proper trim and stability during flight maneuvers.

Table 2.1: Summary of Method of Rollover Index (RI)

2.10 Dynamic Roll Instability

The static rollover threshold (SRT) is not enough to fully evaluate roll instability in cars under dynamic circumstances especially when the vehicle is undergoing transition manoeuvres or is traveling on different types of roadways. The SRT is the maximum lateral acceleration that an vehicle can encounter in a steady-state situation before rollover. Nevertheless, this figure ignores the dynamic forces and moments that arise in short manoeuvres or on uneven ground. In order to better accurately assess dynamic roll instability, a number of techniques have been discovered.

The Rearward Amplification Ratio (RAR) and the Load Transfer Ratio (LTR) are two of the earliest methods that been introduced to overcome rollover. The peak lateral acceleration response ratio is known as the RAR. The objective is to evaluate the relative roll performance when performing high speed steering manoeuvres, as the dynamic coupling between the tractor and trailer units can significantly affect the overall roll stability (Wu et al., 2023).

Besides that, the fundamental component of the Load Transfer Ratio (LTR) is the lateral weight transfer between each axle's right and left tires. According to (Chen et al. ,2022), it has been proposed to assessing the roll stability constraints of commercial vehicles. However, the specific LTR value that corresponds to the relative rollover state is not clearly defined, and real-time LTR measurement can be challenging and costly, often requiring additional sensors and technology to fully functional.

Studies by Odenthal et al. (2017), rollover index (RI) algorithm is one of the techniques to assessing dynamic roll instability. The roll moment around the center of gravity and the equilibrium of vertical forces will be take into account in this technique. Basic Rollover Index (RI):

$$RI = \frac{F_{Z,L} - F_{Z,R}}{F_{Z,L} + F_{Z,R}}$$

(3)

FZ, L and FZ, R represent the left and right vertical tire forces. This equation also can be expressed as:

$$RI_{Ordenthal} = \frac{2m_2}{mT} [(h_R + h \cos \phi) \frac{a_{y,2}}{g} + h\, sin\, \phi]$$

(4)

The variables in this formula are: m2 (body mass), m (total mass), T (wheel track), h (height from the body's center of gravity to the roll center), hR (roll center height), g (gravitational acceleration), φ (roll angle), and ay,2 (lateral acceleration of the body).

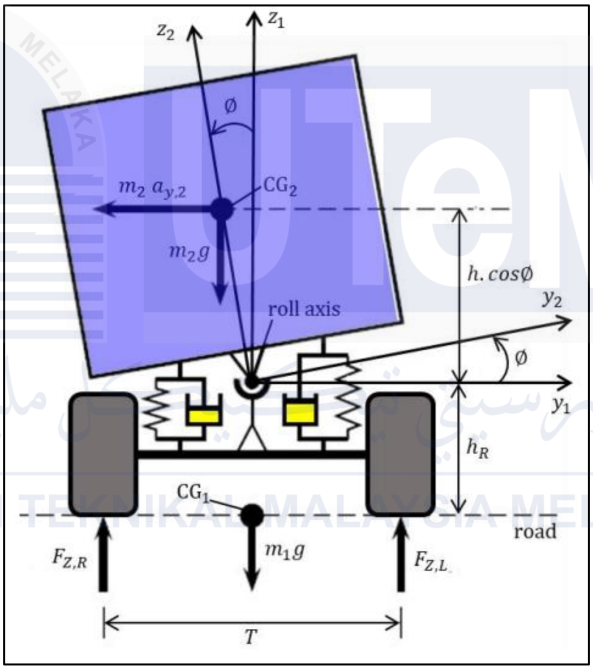


Figure 2.14: Model rollover of the vehicle (17)

The Odenthal's Roll Index (RI) is a method that considers factors like mass distribution, dimensions, and lateral acceleration to evaluate overall vehicle's dynamic roll instability. It's especially useful for assessing vehicles with articulated structures, like heavy trucks, where factors like load conditions can affect stability. By accounting for these variables, the Odenthal's (RI) provides a comprehensive understanding of a vehicle's tendency to roll during dynamic movements. There are other researchers have proposed alternative (RI) formulations based on different modelling approaches and assumptions. Research by (Solmaz et al.) introduced an RI algorithm involving the torque balance equation and load transfer ratio, stated as:

$$RI_{Solmaz} = -\frac{2(c\dot{\phi} + \mathrm{k}\phi)}{mgT}$$

(5)

φ is the roll angle, m is the total mass, g is the gravitational acceleration, T is the wheel track, and c and k are the suspension damping and stiffness coefficients. This formulation incorporates the influence of suspension characteristics on roll dynamics.

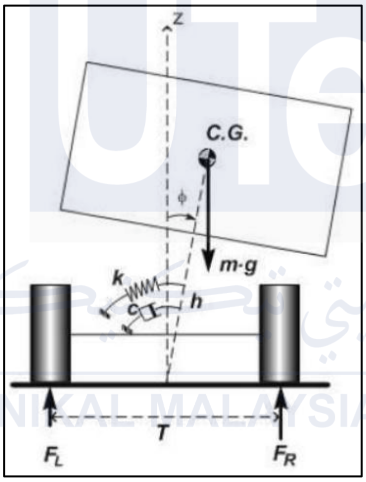


Figure 2.15: Roll degree of freedom (20)

Based on 3-degree-of-freedom rollover model, **Zhao (19)** derived an RI based by:

$$RI_{Zhao} = 2\left[\frac{I_x\ddot{\phi} - mh_0a_y - mgh\,sin\phi}{mgB}\right]$$

(6)

The other parameters are as previously established, with h0 representing the height of the center of gravity, ay representing the lateral acceleration, and B denoting the wheel track. On the roll axis, the moment of inertia is denoted by Ix. Inertial effects and roll acceleration are taken into consideration by this RI.

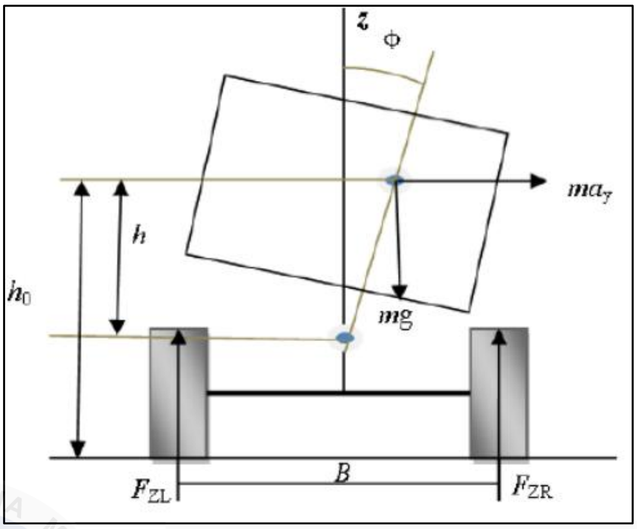


Figure 2.16: 3-DOF rollover model (19)

(Phanomchoeng and Rajamani) proposed an RI have to combine scaled lateral acceleration and roll angle estimator:

$$RI_{Phonamchoeng} = \frac{2m_s a_y h_R}{mgl_w} + \frac{2m_s h_r tan\Phi}{ml_w} \tag{7}$$

where ms is the sprung mass, hR is the roll center height, and lw is the wheel track. The remaining parameters are as previously mentioned above. The purpose of this formulation is to estimate the RI using more easily measured parameters such as roll angle and also lateral acceleration.

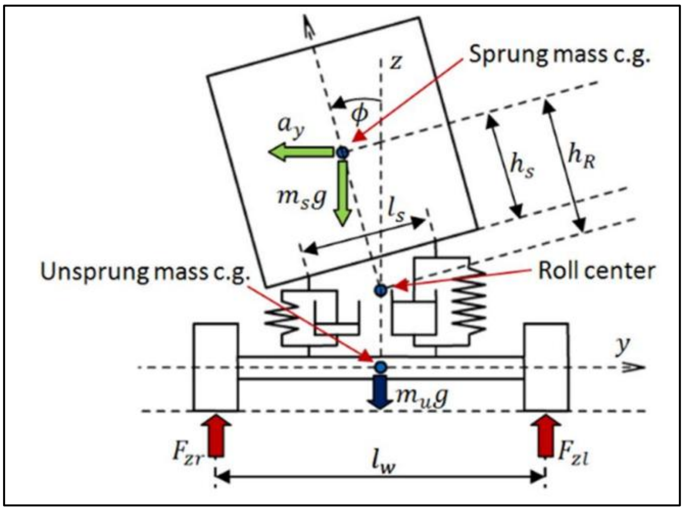


Figure 2.17: Un-tripped rollover model

The other RI methods provide alternative modelling methodologies and assumptions. The Odenthal RI has been particularly well-known for evaluating dynamic roll instability in articulated heavy vehicles since it takes into account a wide range of significant elements. Through these contributions, the understanding of dynamic roll instability in various vehicle designs and operating environments has grown, offering a more comprehensive viewpoint on this crucial component of vehicle dynamics and safety.

Dynamic roll instability	Method	Advantages	Disadvantages	Comment
Load Transfer Ratio (LTR)	Measures the lateral load transfer between the right and left tires of each axle.	Evaluates roll stability limitations, especially for large trucks.	Real-time measurement can be difficult and expensive, and the critical LTR value is not well-defined.	An early approach to assess dynamic roll instability, but practical implementation challenges remain.
Rearward Amplification Ratio (RAR)	Measures the ratio of the peak lateral acceleration response between the tractor and trailer units of an articulated vehicle.	Evaluates the relative roll performance during high-speed steering manoeuvres.	Sensitive to the nature and severity of the manoeuvre being performed.	Provides insight into the dynamic coupling between tractor and trailer units, which can influence overall roll stability.

Table 2.2: Summary of dynamic roll instability

Basically, vehicle rollover might undergo certain criteria such as lateral acceleration, roll angle or roll rate and been used as indications to any possibility to rollover. Studies by (Ataei et al, 2019) propose the implementation of many dynamic risk indicators (RIs) related to vehicle circumstances to enhance the precision of rollover indicators across different environment and situations. Load Transfer Ratio (LTR) is another crucial factor that must be count in dynamic situation by. This is necessary to determines how loads are being distributed on the vehicles that might changing the vehicles forces, motion and direction.

2.11 Implementation and Testing

For implementation and testing, there are two simulations were used to evaluate the solutions which allow simulation be more accurate to replicate real-world condition. The simulation namely Hardware in the Loop (HIL) and Software in the Loop (SIL). The application of these simulation will speed up the development and improves quality control. Furthermore, it will reduce the need for physical prototypes, physical testing, and also save much more time than work exactly in the field. It is possible to conduct simulation experiments almost on every component in a functioning state (Jneid et al., 2023). One of the most important tools for development and research is the simulated experiment. This is because the procedure is safe, quick, repeatable, and reasonably cost-effective (Jneid et al., 2023). It also causes less injuries. One drawback of the experiment is that in order for it to work, complex schema and extra parameters are needed. Furthermore, understanding the precise experimental protocol—which may need much sketching and design—is challenging. Due to the aforementioned, a complex technique involving mathematical and hardware simulation was required for concurrent simulation testing.

Consequently, Model-in-the-Loop (MIL) simulation is a sophisticated co-simulation technique used by researchers. The automotive industry uses this testing system extensively. This is due to the great potential for cost savings and improved ease using this technology (Rosique et al., 2019). Currently, one of the most important validation techniques is the MIL approach. This is because it can assess both virtual and real hardware models using mathematics. The two most important techniques in MIL are Software-in-the-Loop (SIL) and Hardware-in-the-Loop (HIL) simulation. (2021) Hafiz Bin Harun

2.12 Software In the Loop (SIL)

To detect and rectify any system-level problems, unit tests are conducted on code which working to validating code creation. At first phase of software development, Software-in-the-loop (SIL) has been used which permits the execution of the test before activating hardware functionally and help to discover any faults easily. The citation was picked from the research paper published by Ben Ayed et al in 2017. By using Software-in-the-Loop (SIL), it allows to conduct testing for the design before proceed to production process. In contrast to direct hardware testing, SIL simulation testing is conducted virtually. Nonetheless, during software inspection, SIL simulation can be conducted under a range of simulated input scenarios. The main objective of the evaluation is to look at how the software system works under different input conditions. The plant model can be built using a 3D virtual model, multibody dynamics model, or mathematical model. The real and 3D virtual configurations of the plant model are similar.

Any defects that occurred in a system are also mentioned in the SIL simulation methodology before it can be utilized to HIL and Vehicle-In-the-Loop (VIL) simulation methodologies. HIL and VIL techniques refer to the actuator and actual vehicle used in the simulation analysis. (Et al., Rosique, 2019). This reduces the possibility of major errors that could damage the hardware system itself or injure the testers. Additionally, SIL is used to identify any undesirable failure circumstance that might appear during controller design testing.

2.13 Hardware In the Loop

The Hardware-in-the-loop (HIL) includes the control rules which related to the simulated environment, as well as the control implementation, reaction time, and integration verification of the equipment. Besides that, hardware-in-the-loop are widely used for development and testing system in automotive control system by addressing any challenges and inaccuracies that occur from computer-based vehicle model development by focus on the vehicle input instructions and vehicle output. Another advantage from using Hardware-in-the-Loop (HIL) testing is that it removes the need that involve driver participation, personal judgment and custom request from the driver by directly examining the vehicle's hardware. Currently, one of the widely accepted methods for developing various automotive control systems is HIL (Gao et al., 2024). HIL testing is becoming a common resource tool for automotive researchers and designers (Gao et al., 2024).

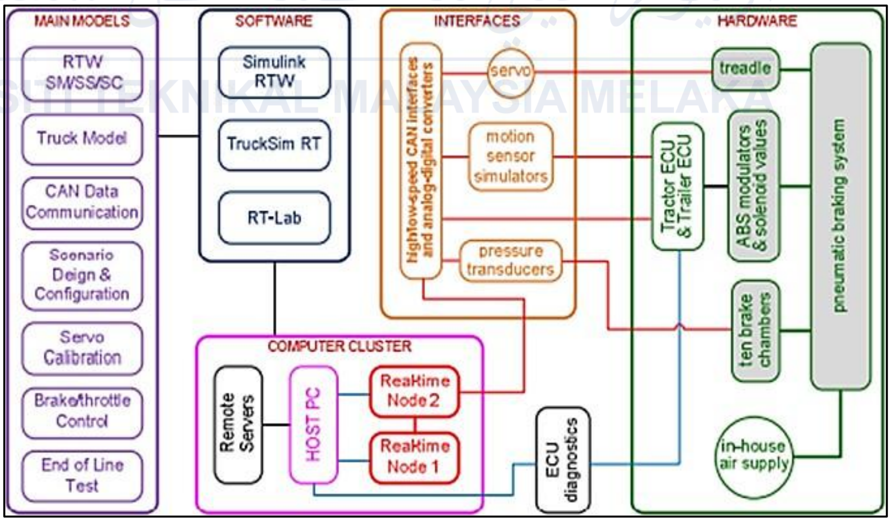


Figure 2.18: Hardware In the Loop System (Svenson & Grygier, 2009)

Model in Loop	Method	Advantage	Disadvantages	Comment
Software-in-the-Loop (SIL)	Simulation-based software validation, blending hardware accuracy with simulator's low cost and flexibility.	Overcomes limitations of conventional simulations, applicable in design and testing phases.	Requires detailed modeling and parameter estimation.	Helps resolve traditional simulation issues related to model validity, enables cost savings through code reuse.
Hardware-in-the-Loop (HIL)	Substitutes mathematical model with actual hardware system testing.	Widely used for developing automotive control systems, helps evaluate intended inputs and disturbances.	Requires dedicated hardware setup.	Identifies potential hardware issues, enhances system robustness, and reduces testing time.

Table 2.3: Summary of Model in The Loop

2.14 Microcontroller

The microcontroller is the brains of contemporary embedded systems are, which are small allowing all-in-one computers. These integrated circuits have a CPU, memory, and input/output peripherals combined into one unit. This allows the unit to perform tasks, communicate with actuators and sensors, and also regulate the actions of numerous electronic devices. Numerous applications, ranging from home appliances to industrial automation and the Internet of Things, are powered by microcontrollers due to their versatility and ubiquity. Microcontrollers are an indispensable element in the ever-changing realm of electronics and technology, offering a wide array of possibilities ranging from 8-bit to 32-bit architectures. This allows them to be customized to precisely match the needs of each embedded project.

2.15 Arduino Board

The Arduino platform has become popular in order to create interactive projects and prototypes. The Arduino board, a microcontroller-based development platform with strong capabilities and an intuitive design, is the hub of the Arduino ecosystem. With the numerous digital and analog input/output (I/O) pins on these boards, connecting sensors, actuators, and other electronic parts is a breeze. An easier-to-learn programming language for Arduino is called the Arduino language, and it's a condensed form of C/C++ that's meant to be accessible to even non-programmers. There are many boards featuring USB connectivity which support for widely used communication, and a modular design that allows for compatible shields to add further functionality, the Arduino platform's connectivity and extensibility are among its main advantages. A large and vibrant community of users, developers, and contributors has been advice to use and learn the Arduino platform's open-source hardware and software, which in turn offers a lot of resources and support for a wide range of projects, from straightforward blinky lights to intricate IoT devices and robotic systems.

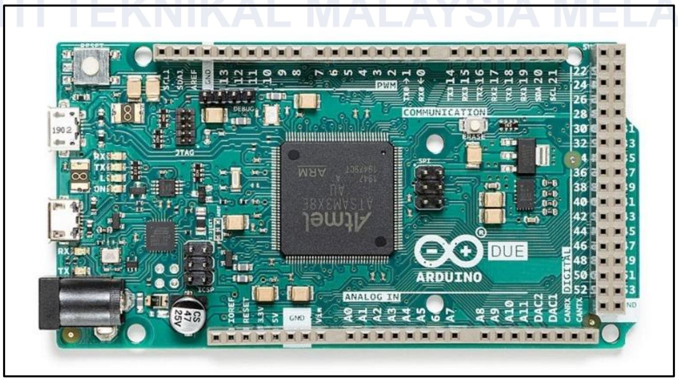


Figure 2.19: Example of Arduino board (Arduino DUE)

2.16 Espressif System (ESP)

The embedded systems have greatly benefited from the ESP (Espressif Systems) microcontrollers. With built-in Bluetooth and Wi-Fi, these low-cost, low-power SoCs are perfect for wireless and Internet of Things applications. Any small projects, students, and creator all will be thankful by the accessible and reasonably priced ESP platform. ESP microcontrollers are equipped with a powerful 32-bit LX6 microprocessor, which powers them. Smart homes and industrial automation are among the many applications that the ESP support series which includes the ESP8266, ESP32, and ESP32-C. The ESP platform's broad acceptance is further facilitated by its open-source design and strong community backing.

