SPEED BUMP AND POTHOLE DETECTION FOR CHILDREN'S SCOOTER

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**A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled “Speed Bump and Pothole Detection for Children’s Scooter” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Muhammd Izzul Islam Bin Mohd Jahid
Date	:	06/02/2024

APPROVAL

I hereby declare that I have checked this thesis and in 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 Honors.

Signature	:	
Supervisor Name	:	Ts. Mohd Hafizi Bin Abdul Rahman
Date	:	7/2/2024

DEDICATION

I would like to dedicate the success of this research to my parents, Mohd Jahid Bin Abdul Salam and Mariana Binti Abdullah. This report is dedicated to them because I want to express my gratitude for all their sacrifices for me throughout my time at this university. Second, this dedication is made to my fellow friends, who assisted me in completing this report through exchange of thougths and opinions, assistance during the on-raod testing, and encouragement. Following that, I'd like to offer my heartfelt appreciation to my supervisor, Ts. Mohd Hafizi Bin Abdul Rahman for his assistance and guidance throughout the course of finishing this Final Year Project.

ABSTRACT

Children’s scooter is one of the most popular toys that parents buy for their cildren and also not only the scooter is exclusive to children, there are also scooters that is made for adults. Other than that, there are also scooters powered by electric motor that moves without using the leg to push it forward. These scooters may seem safe to use but the roads that these scooter moves on may not be so safe due to some hazards and those hazars are speed bumps and potholes. The original purpose of a speed bump is to slow down vehicle in residential areas to avoid drivers hitting people. But a speed bump becomes a hazard to scooter riders especially children scooter riders when they go over the speed bump to fast because the scooter rider does not notice the speed bump and may lead to them falling on the pavement and causing them to sustain injuries. Same goes for potholes, potholes are more dangerous because it is easier to not notice a pothole because of the color of the paved road and the pothole is almost the same. This project is conducted with the aim to detect these hazards and inform the scooter rider of them so that they can slow down and avoid going over them and cause the scooter rider to fall on the road. This project useses an ultrasonic sensor to detect the speed bump and pothole that is connected to an Arduino microcontroller and a buzzer module to produce a sound to aleart the scooter rider of the detected hazard. After obtaining the components and designing the connection of the components to the Arduino microcontroller, the process of uploading a source code into the Arduino microcontroller is done to obtain the detection and alerting system that will be placed on the scooter or children’s scooter. Then, an on-road testing is done where the scooter or children’s scooter that is equiped with the detection and alerting system is placed infront of the speed bump and pothole to see if the detection and alerting system work as intended or not with the aid of a decibel meter application to capture the sound produced by the buzzer. The results of the on-road testing shows that the system works but it is not accurate because when faced with a shorter speed bump, the system will not detect the speed bump and for the pothole detection, the detection system will detect the pothole and also sometime detects the surface of the road because the buzzer will make a sound even though there is no pothole. With the help of these results, this project can be further improved in detecting speed bumps and potholes so that less scooter riders will fall while riding a scooter due to those hazards.

ABSTRAK

Skuter kanak-kanak adalah salah satu mainan paling popular yang ibu bapa beli untuk anak-anak mereka dan juga bukan sahaja skuter itu eksklusif untuk kanak-kanak, terdapat juga skuter yang dibuat untuk orang dewasa. Selain itu, terdapat juga skuter yang dikuasakan oleh motor elektrik yang bergerak tanpa menggunakan kaki untuk menolaknya ke hadapan. Skuter ini mungkin kelihatan selamat untuk digunakan tetapi jalan yang dilalui oleh skuter ini mungkin tidak begitu selamat di sebabkan oleh beberapa bahaya dan bahaya tersebut ialah bonggol dan jalan berlubang. Tujuan asal bonggol adalah untuk memperlahankan kenderaan di kawasan perumahan bagi mengelak pemandu melanggar orang. Tetapi bonggol boleh menjadi bahaya kepada penunggang skuter terutamanya penunggang skuter kanak-kanak apabila mereka melalui atas bonggol dengan laju kerana penunggang skuter tidak menyedari kehadiran bonggol itu dan boleh menyebabkan mereka terjatuh di atas jalan dan menyebabkan mereka mengalami kecederaan. Sama juga dengan jalan berlubang, jalan berlubang lebih bahaya kerana lebih mudah tidak perasan jalan berlubang kerana warna jalan berturap dan jalan berlubang hampir sama. Projek ini dijalankan dengan tujuan untuk mengesan bahaya ini dan memaklumkan kepada penunggang skuter mengenainya supaya mereka boleh memperlahankan pergerakkan mereka dan dapat mengelak daripada melintasi bahaya tersebut dengan laju dan menyebabkan penunggang skuter itu terjatuh di atas jalan. Projek ini menggunakan penderia ultrasonik untuk mengesan bonggol dan jalan berlubang yang disambungkan kepada mikropengawal Arduino dan modul buzzer untuk menghasilkan bunyi untuk menyedarkan penunggang skuter tentang bahaya yang dikesan. Selepas mendapatkan komponen dan mereka bentuk sambungan komponen kepada mikropengawal Arduino, proses memuat naik kod sumber ke dalam mikropengawal Arduino dilakukan untuk mendapatkan sistem pengesanan dan amaran yang akan diletakkan pada skuter atau skuter kanak-kanak. Kemudian, ujian di jalan raya dilakukan di mana skuter atau skuter kanak-kanak yang dilengkapi dengan sistem pengesanan dan amaran diletakkan di hadapan bonggol dan jalan berlubang untuk melihat sama ada sistem pengesanan dan amaran berfungsi seperti yang diharapkan atau tidak dengan bantuan aplikasi meter desibel untuk menangkap bunyi yang dihasilkan oleh buzzer. Hasil ujian on-road menunjukkan sistem berfungsi tetapi tidak tepat kerana apabila berdepan dengan bonggol yang lebih pendek, sistem tidak dapat mengesan bonggol itu dan untuk pengesanan jalan berlubang, sistem pengesan akan mengesan lubang dan juga kadang-kadang mengesan permukaan jalan kerana buzzer akan mengeluarkan bunyi walaupun tiada jalan berlubang. Dengan bantuan keputusan ini, projek ini boleh dipertingkatkan lagi dalam mengesan bonggol dan jalan berlubang supaya dapat mengurangkan penunggang skuter akan jatuh semasa menunggang skuter kerana bahaya tersebut.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to express my heartfelt gratitude to Allah the Almighty for his assistance and guidance during my life and at the moment of fact. I successfully finished my final year project study at Universiti Teknikal Malaysia Melaka's Faculty of Mechanical Technology and Engineering (UTeM). At this time, I would like to express my appreciation to all parties involved, especially Ts. Mohd Hafizi Bin Abdul Rahman, the supervisor of the final year project, for providing me with the opportunity to complete the final year report project.

There are many lessons I can learn when doing this final year study. Finally, I'd like to thank my parents for their encouragement and belief in my ability to complete my Final Year Project Thesis. I'd like to thank everybody once again. Both of their kindness and generosity to me will be honored till the end of time. Thank you so much.

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LIST OF SYMBOLS AND ABBREVIATIONS

UK	-	United Kingdom
PMS	-	Pavement Management System
RCNN	-	Regions With Convolutional Neural Network
YOLO	-	You Only Look Once
SDD	-	Software Design Document
IOT	-	Internet of Things
GPS	-	Global Positioning System
PyQT	-	Python binding of the cross-platform GUI toolkit Qt
MySQL	-	My Structured Query Language
CNN	-	Convolutional Neural Network
VGG	-	Visual Geometry Group
LiDAR	-	Light Detection and Ranging
CCTV	-	Closed-Circuit Television
MAP	-	Morse Assemblers Program
CUDA	-	Compute Unified Device Architecture
DNN	-	Deep Neural Network
SVM	-	Support Vector Machine
RBF	-	Radial Basis Function

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CHAPTER 1

INTRODUCTION

1.1 Background

A small, wheeled vehicle made especially for young riders is called a children's scooter. A lightweight frame, handlebars for steering, and one or two wheels are usually included. In order to meet a range of age groups and skill levels, children's scooters are available in a variety of sizes, designs, and features.

These scooters are a great method for kids to play actively, encourage physical development, and improve their balance and coordination. Children can learn how to change their body weight, steer, and maintain equilibrium while moving ahead by using a scooter.

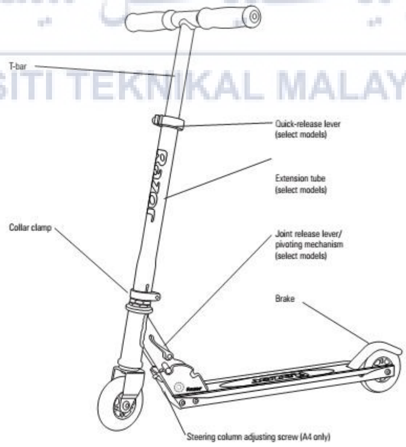


Figure 1 Scooter diagram:
https://thegioitienganhvietnam.wordpress.com/2014/08/01/

Accordingly, safety is an important consideration when choosing a children's scooter, and many models have safety elements as standard equipment. These might feature handbrakes, non-slip footboards, and robust wheels made for stability and smooth rides. It is crucial for parents and other responsible adults to keep an eye on their children at all times, make sure they are wearing the correct safety equipment, like helmets and knee pads, and select a scooter that is appropriate for their age and level of ability.

Despite all of the safety precautions and parental supervision, accidents can still occur due to carelessness or just plain bad luck. This study, on the other hand, is about creating and constructing a safety feature that includes a safety system that can identify road hazards such as speed bumps and potholes in order to prevent accidents involving these road hazards.

1.2 Problem Statement

Potholes and speed bumps are common road hazards that can have an impact on vehicle safety and road conditions. Speed bumps and potholes both play significant roles in road safety, although they perform different functions. Potholes are unintentional road flaws that must be fixed to guarantee smooth and safe driving conditions. Speed bumps try to control and reduce vehicle speeds.

Figure 2 Speed bump: https://www.thestar.com.my/metro/metro-news/2020/10/23/standardising-speed-bumps

This project's goal is to address the road risks caused by speed bumps and potholes. It is a critical initiative that strives to improve road safety for both automobiles and pedestrians. Recognizing the impact of these dangers on transportation infrastructure allows for the implementation of various projects and techniques to solve the issues they represent.

Figure 3 Pothole: https://gempak.com/rojakdaily/news/why-are-there-so-many-potholes-malaysia-we-asked-expert-explain-64088

One of the numerous techniques that can be applied, and the one chosen for this project, is to develop a system that includes an Arduino microcontroller, an ultrasonic sensor and a buzzer module detect the surface condition of the road and inform the rider or the parents who are overseeing the child. This system must be precisely installed and attached to the T-bar area of the children's scooter.

However, problems may arise when carrying out this project, as well as hurdles that must be overcome in order to boost the project's success rate. One of the issues is that this concept already exists, but in the car business. To apply this concept to a children's scooter, some trial and error is required because, when using Arduino, code is required to ensure that the system works as intended.

As a result, the issues that must be addressed in this research include creating the system for the children's scooter, adding compatible source code for the other components to work properly together and optimizing the end product to increase the application's success rate.

1.3 Research Objective

The main aim of this project is to design and fabricate a speed bump and pothole detection and alerting system for children’s scooter. Specifically, the objectives are as follows:

a) To design a speed bump and pothole detection and alert system for children’s scooter.

b) To fabricate the speed bump and pothole sensor and alert system for children’s scooter.

1.4 Scope of Research

The scope of this research are as follows:

- Concertrating on incorporating a speed bump detection and alerting mechanism into children's scooters.
- Conducting system testing with an Arduino and an ultrasonic sensor, in which a source code is entered into the Arduino programmer and the sensor begins to function.
- Fabricating the system that will be integrated into the children’s scooter.
- Performing on road test run using the actual product.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will give a review of the literature on many subjects relating to the study, such as the role of speed bumps in suburban areas, the working principles behind speed bumps, speed bump settings, scooter rider injuries and potholes. It is an attempt to establish the parameters and determine the directions required for the study to be effective. Reading journals, research papers and academic articles provided details and expertise. It will begin with general information on speed bumps on roadways, followed by accidents and injuries that associates with scooter users and information about potholes.

2.2 Speed Bump

To reduce accidents brought on by speeding and to control vehicle speeds, traffic engineers employ a range of strategies. One of the most popular methods is the placement of traffic calming elements like speed bumps and humps. These road obstructions, such as speed bumps and humps, are put in place on different roadways to slow down oncoming cars. The use of speed bumps makes it possible to control vehicle speed in parking lots as well as maintain a continuous flow of traffic on private roads (Lav et al., 2018). One form of road safety device designed to actually slow down cars is the speed bump. Speed bumps are a type of traffic control device that looks like a hump in the road and is frequently identified by reflective dots. They can be used on local roads, access roads, and, in rare circumstances, collective roadways in urban areas (Kosakowska, 2022). Speed humps are elevated pavements that completely or partially cross a roadway, requiring traffic to slow down to lessen the grating bumping or vibrating sensations they cause. Many studies used speed bumps and saw speed drops of 18–20%. Additionally, it was found that the distance between the speed bumps significantly affected how quickly the speed dropped (Kiran et al., 2020). Speed bumps are traffic calming devices that are used to slow down vehicles in residential areas, parking lots, and other areas where a reduction in speed is required. They are often built as raised portions of pavement across the roadway, requiring drivers to slow down as they pass over them. Speed bumps are typically circular in shape and climb in height gradually. The dimensions and specifications may differ depending on local laws or regulations. They are typically built of asphalt or concrete, however there are rubber and plastic versions.