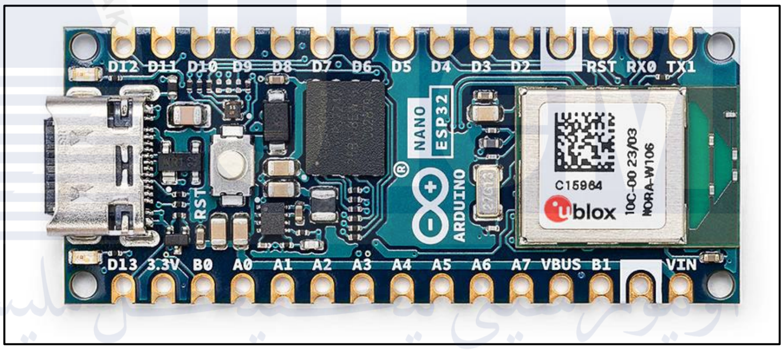


Figure 2.20: Example of ESP (ESP 32)

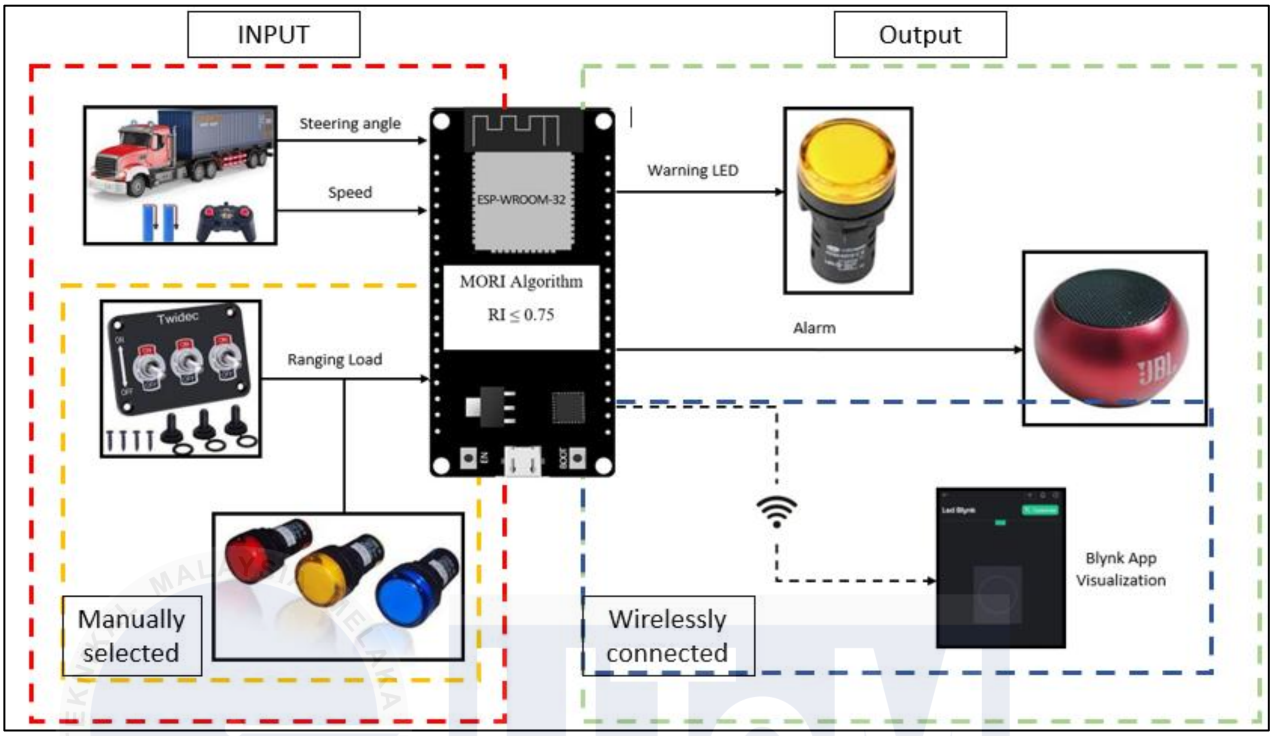


Figure 2.21: Input and Output for ESP-32 microcontroller

2.17 Raspberry Pi

Strong computing systems are more widely accessible thanks to the Raspberry Pi single-board computer. It boasts ARM-based processors, flexible I/O, and a broad range of compatible operating systems, all of which make it an outstanding device despite its small size. A thriving community of users, developers, and enthusiasts has been stimulated by the Raspberry Pi's accessibility to a wide audience due to its reasonably priced range of 5 to 35. With its uses in science computing, education, DIY projects, industrial automation, and other fields, the Raspberry Pi has completely changed the computer and electronics environment and cemented its place as a revolutionary product in the tech sector.

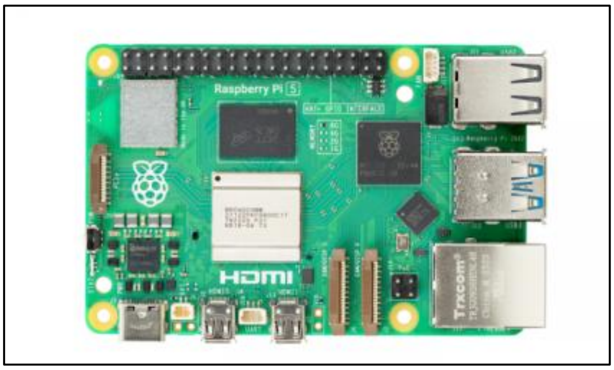


Figure 2.22: Example of Raspberry Pi (Raspberry Pi 5 Model B)

2.18 Blynk

With help from Blynk, creating Internet of Things (IoT) might be simple without attending long class to master any complicated code. It offers to develop mobile applications that might be helpful to interface remote hardware control. To connect with desired linked devices, users can create customs interfaces that include buttons, sliders, graphs, and other widgets. Blynk is much adaptable for a variety of Internet of Things applications compare to other software which might be little bit complicated whenever like to transfer the data. Blynk also capable to create and develop several types of coding including robotics, home automation, automotive remapping, environmental monitoring, and more. It allows the process of developing and implementing Internet of Things solutions to be much easier, especially for people without programming experience.

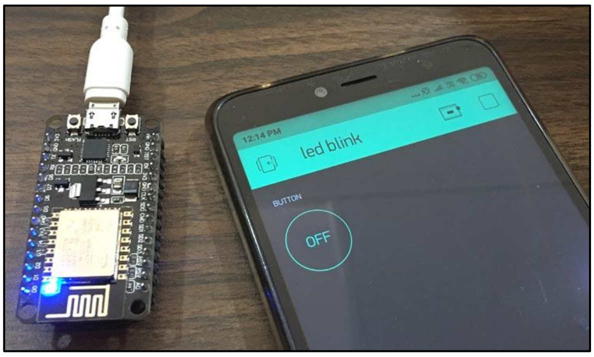


Figure 2.23: Example of Blynk Connected with esp8266

2.19 ThingSpeak

ThingSpeak is an Internet of Things (IoT) platform that allow the users to gather, store, and evaluate data in real-time from sensors and devices. It can interpret any data from different IoT devices or sensors by offering tools IoT applications. Any kind of sensor data such as GPS coordinates, temperature, and humidity was included in this data. By using ThingSpeak, users have the ability to share their data publicly or privately in which is very helpful for group projects or disseminating information to a larger audience. Afterwards, ThingSpeak allow the user to design any bespoke dashboards and visualizations to better track and comprehend the data. Applications and websites can incorporate all of these graphics.

Types of Micro-controller	Advantage	Disadvantage	Comment
Arduino board	Affordable and accessible, with a large community, great for beginners and hobbyists.	Limited processing power, may not suit complex projects.	Versatile for simple, low-power projects and prototyping.
ESP	Integrated Wi-Fi and Bluetooth, ideal for IoT and wireless applications.	Limited on-board peripherals, may require additional components.	Compelling balance of cost, power, and connectivity for IoT and embedded systems.
Raspberry Pi	Powerful computing in a compact, affordable package, suitable for a wide range of applications.	Higher power consumption, not ideal for battery-powered or low-power projects.	Versatile single-board computer excels in applications needing greater processing power.
Blynk	Allow the user to connect with any IoT devices with simple coding and easy to use although for the beginner in coding world.	IoT devices could not work perfectly in poor or inconsistent internet access since Blynk depends on internet connectivity for communication.	The Blynk apps might be useful since it only applied simple type of language which is much easy to understand.
ThingSpeak	Much more user friendly which it used configuration process with straightforward setup suitable for the beginner.	Any user that not familiar with MATLAB might have some difficulty to using ThingSpeak.	Suitable for the beginner such as any hobbyist, students and small scale IoT projects without requirement for a significant financial investment

Table 2.4: Summary of Microcontroller

2.20 Internet of Things (IoT)

The Internet of Things (IoT) is a network of wirelessly linked devices and equipment that can send and receive data wirelessly through Wi-Fi connectivity without the need for human interaction. Furthermore, the term "Internet of Things" (IoT) can also refer to a software element that made it possible for modern, commonly used products to be connected to the internet. Any computer with Internet of Things capability can communicate with other computers and carry out any task at a distance.

The Internet of Things (IoT) has the potential to stimulate innovation in vehicle development while simultaneously enhancing driving safety and overall driving pleasure. It will support all technological advancements that benefit the automotive sector, particularly those related to safety situations that require constant attention. Permitted sensor connectivity can increase utilization and functionality appropriate for all circumstances and occurrences.

2.21 Smartphones

There are already guidelines available for employing cellphones for automatic collision tracking according to studies by (Varma Sri Krishna Chaitanya, 2013). General Motors and BMW have integrated automated collision warning systems. Airbag deployment indications and accelerometers, among other sensors, are used in the analysis of the accident event. Integrated cellular radios are subsequently used to transmit the gathered data to a reaction center. Unfortunately, most cars do not have an automated collision warning system. As a result, a smartphone that can recognize injuries and quickly notify the relevant authority has taken replacement for device and equipment. There are a number of advantages to using smartphones instead of automated crash alert systems.

CHAPTER 3

METHODOLOGY

3.1 Introduction

We often hear rollover incidents happens which also involving other vehicles and cause it to flip to side or roof. Rollover events will be much more concerning when involving any commercial vehicles such as trucks or heavy vehicles with certain loads on it that. Excessive speed plus with sharp turning may leading to cause imbalanced to load or weight distribution and cause the vehicle loss control for steer. Besides, another factor that can be a contributed factor for rollover event was lack of sufficient time for respond that should be warned to the driver to apply any counter measure which is crucial to avoid that particular destructive incidents to happen. By that reason, any warning must be given to driver at exact timing to allow them aware and alert whenever rollover potentially to happen that will cause disaster to other people and also the driver itself.

For the result, early warning shift devices are designed and manufactured to overcome all of these very concerning events. The actual main purpose of the devices being created is to allow an early warning for the driver at absolute timing to execute any suitable counter measure for the rolling over vehicles that surely will do harm to others vehicle and surrounding. This early warning shift devices that will assist commercial vehicles driver is built by using MATLAB Simulink and been apply in TruckSim to get it operational and prediction when there are input is applied and observe the output for the resulting and improvisation.

3.2 Project Flowchart Process

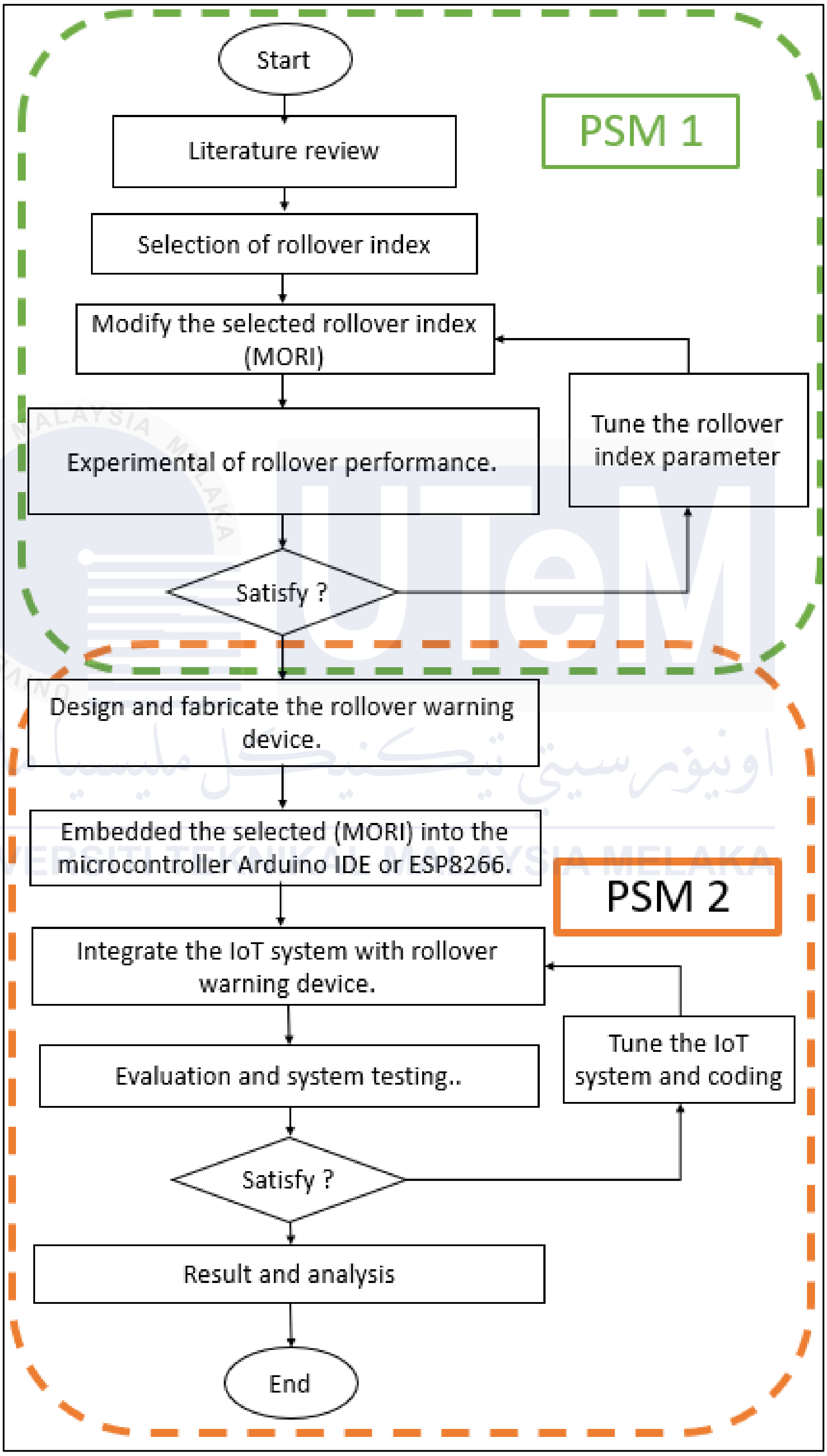


Figure 3.1: Project Flowchart Process

3.3 Gantt Chart

TASK	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
PSM 1														
Project Background	X													
LITERATURE REVIEW (finding journal, article, and citation)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Selection of rollover index using SIL		X	X	X										
Modified the rollover index		X	X	X	X									
Testing using Software-in-the-loop						X	X							
Design rollover warning device							X							
Component selection for rollover warning device							X							
Integrate the IoT								X						
Testing the devices using HIL								X	X					
Report writing (PSM 1)										X	X			
PSM 2														
Fabrication of the rollover warning devices and wiring set-up	X	X												
Working on IoT development			X	X	X									
Troubleshooting any failure						X								
Working on final design for the product and parts assembly							X							
Product testing								X						
Result and analysis									X	X				
Report Writing											X	X		

Figure 3.2: Gantt Chart

3.4 Software In the Loop (SIL)

As seen in Figure 3.3, the input method that will be used for Software-in-the-Loop (SIL) is by using Trucksim driving simulator which allow input like vehicle type, steer angle and speed data been inserted. Besides that, Trucksim simulator will generate all the input and velocity, (v) that necessary as the input for the second block input for rollover index calculation. After that, rollover index algorithm will be implemented to the MATLAB/Simulink program to create the rollover index technique. This diagram may be used to ensure if the vehicle has the tendency to undergo a rollover or not. The index value will reach ≥ 1 whenever the vehicle is on the threshold of rolling over. When the value exceeds one, the speaker will emit a warning sound, the LED set will flash and the application will notify any user about that event.

Figure 3.3: Input from Algorithms in Software in the Loop

3.4.1 TruckSim

One important tool for this study project is the TruckSim driving simulator. This tool is used to generate input data, simulate vehicle dynamics, and evaluate the rollover prediction algorithm's performance. Prior to putting the method into practice on hardware, it enables testing and optimization in a virtual environment. Input data for the MATLAB/Simulink rollover index calculation method, such as truck speed and steering angle, are provided by the TruckSim simulator. The output of the program is then used to assess the algorithms' performance and analyze rollover forecasts.

3.4.2 Step Steer Cornering Test

By using Trucksim, a study involves doing a step steer cornering simulation at speeds ranging from 60 km/h to 90 km/h. Figure 3.4 shown the large truck used in TruckSim to illustrate the step steer cornering test conducted. The variables employed in this simulation. The simulation parameters for the truck model are listed in Table 3.1.

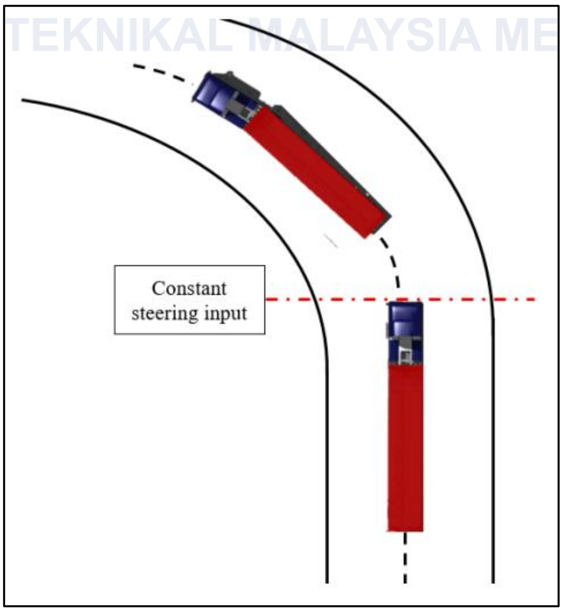


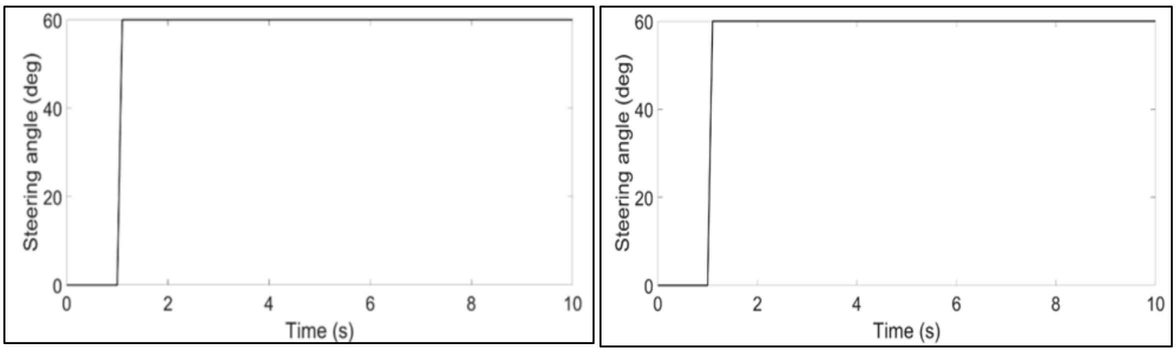
Figure 3.4: Step steer cornering test track in Trucksim

Parameter	Value
Sprung Mass, M_s	6,360 kg
Unsprung mass, M_u	530 kg
Tire stifness, K_t	900,000 N/m
Front spring stiffness, K_{sf}	250,00 N/m
Rear spring stifness, K_{sr}	1,083,004 N/m
Front damper coefficient, C_{sf}	15,000 N/m
Rear damper coefficient, C_{sr}	26,000 N/m
Track width, *t*	2.6 m
Length, *l*	M
A	3.012 m
B	4.9 m
Height, h	2270 mm
I_{xx}	7,695.6 $kg.m^2$
I_{yy}	30,782.4 $kg.m^2$

Table 3.1: Simulation parameters for truck model

3.4.3 Heavy Truck Response on Step Steer Cornering Test

From this part, step steer cornering test (SSC) is conducted to examines the model responds. The steering input for the step steer cornering test at speeds of 60 km/h and 90 km/h can be seen in Figure 3.5, (a) and (b).



(a) (b)

Figure 3.5 Steering input for SSC test; (a) at speed of 60 km/h, (b) at speed of 90 km/h

Figures 3.6(a) and 3.6(b) depict the lateral acceleration response of the heavy truck during the step steering cornering (SSC) test at speeds of 60 km/h and 90 km/h, respectively. There is an observed disturbance in the tractor model reaction in TruckSim at around 1.11 seconds. The disturbance is caused by a rapid change in steering input, going from 0 to 60 degrees in 1 second. This change altered the lateral acceleration of the vehicle's body, which then stabilised after 1.1 seconds. This observed disruption is characterised as the influence of the driver's steering input on the truck unit's dynamics.

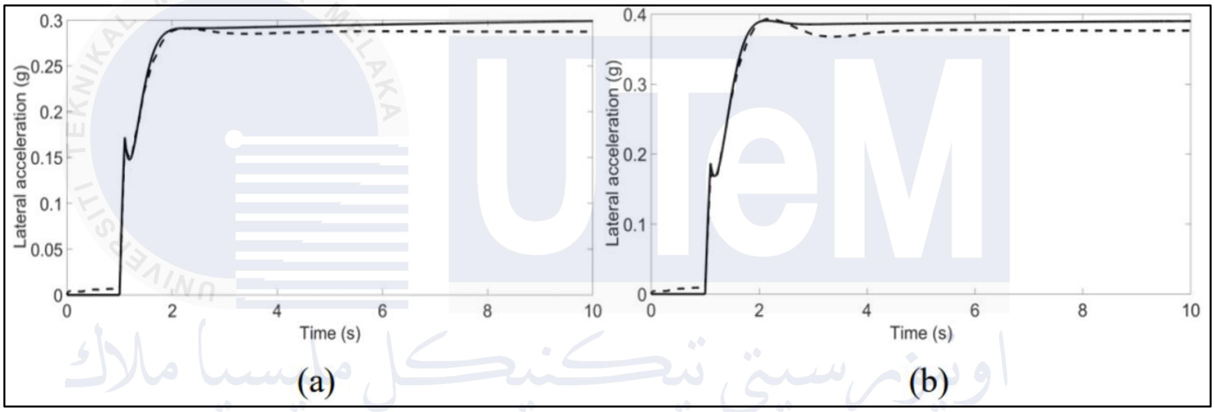


Figure 3.6: Heavy truck lateral acceleration response due to the SSC; (a) at speed of 60 km/h, (b) at speed of 90 km/h

3.4.4 MATLAB

In this project, MATLAB is used to create the rollover warning system for commercial vehicles easier to be improve, and simulate. The rollover index algorithm is run and evaluated, its parameters are adjusted and various driving scenarios are simulated by the researchers using MATLAB/Simulink to validate the improved Odenthal rollover index approach. When MATLAB and Simulink are used together, a firm framework for precisely predicting and warning against potential rollover occurrences will be counted and provided, hence increasing the safety of commercial vehicles.

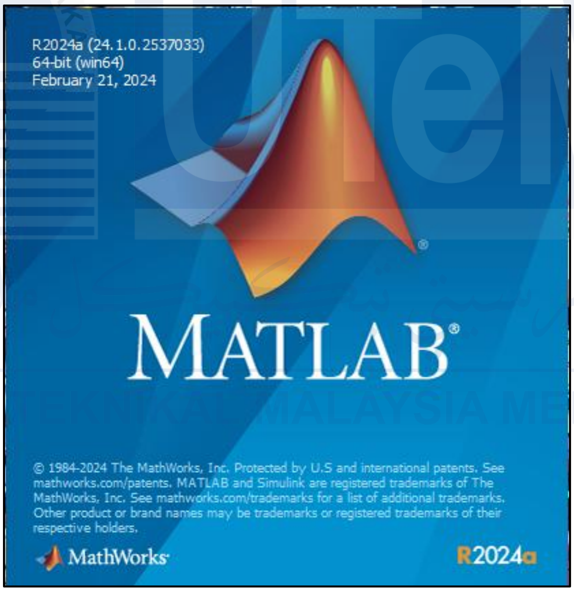


Figure 3.7: MATLAB version R2024a

3.4.5 Rollover Index Selection

In this section, commercial vehicles rollover index will be tested by two criteria which Time To Warn (TTW) and Time To Respond (TTR). TTW refers to the time generated by RI in order to promptly alert the driver about any instability in the vehicle's motion. Time To respond (TTR) refers to the duration of time given to drivers to make any adjustment to the current manoeuvring situation, such as lowering the speed of the vehicle or making adjustments by turning the steering input, following the TTW reaction. This study establishes that TTW (Time-to-Warn) is designed to provide the shortest possible response time to drivers, while TTR (Time-to-React) allows the drivers to buy sufficient time to correct their manoeuvres. Figure 3.8 displays the time reactions of heavy trucks, including illustrations of TTW and TTR.

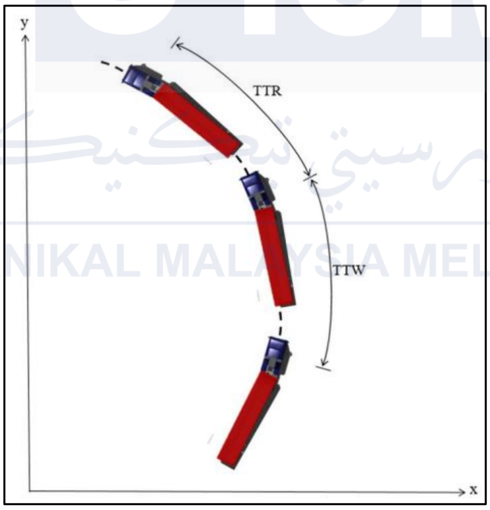


Figure 3.8: Heavy truck time responses

MATLAB/Simulink and TruckSim software are used to conduct a simulation in order to determine the rollover index response, which is then used for rollover index selection. The simulation will run step steer cornering at a speed of 100 km/h. Whenever the tire losing contact with the ground, the Rollover Index (RI) value will reach 1 and active the warning system. The reaction of rollover index for commercial vehicles is shown in Figure 3.9 and Table 3.2. The RI algorithm created by Solmaz reaches the RSF line in 1.61 seconds after a 1-second delay when the heavy truck receives its steering input.

The commercial vehicle's reflexes are also affected by the suspension spring stiffness and damping coefficient, which can contribute to this reaction. Meanwhile, the RI algorithm developed by Zhao and Phanomchoeng illustrate a progressive growth and surpasses the RSF line at 1.59 and 1.58 seconds, respectively. Besides that, the RI method suggested by Odenthal shows to be disrupted within a duration of 1.11 seconds. The sudden change in steering input from 0 to 60 degrees within 1 second will absolutely give impact to the lateral acceleration of the vehicle, the height of the vehicle's centre of gravity above the ground, and the angle at which the vehicle rolls. These effects continue until the vehicle turn to stable after 1.1 seconds.

The Odenthal rollover index algorithm will include and calculates the impact of the multiplication of the body's lateral acceleration, body roll angle, and height of the body's centre of gravity to the ground. However, based on Figure 3.9, it is clear that the RI suggested by Odenthal intersects with the RSF line in 1.51 seconds.

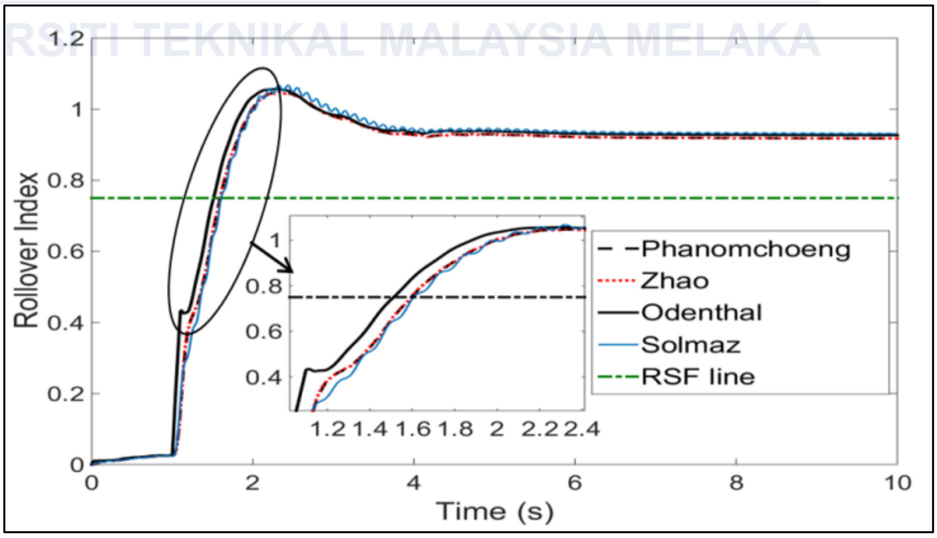


Figure 3.9 heavy truck rollover index responses

Author	Truck RI Time Respones
Odenthal	1.51
Solmaz	1.61
Phanomchoeng	1.58
Zhao	1.59

Table 3.2: Heavy truck rollover index responses

The responses of the vehicle during a step steer cornering simulation at speeds between 80 and 100 km/h are displayed in Table 3.3. The truck's lateral acceleration, roll angle, and rollover index are all monitored during this simulation. At 80 km/h, the commercial vehicle will undergo a maximum lateral acceleration of 0.351 g. At this velocity, a rollover index is 0.88. At speeds of 85 km/h and 90 km/h, the rollover index values does not going above 1, suggesting that the tires are starting to lift off. The large vehicles maximum lateral acceleration rises to 0.411 g when it reaches 95 km/h. The big vehicle's lateral acceleration trend increases gradually to 0.433 g as its speed reaches 100 km/h. The speed and the lateral acceleration are directly correlated.

Velocity (Km/h)	Lateral Acceleration (g)	Roll angle (degree)	Rollover Index
80	0.351	0.90	0.880
85	0.376	1.10	0.910
90	0.386	1.20	0.955
95	0.411	1.28	1
100	0.433	1.30	1

Table 3.3: Heavy truck response at speed of 80 km/h to 100 km/h

Conversely, it is correct that the commercial vehicles tyres will lose touch with the ground at a lower lateral acceleration value when the traveling speed reach at 95 km/h and 100 km/h and reach Rollover Index (RI) and the value reach to 1. An acceptable early warning indicator for rollover is the decreased lateral acceleration value seen in the large vehicle prior to tyre lift-off.

However, even with the most efficient method, it can be deduced that the rollover index algorithm proposed by Odenthal took 0.51 seconds in total for the driver to predict the impending rollover. By that reason, a better algorithm must be provided that can provide an early warning and enough Time-to-Rollover (TTR) to trigger the application of corrective actions in case of an impending rollover. The suggested method, referred to as the Modified Odenthal Rollover Index (MORI) which derived from the original Odenthal equation.

3.4.6 Modified Odenthal Rollover Index

The original rollover index calculated by vertical forces acting on the tires are approximately represented by FZL and FZR as Equation (8):

$$RI = \frac{Fzr - Fzl}{Fzr + Fzl}, -1 \le R \le 1 \tag{8}$$

Where FZL denote the force exerted on the left tire, and FZR represent the force exerted on the right tire.

According to Odenthal's formulation, Rollover Index (RI) is given by:

$$RI = RI_{Odenthal} = \frac{2m_2}{mT}\left[(h_R + h\cos\phi)\frac{a_{y,2}}{g} + h\sin\phi\right] \tag{9}$$

Equation (9) is utilized to evaluate the rollover index's capabilities based on Odenthal's fastest warning response time. Furthermore, according to Odenthal et al. (2015):

$$h_R + h\cos\phi = h_{cg2} \tag{10}$$

Equation (9) can also be stated as follows:

$$RI_{Odenthal} = \frac{2m_2(h_{cg2})a_{y,2}}{mgT} + \frac{2m_2 h\sin\phi}{mT} \tag{11}$$

The equations include several variables such as m_2 represent the sprung mass, m represents the total mass, T stands for the track width, h denote the height of the sprung mass centre of gravity, ϕ represent the roll angle, a_(y,2) represents the body lateral acceleration, g represents the acceleration due to gravity, and h_cg2 shows the height of the sprung mass centre of gravity with respect to the roll axis.

In order to compute a reliable Rollover Index (RI), Odenthal et al. (2015) proposed a formulation that considers the dynamics of the vehicle, such as roll angle, lateral acceleration, and distribution of vertical forces on the tires.

Based on the Equation (11), it shows that Rollover Index (RI) is influence by the body's lateral acceleration, a_(y,2), and the body's roll angle, φ. As Modified Odenthal Rollover Index (MORI) will enhance current Odenthal RI by add additional parameter Ka and Kr.

Modified Odenthal Rollover Index (MORI) algorithm is stated as:

$$RI_{Modified\ Odenthal} = K_a \left[\frac{2m_2(h_{cg2})}{mgT}\right] a_{y,2} + K_r \left[\frac{2m_2 h}{mT}\right] sin\phi \quad (12)$$

From the Equation (12), variable Ka is introduced as the gain factor which will impact the forces apply on the sensitivity of the vehicle body's lateral acceleration, denoted as a_(y,2). Besides that, variable Kr will regulate and influence the body roll angle ϕ on the reaction of the system. The value for both Ka and Kr are calculated using the sensitivity analysis technique as proposed by (Hafizah Amer et al, 2021) which will improve the practicality, effectiveness and responsiveness to enhance the current Odenthal equation. Particle Swan Optimization (PSO) is used to determine the value of Ka and Kr in which will getting the optimal value to balance the commercial vehicle.

Load Condition	K_a	K_r
Unladen	1.2083	4.0049
Half-Laden	1.4934	4.2213
Laden	1.8775	4.2327

Table 3.4: Optimize Parameter value of Ka and Kr for each load condition

3.4.7 Optimizing Rollover Algorithm Using Sensitivity Analysis of Ka and Kr

The Modified Odenthal Rollover Index (MORI) performance will be determined by the value of Ka and Kr. By the help from Particle Swan Optimization (PSO) method, more sensitive analysis can be conducted which will affect the response of the RI. For this study, the range value of Ka is set from 0.97 to 1.10 with the increment of 0.01 for each 15 simulation runs. As the value of Kr will be set in range 4.5 until 11.0 by the increment 0.5 with total 14 simulation. The values of Ka and Kr can be found by running a simulation on a commercial vehicle model that performs a 60-degree step steer turning manoeuvre at speed 100 km/h. The impact of Ka can be seen on the commercial vehicles shown in Figure 3.9. The graph shows the correlation of the Rollover Index and the Truck Tractor Weight (TTW) while Figure 3.10 illustrate the value of Ka ranges from 0.97 to 1.10. The selection of these numbers is predicated on the incidence of vehicle tire lift-off and the subsequent return of the tire to normal condition. The left tire of the vehicle's third axle starts to lift off the ground at 2.15 seconds and returns to its normal state at 2.42 seconds, with Ka value of 0.97. The current maximum RI is 1.0046. The vehicle's third axle's left tire starts to lift off at 2.05 seconds with a Ka value of 0.98. By the maximum RI of 1.0150, it returns to normal in 2.51 seconds.

Moreover, the left tyre on the third axle starts to lift off at 1.74 seconds and returns to normal after 8.91 seconds, when the coefficient of acceleration (Ka) reached its maximum value of 1.10. This Ka value yields the greatest refractive index of 1.1392. After that, the Rollover Index (RI) value will continue to surpass 1 when the Ka value hits the value 1.11, as shown by the dotted line in Figure 3.10. The possibility of the commercial vehicles to rollover is increased as it implies that one side of the tractor tire is elevated off the ground. The rollover index data also shows that the vehicle settles in 4.30 seconds when the Ka value is between 0.97 and 1.10. Besides, it indicates that the vehicle maintains its stability after 4.30 seconds, given that the Ka value is between 0.97 and 1.10. The effect of Ka on Time To Warning (TTW) is shown in Figure 3.11. It is clear that there is a relationship between the increment in Ka value and the fall in warning time.

It shows that Ka surely affects the vehicle's lateral acceleration. This phenomenon happens as a result of the steering angle action during this manoeuvre, which significantly increases lateral acceleration on the high-friction surface. The available empirical data indicates that the Ka value can have an impact on TTW. As shown in Figure 3.11, Based on the test results, 1.10 is the optimal Ka value. The commercial vehicles might have a probability to rollover if the Ka value is greater than 1.10 because it causes one side of the tire to rise off the ground. This phenomenon will might be impossible for the driver to adjust the manoeuvres, which will raise the risk of the tractor rolling over.

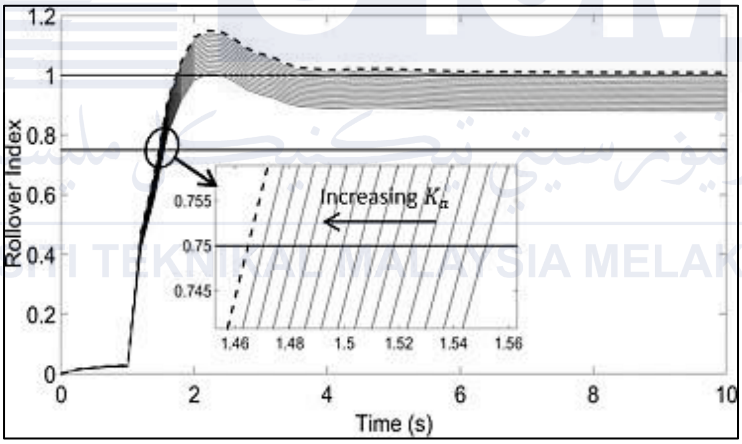


Figure 3.10: Heavy vehicle Rollover Affected by Ka

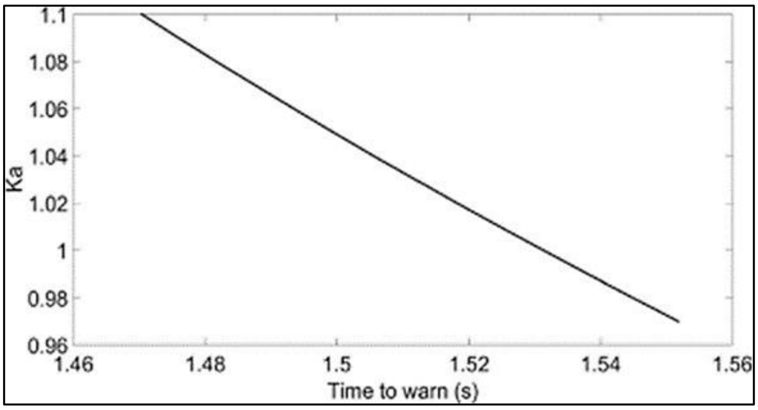


Figure 3.11: Ka influence on TTW

The optimal value for Kr is determined by applying the sensitivity analysis method. Using the same process as Ka, the ideal value of Kr is determined when if the RI value exceeds 1 and then returns to its normal state. These calculations are based on the 100 km/h step steering manoeuvres performed by large vehicles in TruckSim.