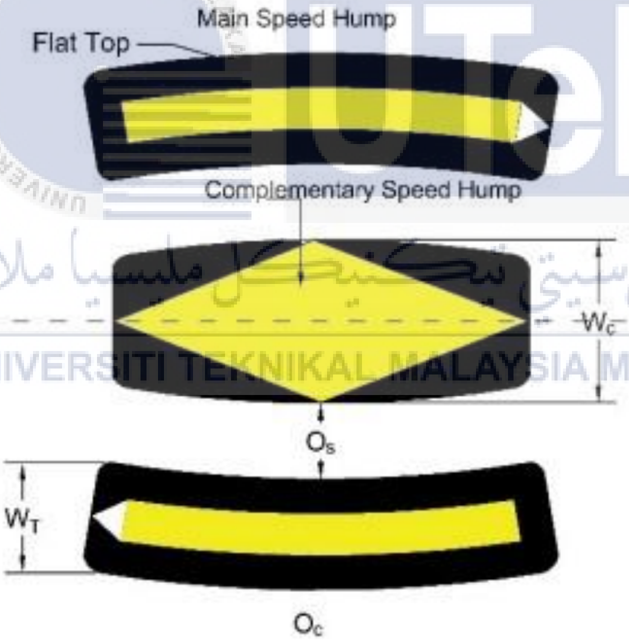


Figure 4 Plan view of a typical Curved Speed Hump on a Two-lane Road (Kiran et al., 2020).

2.2.1 Speed Bump Characteristic

Testing speed bumps with widths ranging from 1 to 10 cm in 1 cm increments while keeping height constant at 1 cm allowed engineers to establish the ideal width. While keeping the width at 5 cm constant, the test heights were adjusted from 0.7 to 3.4 cm in 0.3

cm increments to find the ideal height. Motion detectors and computer software were used simultaneously to measure two crucial mechanical aspects of the performance of speed bumps: peak vertical acceleration, which is believed to be one of the primary factors affecting passenger comfort, and velocity reduction, which is the measurement of the wheel's decrease in velocity (Lav et al., 2018). Speed bumps are typically circular in shape and climb in height gradually. The dimensions and specifications may differ depending on local laws or regulations. They are typically built of asphalt or concrete, however there are rubber and plastic versions. They cannot be placed more than 60 meters from the stop line at signs B-20 (a stop sign) and B-32 (a sign informing drivers that they must stop for customs control), according to the Journal of Laws No. 220 in Poland. Additionally, they cannot be put in a place on a road with a maximum internal radius of 25 meters and a turn angle greater than 70 degrees that is more than 40 meters from the end of a horizontal curve. Additionally, they must be positioned at least 40 meters away from road or street intersections, 20 meters away from the point where a road horizontally curves, and 20 meters away from the point where a road declines when the grade is greater than 10%, 15 meters before and after the tram crossing, 20 meters before and after the railway crossing, and 25 meters away from the closest load-bearing structure, like a viaduct. Additionally, they cannot be placed above or in buildings like culverts or subways, or in constructions like tunnels or bridges (Kosakowska, 2022). Local governments or transportation departments normally regulate the building and placement of speed bumps. They may have particular requirements for the dimensions, spacing, and positions of speed bumps. These guidelines strive to strike a compromise between the necessity for traffic calming and ensuring smooth traffic flow while minimizing any negative consequences. Other traffic calming solutions, in addition to speed bumps, are available, depending on the individual demands of a location. Speed humps (similar to speed bumps but with a greater span), chicanes, raised crosswalks, roundabouts, and radar speed signs are examples of these. Each measure has benefits and drawbacks, and the choice is influenced by factors such as traffic volume, road design, and community preferences.

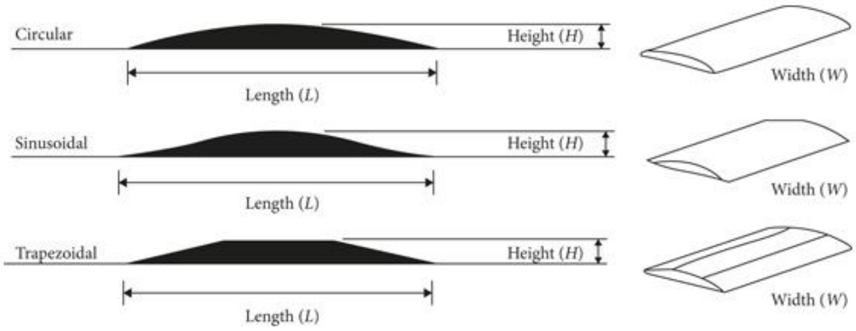


Figure 5 Speed bump design parameters: https://www.hindawi.com/journals/ace/2018/3093594/

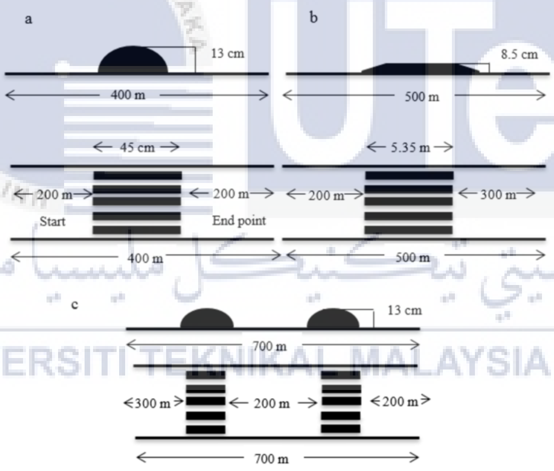


Figure 6 Section view and plan view of (a) 400m stretch with speed bump; (b) 500m stretch with speed hump; (c) 700m stretch with two speed bumps (Kiran et al., 2020).

2.2.2 Advantages of Speed Bump

One of the key benefits of speed bumps is that they slow down automobiles. Speed bumps assist maintain safer speeds in places with heavy pedestrian activity, such as residential zones, school zones, or parking lots, by compelling automobiles to slow down. This can improve overall road safety and lower the likelihood of an accident. Speed bumps reduce vehicle speed, traffic volume, and the number of accidents, but they also cause damage to the road surface and automobiles, particularly if they are badly engineered or are employed to promote safety on an inappropriately planned road (Kosakowska, 2022). Speed bumps and humps are utilized as means of calming traffic and controlling vehicular speed. Needless to say, bumps and humps of large dimensions in length and width force drivers to significantly reduce their driving speeds so as to avoid significant vehicle vertical acceleration. Traffic engineers use a variety of strategies to control vehicle speeds and avoid accidents brought on by speeding. The installation of traffic-calming tools, such as speed bumps and humps, is one of the most common strategies. These road obstructions, including speed bumps and humps, are there to slow down oncoming traffic. The use of speed bumps makes it possible to control vehicle speed in parking lots as well as maintain a steady flow of traffic on private roads (Lav et al., 2018). When a decelerating car strikes a speed bump in the road, a sizable quantity of kinetic energy is lost as vibrations. In order to power electronic equipment located on highways, mechanical energy harvesting devices can convert this waste kinetic energy into electrical power, which can then be stored in batteries (Azam et al., 2021). Despite these benefits, it is important to note that speed bumps have downsides. They can be inconvenient for passengers and drivers, increase noise and pollution owing to repeated accelerating and deceleration, and pose a risk to specific vehicles, such as emergency vehicles or motorcyclists. As a result, it's critical to carefully analyze the placement and design of speed bumps in each case, comparing their benefits against potential drawbacks.

2.2.3 Disadvantages of Speed Bump

There are some disadvantages and considerations to using speed bumps. They can be uncomfortable for passengers and increase vehicle wear and tear, especially if drivers do not slow down sufficiently. Speed bumps may interfere with emergency vehicles such as ambulances and fire trucks, potentially delaying response times. Furthermore, if speed bumps are positioned too close together or are too huge, they can cause driver annoyance or even accidents. One in five drivers in the UK said that speed bumps had damaged their car, and local governments spent more than £35,000 between 2015 and 2017 to make up for the inconvenience. Vehicles most frequently suffer suspension or tire problems as a result of speed bumps, which can lead to expensive repairs. The reports mentioned are only for private vehicles, which are required to follow the law and move more slowly on speed bump-equipped roads. But emergency vehicles might not always follow posted speed restrictions on the roads, and speed bumps pose a serious obstacle to their rescue efforts (Kosakowska, 2022). At speeds over 20 kph, the people in the car experienced excruciating anguish, and the transferred patient may experience even more discomfort after they cross the barrier if they have a spine injury or an issue similar to it. Items that are not fastened or that passengers are holding could be propelled into the air. A situation like that could make it very difficult to provide assistance when conducting rescue operations. Furthermore, hitting the speed bump at such a high rate of speed could harm the car and significantly shorten its lifespan. Only at a speed of 15 km/h was the impact of speed on passengers when crossing the speed bump lessened, but the passengers still felt discomfort, and the impact might be very harmful to the patient's health. Only at a speed of 8 km/h did all of the effects of the collision become so minimal that the occupants of the car hardly or almost did not experience them (Kosakowska, 2022).

2.3 Pothole

Road potholes are depressions or holes in the road's surface that are often made of asphalt or concrete. They are a widespread issue in transportation infrastructure, and they can be caused by a variety of factors such as weather, heavy traffic, faulty construction, and ageing road surfaces. Asphalt pavements are made up of aggregates that withstand traffic loading and asphalt that holds the aggregates together. Asphalt binder breakdown chemically as a result of environmental exposure and traffic loads, resulting in a loss of adhesion between aggregates and binders, which promotes crack propagation and the production of bowl-shaped potholes of varied diameters. Potholes on urban highways and streets are a regular occurrence with the start of the monsoon, and rehabilitation work is expensive (Shiva Kumar et al., 2023). Potholes have long posed a challenging risk to automated systems due to their random and stochastic shapes and the reflectiveness of their surface when filled with water, whether it is “muddy” water or clear water (Dib et al., 2023). With the advantages of smooth wear resistance, noise reduction, skid resistance, and comfortable driving, asphalt mixture is usually used in high-grade pavement. However, some pavement distresses such as cracks, potholes, and rutting appear and bring more challenges to maintenance due to the effect of vehicle load and water-temperature cycle, causing asphalt mixture degradation. In 2022, data from the Ministry of Transport of the People’s Republic of China showed that the total mileage of road was 5,280,700 km, and maintenance mileage occupied 99.4% of the total road mileage. Maintenance assignment gradually increased with the increase of national road construction year by year (Gong et al., 2023). Potholes range in size from little divots to enormous craters that can endanger both automobiles and people. They are especially troublesome for drivers because they can damage tiers, wheels, and suspension systems, resulting in pricey repairs. Furthermore, potholes increase the chance of an accident, particularly if drivers swerve to avoid them or lose control when driving over them.

Figure 7 Different pictures of potholes (Dib et al., 2023).

2.3.1 Pothole Detection

Over time, techniques for locating potholes and imperfections in the road surface have changed. Three methods have been employed historically to monitor the condition of roads: 3D reconstruction, computer vision-based, and vibration-based. The 3D reconstruction approach requires a 3D laser scanner to scan the surface and create an accurate representation of the current state of the road surface, which is then compared to the original state to find abnormalities. These laser scanners are pricey, though, and the methods rely on the local accuracy of the 2D scan. To determine the difference between horizontal and vertical polarization, the polarization method was proposed. Polarization filters, however, may reduce detection accuracy by reducing image quality. These methods rely on the local precision of the 2D scan and these laser scanners are pricey. Computer vision-based techniques need sophisticated image processing algorithms to extract relevant texture. Then, in order to find surface imperfections, this is contrasted with the typical texture. These systems install a camera inside the vehicle that is directed downward to capture a picture of the road surface. Metadata like longitude and latitude are also included in the acquired images. Then, imperfections in the road surface are found using edge detection methods like Canny edge detection. Image-based techniques are less expensive than 3D laser scan technology. On the other hand, an image-based method is sensitive to external factors like light, shadow, rain, and so forth. Additionally, image-based solutions require a lot of computing, and in some cases, the employment of antiquated computer vision algorithms reduces the accuracy of identifying potholes and obstructs real-time data delivery (Pandey et al., 2022). A useful decision-making tool for assessing broader evaluation methodologies for various pavement conditions and predicting the pavement performance life expectancy of metropolitan highways should be developed in order to protect standard pavements. As is generally known, there is a strong correlation between potholes and PMS; the more potholes there are, the more serious the PMS worry. In earlier studies, forecast models for potholes were created in South Korea using meteorological and traffic data. These forecasting models, however, were only accurate for the period in which they were created and tested. The current work used regression analysis, machine learning, and empirical-mechanical estimation of independent variables to rebuild an existing predictive model. The government can manage roads with enough funding and provide safe driving conditions if it can anticipate potholes (Lee et al., 2023).