Based on Figure 3.12, shows the definition of the commercial vehicle rollover index is influenced by the value of Kr. The vehicle tire's Kr value is initially set at 4.5 and will rises up to 11.0 when it starts to lift off before returning to its normal state. The left tire on the third axle starts to lift off at 2.04 seconds and returns to normal in 2.40 seconds, with a Kr value of 4.5. Right now, 1.0064 is the greatest refractive index (RI). The left tire of the tractor's third axle starts to lift off at 1.97 seconds with a Kr value of 0.5. It returns to normal in 2.48 seconds, gaining a maximum RI of 1.0170.

Additionally, the third axle left tire starts to lift off after 1.57 seconds and returns to its normal after 8.81 seconds, as Kr reaches its maximum value of 11.0. The maximum refractive index (RI) that may be determined is 1.1546 with this Kr value. The left tire of the commercial vehicle's third axle lifts off faster and takes much longer time to return to normal as a result of the increasing Kr value.

However, when the Kr value becomes close to 11.5, the value of Rollover Index (RI) value still exceeds 1, as the dotted line shown in Figure 3.12 It implies that the vehicle tire is lifted above the ground on one side, increasing the risk of a rollover. From an alternative viewpoint, the rollover index data shows that for Kr values between 4.5 and 11.0, the vehicle always takes 4.30 seconds to settle after starting.

Whenever the value of Kr is in between 4.5 and 11.0, the vehicle will stay stable after 4.30 seconds. Figure 3.3.4.4 shows how Time To Warn (TTW) is affected by Kr. It is clear that when the Kr value rises, the TTW exhibits increased speed. In addition, the TTW drops dramatically to 1.19 seconds, as shown in Figure 3.12. As a result, 11.0 is the optimal Kr value and also as proof points to Kr having a absolute influence on the commercial vehicle roll effect occurrence. As Equations 3.6 and 3.7, the body's roll motion ultimately results in the body's lateral acceleration (ay,2) and body roll angle (υ), which puts the driver's control ability of the vehicle at risk. Consequently, this gives the driver less time to apply counter measure move.

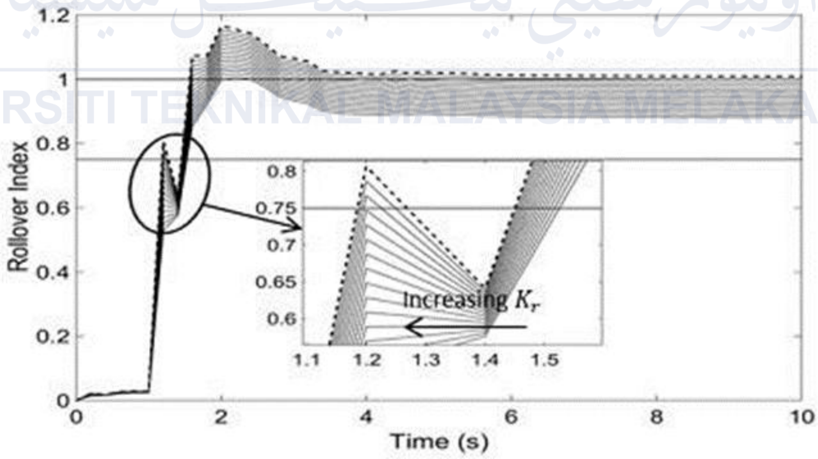


Figure 3.12: Heavy vehicle Rollover Affected by Kr

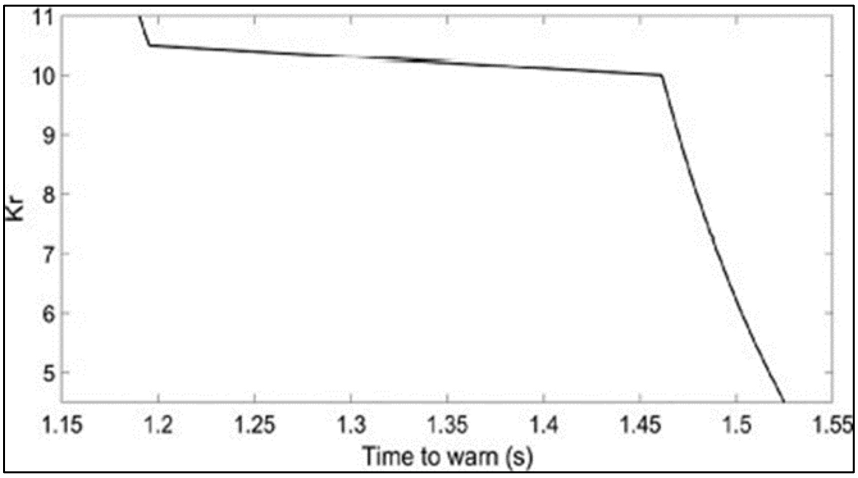


Figure 3.13: Kr influence to TTW

The results of the study show how to apply the Modified Odenthal Rollover Index algorithm, which will enhance the prediction and prevention for the commercial vehicle to rollovers by combining steering and vehicle velocity inputs. The Equations (13) and (14) by formulated by (Worden and Tomlinson, 2019) benefitted in MORI algorithm.

$$a_y = \left[\frac{\frac{v^2}{57.3Lg}}{1 + \frac{Kv^2}{57.3Lg}} \right] \delta$$

(13)

$$\ddot{\phi} = \frac{ma_y h_R cos\phi + \ mgh_R sin\phi - \frac{1}{2} k{l_s}^2 sin\phi - \frac{1}{2} c{l_2}^2 cos\phi(\dot{\phi})}{I_{xx} + m{h_R}^2}$$

(14)

Equation (13) shows relationship between vehicle speed (v), wheelbase (L), steer gradient (K), and steering angle (δ). Equation (14) relates roll acceleration ($\ddot{\phi}$), roll rate ($\dot{\phi}$), roll angle (ϕ), stiffness (k), damping coefficient (c), suspension spring distance (l_s), and roll inertia (I_xx). However, it is must put to account that Worden and Tomlinson (2019) have stated that the driver's ability to perceive the motion of the vehicle influences their steering angle input during the move. The output represents the vehicle's lateral acceleration, and during the manoeuvre, it is predicted that the vehicle will maintain continuous constant velocity and follow a radial curve. The MORI algorithm's roll angle response is adjusted by using the roll angle that is shown from Equations 3.6 and 3.7. Unlike the approaches suggested in the research works of Yurtsever et al. (2020), this research study stands out for using a unique roll angle estimate method.

3.5 Hardware In the Loop (HIL)

Researchers can evaluate and confirm the effectiveness of the warning device and rollover index algorithm in a safe and accurate simulated setting by using the Hardware In the Loop (HIL) technique. This method will helps evaluate the system's performance and make sure its effectiveness before it been installed in the actual vehicles. The HIL simulation provides an accurate and comprehensive depiction of the rollover warning system's behaviour by fusing real hardware components with a simulated vehicle model. Ensuring the safety and dependability of huge vehicles requires this.

To make observation and analysis the rollover predictions, TruckSim Simulation software was used to get actual truck simulation. TruckSim Simulation software also will provide the output graph for comparison with the result obtained in MATLAB Simulink software that might be useful to determine certain condition for rollover to happen. Firstly, a block model collection is created for applying the rollover index parameter and being embedded into Arduino IDE and ESP 8266 for IoT purposes.

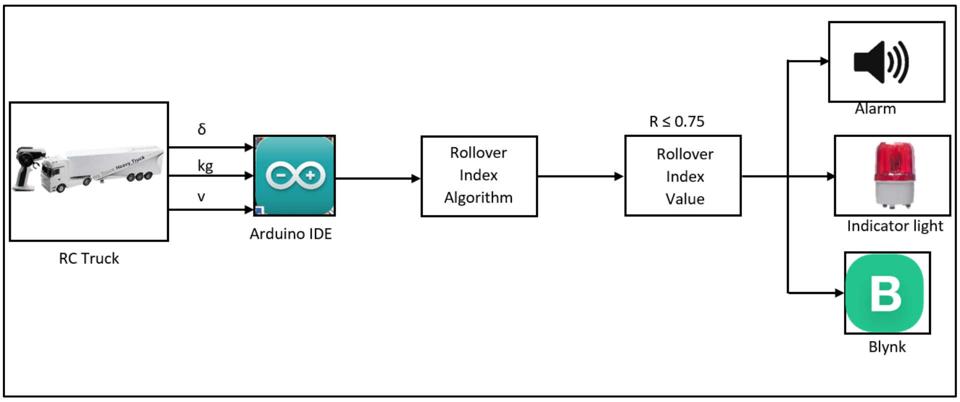


Figure 3.14: Input from Algorithms in Hardware in the Loop

3.5.1 Remote Control Truck

To calculate any possibility of rollover, the modified Odenthal rollover index (MORI) algorithm is used by the system based on input data from an remote Control (RC) truck. The technology will trigger the alarm, activate light indicators, and transmits all the data to the Blynk app for real-time monitoring when the index rises above the safety level. Before the final implementation on the RC truck, extensive testing is conducted to ensure all function is working as planned.

Figure 3.15: Example of Remoted Control Truck

3.5.2 Arduino IDE

The Rollover Index algorithm and the entire control circuitry may be integrated and embedded into the ESP8266 microcontroller board by the help of the Arduino IDE, which is essential to this project. As the primary processing unit, the ESP8266 deals with the steering angle, vehicle speed, and load condition switches on the RC truck. The Rollover Index (RI) algorithm, which was already developed in MATLAB, may be translated into C code and run in real-time on the ESP8266. Whenever the microcontroller detects any potential rollover, it reliably computes the Rollover Index, compares it to a preset threshold, and initiates prepared outputs such alarms and visual indications. Furthermore, Rollover Index data also can be transferred to the Blynk app via the ESP8266's Wi-Fi capabilities when used in conjunction with the Arduino IDE. This allows for early detection of likely rollover events and remote monitoring.

3.5.3 Blynk App

To provide a remote monitoring of the Rollover Warning Device, the Blynk app is a crucial interface. The Rollover Index, speed, steering angle, and load status of the vehicle are all visualized in real-time. The user can get much early warning and allow the driver to react quickly by using this feature whenever any potential rollover situation happen. There are several of upgrades can be researched to expand the app's features. It is advised to further develop the data visualisation, incorporate advanced alerts and warnings which will interface with other systems. The system also offered historical data analysis in order to significantly increase the app's use in tracking and preventing commercial vehicle rollovers for the safety purposes.

The Blynk app is an essential interface for remotely monitoring the Rollover Warning Device. It provides real-time visualisation of the vehicle's Rollover Index, speed, steering angle, and load status. This feature allows for the early identification of possible rollover incidents, giving the user the ability to promptly respond. In order to augment the app's functionalities, many enhancements can be investigated. To greatly enhance the usefulness of the app in monitoring and avoiding commercial vehicle rollovers, it is recommended to improve the data visualisation, implement sophisticated warnings and notifications, integrate with other systems, and provide historical data analysis.

3.6 Component of The Hardware

The components used in this project will be explained in detailed in this section. Each and every component required to support every function offered by this device including the Model In the Loop methodology method employed in this study will be installed.

3.6.1 ESP-32

The central processing unit (CPU) is always be in charge of several crucial functions. The vehicle mass, steering input, and speed of the RC truck are among the live sensor data that will be gathered by the ESP-32. After that, the rollover index is calculated using the Modified Odenthal Rollover Index (MORI) method and then contrasted with the safety line. An alarm and light indications are among the warning signs that the ESP-32 will triggers to alert the driver when it perceives a possible rollover hazard.

Furthermore, the ESP-32's wireless connectivity features such as Wi-Fi and Bluetooth. Which is much easier to send the calculated rollover index and alert data to the Blynk app on a user's smartphone for distant observation and visualization. The efficiency design of the ESP-32 ensures consistent system performance in the context of commercial vehicles.

3.6.2 Speaker

In order to alert the commercial vehicle drivers when the estimated rollover index exceeds the safety threshold, the speaker/alarm will play an essential component of the rollover warning system. Its timely notification increases the driver's awareness of the risk for a rollover, allowing them to take counter measure action and finally preventing the occurrence of a potentially disastrous rollover incident.

Figure 3.16**:** Mini Speaker UBL

3.6.3 Indicator Light

The essential visual component in the rollover warning system, the indicator light gives the driver a quick and obvious signal of the vehicle's stability condition. The indication light comes as addition to the auditory alarm to improve the driver's overall situational awareness when the calculated rollover index approaches or reach the safety threshold. By assisting the driver for immediately recognizing and addressing possible rollover hazards, our dual-mode warning system eventually assists to prevent rollover.

Figure 3.17: Indicator light

3.6.4 Toggle Switch

The rollover warning system can be turned on or off by the vehicle drivers with the use of the toggle switch which an essential part of the user interface. With the freedom to turn the system on or off while driving in high-risk situation. This feature makes sure the system operates depends to the driver's preferences and the particular driving conditions. The rollover warning system's toggle switch can also be used as a troubleshooting tool which allow the driver to rapidly identify and isolate any problems occur.

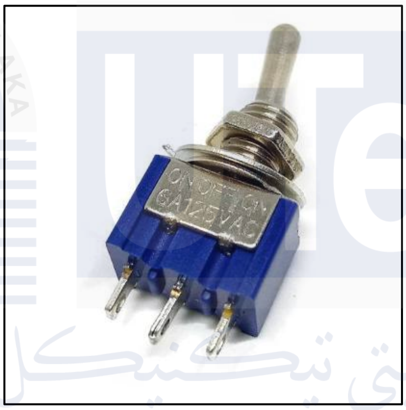


Figure 3.18: 3 pin toggle Switch

3.7 Summary

This project will not to be success of Hardware-in-the-Loop (HIL) and System-in-the-Loop (SIL) technologies. The Modified Odenthal Rollover Index (MORI) rollover prediction system is created, developed and improved by the SIL component using TruckSim and MATLAB/Simulink. By using vehicle factors including roll angle and lateral acceleration, this method is able to properly estimate the any probability of a rollover. The MORI method's parameters are improved via the PSO algorithm. Using the MORI algorithm, an ESP32 microcontroller, an RC truck, sensors, and a Blynk software, the HIL component creates a rollover warning system. Using this thorough approach, a solid and dependable system for anticipating and alerting against large truck rollovers is built.

CHAPTER 4

RESULT AND DATA

4.1 Introduction

In this chapter, any expected result will be summarized which refer to the analysis of this project and the expected result will focus on the Time To Warn (TTW) and also the effectiveness of the warning indicator whenever commercial vehicles rollover simulation is running. The result for this project will be observe on the simulation or experiment in lab which will totally depends on the theorical learning only. All the data will be collected and shown in different form such as graph, table and pictures.

4.1.1 Results and Analysis

Based on the previous data given and also from the result gain from the simulation, there are different result will be obtained which is depending on road condition, steering angle and also the weight of the commercial vehicle. From the TruckSim simulation, the commercial vehicle’s center of gravity might be move and the load applied may not be distributed evenly and cause the vehicle rollover at high speed.

4.1.2 Time To Warn

Two methods are being used for determining the probability of rollovers are the TTR (Tilt Table Ratio) and the RI (Resistance Index) which is useful to determine Time To Warn (TTW). The MORI's capacity was assessed by applied in Matlab/Simulink software and the TruckSim driving simulator. Step-steering is used to manoeuvre the commercial vehicle at speeds range in between 60 km/h and 120 km/h. 11,500 kg of load in total, 8,500 kg of which is partially loaded and 5,000 kg of which is unloaded, are being carried by the vehicle. The vehicle's reaction capabilities are determined by these combinations.

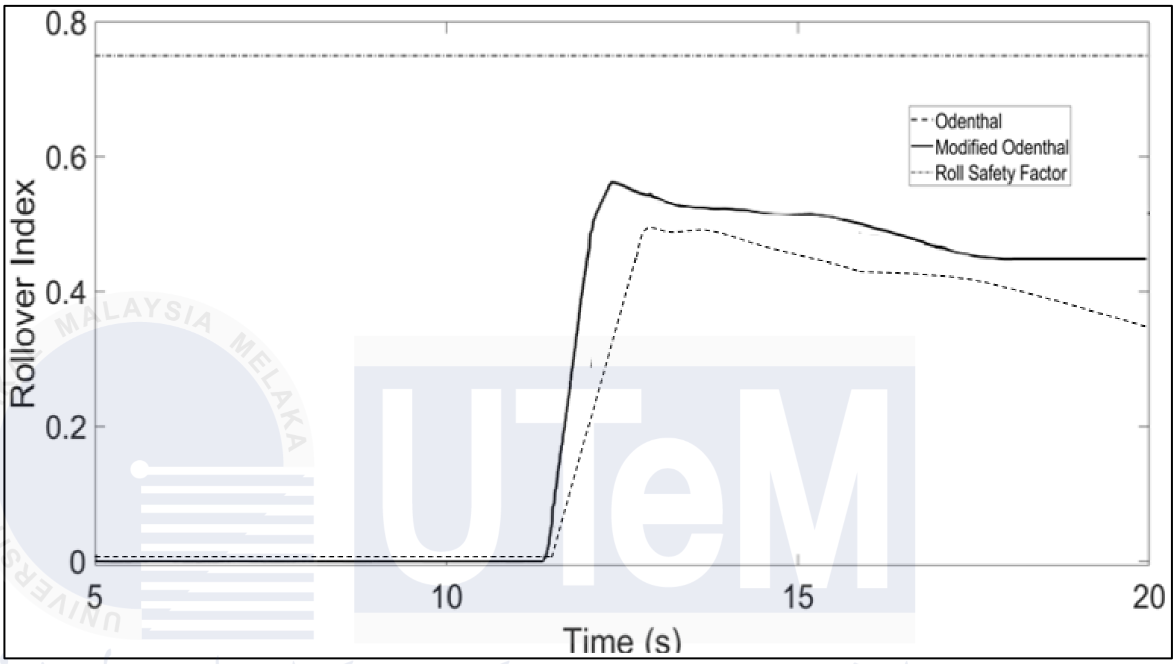


Figure 4.1: Unladen State with a Velocity of 80km/h

Based on data gain from Figure 4.1, there is no rollover indices are moving above the RSF threshold and by that reason the commercial vehicle's driver might not be warn. The graph also shown the TTW from Modified Odenthal Rollover Index (MORI) was much less compared to Odenthal rollover index at speed 80 km/h in unladen state.