The suggested system's image processing and deep learning technique are used to identify potholes in the road for virtual images and video clips. Image processing techniques are used to crop photos for the dataset and annotate labels. Three models are used: RCNN with Inception v2 as the backbone model, YOLO v3 model, and SDD with Inception v2 as the backbone model. The cloud system will store the information and display the potholes on the roadmap web application. The IOT system will gather the position of potholes on roads, and the GPS location will be relayed to the cloud system. The system's accuracy rate was at its highest while using the YOLO v3 model. This technique uses image processing and machine learning to find potholes. collecting images from the camera and saving them in a database so the model can be trained. In addition to blurring and edge detection, image preprocessing techniques like denoising, frame extraction, and grey scaling are used. A Raspberry Pi hardware component is utilized to find potholes. The proposed study uses a deep learning CNN model and a simple image processing technique to assess the condition of the road and has developed a graphical user interface to help users and administrators spot potholes. All graphical user interface design techniques, including dropdown, screen display, textbox, and others, will be included in the PyQT module. User data is kept in the MySQL database so that users' access to the program may be verified. Image processing techniques including contour image, smoothen image, and greyscale image conversion are used to prepare images. Potholes may be predicted with excellent accuracy using the CNN model. This system uses image analysis to determine the state of the roads. The system will notify the government website requesting road work if the road is in poor condition. The shape and size of the pothole photographs are used as a dataset in a study that is based on methods to recognize potholes. photographs are taken from a variety of real-world scenarios, such as random-bump potholes, under different conditions. The YOLO v2, F2-ANCHOR, and DEN-F2-ANCHOR models are used to assess the model and make significant parameter adjustments to get the highest accuracy. The anchor box concept is used to find items of various sizes and ratios. Different instances of data were gathered to analyze various types of images, including those taken on bright, dry, cloudy, and wet days, in order to detect the objects at Electronics City Phase, Bangalore. Using labelling, you may annotate photos with bounding boxes to identify the objects they include. In this work, the effectiveness of pothole detecting deep learning models such Resnet18, YOLO v2, and faster RCNN with VGG-16 will be assessed. In terms of accuracy, the YOLO v2 model exceeds all other models with the fewest parameters. Through the Raspberry Pi, the system is connected to a portable camera, allowing us to shoot potholes in real time while driving. Pothole detection and picture dimension estimation are the main topics of this study. A method for estimating the dimensions of potholes in images is constructed using the triangle similarity measure. The YOLO v3 and YOLO v4 models are used to find the potholes. Bounding box prediction and class prediction are the two main applications of the YOLO v3 model. The YOLO v4 model optimizes parallel processing and object detection for the proposed system. Utilizing MAP and IOU, the validation set for the acquired results is contrasted. A low error rate and high degree of precision are used to estimate the dimensions of the found potholes. YOLO v4 can more accurately estimate pothole size because it has a higher IOU. A camera mounted on a car's dashboard and connected to the internet is used to locate potholes on roads using a deep learning-based pothole identification method. The classification process's dataset is used to train and evaluate CNN models such Faster R-CNN, YOLO v3, SSD, and HOG with SVM. Existing data will be transformed into labelled picture files for the training dataset, which the models will use as input. The selected models' hyper parameters are altered to determine the pothole's size in order to deliver accurate results. The YOLO v3 model fared well in comparison to other models. For training and testing, a proposed system-based annotated image dataset is used. The K-mean clustering method is used to determine the number of bounding boxes in an image. Use is made of deep learning architectures such the YOLO v3, YOLO v2, and tiny YOLO v3.to speed up the calculation process and make greater use of CUDA, the defect in the proposed system must be found. The pre-trained CNN model Darknet53 is utilized for YOLO v3, while Darknet19 is used for YOLO v2. The YOLO v3 model exhibits a respectable level of accuracy when these models are contrasted using map, precision, and recall. proposed deep learning-based work in a two-step cross-verification process, they used the android phone's camera, accelerometer, and gyroscope sensors. Tensor Flow object identification, a custom trained API, is used for camera-based picture detection. Both the SSD model from deep learning and the support vector model from machine learning are used. Tensor Flow Lite was used to integrate two trained models into a single Android application.in this program, real-time photographs from the camera are taken, and an object detection model is used to find potholes. After finding potholes, the database's information will be updated, and the found potholes will be shown on a map of their location. In contrast to machine learning methods, the DNN model offers higher accuracy while SSD enables faster real-time pothole spotting (Saisree & U, 2023).

Figure 8 (a) Sample wide area 2D-image frames acquired using smartphone. (b) Selected image tile visualization and detection of potholes and linear distresses on asphalt pavements (Ouma & Hahn, 2017).

In recent years, a number of pothole detection devices have been proposed. Kulkarni et al. (2014) classify existing pothole detection systems into vibration-based methods, 3D reconstruction-based methods, and vision-based methods. Accelerometers, which are often found on mobile devices, are used in the vibration-based method. The authors assessed the efficacy of various threshold-based approaches using data from z-axis mobile sensing. The authors assert a true positive rate of up to 90% for a small dataset. A threshold-based method was also applied. A method for detecting potholes based on machine learning was employed. The characteristics used in this method were extracted using CarSim from crowdsourced, under-sampled data from simulated vehicle sensors. The authors asserted a simulated accuracy of 99.6% and an actual experiment accuracy of 88.9% based on the simulated model. It will be challenging to replicate the authors' choice to combine simulated data from 500 automobiles in real-world settings. There are further GPS error concerns, missing data, shifting sensor setups, and challenges generalizing the simulation platform, as seen by the accuracy lowering to 88.9% on a specific stretch of road. The authors gathered 21,300 accelerometer and gyroscope measurements from 96 potholes from a single car using an iPhone 6Ss. They found that the best accuracy was achieved by SVM using an RBF kernel and gradient boosting, with 92.9% and 92.02%, respectively. However, the actual recall (0.42) and precision (0.78) are far lower. The image/vision-based method uses cameras (for photos or movies) to gather data on potholes. On a small data set, the authors used a variety of image processing algorithms to find potholes. Other researchers have trained a deep neural network using the texture and spatial information of a camera image. 969 pictures were used to test the model. The results were 92.4, 93.8, and 93.0% for recall, precision, and F-score, respectively. However, this method is less suited for real-time detection because it requires a lot of processing resources. For the most bulk of this research, pothole detection has been done using an image-based method. The accuracy of the non-machine learning model can be affected by variations in pothole size, road markings, or even the presence of dirt on the road because they rely on libraries of real potholes. This method requires a lot of processing power due to its computational complexity. It is therefore inappropriate for real-time pothole identification. The threshold-based paradigm makes it easier to find potholes. On the other hand, the heuristic method of determining the thresholds takes a long time and is subject to human error. Furthermore, there is a good chance that the model won't generalize when used with other kinds of vehicles, road surfaces, or pothole sizes. The majority of current pothole detection techniques either rely on specialized, expensive technology, are less accurate in finding potholes, or are not reliable enough to find all sorts of potholes. Additionally, a few of the models use accuracy as a performance indicator. It's common to confuse this with enhanced model performance. Some previous studies highlighted the challenges they had in correctly recognizing potholes by demonstrating higher accuracy with noticeably poorer precision and recall ratings (Egaji et al., 2021).

In the development of Advanced Driver Assistance Systems (ADAS), automation levels 1-3, the identification of the road surface was already an important part of environment detection, and it will become more crucial as automation levels increase. In this aspect, the state of the road is crucial. Investigations are conducted into the type of road covering (concrete, cobblestone, asphalt), the road's surface climate (dry, wet, ice), and important road issues such potholes and cracks (Kortmann et al., 2022). The most popular technique for finding potholes in 2D images is pavement image segmentation. The most popular segmentation techniques include region extraction, edge detection, thresholding, and clustering. Each point in the data collection can often only have two clusters of data and no data using these conventional techniques. Hard segmentation techniques are also sensitive to noise and image distortions because they can only preserve a limited amount of information. Since each pixel of the image belongs to exactly one class, the segmentation results are typically sharp (Ouma & Hahn, 2017).

Figure 9 Placement of the smartphone (Pandey et al., 2022).

Figure 10 A pothole seen from smartphone (Pandey et al., 2022).

2.4 Road Surface Detection System

Advanced driver assistance systems (ADAS) and intelligent transport systems both rely heavily on road detection. Numerous sensing modalities, including LiDAR and vision imaging, have been developed for road detection. Examples of vision-based methods include passive monocular and stereo imaging in the visible spectrum employing high-resolution color, texture, and lane marking information for road recognition. A disparity map, which performs better than monocular cameras but offers less information than 3D LiDAR, is the source of the depth information used in stereo imaging. Low-light situations, such as complete darkness, can readily affect the performance of vision-based approaches. LiDAR, on the other hand, uses an active light source to measure the 3D structure of the area around the vehicle. It is an active way of road detection. LiDAR can continuously observe, but not when it's dusty, foggy, or raining. Thermal infrared cameras are frequently used at night to identify humans and animals on the road. They also aid in the detection of the road zone in low-light settings when combined with color and temporal information (Li et al., 2021). One of the leading causes of traffic accidents in Thailand is driving in the incorrect direction. We suggested a system that can track moving vehicles from CCTV using deep learning and image processing approaches to detect wrong-way driving vehicles efficiently. Our suggested system is made up of two key algorithms: Road Lane Boundary Detection from CCTV (RLB-CCTV) and Majority-Based Correct Direction Detection (MBCDD) (Suttiponpisarn et al., 2022).

Figure 11 Road lane boundaries were manually drawn by a user (Suttiponpisarn et al., 2022).

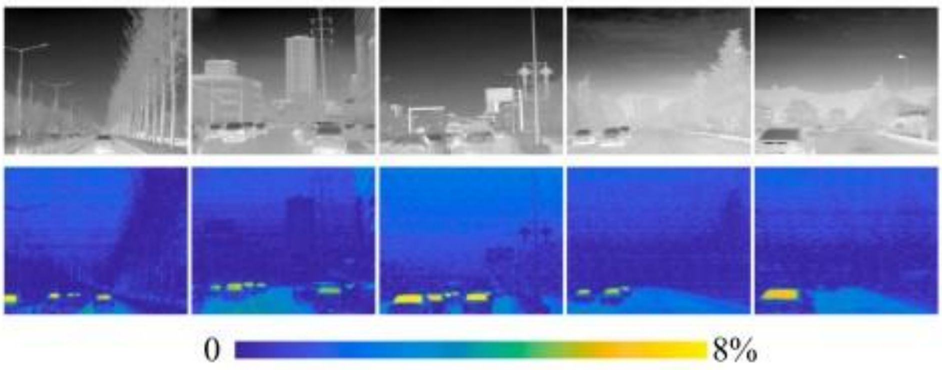


Figure 12 Top: example images (S0) in LDDRS. Bottom: corresponding DoP images (Li et al., 2021).

Target tracking is the term used to describe the difficulty in predicting the states of a moving object. Target tracking is a technique that many Advanced Driver Assistance Systems (ADAS) in vehicle engineering utilize to track moving objects on the road. To find and follow road targets, sensors like radar, cameras, and point-cloud lidar have typically been utilized. inexpensive-density flash lidars are new to the commercial market and have caught the attention of researchers and automakers because to their inexpensive cost. However, the literature hasn't given much attention to how they may be used to track road targets. Because they detect reflections from an area rather than a point, flash lidars differ from their point-cloud counterparts. In this article, "low-density" flash lidars are used to describe sensors whose angular resolution is limited due to the low number of photo detectors used to capture reflected light. Processing data from a low-density flash lidar would not be suitable for standard point-cloud processing methods (Kumar et al., 2022). Recently, a promising method for gathering high resolution micro-level traffic data (HRMTD) to close the data gap in the autonomous vehicle (AV) environment has emerged: the deployment of light detection and ranging sensor (LiDAR) as intelligent roadside units (IRU). A vital component of AVs is dynamic decision-making, control, and collision avoidance. LiDAR sensors can assist the functioning as wayside devices by giving HRMTD of road users who are outside the AVs' optical range. In order to help create a completely linked world, roadside

LiDAR sensors can also supply real-time data on unconnected road users. Real-time HRMTD from roadside LiDAR can also be used for other intelligent traffic applications, such as traffic accident prediction and prevention, traffic emissions evaluation and analysis, and adaptive traffic signal optimization and control (Lin et al., 2023). In this SHREC track, we look at systems that automate crack and pothole recognition by enabling timely monitoring of significant portions of road pavement using Deep Learning (DL) approaches. The objective is to identify and segment potholes and cracks in images and movies using a training set of photos enhanced with RGB-D video clips. To be complete, it is crucial to note that several sorts of data can be used when carrying out tasks relating to the road. To survey what is on and below the road surface, Ground Penetrating Radar (GPR) data, for instance, uses electromagnetic waves. However, operating this data source is highly expensive and requires expert personnel (Moscoso Thompson et al., 2022). Road obstacle detection is used by autonomous driving systems for obstacle detecting, tracking, distance, and speed measurement. Despite the availability of detection technologies with excellent detection accuracy and durability, such as millimeter wave radar and LiDAR, their application in low-cost vehicles is constrained by their high cost. Comprehensive detection information, low cost, excellent scalability, minimal hardware needs, and strong programmability are all advantages of vision-based obstacle detection. Vision-based obstacle detection systems are classed as morphology-based, machine based on learning or motion compensation. Morphology-based techniques are rarely used in autonomous driving systems due to their poor detection accuracy (Wang et al., 2023).

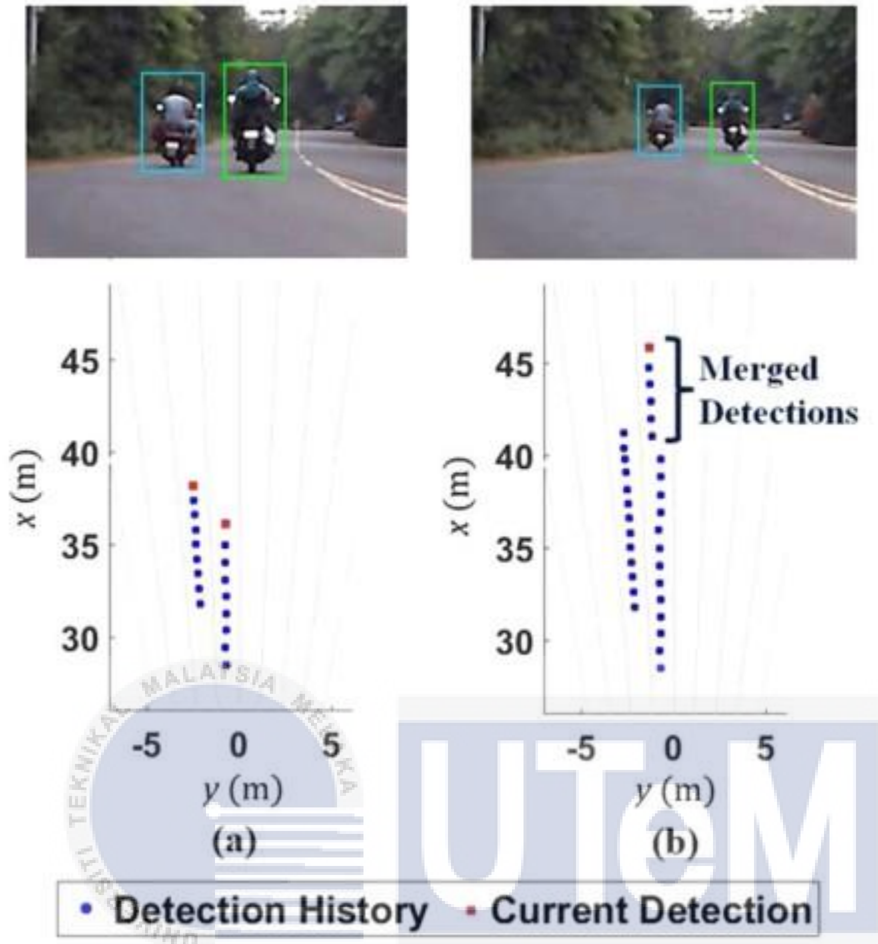


Figure 13 Depiction of measurement merging when one motorcycle overtakes the other. a) Two targets are well separated. b) The targets are closely spaced and hence their detections are clustered into a single detection. The detections shown here are the clustered detections (Kumar et al., 2022).

2.4.1 Detection Method

Real-time illumination-invariant road detection utilizing polarization information necessitates the use of a high-speed integrated infrared polarization imaging system. A great substitute for such a device is infrared polarization imaging technology with division of focal plane (DoFP). A micro polarizer array (MPA) and a conventional infrared focus plane are combined in a DoFP infrared polarization camera to acquire polarization data in real time. DoFP cameras are appropriate for placement in autos since they are similar to conventional thermal cameras in terms of weight, size, and power consumption. To get real-time polarization data from the road, we employ an infrared DoFP polarimeter as a sensing modality. A straightforward yet efficient full-time road detection and tracking system is developed using long-wave infrared (LWIR) polarization information. The proposed road recognition and tracking method distinguishes drivable road segments from the background in real time. When compared to the backdrop, the road exhibits distinct polarization characteristics in LWIR, making polarization information more effective and suitable for road detection than heat information. a straightforward yet effective long-wave infrared (LWIR) polarization-based full-time road detection and tracking system. The proposed road recognition and tracking method distinguishes drivable road segments from the background in real time. When compared to the backdrop, the road exhibits distinct polarization characteristics in LWIR, making polarization information more effective and suitable for road detection than heat information. The suggested road detection and tracking method is based on the road's LWIR polarization characteristics, or PCRL for short. The PCRL consists of the difference in Degree of Polarization (DoP) between the road and a vehicle, as well as the zero-distribution of the Angle of Polarization (AoP) of the road region. We must first identify the road portion in the first frame in order to follow it in subsequent video frames. The road and the background have a significant AoP difference because of the zero-distribution of AoP. In order to make a rough road mask, we use the AoP zero-distribution. Then, using assumptions about roads vanishing, we provide a prediction technique to find the horizon. The ground's road zone is constrained by the horizon, greatly reducing the computing cost. The road region is extracted from the picture using the edge information, the difference of DoP, and the zero-distribution of AoP. A road confidence map is then used to modify the detection result by removing fragmented parts with low confidence (Li et al., 2021).

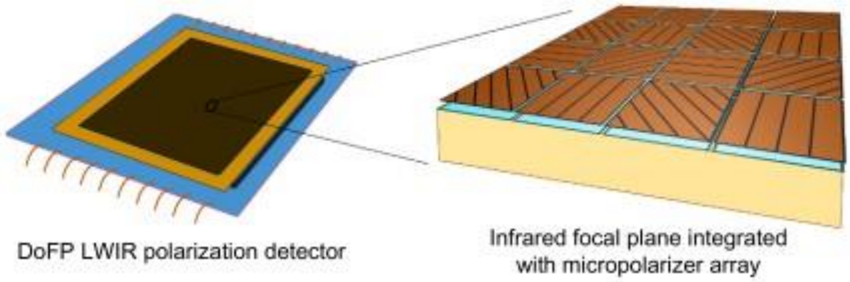


Figure 14 A DoFP infrared polarization imaging detector with a MPA (Li et al., 2021).

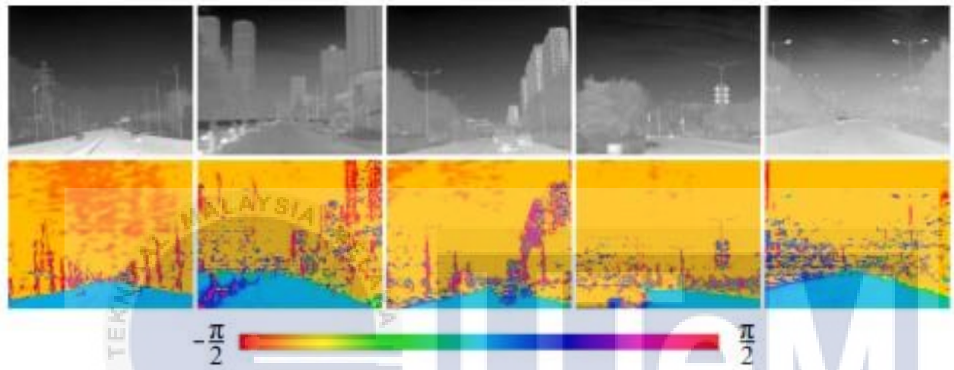


Figure 15 Top: example images (S0) in LDDRS. Bottom: corresponding AoP images (Li et al., 2021).

Along with the quick advancement of computer vision and machine learning, the demands for accuracy and speed in monocular obstacle detection are rising. The ability of vision-based obstacle detection to classify objects is enhanced by machine learning, making this method the standard for automatic driving environment perception. However, the machine learning-based monocular vision obstacle recognition system is only able to recognize a limited set of obstacles. There are usually unidentified obstacles in the way of vehicles in an emergency that could be detrimental. Therefore, it is essential for enhancing road traffic safety to incorporate a generalized obstacle detection approach capable of identifying any three-dimensional barrier into a monocular vision obstacle detection system. Motion compensation techniques, such as the optical flow method, can be used to find obstructions above the road's surface. Prior to using epipolar geometry to separate foreground and background, feature points were extracted using the Harris detector. To find the target, these techniques rely on pixel changes. As the detection result is more accurate, more feature points will be produced. Stable zones cover a larger portion of the pixels. Region detection may identify fewer and more consistent numbers when compared to the feature point detection technique, making it simpler to monitor a target. The Maximally Stable Extremal Regions (MSER) approach for identifying and matching extreme regions in consecutive frames was improved by prior research. Additionally, it was proposed that the VIDAR (Vision-IMU-based Detection and Range approach) might effectively detect obstructions higher above the road surface (thus, barriers of unknown nature) by using MSER and pinhole imaging (Wang et al., 2023).

Figure 16 Detection result of emergencies with unknown types of obstacles using the YOLO v3 (Wang et al., 2023).

2.5 Scooter

A children's scooter is a small wheeled gadget that is specifically designed for children to ride on. It provides children with an exciting and engaging form of transportation and pleasure, encouraging them to be active and enjoy outdoor activities. These scooters are specifically designed to meet the requirements and skills of young riders. Dock less electric scooters (e-scooters) are a popular shared mobility service that can replace automobile trips and boost transportation accessibility in metropolitan areas. The necessity for last mile transportation is obvious, as 60% of automobile trips in the United States are fewer than 6 miles long (White et al., 2023). Active and non-motorized forms of transportation offer a variety of advantages to users and society. This includes addressing environmental concerns posed by motorized vehicles that run on fossil fuels, lowering the risk of obesity, and combating constipation. As a result, government support for active mobility has increased in recent decades. Powered micro-mobility, which includes electric bikes (e-bikes) and electric scooters (e-scooters), is a revolutionary kind of transportation. This mode's electrically assisted riding experience enhances users' journey satisfaction. As a result, the global market for powered micro-mobility has grown fast (Kazemzadeh et al., 2023). Electronic scooters (e-scooters) and electric bikes (e-bikes) have seen a remarkable increase in popularity as handy and affordable ways of transportation in large urban areas during the last decade (Fisher et al., 2023). Different regions and cities have different restrictions regulating the use of e-scooters. Some places allow e-scooters on bike lanes or roads, while others limit their use to specified locations or impose speed limits. Before riding an e-scooter, you should become acquainted with the local regulations.

Figure 17 Scooter image with lable: https://www.inercia.com/blog/en/buying-guide-for-scooters-for-adults-and-children/

2.5.1 Scooter Sharing

Using information and communication technology (ICT) and, in most cases, a booking app, many cities have established various types of shared mobility services for bikes, automobiles, standing scooters, and moped-type scooters. The development of vehicle electrification also enables shared mobility services to use electric vehicles to achieve extra environmental advantages of sustainability. In addition to standing electric scooter sharing, moped-style e-scooter sharing is growing and completing a gap in urban mobility by not only meeting first- and last-mile mobility needs but also offering a faster way to commute over longer distances in cities. Particularly in many Asian motorcycle-dominant nations like Taiwan, it is questionable if moped-style electric scooter sharing (referred to as e-scooter sharing for convenience hereafter) will persuade private motorcycle riders to use the shared e-scooter service and function as a sustainable transportation option. For e-scooter sharing to be successful and last, potential customers' adoption (or acceptance) during the early stages of the service launch and consumers' ongoing use during the later stages are essential. Previous research has examined consumers' adoption intentions for e-scooter sharing services and its drivers using behavioral theories like the theory of planned behaviors, the technology acceptance model, and the unified theory of acceptance and use of technology. When analyzing the introduction of e-scooter sharing schemes, a number of factors have been shown to affect people's desire to adopt, including attitudes, subjective norms, perceived ease of use, perceived usefulness, facilitating conditions, hedonic reasons, and price value. However, meta-analysis research shows that only 28% of the variance in actual behaviors can be attributed to behavioral goals. In other words, there is frequently a discrepancy between what is known as the intention-behavior gap and actual behaviors in practice. Additionally, it is important to distinguish between factors impacting the readiness to adopt and those driving the continued use of the e-scooter sharing system. Prior to actual use, people's opinions and attitudes about the relevant system are more crucial to the latter variables. Gaining knowledge from the use experience and post-use behaviors of current customers is essential to achieving successful customer-oriented service design and provision. However, there aren't many studies in the field of e-scooter sharing services that specifically examine actual users' service evaluation (such as service quality), use experience (such as perceived value and satisfaction), and post-use behaviors (such as customer loyalty and cocreation behaviors), which go beyond adoption intention (Chen & Lee, 2023).

The shared version of micro mobility refers to the pay-as-you-go use of such cars, which are often classified as a collection of small vehicles weighing less than 350 kilograms and having a top speed of 45 kilometers per hour. This category includes bicycles, e-bikes, skates, self-balancing unicycles, segways, and scooters. One of the most recent additions to the shared-micro mobility modality is shared standing (kick) e-scooters, also known as scooters. In July 2017 in Santa Monica, California, Lime (www.li.me) launched the first shared scooter system in the world, ushering in a revolutionary era of shared micro mobility (Abouelela et al., 2023). Around the world, shared e-scooters are a well-liked mobility option. They are often promoted as a green mode of transportation that can reduce first/last mile problems, traffic, and other transportation-related externalities. According to NACTO (2019), there were 86 million shared e-scooter trips in the US in 2019, but this number dropped to 35 million in 2020 as a result of the pandemic. 62 million journeys were made in the United States in 2021 as a result of the majority of COVID-related mobility limitations being lifted (NACTO, 2021). In spite of this, there were regional and operator-specific variations in this conduct. According to Lime (2019), there were 16 million shared e-scooter trips in Paris between 2020 and 2022, up from 1.2 million trips in 2018 and 2019. This indicates a rebound impact following the pandemic (Félix et al., 2023). Recent years have seen an increase in the use of shared micro mobility solutions including docked bike sharing, dock less e-scooters, and dock less e-bikes. Just two years after shared e-scooters made their North American debut, the number of e-scooter trips (86 million) in 2019 was more than double that of station-based bike sharing trips (40 million), demonstrating the expansion of shared e-scooter travels. Ridership of e-scooters fell sharply when the COVID-19 outbreak started in March 2020 but quickly increased again. According to the 2021 Shared Micro mobility State of the Industry Report, the number of shared micro mobility systems and vehicles in North America has reached 2019 levels. It is crucial to consider whether and how shared micro mobility systems may help achieve long-term transport objectives like accessibility, equity, and environmental sustainability as their popularity soars in the post-COVID era (Yan et al., 2023).