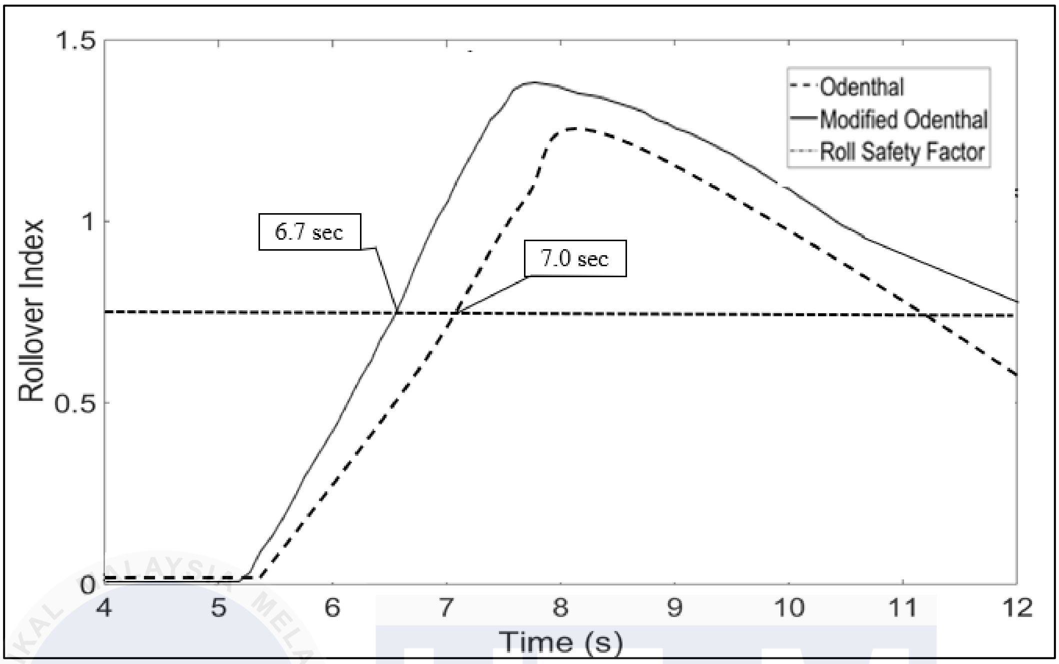


Figure 4.2: Unladen State with 110kmh of Velocity

But, when the velocity rise up to 110 km/h, (MORI) rollover index line and the Odenthal rollover index line will both intersect with the RSF line simultaneously at the state unladen. Based on data shown in Figure 4.2, when an instantaneous steering input is made, Odenthal's rollover index nearly reach 1.2 and crosses the RSF line after 7.2 seconds. This phenomenon arises when the steering input is brief or transitory. For MORI rollover index line, it attains the peak rollover index nearly at 1.5, there is a period of 6.5 seconds till the RSF line is reached.

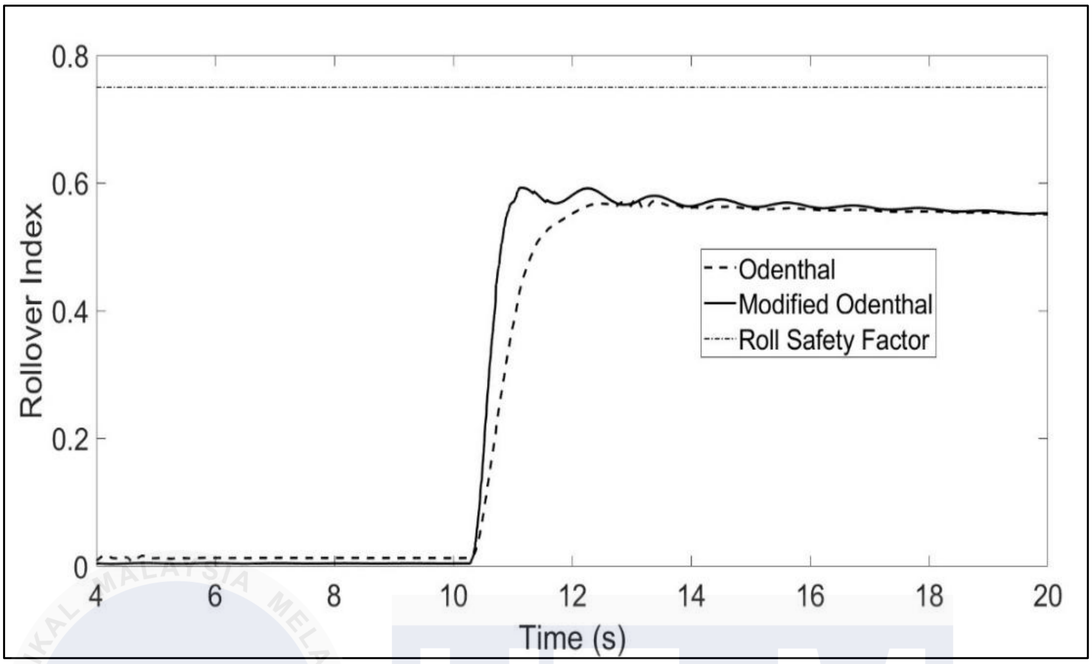


Figure 4.3: Half-Laden State with a Velocity of 60km/h

To determine MORI's capacity of weight, load of 3,500 kg is added on the commercial vehicle which resulting in a total weight of 8,500 kg. This represents 50% of the maximum load. Both MORI and Odenthal's study revealed that a rollover index of 0.64 is attained by driving at a velocity 60 km/h and maneuvers the steering wheel for 4 seconds. In the loaded state, the rollover index rises by 0.08 points compared to the no-load condition. Nevertheless, if the centrifugal force surpasses the centripetal force, the track will begin an outward rotation. The computed rollover index is below 0.75, indicating that the vehicle is safe to operate, and the rollover warning system is not engaged.

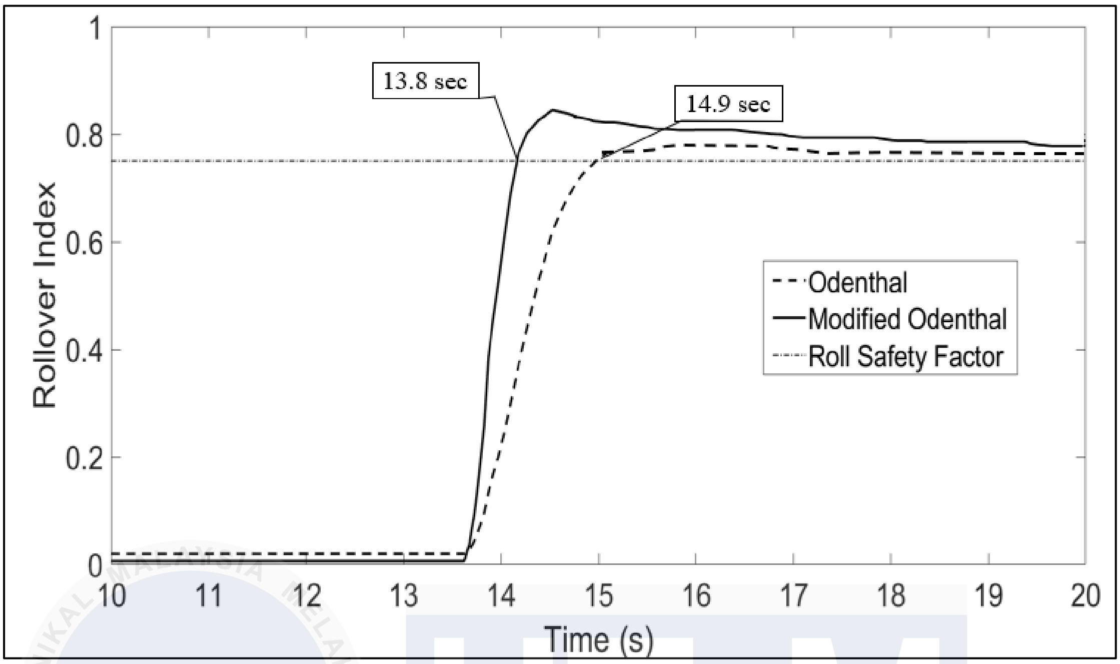


Figure 4.4 Half-Laden State with a Velocity of 90km/h

Based on Figure 4.4, half-loaded commercial vehicle speeding from 60 km/h until 90 km/h and the steering input was given within 2 seconds causes an instantaneous rise in the vehicle's rollover index resulting Odenthal obtained a rollover index of 0.82, crossing the RSF line in 3.38 seconds. MORI rollover index reaches the greatest rollover index of 0.92 and passed the RSF line 1.1 seconds quicker than Odenthal.

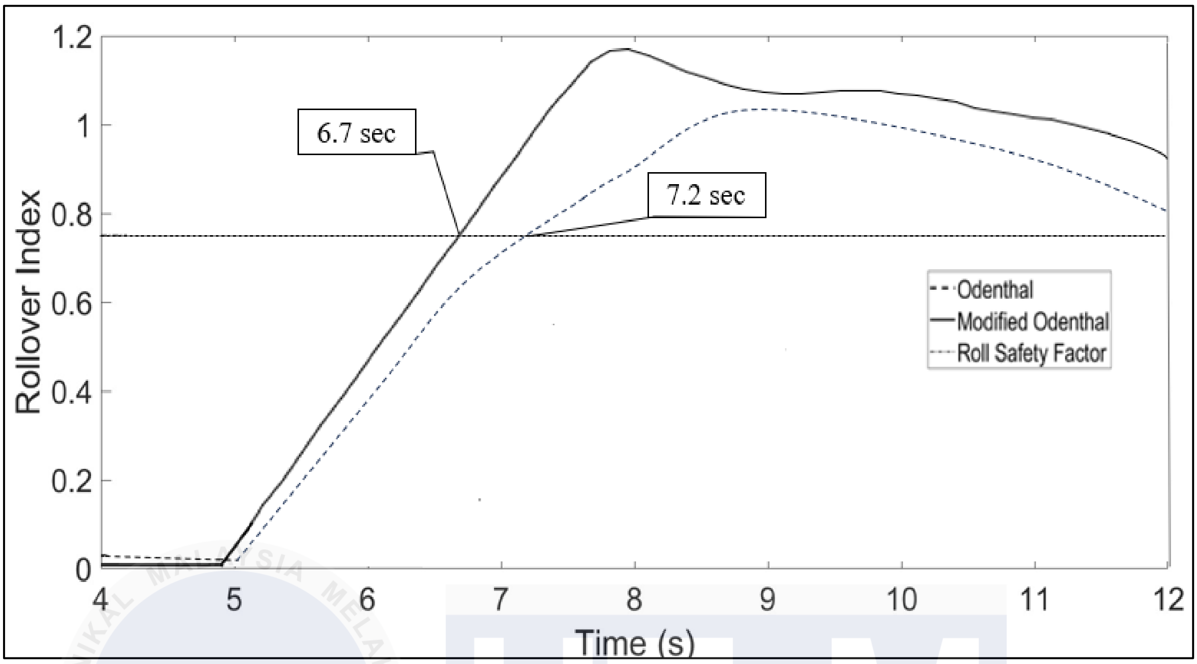


Figure 4.5: Half-laden State with 100km/h of Velocity

Figure 4.5 shows MORI and Odenthal rollover index values for a vehicle that is half-loaded at speed 90 km/h until 100 km/h. By using TruckSim driving simulator, which resulting that the commercial vehicles experience rollovers when exceeding speeds of 100 km/h. As shown, the MORI estimate of the rollover index obtained quicker (TTW) than the Odenthal estimate. The rollover index value of Odenthal reached its highest point at 1.18 while the vehicle was traveling at a speed of 100 km/h. This occurred after 3 seconds of sudden steering input. The vehicle then crossed the RSF line in 3.18 seconds to rectify the maneuver before the tires started to lose grip. Conversely, MORI surpasses the RSF threshold in just 2.36 seconds, enabling timely alerts to drivers to avert rollover accidents.

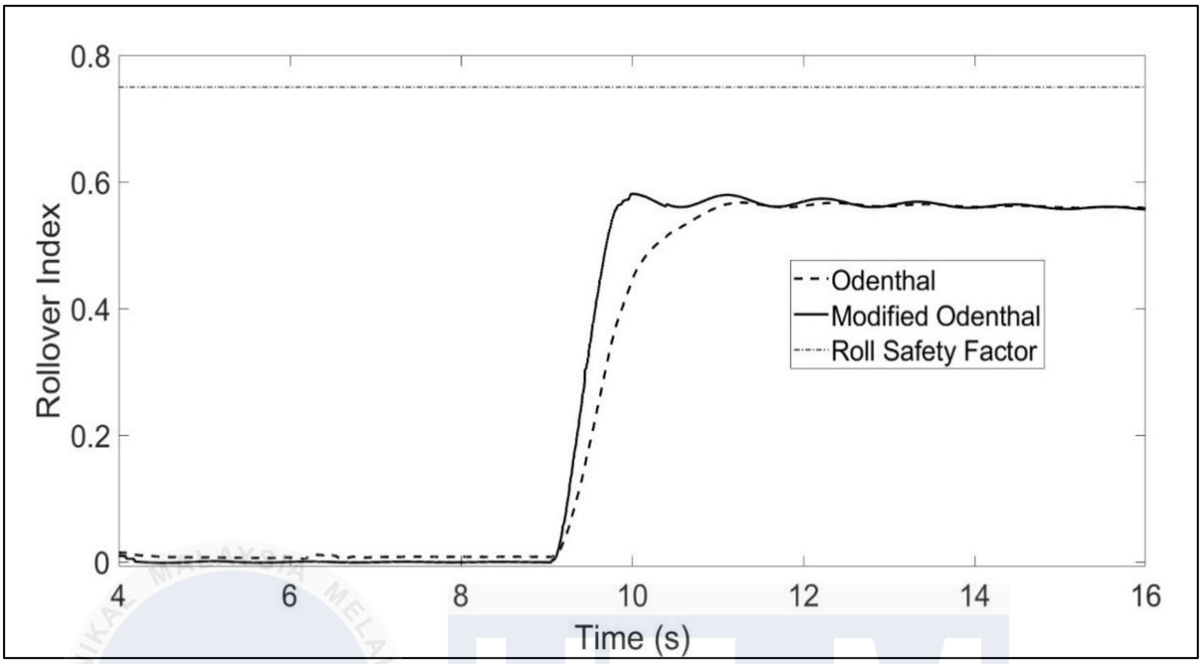


Figure 4.6: Laden State with 60km/h of Velocity

The MORI are placed at its maximum capacity when loaded with a total weight of 11,500 kg been applied. The commercial vehicle reaches a velocity of 60 kilometers per hour while it is carrying its maximum capacity while the steering system responds with fast intervention after a delay of 2 seconds. From Figure 4.7 displays, the rollover both for MORI and Odenthal started to increase by 2 seconds each. The RSF lines do not align with the highest value of any rollover index which cause the RI lines does not intersect. Figure 4.6 demonstrates that the vehicle is capable of maintaining the speed even while carrying a heavy load and receiving sudden steering commands. Consequently, it may be said that the commercial vehicle will maintains its equilibrium while travelling at low to moderate the velocities.

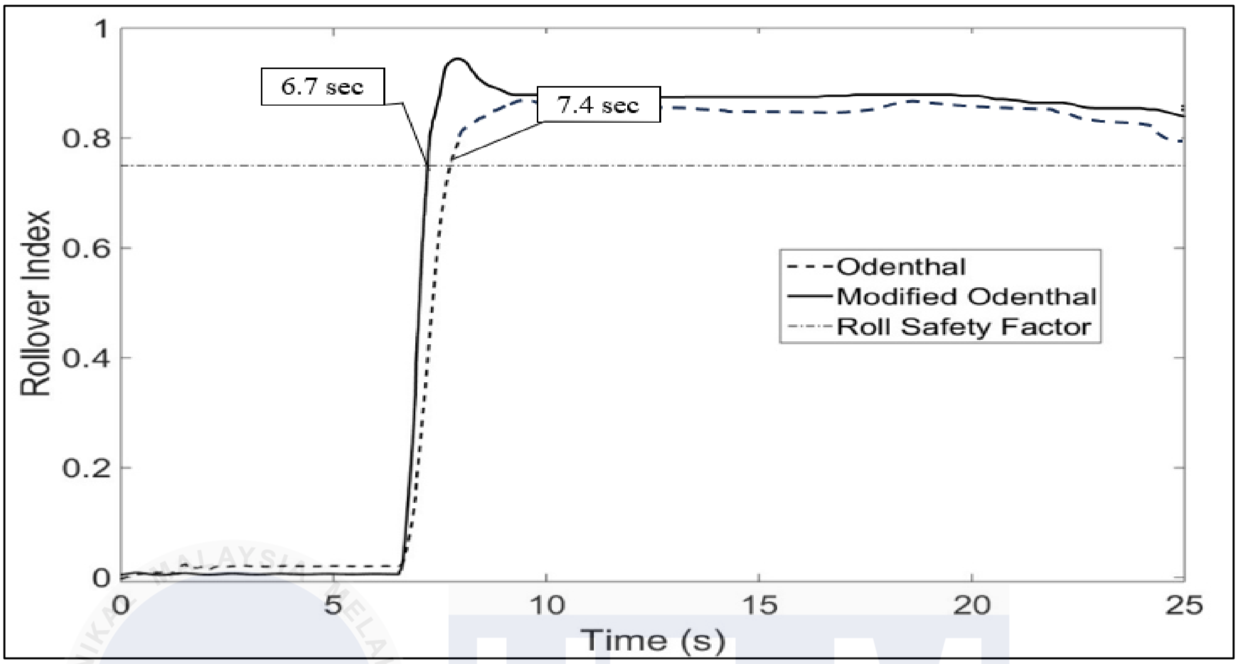


Figure 4.7: Laden State with 80km/h of Velocity

Figure 4.7 shows that heavily laden vehicle accelerates to 80 km/h and has a sudden change in direction lasting 4 seconds, it caused the vehicle almost to rolls over. The MORI line rise up in 2.58 seconds. At 2.58 seconds before the crossing of the RSF line by the Odenthal line, the rollover index was measured to be 0.75. In addition, Odenthal's rollover index is equivalent to MORI's at 0.75. However, Odenthal's indicate that the line had hits the RSF line 0.7 seconds after MORI. Hence, the different components of the vehicle interact to different extents. During this scenario, the truck undergoes an early phase of rolling over, when only one side of the vehicle is in touch with the ground.