As a component of the transportation system, shared micro mobility services, in particular shared e-scooters, were similarly impacted. Since their launch, shared electric scooter usage has expanded quickly across the US, with an average adoption rate of 3.6% and roughly 38.5 million trips made in 2018. However, the Pandemic had a considerable effect on them, with 12% of the systems fearing irreversible shutdown and 50% of the systems stopping operations. Only 37% of shared e-scooters were still in use in the United States as of December 2020, and the Pandemic's effects on them varied depending on the size of the city and the COVID-19 spread pattern. The practice of sharing transport, also referred to as "shared mobility," has rapidly expanded in recent years. Shared mobility "enables users to obtain temporary access to transport modes as needed." The growth of shared mobility is mostly due to two factors. First, thanks to developments in information and communication technology (ICT), options for shared mobility are now available through mobile devices and apps. Second, alternative, supplementary mobility choices in cities are being sought after by the transport sector, notably start-ups, in order to achieve more accessible and ecologically responsible mobility. Cities have seen the introduction of new modes of transportation due to the growth of shared mobility, including ridesharing (like Uber or Lyft) and the sharing of electric scooters (sometimes known as "e-scooters"). Earlier forms of shared transport have also been strengthened, particularly car- and bike-sharing. In most cases, people hire bicycles, e-scooters, cars, and transportation from private businesses or cooperatives rather than sharing them. Shared mobility can function as a peer-to-peer (P2P) relationship or as a business-to-consumer (B2C) relationship (Mouratidis, 2022).

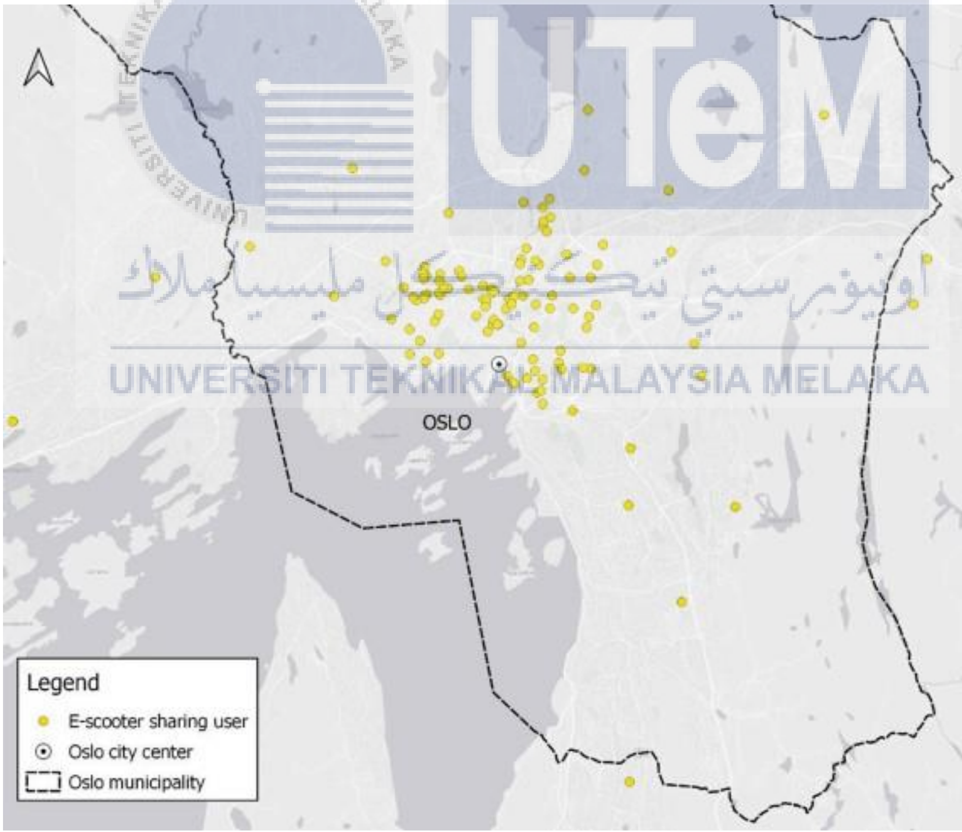


Figure 18 Map of Oslo showing residential locations of e-scooter sharing users (Mouratidis, 2022).

A new micro mobility alternative for urban travel has been offered by the sharing of e-scooters, although its importance for urban transportation systems is yet unclear. Particularly shared micro mobility modes that are used for short-distance commuting include sharing of e-scooters and bikes. They will therefore probably compete for riders. In order to create strategies to connect the two systems and better serve the public and use public resources, it is crucial for government organizations to investigate how the introduction of ESS affects bike sharing ridership. Examples include moving bike sharing stations, changing the capacities of various stations, setting prices, and deciding the operating zones for e-scooter sharing. This topic has not been extensively studied in the past. This study aims to measure the impact of shared electric scooters on bike share ridership. Data from Chicago is used and evaluated because the city gives public access to the travel data for both its e-scooter and bike sharing programs. On June 15, 2019, the Chicago e-scooter sharing trial program debuted. Over the course of almost four months, 2500 electric scooters were used, accounting for more than 800,000 rides. The Chicago bike sharing program launched on June 27, 2013, with 75 stations and 750 bicycles. By December 2019, the number of stations had increased to 612 and the number of bicycles had topped 6000. The rate of utilization had increased every year. We plan to carry out a quantitative investigation of how the use of bike sharing is impacted by the sharing of e-scooters (Yang et al., 2021). Recent years have seen a lot of interest in micro mobility, which includes everything from dock less bike sharing and e-scooter sharing to station-based bike sharing. Shared e-scooters (in this study, "e-scooter" refers to "kicked e-scooter" unless otherwise specified). For short-distance travel, these types of transportation give passengers a practical choice. Similar to dock less bike sharing, shared e-scooters can be picked up and dropped off at any location within the service area. Due to its simplicity, enjoyable riding experience, and flexibility, e-scooter sharing has re-energized the micro mobility trend started by Lime and Bird in the United States.

Compared to other shared mobility modes (such as bike-sharing and car-sharing), shared e-scooters have taken off quickly since their introduction in Santa Monica, California, in late 2017. By the end of 2018, the number of e-scooter-sharing trips had surpassed the number of station-based bike-sharing trips, making it the most common shared micro mobility mode in the United States. With a top speed of 15 mph, shared e-scooters are competitive with more established modes of transportation and can replace walking and bicycling for all types of trips. According to survey findings from numerous cities, shared e-scooters have a great deal of potential to replace auto travel (driving in a private vehicle, TNC/taxi) (Guo & Zhang, 2021).

2.5.2 Injury Cases Involving Scooter

Scooter injuries can happen when people are engaged in accidents or wrecks while riding their scooters. The severity of injuries varies based on the circumstances of the accident, the speed of the scooter, and whether or not the rider was wearing protective gear. With the rising proliferation of e-scooter services has come a surge in hospital visits for e-scooter injuries, highlighting an urgent need to address safety concerns and investigate associated risk factors. To present, the majority of e-scooter safety studies have relied on hospital records, and while these studies do collect certain statistics concerning e-scooter collisions, they do not reliably identify or quantify the risks associated with e-scooter riding. A one-year study at UCLA Santa Monica's emergency room found 249 visits for e-scooter injuries, compared to 195 for bicycles and 181 for walkers. Furthermore, in Auckland, New Zealand, the rate of e-scooter-related injury was assessed to be 60 per 100,000 journeys, while the rate of hospital presentation was 20 per 100,000 travels (White et al., 2023). Riding e-scooters has long been seen as a pleasurable pastime. The e-scooters' compact size and rapid speed boost their agility and allow them to navigate varied infrastructures such as sidewalks and bike lanes. Regardless of their benefits, the use of e-scooters on public roads raises severe safety concerns. Because their speed regimes are so different, there is a substantial potential of conflict between e-scooters and walkers on sidewalks. According to current figures, the number of e-scooter accidents is steadily increasing. For example, after the introduction of e-scooters in Swedish cities in 2018, the incidence of e-scooter accidents has skyrocketed. Globally, emergency department admissions reflect a similar pattern of increasing accidents. Several studies in the United States have used existing hospital records to document the rising trend of e-scooter accidents (Kazemzadeh et al., 2023). Multiple studies have found a substantial number of e-scooter-related injuries quickly following the introduction of e-scooters in various cities and nations. However, e-scooters are only now becoming more common in New York City. Ride-hailing e-scooters first emerged in New York City in the spring of 2020, but were shortly halted following multiple e-scooter-related fatalities, and then re-introduced with allegedly stricter and safer service. However, e-scooter and e-bike injuries have remained a problem, particularly in many metropolitan cities (Fisher et al., 2023). According to a study of the current literature on electric scooter injuries, there are currently just a few studies from emergency departments that analyze the overall damage patterns associated to electric scooter accidents (musculoskeletal, neurologic, etc.). There are a few worldwide studies, largely from New Zealand, that have assessed the injury patterns and healthcare costs for electric scooter-related injuries (Rizzo et al., 2022). Despite recommendations, municipal infrastructure such as separate bike lanes and policy enforcement were not properly and quickly implemented, resulting in thousands of e-scooters sharing streets and walkways with car drivers, cyclists, and pedestrians, resulting in a high number of accidents requiring emergency department (ED) visits. Because of the combination of serious traumatic cranial, abdominal, and musculoskeletal injuries, these accidents frequently necessitate multidisciplinary medical care, putting a strain on the healthcare system (Shichman et al., 2023).

Figure 19 Ankle fracture patterns. (A&B) Radiographs of an isolated vertical medial malleolar fracture and (CeF) radiographs and CT scan of an isolated posterior malleolar fracture sustained due to e-scooter injuries (Fisher et al., 2023).

2.6 Summary

This chapter represents all the study that has been made on various topics related to some important things for Speed Bumps and Pothole Sensor for Children's Scooter. Some of the topics that has been covered are information on speed bumps, pothole detection and injuries sustain from riding scooters. It is important to gain knowledge and understanding on all the important topics as to establish a good vision and planning on how the study will be conducted until it is successfully completed.

From the literature review, speed bumps play a major role as a safety device in slowing down vehicles. The shape, parameters, color and positioning of the speed bumps determines the effectiveness of the speed bumps in slowing down a vehicle. As it plays as a safety device, speed bumps also cause disadvantages such as accidents and injuries to road users if the speed bump is in bad condition. For example, the yellow stripes on the speed bumps have faded.

Besides that, potholes are one of many road hazards that causes the most accidents when water fills it up and make it less visible to road users. Many potholes detection program have been conducted to help government to quickly resolve the problem by patching it up using asphalt mixtures.

Other than that, road surface detection has been advancing through the years because of the urgency to have a detection system where it can detect foreign objects that have presented themselves on a road. Some detection system uses infrared and some uses camera from road CCTV while other uses light detection.

Finally, scooters have been increasingly popular in many countries because of the mobility and sizing factor. In addition, the development of electric scooter or e-scooter have been rapidly improving further increasing its popularity because of the lack of using human effort while riding it. According to the rise in popularity of e-scooter, the number of accidents involving the also have been increasing due to the lack of road regulations directed to e-scooter users.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will go over the flow of the study from start to finish in great detail. One of the sections in this chapter will be about how the study will be carried out over the course of time. Aside from that, the purpose of this chapter is to provide specifics and proof on how this study would be carried out. The flowchart is intended to depict the sequence of operations required to complete the work. In most cases, the flowchart is created in the early stages. Meanwhile, the Gantt Chart displays how the project is scheduled, allowing you to determine whether the study is behind or ahead of time. The Gantt Chart's job is to direct the project plan's direction.

Furthermore, this chapter will go into how the Arduino source code will be verified to see if it is compatible with the other components, which include an ultrasonic sensor and a buzzer module. Aside from that, how the system will be installed on the children's scooter and how the total project will be tested will be covered in this chapter.

3.2 Gantt Chart

A Gantt chart is a graphical representation of a project schedule that aids in work planning, coordination, and tracking. It displays project operations, their durations, and their dependencies on a timeline. Gantt charts are made up of horizontal bars, each of which represents a task or activity in the project. The length of the bar corresponds to the task's duration, and its position on the timeline indicates when the task begins and concludes. Furthermore, interdependence between tasks is represented by arrows connecting the bars, showing the order in which activities must be done. The Gantt chart will be shown in Appendix A and Appendix B.

3.3 Flowchart

A flowchart is a graphical depiction of a process or system that depicts the order of steps, decision points, and actions. It depicts the flow of information or activities from one stage to the next using standardized symbols and arrows. Flowcharts are widely utilized in a variety of industries, including software development, business process analysis, project management, and issue solving. Flowcharts show processes visually, making them easier to understand and analyze. They aid in the identification of bottlenecks, inefficiencies, and decision points in a system. Flowcharts can be used to describe existing processes, communicate process improvements, identify possible areas for improvement, and aid in problem-solving and troubleshooting.