		RSF Lines			
Load Type	Velocity(km/h)	Modified Odenthal(s)	Odenthal(s)	Time differences(s)	Percentages (%)
Unladen	60	-	-	-	-
	90	-	-	-	-
	120	2.38	2.72	0.34	12.5%
Half-Laden	60	-	-	-	-
	90	2.52	3.38	0.86	25.44%
	120	2.36	3.18	0.82	25.79%
Laden	60	-	-	-	-
	90	2.58	3.90	1.32	39.5%
	-	-	-	-	-

Table 4.1: Modified Odenthal and Odenthal Rollover Index Time Reactions

4.2 Relationship between Blynk Apps

This According to previous researchers, Odenthal's rollover index (RTI) algorithm is the most efficient algorithm. According to the findings of Mohammad Hafiz Haroun et al. 2021, Odenthal's RTI algorithm required 0,51 seconds for a driver to detect an oncoming rollover. Since the speed of the lead vehicle significantly impacted the response time, in this case, the response time increased by only 70 ms, or 0,70 seconds for every 10 km/s, the required response time may be considered too long (Mutual, 2017). Therefore, the proposed method will need an improved algorithm to generate advanced warnings and appropriate TTR in the event of a rollover. As the name indicates, the method is based on an older version of the Odenthal RTI algorithm. Besides, data gained from Blynk Apps also play a crucial role as the time taken to notify the user in the application for monitoring purposes. As the data and reaction from the Blynk Apps must be as fast as possible and accurate timing. This sub-topic also will discuss how and why the respond time from Blynk apps will also play a crucial role to achieve our objective as monitoring purposes. All data will be shown in the graph and been run in real-live time which to prove the time taken for the notification pop up whenever been triggered by the Rollover Warning Device.

4.2.1 Unladen

Condition: Unladen load state with velocity 60 kilometers per hour

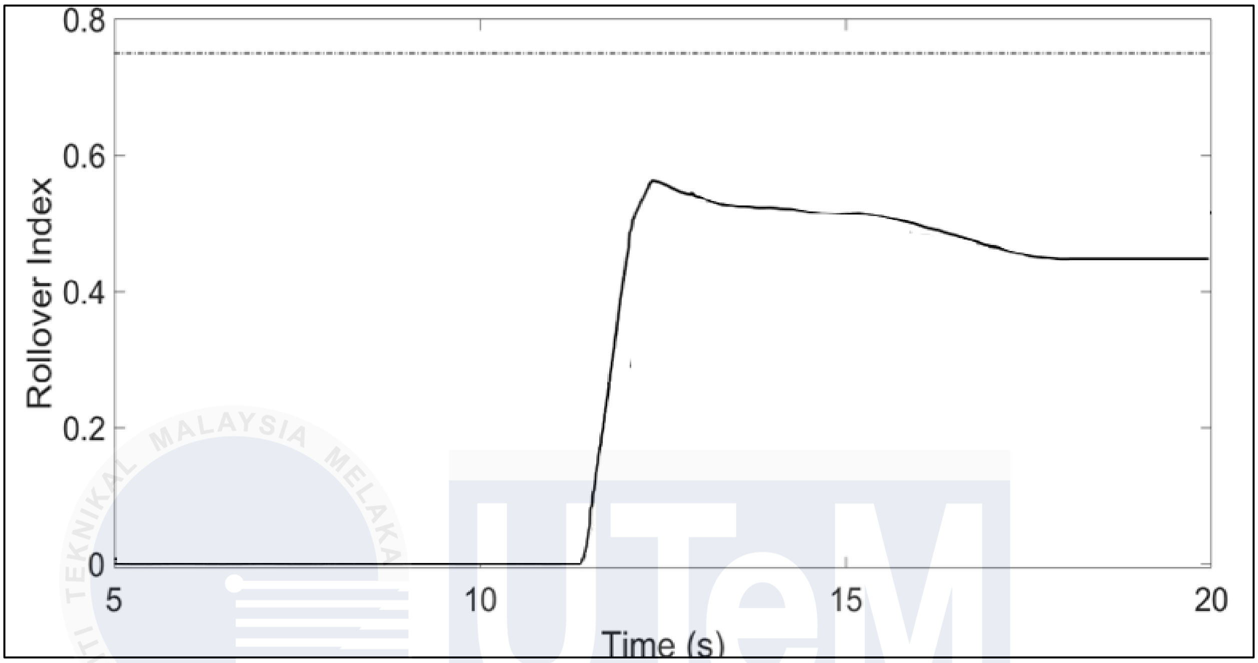


Figure 4.8 Unladen state with velocity 60 km/h

Figure 4.9 Blynk generated graph for unladen with 60 km/h

Based on data shown in Figure 4.8, the Modified Odenthal graph does not reach roll safety factor placed. The result from that will not put any trigger to the device which will not give any warning to the commercial truck driver by LED light warning and also warning from audio speaker. From this graph, it shows that the driver might drive in slow and safe speed even though with condition unladen. The safe speed for unladen commercial vehicle is around 0 km/h until 90 km/h and this data can be obtain based on experiment and test conducted in Matlab. After that, data obtained from Figure 4.9 shows that there are no responds in Blynk apps at this condition. This data is the result when there is no input for the apps as the safety factor line does not been reached.

Condition: Unladen load state with velocity 110 kilometer per hour

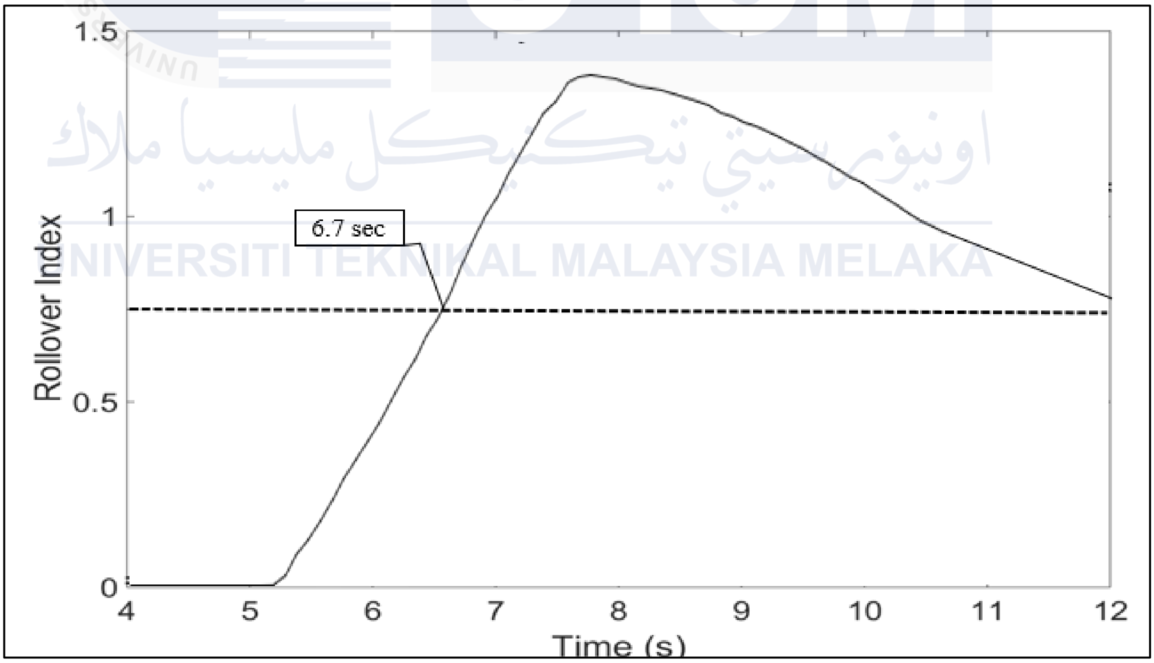


Figure 4.10 Unladen state with velocity 110 km/h

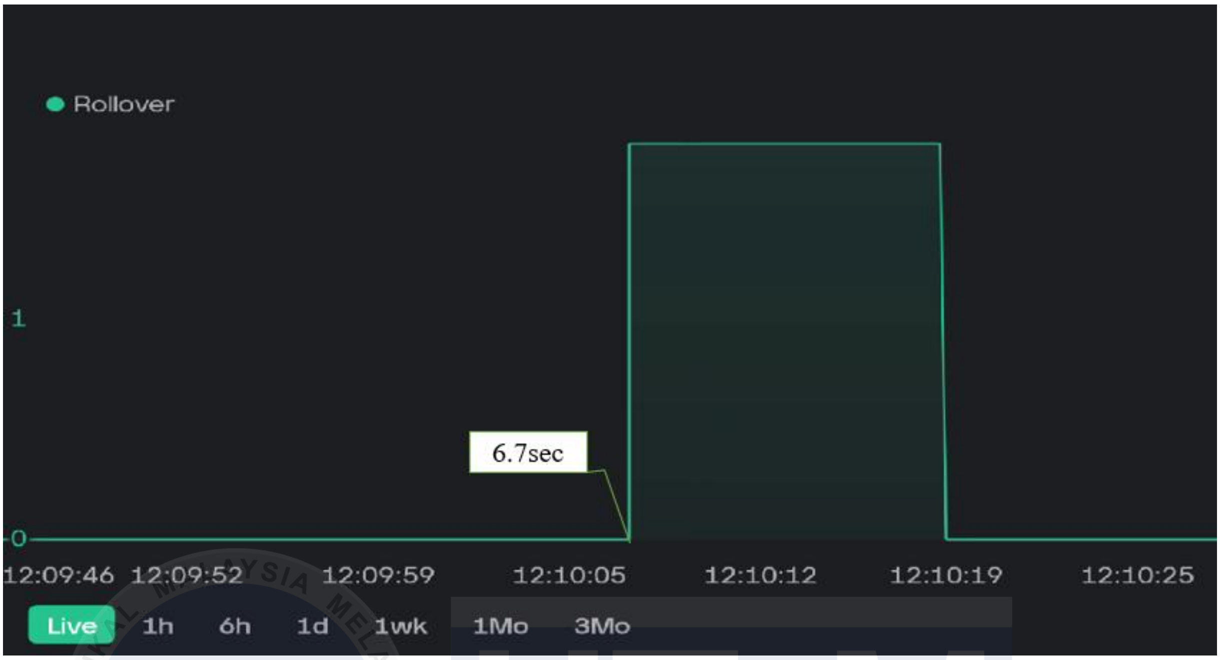


Figure 4.11 Blynk generated graph for unladen with 110 km/h

Based on graph obtained in Figure 4.10 with condition unladen state with velocity 110km/h, the Modified Odenthal line have surpass the rollover safety factor and start to trigger the device to start the LED warning light and play the audio by the speaker which will warn the driver about the rollover possibilities that might be happen. From this graph in. After that, Figure 4.11 shows that graph generated from Blynk apps also react at 6.3 second which is instant as the graph shown and the data from the Blynk apps is shows in live real-time format.

4.2.2 Half-laden

Condition: Half-laden load state with velocity 60 kilometer per hour.

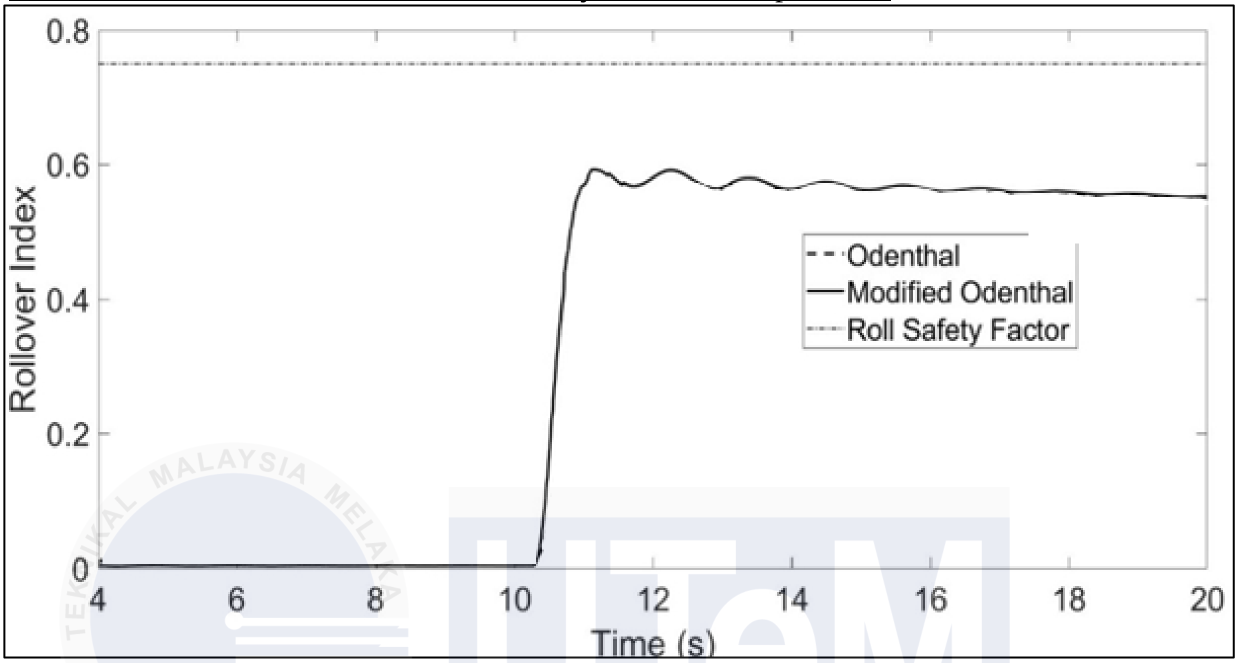


Figure 4.12 Half-Laden state with Velocity 60 km/h

Figure 4.13 Blynk generated graph for half-laden with 60 km/h

From the graph shown above in Figure 4.12, it does not surpass the Rollover Safety Factor line as the state of commercial truck does not reach the specific requirement as the load at half laden state and the driver drove the vehicle at 60 km/h. The Modified Odenthal Rollover

Index (MORI) only reaches around 0.6 and the result will show that there is no reaction to trigger the device to send any signal to Blynk apps. On Blynk generated graph in Figure 4.13, we can obtain that there is no signal given to show any curves of reaction to the host. As monitoring purposes, the company can identify that the driver were driving in slow and safe condition which there is no warning notification received from the Blynk apps.

<u>Condition: Half-laden load state with velocity 80 kilometer per hour</u>

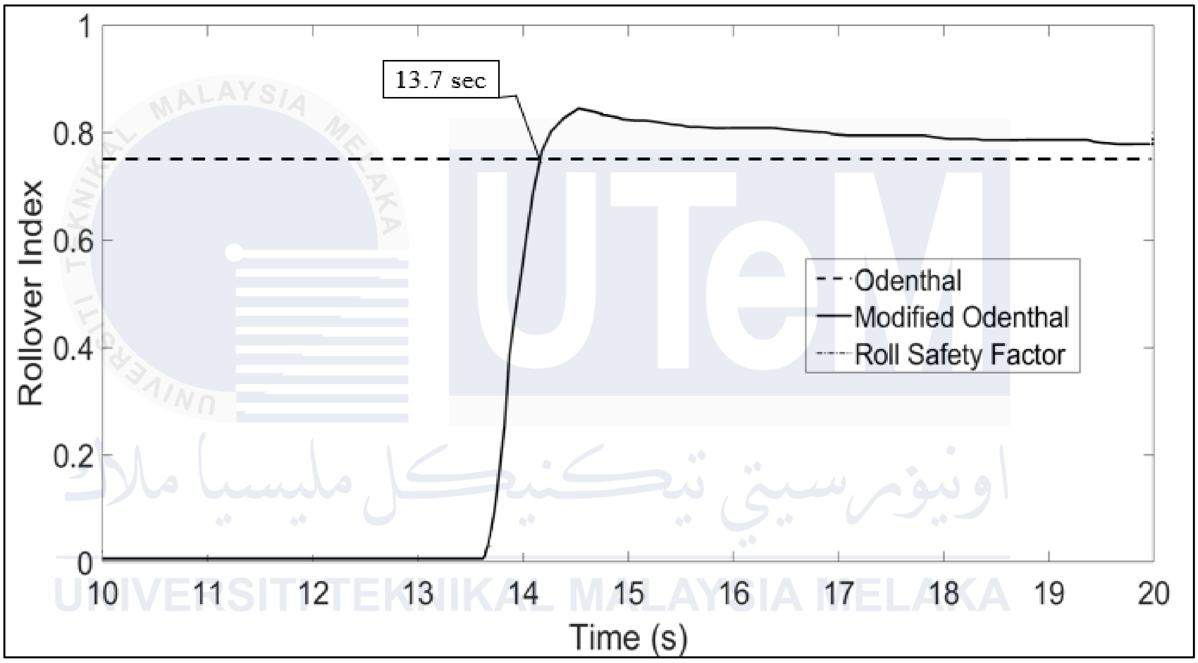


Figure 4.14 Half-Laden state with velocity 80 km/h

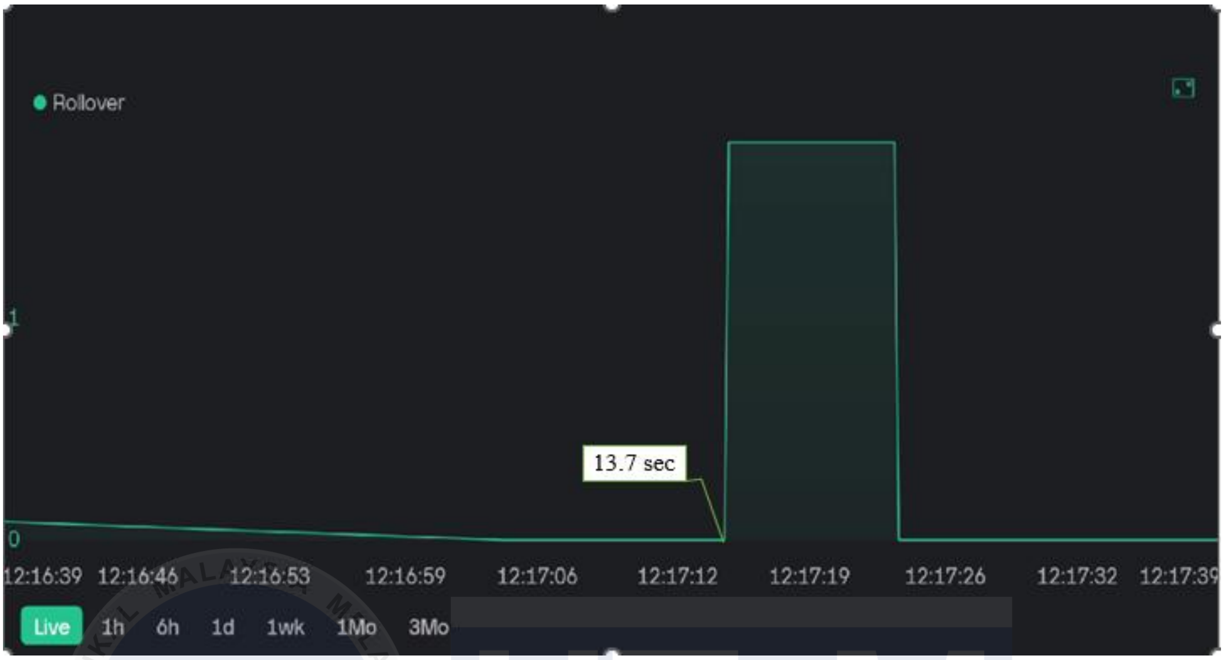


Figure 4.15 Blynk generated graph for half-laden with velocity 80 km/h

From the graph shown above, modified Odenthal line has already surpass the rollover safety factor line when the vehicle reaches velocity 80 km/h at half laden state starting at 13.7 seconds. As that condition, the device will detect the activity and start to trigger the warning light to be activated. Besides that, the alarm speaker will warn the driver in the cabin as the roll safety factor have been reached. At generated graph from Blynk apps, the signal received will form a digital form graph that will be continuous for approximately 9 seconds to 10 seconds. Data from Blynk apps was generated from real live situations which is in 24-hours format and it will make the monitoring purposes became much easier where the time and date are shows.