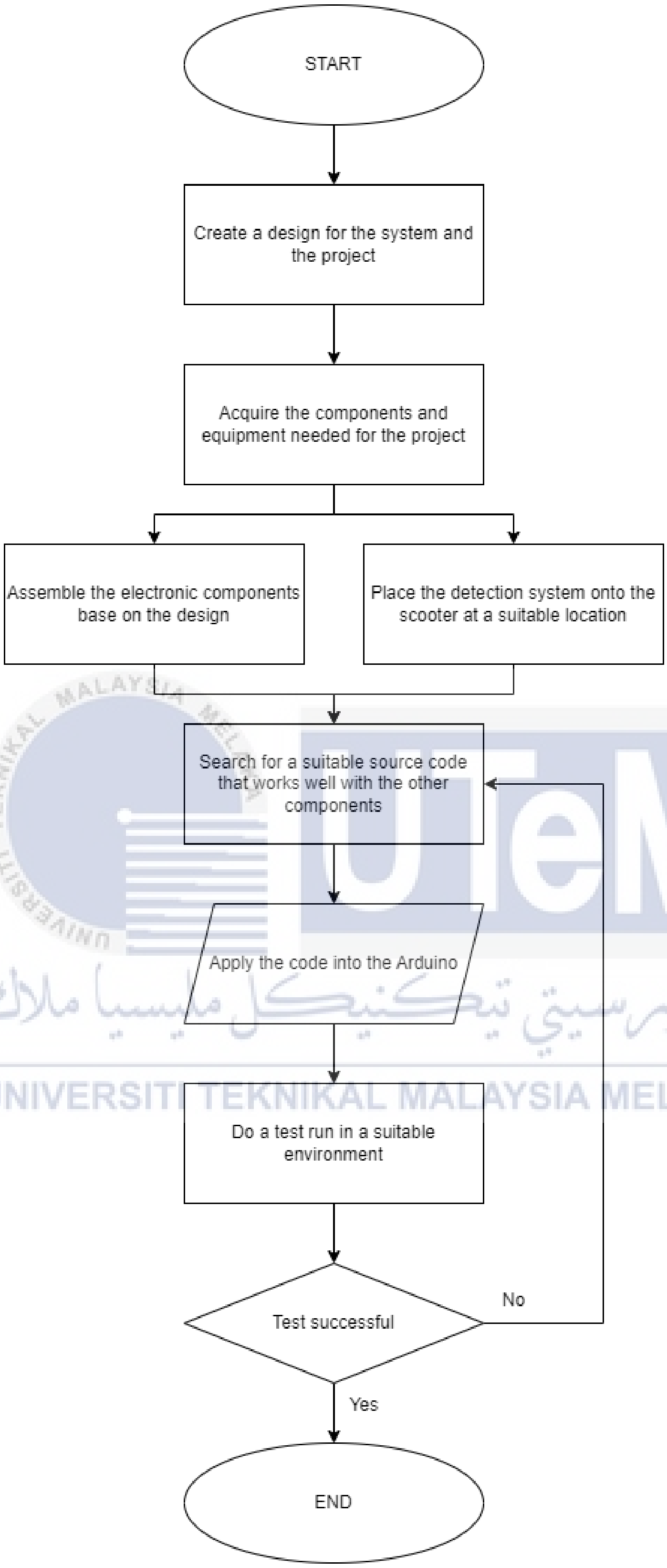


Figure 20 Flowchart: Project work process

3.4 Process Explanation

This is the part where it contains the detailed explanation about every part in the flow of the study that is being carried out. In every sub-topic, the completion of the study will be explained in a chronological order.

3.4.1 System and Project Design

Creating or designing a design is an important part of any project since it lays the groundwork for its successful implementation. When it comes to improving the safety factor on a children's scooter by incorporating a detecting system and an alerting system, the design process becomes even more crucial. The overall goal of putting a detecting and alerting mechanism into the children's scooter is to ensure the rider's safety. It is easy to construct the needed functions by utilizing electronic components such as an Arduino microcontroller, an ultrasonic sensor and a buzzer module. It is critical to consider variables such as the placement of the ultrasonic sensor on the scooter, the power source for the electrical components, the wire connections, and the integration of the Arduino board into the scooter's construction during the design process. The design step includes layout planning, circuit diagram creation, component selection, and programming the Arduino to perform the specified functions. It is critical to ensure that the design is properly thought out, taking considerations such as power consumption, component compatibility, and human interaction into mind. Once the design is complete, it may be put into action by building the necessary components, connecting them according to the circuit design, and uploading the proper code to the Arduino.

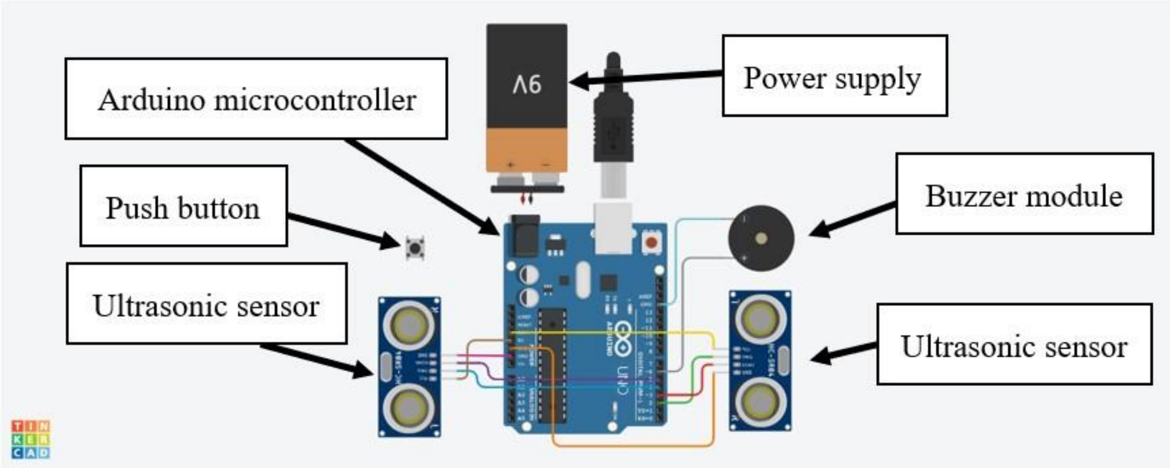


Figure 21 Design of The System

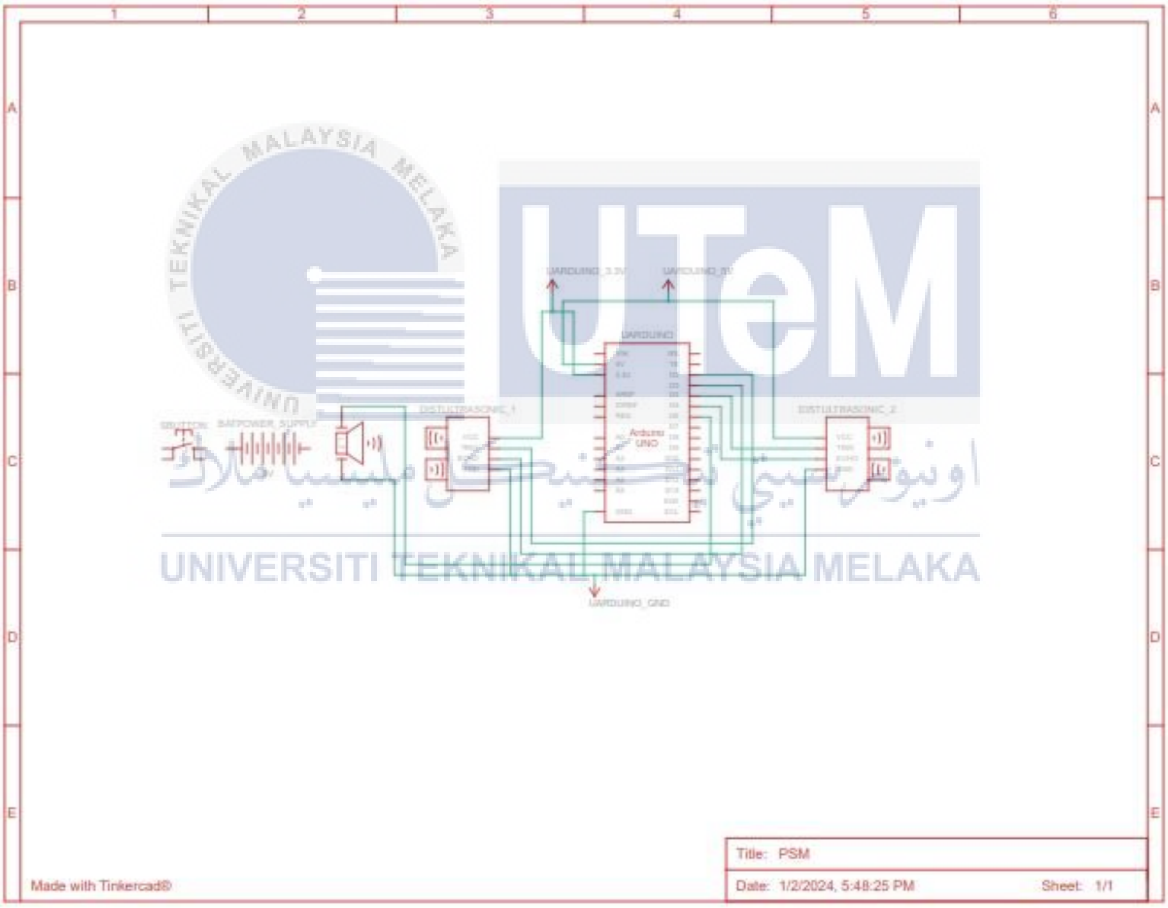


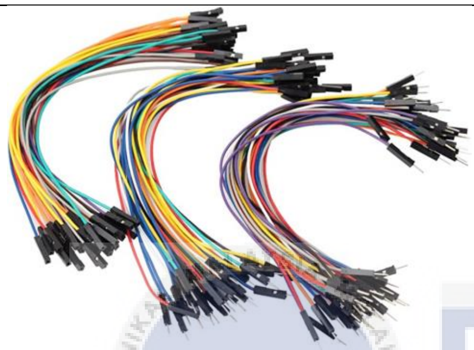
Figure 22 System Schematic Diagram

3.4.2 Acquiring the Components

After the system's design has been finalized, the next stage is to obtain the essential electronic components. Prior to this critical stage, however, a thorough scouting effort is required to find the establishments that offer these components and determine their respective prices. This scouting process serves two purposes: first, it allows for a thorough evaluation of the available options, ensuring that the components can be sourced reliably and efficiently; and second, it allows for a cost analysis to ensure that the total expenses incurred in purchasing the components do not exceed the predetermined maximum budget of RM200. The following table shows the list of components:

Table 1 List of Components

Component	**Purpose**
 Figure 3.4 Arduino UNO	The Arduino UNO function is to send out commands to other components to do their individual tasks.
 Figure 3.5 Ultrasonic sensor	The ultrasonic sensor function is to detect the speed bumps and pothole via soundwaves.

 Figure 3.6 Buzzer	The buzzer fuction is to aleart the scooter rider or the person supervising the scooter rider by producing a loud sound.
 Figure 3.8 Wire connectors	The wire connectors function is to serve as connections between other components.

3.4.3 Assembly of Components

Following the acquisition of the components, the following stage is to assemble them in accordance with the final design. This procedure is simple and begins with acquiring all of the necessary tools and materials. Each component is carefully linked using jumper wires or connectors, ensuring perfect alignment and orientation, using the final design plan as a guide. Double-checking connections and evaluating their functionality on a regular basis requires meticulous attention to detail. A final inspection is performed after all of the components have been securely connected and tested to ensure the overall integrity of the design. We may effectively put the components together by following these procedures with precision and care, resulting in a functional and reliable finished product ready to fulfil its intended purpose.

3.4.4 Placement of The System on The Scooter

The placement of the detection system on the scooter is carefully chosen at this key step of the process, taking into account a variety of criteria to ensure optimal operation. The system's location is critical since it directly effects the system's ability to fulfil its intended purpose efficiently. Finding the perfect position where the sensor is practically parallel to the road surface is critical. This alignment is critical because the sensor's principal function is to scan the road's surface, carefully inspecting the surface condition of the road and detecting the presence of potential obstructions such as speed bumps and potholes. By positioning the detection system in this manner, the sensor has the best possible line of sight, allowing it to precisely collect and analyze the road conditions ahead. Such exact positioning means that the detecting system can perform its function of delivering real-time input to the rider, informing them of any possible risks ahead, and contributing to a safer and more comfortable riding experience. As a result, the detecting system's alignment plays a crucial role in optimizing its performance and supplying valuable information to improve scooter safety through careful consideration and meticulous placement.