Condition: Half-laden load state with velocity 100 kilometer per hour

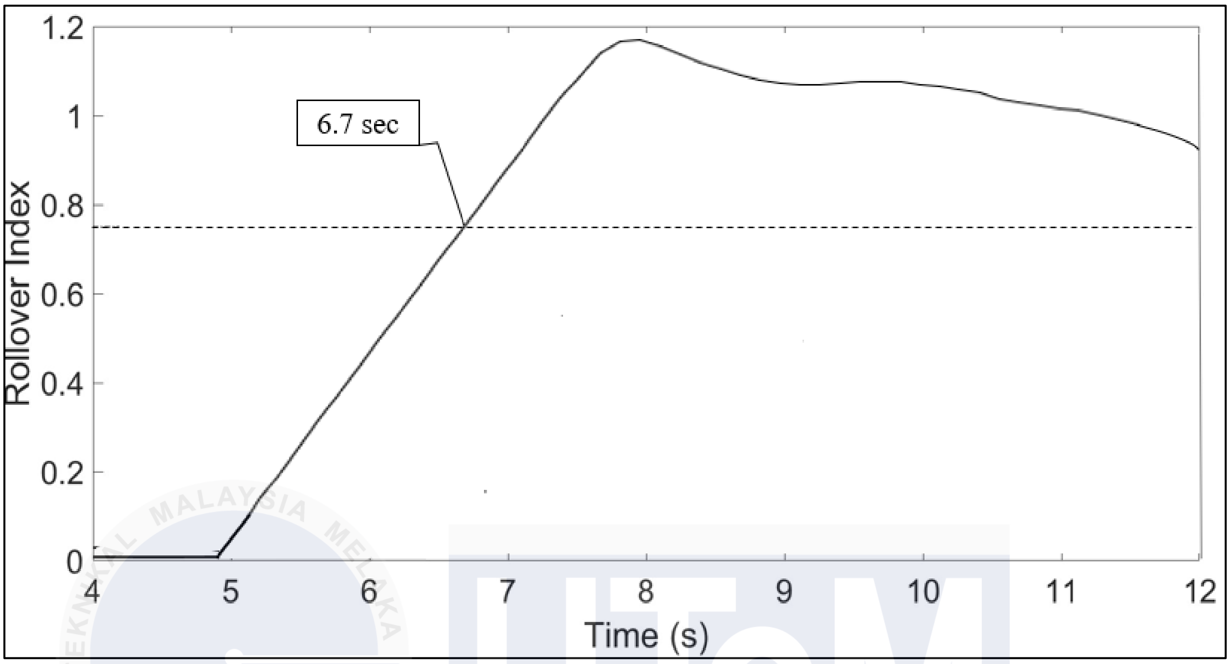


Figure 4.16 Half-Laden state with Velocity 100 km/h

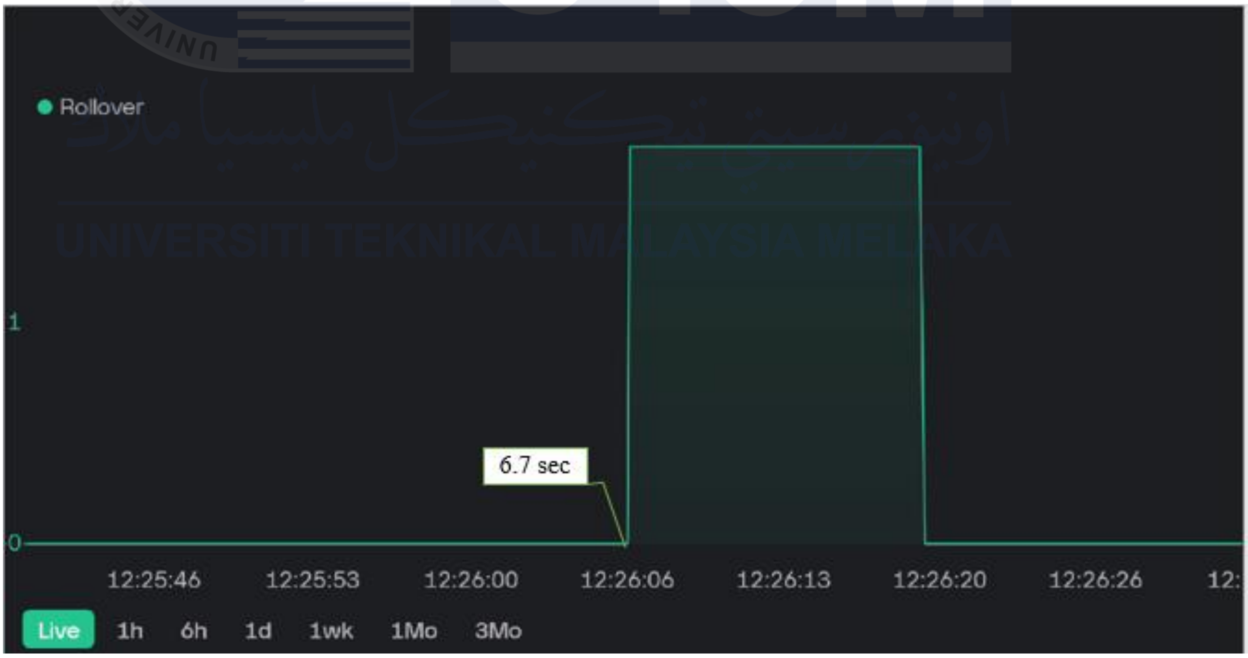


Figure 4.17 Blynk generated graph for half-laden with velocity 100 km/h

When the condition been set-up to half-laden load state with driving velocity up to 100 km/h, data from Figure 4.16 shows that the Modified Odenthal line have surpass the roll safety factor starting at 6.4 which is much more fast compare to ordinary Odenthal line. For this condition the driver will certainly receive warning from the device by blinking LED warning light and also loud alarm from the speaker. After that, Figure 4.17 shows digital graph generated from Blynk apps when receiving signal from the device and start to notify the host about the rollover event. As the host, all the data about the devices can be monitored continuously and the history about driving behaviors also can be observe from the apps.

4.2.3 Full-Laden

<u>Condition: Laden load state with velocity 60 kilometer per hour</u>

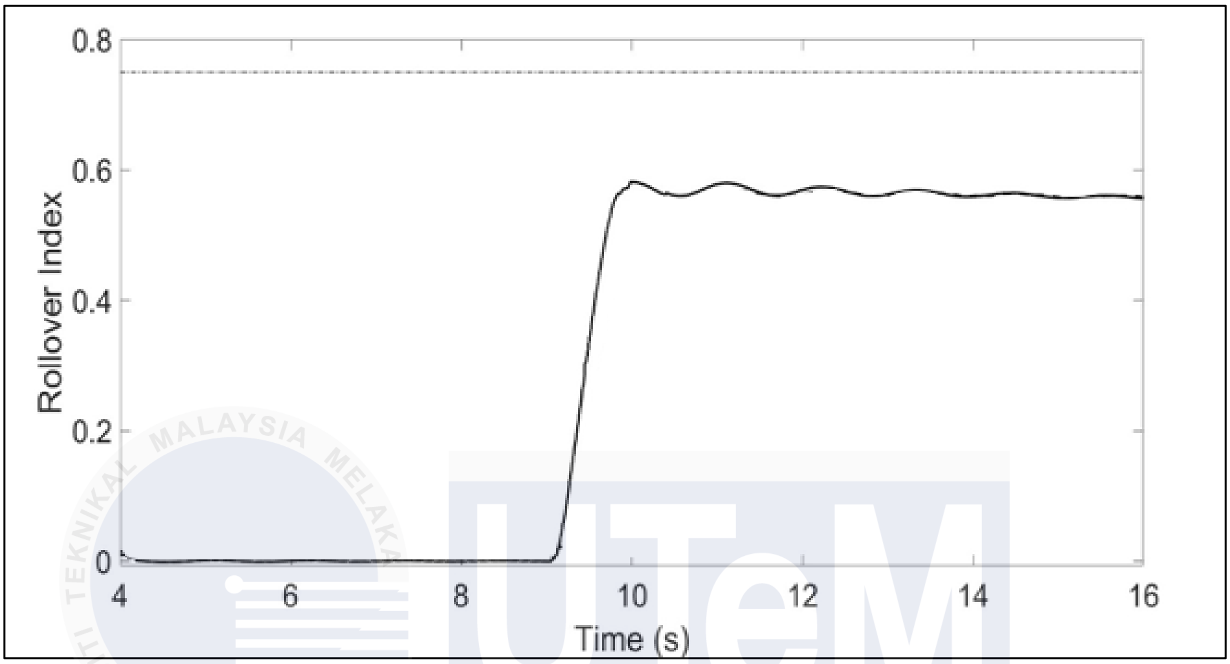


Figure 4.18 Laden state with Velocity 60 km/h

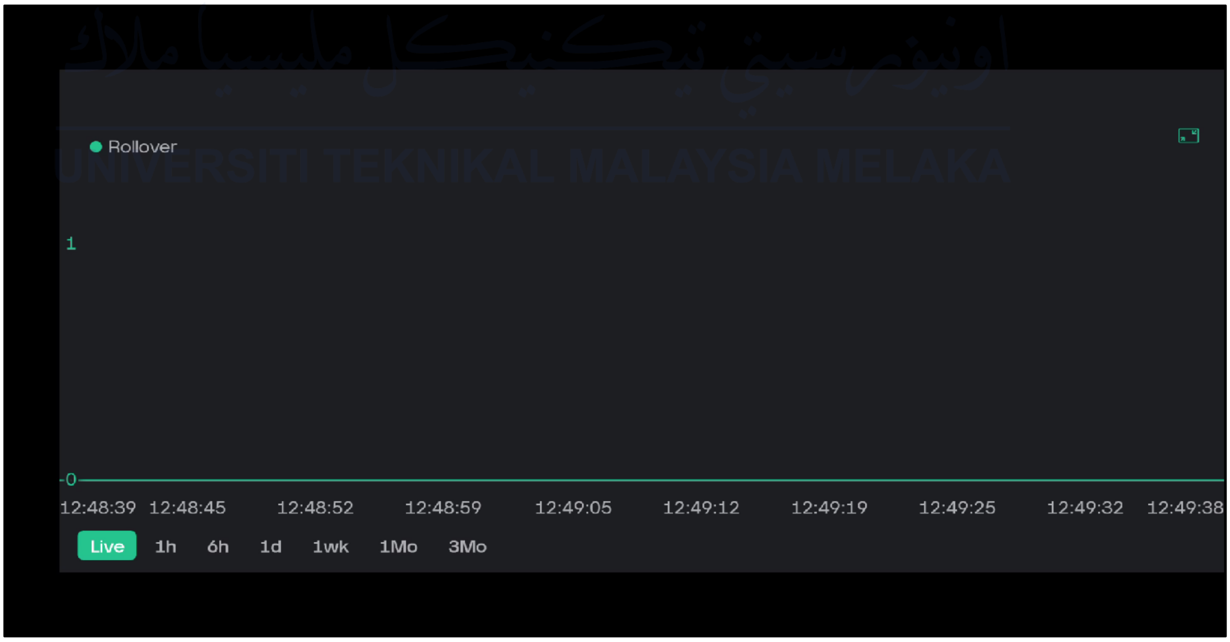


Figure 4.19 Blynk generated graph for laden with velocity 60 km/h

Based on data shown in Figure 4.18, the Modified Odenthal graph does not reach roll safety factor placed. The result from that will not put any trigger to the device which will not give any warning to the commercial truck driver by LED light warning and also warning from audio speaker. From this graph, it shows that the driver might drive in slow and safe speed even though with condition unladen. After that, data obtained from Figure 4.19. shows that there are no responds in Blynk apps at this condition. This data is the result when there is no input for the apps as the safety factor line does not been reached.

Condition: Laden load state with velocity 80 kilometer per hour

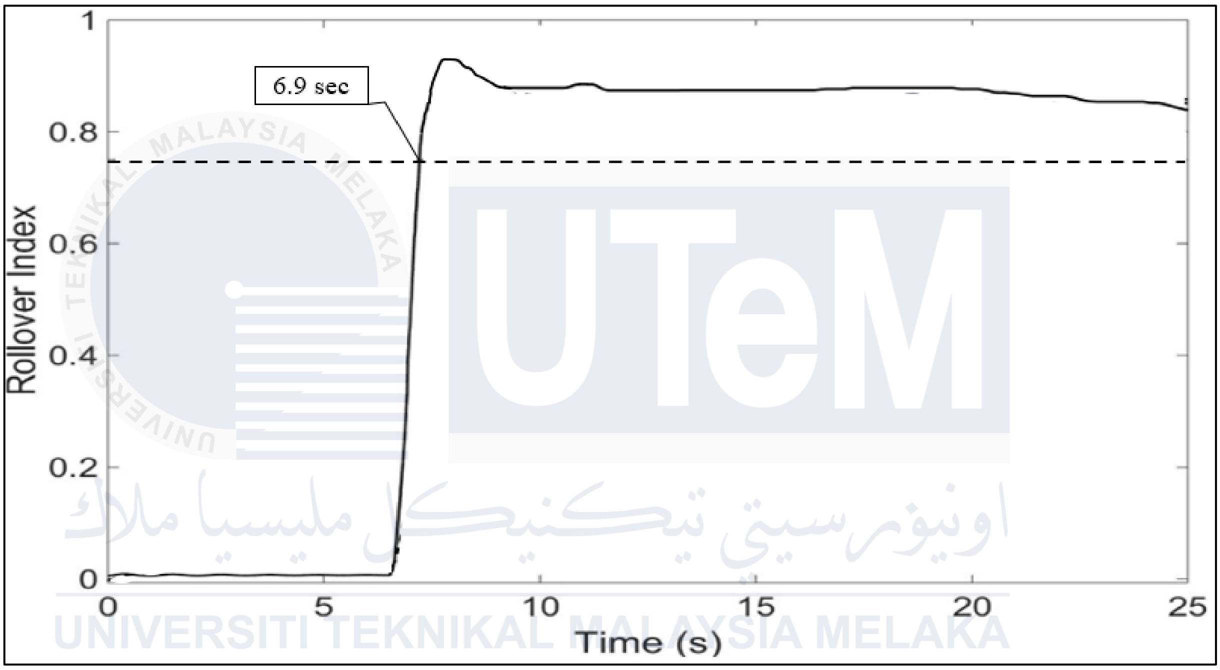


Figure 4.20 Laden state with Velocity 80 km/h

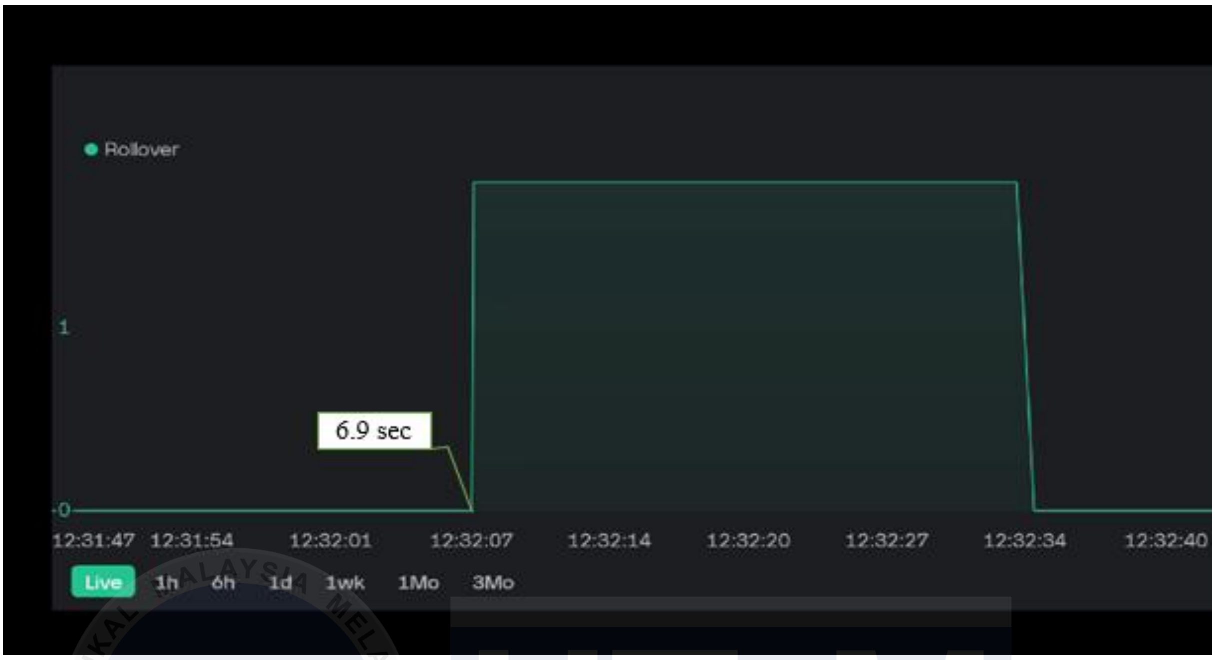


Figure 4.21 Blynk generated graph for laden with velocity 80 km/h

When the condition been set-up to full-laden load state with driving velocity up to 80 km/h, data from Figure 4.20 shows that the Modified Odenthal line have surpass the roll safety factor starting at 6.9 second which is much faster compare to ordinary Odenthal line. For this condition the driver will certainly receive warning from the device by blinking LED warning light and loud alarm from the speaker. After that, Figure 4.21 shows digital graph generated from Blynk apps when receiving signal from the device and starts to notify the host about the rollover event. As the host, all the data about the devices can be monitor continuously and the history about driving behaviors also can be observe from the apps.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The journey through this project has been an enlightening lot of experience and learning process, marked by the exploration of key concepts. The application of theoretical knowledge from any lecture sessions, and the practical challenges encountered along the way have been. This conclusion summarizes the significant findings, highlights the achievement of the project objectives, and reflects on the impact of the work completed. Furthermore, it outlines the limitations encountered and offers recommendations for future work, providing comprehensive closure to the research.

5.2 Conclusion on Result

Based on the results obtained from all the experiment, the objective for this project have achieved the objective which is to provides a system that will help to monitor any rollover event that might be happen under certain circumstance and condition. The MORI algorithm, driver steering input, and vehicle speed are the three fundamental components that provide the foundation of the rollover index methodology. These three components might be the simples part that will allow Modified Odenthal Rollover Index (MORI) to be chosen and reliable to provide the fastest response whenever rollovers tend to happen for commercial vehicles. Besides that, Odenthal's rollover index had shown its weakness when all the data gained shows that there is always late respond compared to Modified Odenthal Rollover Index (MORI). Fast respond to warn should be crucial for allowing the commercial vehicle's driver apply counter measure to avoid any incident to happen.

After that, this project has successfully embedded the IoT system in Rollover Warning Device for commercial vehicles monitoring purposes. By applying the suitable and reliable coding into Blynk apps which will connected to internet which allowing the host to get a notification whenever the vehicles reach the Rollover Safety Factor (RSF) line that will be adjusted based on vehicle's state conditions which is unladen, half-laden and full-laden. Then, this Internet of Things (IoT) will also a section that provide the driving history which is very important to monitor the driving behavior and vehicle's condition. The reaction from Blynk apps shows that its immediate respond to notify the host is crucial to get the exact time as the data will be generated in live situations with date. This data will also be useful for the authorities to conduct any investigation about the incident. As that reasons, this device will be helpful to ensure that all the data given be more accurate.

5.3 Recommendation

To improve road safety and emergency response times when any incident that involve heavy commercial vehicles, we recommend integrating GPS technology into the device working together with the IoT for detecting and communicating the location of accidents. GPS systems can precisely identify a vehicle's location at any time. In any event of an accident, this data can be automatically transmitted to emergency responders, enabling them to reach the site quickly and efficiently. It also will help to allow the emergency response team get to the exact location. Modern GPS systems often include accelerometers and sensors that can detect sudden impacts or changes in vehicle movement, which are indicative of accidents. When such an event is detected, the system can trigger an automatic alert to emergency services.

Built-in SOS buttons or apps that allow drivers or passengers to manually send their location to emergency contacts or services in case of distress. Once an incident is detected, the system automatically sends an SOS alert to emergency services, fleet managers, or designated contacts. By installing this type safety device, it can help to inform as many people as desired about any emergency status during their journey. Based on that reason, SOS button is recommended to be installed to all heavy commercial vehicles as additional emergency precautions.

REFERENCE

Ataei, M., Khajepour, A., & Jeon, S. (2019). A general rollover index for tripped and un-tripped rollovers on flat and sloped roads. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *233*(2), 304–316.

Dorigo, M., & Stützle, T. (2019). Ant colony optimization: Overview and recent advances. In *International Series in Operations Research and Management Science* (Vol. 272). https://doi.org/10.1007/978-3-319-91086-4_10

El-Shorbagy, M. A., & Hassanien, A. E. (2018). Particle Swarm Optimization from Theory to Applications. *International Journal of Rough Sets and Data Analysis*, *5*(2), 1–24.

https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/safety/data-and-statistics/Large-Truck-and-Bus-Crash-Facts-2015.pdf

https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813452.pdf

https://www.kosmo.com.my/2022/08/08/kemalangan-melibatkan-lori-meningkat-28-peratus-tahun-ini/

Hafizah Amer, N., Hudha, K., Zamzuri, H., Rau Aparow, V., Faiz Zainal Abidin, A., Abd Kadir, Z., & Murrad, M. (2021). Knowledge-Based Controller Optimised with Particle Swarm Optimisation for Adaptive Path Tracking Control of an Autonomous Heavy Vehicle. *Automation and Control*. https://doi.org/10.5772/intechopen.92667

Harun, M. H., Hudha, K., Samin, P. M., Bakar, S. A. A., & Ubaidillah, U. (2020). Stability and roll effect of the straight truck suspension system. *Journal of Advanced Manufacturing Technology*, *14*(1), 89–100.

Kazemian, A. H., Fooladi, M., & Darijani, H. (2017). Rollover index for the diagnosis of tripped and untripped rollovers. *Latin American Journal of Solids and Structures*, *14*(11), 1979–1999. https://doi.org/10.1590/1679-78253576

Mohan K Ramanujam. (2022). *Car Reviews 2022*. Statistics Car Accident 2022. https://paultan.org/2022/01/27/255532-road-accidents-jan-sep-2021-3302-deaths/#:~:text=A total of 255%2C532 road,were recorded%2C with 4%2C634 fatalities

Muttart, J. W. (2017). *Quantifying Driver Response Times Based upon Research and Real Life Data*. 9–17. https://doi.org/10.17077/drivingassessment.1137

Odenthal, D., Bunte, T., & Ackermann, J. (2015). Nonlinear steering and braking control for vehicle rollover avoidance. *European Control Conference, ECC 1999 - Conference Proceedings*, 598–603. https://doi.org/10.23919/ecc.1999.7099370

Okwu, M. O., & Tartibu, L. K. (2021). Particle Swarm Optimisation. *Studies in Computational Intelligence*, *927*, 5–13. https://doi.org/10.1007/978-3-030-61111-8_2

Parenteau, C. S., Viano, D. C., Shah, M., Gopal, M., Davies, J., Nichols, D., & Broden, J. (2003). Field relevance of a suite of rollover tests to real-world crashes and injuries. *Accident Analysis and Prevention*, *35*(1), 103–110. https://doi.org/10.1016/S0001-4575(01)00094-X

Phanomchoeng, G., & Rajamani, R. (2013). New rollover index for the detection of tripped and untripped rollovers. *IEEE Transactions on Industrial Electronics*, *60*(10), 4726– 4736. https://doi.org/10.1109/TIE.2012.2211312

Presented, M. E., & Fulfillment, P. (1999). Analysis, Detection and Early Warning Control of Dyaamic Rollover. *PhD Thesis, Concordia University, Montreal, Quebec, Canada, January*.

Rajamani, R., Piyabongkam, D., Tsourapas, V., & Lew, I. Y. (2009). Real-time estimation of roll angle and CG height for active rollover prevention applications. *Proceedings of the*

American Control Conference, 433–438. https://doi.org/10.1109/ACC.2009.5160045
Rajamani, R., Piyabongkarn, D., Tsourapas, V., & Lew, J. Y. (2011). Parameter and state estimation in vehicle roll dynamics. *IEEE Transactions on Intelligent Transportation Systems*, *12*(4), 1558–1567. https://doi.org/10.1109/TITS.2011.2164246
Rashedi, E., Nezamabadi-pour, H., & Saryazdi, S. (2009). GSA: A Gravitational Search Algorithm. *Information Sciences*, *179*(13), 2232–2248. https://doi.org/10.1016/j.ins.2009.03.004
Sabri, N. M., Puteh, M., & Mahmood, M. R. (2013). An overview of Gravitational Search Algorithm utilization in optimization problems. *Proceedings - 2013 IEEE 3rd International Conference on System Engineering and Technology, ICSET 2013*, 61–66. https://doi.org/10.1109/ICSEngT.2013.6650144
Tota, A., Dimauro, L., Velardocchia, F., Paciullo, G., & Velardocchia, M. (2022). An Intelligent Predictive Algorithm for the Anti-Rollover Prevention of Heavy Vehicles for Off-Road Applications. *Machines*, *10*(10). https://doi.org/10.3390/machines10100835
Xu, J., Xin, T., Gao, C., & Sun, Z. (2022). Study on the Maximum Safe Instantaneous Input of the Steering Wheel against Rollover for Trucks on Horizontal Curves. *International Journal of Environmental Research and Public Health*, *19*(4). https://doi.org/10.3390/ijerph19042025
Zi, S. Q. (2011). *Design of electronic stability control for rollover prevention using sliding mode control Bo-Chiuan Chen *, Cheng-Chi Yu and Wei-Feng Hsu Min-Fang Lo*. *56*, 224–245.
Bruno Fernandes, V. G. (2015). Mobile Application for Automatic Accident Detection and Multimodal Alert. *Instituto de Telecomunicações Universidade de Aveiro, Portugal*.
Carolina Pinart, ,. J. (n.d.). ECall-compliant early crash notification service for portable and nomadic devices. *Massachusetts Institute of Technology (MIT) 77 Massachusetts Ave, Cambridge, MA, USA 02139*.

Chen, Y., Zheng, X., Zhang, Z., & Ahmadian, M. (2022). Effect of off-centred loading on roll stability of multi-trailer trucks. *International Journal of Vehicle Performance*, *8*(2–3), 271–295. https://doi.org/10.1504/IJVP.2022.122046
Gao, X., Jiang, Q., Zhang, G., & -, al. (2024). Dynamic system for the study of bouncing vibrations of a car with active suspension model for an independent suspension. *IOP Conference Series: Materials Science and Engineering*, *1303*(1), 012038. https://doi.org/10.1088/1757-899X/1303/1/012038
Guillermo Moreno Contreras, G., Nicolazzi, L., de Souza Vieira, R., & Martins, D. (n.d.). *ROLLOVER OF HEAVY TRUCK USING DAVIES METHOD*.
Hafiz Bin Harun, M. (2021). *ROLLOVER W ARNING SYSTEM FOR TRACTOR-SEMITRAILER USING A MODIFIED ODENTHAL ROLLOVER INDEX ALGORITHM*.
Jneid, M. S., Zöldy, M., & Harth, P. (2023). Sensorless optimal control of electronic wedge brake based on dynamic model and Kalman filter state multiple-estimation. *Https://Doi.Org/10.1177/09544070231168168*. https://doi.org/10.1177/09544070231168168
John, F. L., Lakshmi, D., & Kuncharam, M. (2023). Introduction to the Internet of Things. *Smart Grids and Internet of Things: An Energy Perspective*, 1–34. https://doi.org/10.1002/9781119812524.CH1
Moreno, G., Figueroa, S., & Ramon, B. (2018). Stability models of heavy vehicle. *Contemporary Engineering Sciences*, *11*(92), 4569–4579. https://doi.org/10.12988/ces.2018.89503
Moreno, G., Serrano, J. C., & Figueroa-Salgado, S. (2020). Análisis bidimensional de la estabilidad de vehículos pesados tipo carro-tanque. *Revista UIS Ingenierías*, *19*(3), 31–36.

https://doi.org/10.18273/revuin.v19n3-2020003

(Open Access) Dynamic Stability and Control of Tripped and Untripped Vehicle Rollover (2019) | Zhilin Jin. (n.d.). Retrieved May 24, 2024, from https://typeset.io/papers/dynamic-stability-and-control-of-tripped-and-untripped-44ulaaky1b

Rosique, F., Navarro, P. J., Fernández, C., & Padilla, A. (2019a). A Systematic Review of Perception System and Simulators for Autonomous Vehicles Research. *Sensors 2019, Vol. 19, Page 648*, *19*(3), 648. https://doi.org/10.3390/S19030648

Seyedi, M. R., Jung, S., Wekezer, J., Kerrigan, J. R., & Gepner, B. (2020). Rollover crashworthiness analyses–an overview and state of the art. In *International Journal of Crashworthiness* (Vol. 25, Issue 3, pp. 328–350). Taylor and Francis Ltd. https://doi.org/10.1080/13588265.2019.1593290

Wang, R., Xu, X., Chen, S., Guo, N., & Yu, Z. (2023a). Vehicle Rollover Warning and Control Based on Attitude Detection and Fuzzy PID. *Applied Sciences (Switzerland)*, *13*(7). https://doi.org/10.3390/app13074339

Wolf, J. C. (n.d.). *Early warning of pedestrians and cyclists*.

Wu, X., Yang, X., Zhang, S., Wu, T., & Feng, C. (2023). Dynamics stability oriented configuration optimisation of a tractor semi-trailer tank vehicle based on a coupling lateral vehicle dynamics model. *International Journal of Heavy Vehicle Systems*, *30*(2), 167–200. https://doi.org/10.1504/IJHVS.2023.132312

Zhou, C. (2020). Algorithm Design of Early Warning Seatbelt Intelligent Adjustment System Based on Neural Network and Big Data Analysis. *Mathematical Problems in Engineering*, *2020*. https://doi.org/10.1155/2020/7268963

APPENDIX

Vx
60.000000000000000
59.987430572509766
59.973617553710938
59.959732055664063
59.945945739746094
59.932361602783203
59.919052124023438
59.906059265136719
59.893402099609375
59.881114959716797
59.869228363037109
59.857761383056641
59.846733093261719
59.836147308349609
59.826007843017578
59.816314697265625
59.807075500488281
59.798309326171875
59.790031433105469
59.782257080078125
59.775001525878906

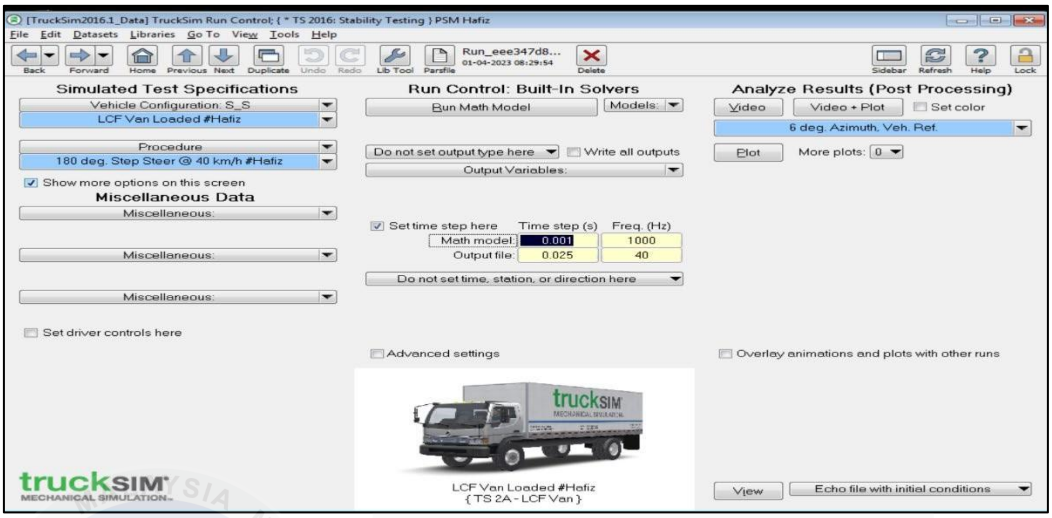
Appendix 1 Velocity of 60km/h

Vx
90.000000000000000
89.975387573242188
89.949470520019531
89.923522949218750
89.897956848144531
89.872978210449219
89.848731994628906
89.825286865234375
89.802734375000000
89.781150817871094
89.760574340820313
89.741020202636719
89.722450256347656
89.704818725585937
89.688064575195313
89.672157287597656
89.657073974609375
89.642814636230469
89.629371643066406
89.616775512695313
89.605018615722656

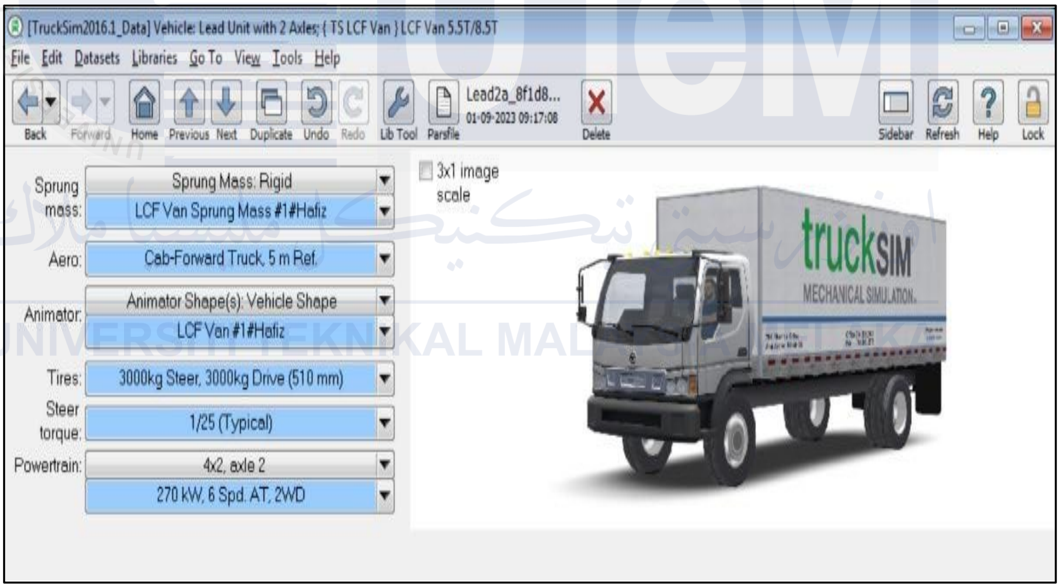
Appendix 2 Velocity of 90km/h

Vx
120.000000000000000
119.966560363769530
119.931663513183590
119.896835327148440
119.862617492675780
119.829315185546870
119.797203063964840
119.766441345214840
119.737052917480470
119.708976745605470
119.682136535644530
119.656455993652340
119.631851196289060
119.608261108398440
119.585632324218750
119.563941955566410
119.543190002441410
119.523376464843750
119.504508972167970
119.486587524414060
119.469635009765620

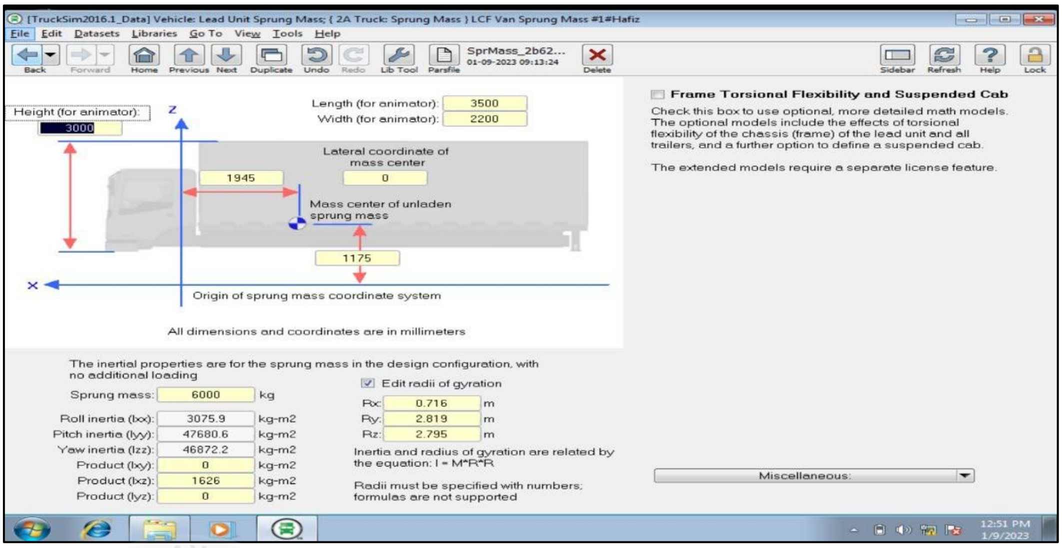
Appendix 3 Velocity of 120km/h



Appendix 4: Trucksim home appearance setting



Appendix 5: Vehicle appearance setting



Appendix 6: Truck interference setting

adam luqman

Design and Fabrication of Commercial Vehicle

PSM-2024-2025

PSM-2024-2025

Universiti Teknikal Malaysia Melaka - Library

Document Details

Submission ID

trn:oid:::1:3125839614

Submission Date

Jan 8, 2025, 3:19 PM GMT+8

Download Date

Jan 8, 2025, 3:25 PM GMT+8

File Name

PSM_Ai_and_turnitin_check_purpose_ADAM.docx

File Size

5.8 MB

105 Pages

16,645 Words

89,578 Characters

*% detected as AI

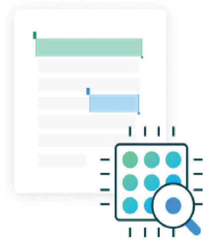
AI detection includes the possibility of false positives. Although some text in this submission is likely AI generated, scores below the 20% threshold are not surfaced because they have a higher likelihood of false positives.

Caution: Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.

Frequently Asked Questions

How should I interpret Turnitin's AI writing percentage and false positives?
The percentage shown in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was either likely AI-generated text from a large-language model or likely AI-generated text that was likely revised using an AI-paraphrase tool or word spinner.



False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.