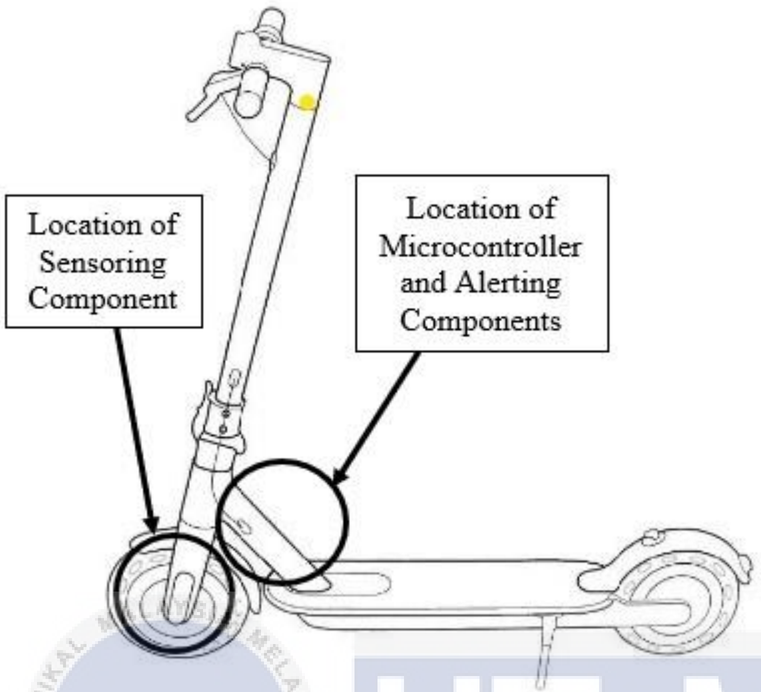


Figure 23 Location Placement of Detection and Alerting System Onto The Scooter

3.4.5 Search for Arduino Coding

Following the successful completion of the previous process, the workflow continues with a rigorous search for acceptable source code that can be effortlessly integrated into the Arduino software. This critical code is the driving force behind the Arduino's ability to efficiently communicate and relay commands to the interconnected components, orchestrating their synchronized functionality. The Arduino is equipped with the necessary instructions to successfully direct and control the actions of the linked devices by carefully selecting and implementing the right source code. This critical stage of the project necessitates extensive study and evaluation of available resources to ensure compatibility with the Arduino platform and alignment with the intended functionalities. With the proper source code, the Arduino software transforms into a versatile medium for sending commands, activating and directing the interdependent functions of the interconnected components, and eventually attaining the required results.

sketch_dec16a.ino

```
// Define the pin numbers for the ultrasonic sensors and buzzer
const int leftSensorTrigger = 2;   // Trigger pin of the left ultrasonic sensor
const int leftSensorEcho = 3;      // Echo pin of the left ultrasonic sensor
const int rightSensorTrigger = 4;  // Trigger pin of the right ultrasonic sensor
const int rightSensorEcho = 5;     // Echo pin of the right ultrasonic sensor
const int buzzerPin = 6;           // Buzzer pin

// Set the threshold distance for detecting obstacles (speed bumps or potholes)
const float obstacleThreshold = 100.0;  // Adjust this value based on your specific setup

void setup() {
  // Initialize serial communication for debugging (optional)
  Serial.begin(9600);

  // Configure the ultrasonic sensor pins
  pinMode(leftSensorTrigger, OUTPUT);
  pinMode(leftSensorEcho, INPUT);
  pinMode(rightSensorTrigger, OUTPUT);
  pinMode(rightSensorEcho, INPUT);

  // Configure the buzzer pin
  pinMode(buzzerPin, OUTPUT);
}

void loop() {
  // Measure distances from the left and right ultrasonic sensors
  float leftDistance = getDistance(leftSensorTrigger, leftSensorEcho);
  float rightDistance = getDistance(rightSensorTrigger, rightSensorEcho);

  // Check if an obstacle (speed bump or pothole) is detected
  if (leftDistance < obstacleThreshold || rightDistance < obstacleThreshold) {
    // Determine which side the obstacle is on
    if (leftDistance < rightDistance) {
      // If the obstacle is on the left, play a different sound for a speed bump
      playSpeedBumpSound();
    } else {
      // If the obstacle is on the right, play a different sound for a pothole
      playPotholeSound();
    }
  }

  // Print distances for debugging (optional)
  Serial.print("Left Distance: ");
  Serial.print(leftDistance);
  Serial.print(" cm\t");

  Serial.print("Right Distance: ");
  Serial.print(rightDistance);
  Serial.println(" cm");

  // Add a delay to control the sampling rate
  delay(100);
}

// Function to measure distance using an ultrasonic sensor
float getDistance(int triggerPin, int echoPin) {
  // Trigger the ultrasonic sensor to send a pulse
  digitalWrite(triggerPin, LOW);
  delayMicroseconds(2);
  digitalWrite(triggerPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(triggerPin, LOW);

  // Measure the duration of the pulse from the echo pin
  unsigned long duration = pulseIn(echoPin, HIGH);

  // Calculate the distance based on the speed of sound (340 m/s)
  float distance = (duration * 0.034) / 2;

  return distance;
}

// Function to play a sound for a speed bump
void playSpeedBumpSound() {
  digitalWrite(buzzerPin, HIGH);  // Adjust the frequency for speed bumps
  delay(500);                // Adjust the duration of the sound
  noTone(buzzerPin);         // Stop the buzzer
}

// Function to play a sound for a pothole
void playPotholeSound() {
  tone(buzzerPin, 3000);  // Adjust the frequency for potholes
  delay(500);             // Adjust the duration of the sound
  noTone(buzzerPin);      // Stop the buzzer
}
```


Figure 24 Arduino Coding

3.4.6 Applying Coding into Arduino

The appropriate coding discovered in the previous stage must be inserted into the Arduino software during this stage of the procedure. On the computer, the Arduino software, which serves as a development environment, is started. To offer a platform for the code, a new sketch is produced. The code is copied and pasted into the sketch window after ensuring that the Arduino board is properly connected via USB. The code is then verified for syntax mistakes or difficulties, and if successful, it is uploaded to the Arduino board. The software talks with the board to transfer the built code, which is then stored in the board's memory. Various electronic components can be attached to the board to observe the code's output. This stage completes the integration process, allowing for further testing and tweaks to ensure the project works as intended.

3.4.7 On-Road Testing

During the on-road testing phase, the finished product will be subjected to extensive evaluations to determine its overall functionality and performance. This critical stage involves testing in real-world settings, specifically in a site with both a speed bump and a pothole on the road. The presence of these obstacles enables a detailed analysis of the product's ability to detect various road conditions. This will determine whether the product will perform as anticipated or if any issues need to be solved by putting it to these scenarios. The testing findings will provide significant information for further refining and improving the product's design and functioning.

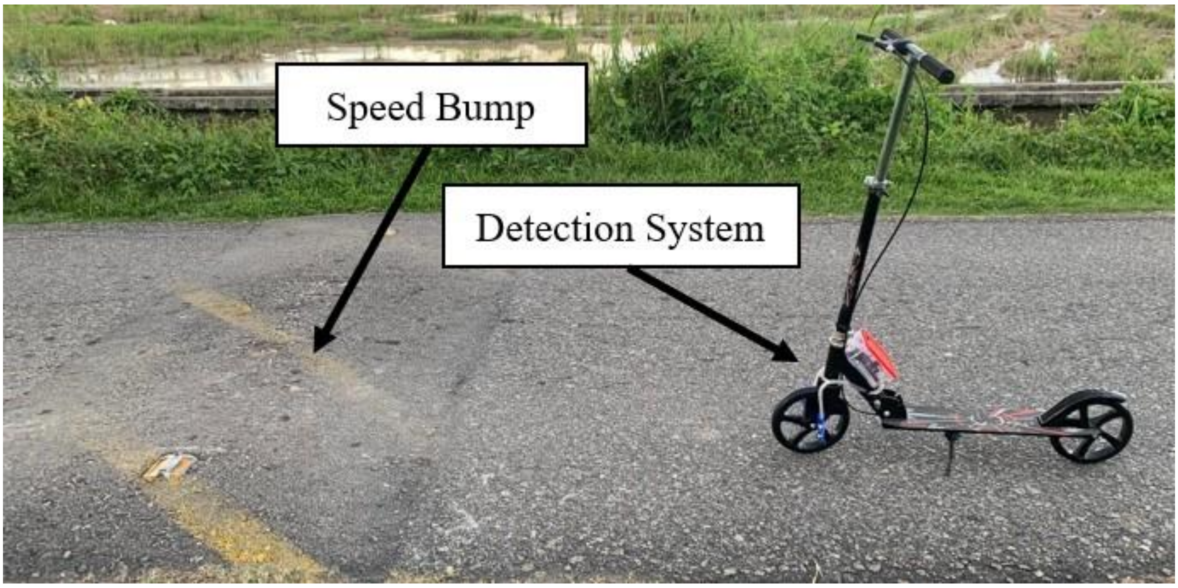


Figure 25 On-Road Speed Bump Test Setup

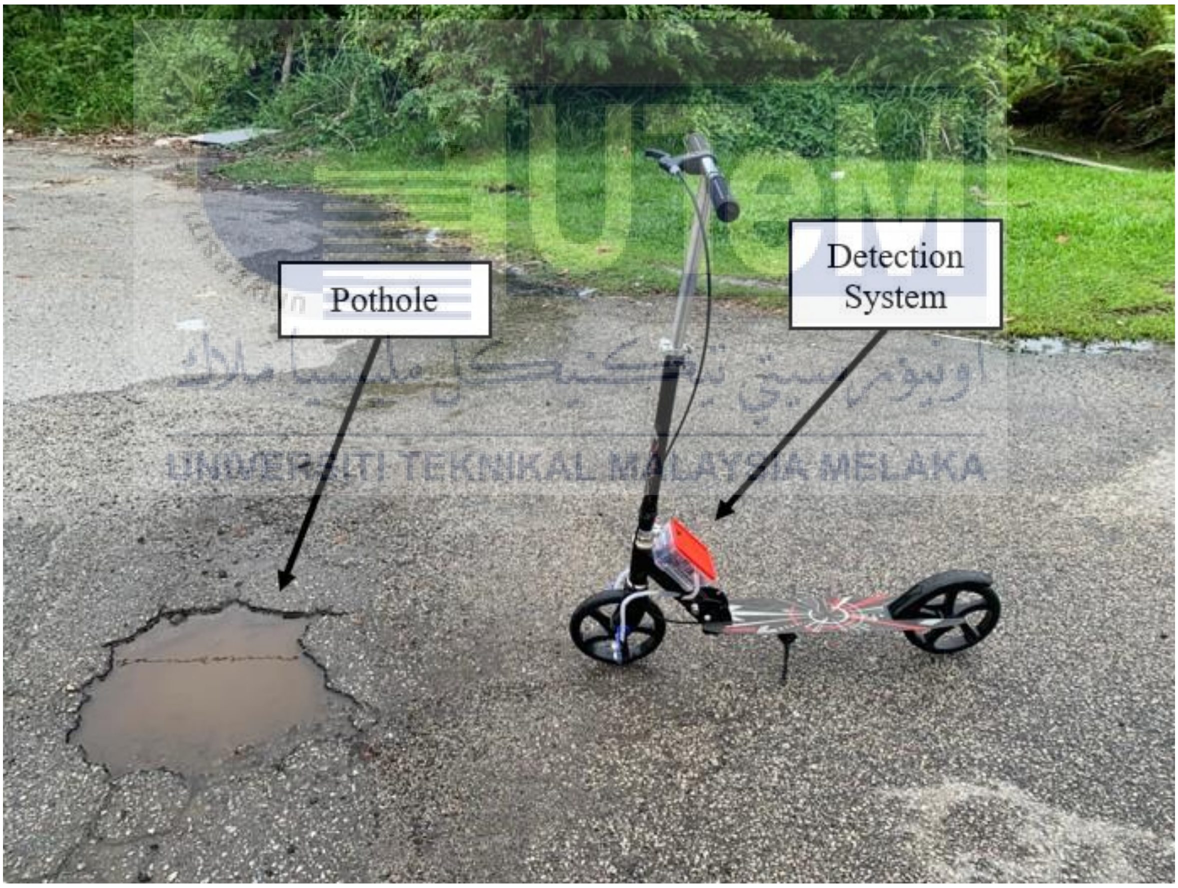


Figure 26 On-Road Pothole Test Setup

3.5 Summary

This chapter presents the overview of the methodology in order to develop the procedure to design and fabricate the speed bumps and pothole detection system for children’s scooter. The Gantt Chart has been established for it to become the guidance towards projects from the beginning until the end. A flowchart also has been developed to show the sequence and steps of the procedure to complete this project. The design of the system and the list of components that is being used in his project has been al shown in this chapter.

Other than that, the schematic diagram for the system has also been develop for the purpose of guidance during the assembly process. The coding that is required to be inserted into the Arduino software has also been develop and shown in this chapter. Finally, the overall project will be tested to see if any error will occur and if any error dose occurs, the process will go back to the searching for Arduino coding process.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results that are related to the objective of this project will be presented. Firstly, the results for the first objective are more related to designing the detection and alerting system that will be applied to the children's scooter. Next is the results for the second objective that is more associated to fabricating and constructing the physical appearance of the product. Lastly, this chapter will also be presenting the results for the outcome of the overall function of the project which is, is the system going to work as intended or not.

4.2 Design Related Results

This part is more about the results for the designing process of the project where the final results for designing the system are stated in this section. The parameters that this chapter cover is about the connections between the Arduino and the components and on the coding used to upload into the Arduino microcontroller.

4.2.1 Arduino Schematics and Connection

Figure 26 shows the schematic view of the final design for the detection and alerting system. Notice that two components are not connected to the Arduino UNO microcontroller that is the push button switch and the 9V battery due to the web simulation site lacks some features.

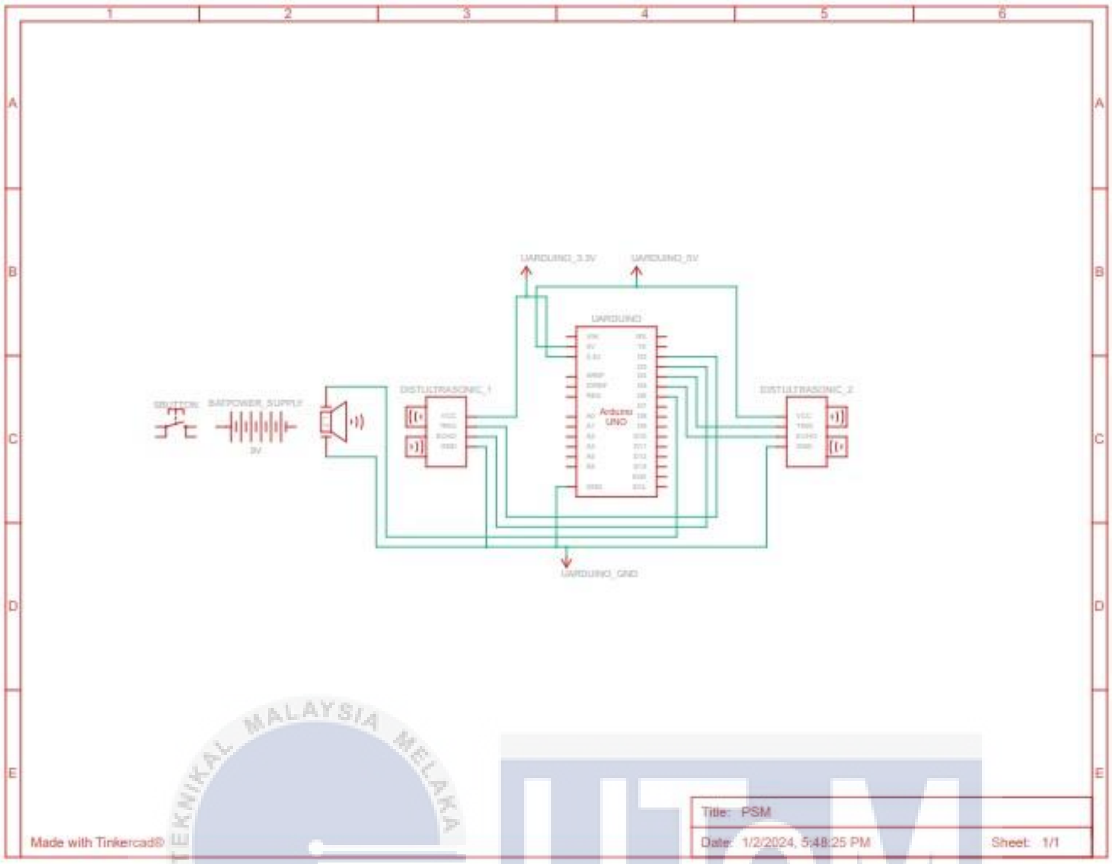


Figure 27 Arduino Schematic View

Figure 27 shows the connection view for the final design of the detection and alerting system. In this diagram, the connections are done by following the guide stated in the coding sketch. There are two components that cannot be connected to the Arduino that is the battery and push button due to lack of features of the web simulation site.

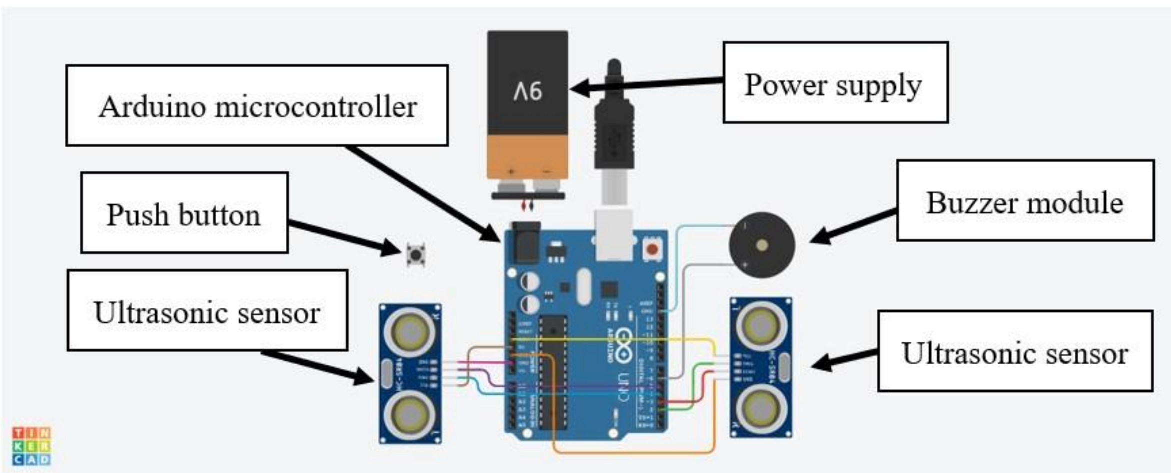


Figure 28 Arduino Connection Diagram

4.2.2 Arduino Coding

For the source code that is used in this project, the code is developed through the aid of AI on the internet. The method is to type in the list of components used and what tasks will be done by the components and the AI will help generate the code that will be uploaded into the Arduino microcontroller. Better results can be obtained when the list of components and tasks are more specific. After many trials and error in obtaining the code and uploading it into the Arduino and repeating the process, Figure 28 shows the final source code that is used in this project.

sketch_dec16a.ino

```
// Define the pin numbers for the ultrasonic sensors and buzzer
const int leftSensorTrigger = 2;  // Trigger pin of the left ultrasonic sensor
const int leftSensorEcho = 3;     // Echo pin of the left ultrasonic sensor
const int rightSensorTrigger = 4; // Trigger pin of the right ultrasonic sensor
const int rightSensorEcho = 5;    // Echo pin of the right ultrasonic sensor
const int buzzerPin = 6;          // Buzzer pin

// Set the threshold distance for detecting obstacles (speed bumps or potholes)
const float obstacleThreshold = 100.0;  // Adjust this value based on your specific setup

void setup() {
  // Initialize serial communication for debugging (optional)
  Serial.begin(9600);

  // Configure the ultrasonic sensor pins
  pinMode(leftSensorTrigger, OUTPUT);
  pinMode(leftSensorEcho, INPUT);
  pinMode(rightSensorTrigger, OUTPUT);
  pinMode(rightSensorEcho, INPUT);

  // Configure the buzzer pin
  pinMode(buzzerPin, OUTPUT);
}

void loop() {
  // Measure distances from the left and right ultrasonic sensors
  float leftDistance = getDistance(leftSensorTrigger, leftSensorEcho);
  float rightDistance = getDistance(rightSensorTrigger, rightSensorEcho);

  // Check if an obstacle (speed bump or pothole) is detected
  if (leftDistance < obstacleThreshold || rightDistance < obstacleThreshold) {
    // Determine which side the obstacle is on
    if (leftDistance < rightDistance) {
      // If the obstacle is on the left, play a different sound for a speed bump
      playSpeedBumpSound();
    } else {
      // If the obstacle is on the right, play a different sound for a pothole
      playPotholeSound();
    }
  }

  // Print distances for debugging (optional)
  Serial.print("Left Distance: ");
  Serial.print(leftDistance);
  Serial.print(" cm\t");

  Serial.print("Right Distance: ");
  Serial.print(rightDistance);
  Serial.println(" cm");

  // Add a delay to control the sampling rate
  delay(100);
}

// Function to measure distance using an ultrasonic sensor
float getDistance(int triggerPin, int echoPin) {
  // Trigger the ultrasonic sensor to send a pulse
  digitalWrite(triggerPin, LOW);
  delayMicroseconds(2);
  digitalWrite(triggerPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(triggerPin, LOW);

  // Measure the duration of the pulse from the echo pin
  unsigned long duration = pulseIn(echoPin, HIGH);

  // Calculate the distance based on the speed of sound (340 m/s)
  float distance = (duration * 0.034) / 2;

  return distance;
}

// Function to play a sound for a speed bump
void playSpeedBumpSound() {
  digitalWrite(buzzerPin, HIGH);  // Adjust the frequency for speed bumps
  delay(500);             // Adjust the duration of the sound
  noTone(buzzerPin);      // Stop the buzzer
}

// Function to play a sound for a pothole
void playPotholeSound() {
  tone(buzzerPin, 3000);  // Adjust the frequency for potholes
  delay(500);             // Adjust the duration of the sound
  noTone(buzzerPin);      // Stop the buzzer
}
```


Figure 29 Arduino Source Code

4.3 Fabrication Related Results

This part is more about the results for the fabrication process of the project where the final results on the fabrication of the product will covered in this section. The content in this part will show the final and overall results on how the product will look like and how the product will function.

4.3.1 System Location on Children's Scooter

The location of the system can be divided into two part that is part one is the location of the sensors and the second part is the location of the Arduino microcontroller. Figure 29 shows the location of the sensors where it is located on the left and right of the front wheel. The sensors are situated at that location because it allows the sensor to detect the speed bumps and potholes better.

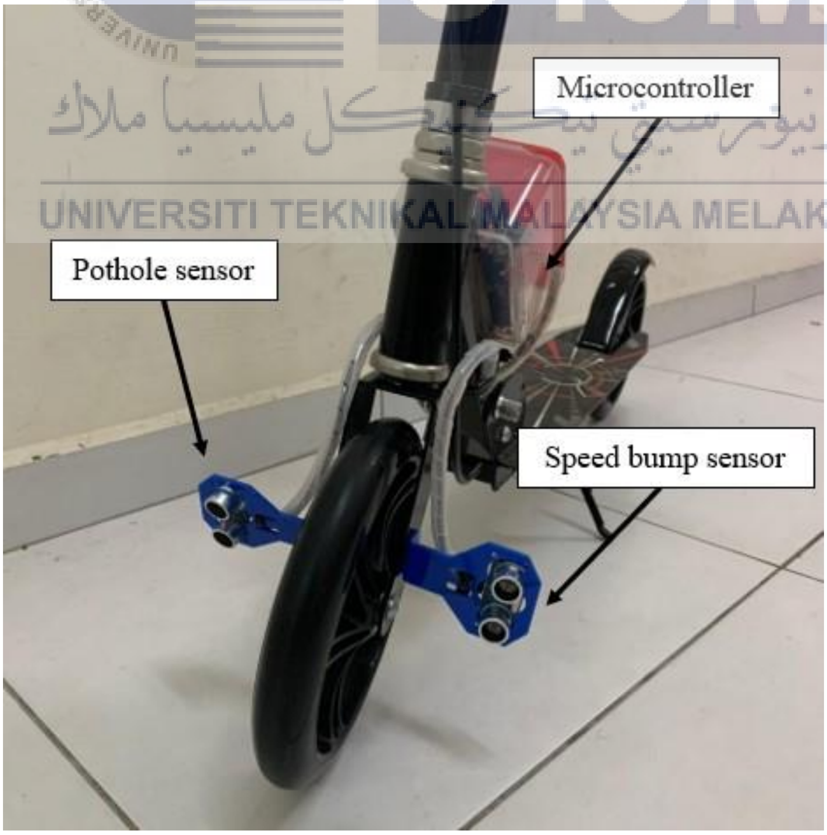


Figure 30 Sensor Location

In Figure 30, it shows the location of the Arduino microcontroller where it is situated near the front wheel of the scooter. The Arduino microcontroller is placed in that location is due to that location being the most suitable area to place the case containing the microcontroller.

Figure 31 Microcontroller Location

4.3.2 Fabrication of Pothole and Speed Bump Detection System

In the fabrication section, it will show the assembly of the detection and alerting system onto the children's scooter. Firstly, the connection between the Arduino microcontroller and the buzzer module and ultrasonic sensor is presented. Next, the placement of the case containing the Arduino microcontroller onto the children's scooter at the predetermine location will be shown in this part. Then, the testing of the connected components to the power supply to determine does the system turns on or not. After that, the placement and adjustment of the sensor component will be shown here. Figure 31 shows the connection of components that is sensor and alerting components connected to the microcontroller.

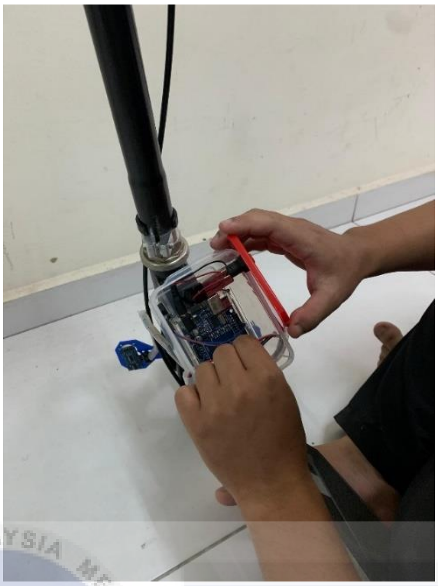


Figure 32 Connection of Wire Connectors From Sensor and Buzzer to Arduino Microcontroller

Figure 32 shows the placement of the case containing the Arduino microcontroller onto the most suitable location that has been determined so that the case is secured and does not easily falls of.

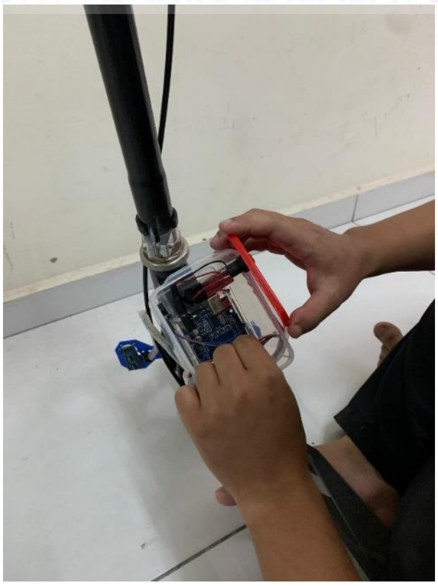


Figure 33 Placement of Case Containing Arduino Microcontroller

Figure 33 shows the testing of the components that has been connected properly to the power supply to see if the system turns on or not.

Figure 34 System Connection to Power Supply Testing

Figure 34 will show the placement of the detection sensor on the side of the front wheel of the children's scooter. The location of the sensors is there because if the sensors are located higher, it will not detect the speed bumps.

Figure 35 Detection Sensors Placement

Figure 35 shows the adjustment of the detection sensor where the sensor is adjusted to where it should be pointed and that is in front of the children's scooter.

Figure 36 Detection Sensors Adjustment

4.4 Overall Function of Pothole and Speed Bump Detection System

This section of the report will present the overall function of the detection system where the system will be tested on real speed bumps and potholes to see if the system will work or not. To show that the system detects the obstacle, the use of a decibel meter application is required to capture the sound produce by the buzzer.

4.4.1 Speed Bump On-Road Test

Figure 36 shows the test setup for speed bump detection where the children's scooter with the detection system is placed near a speed bump. The children's scooter will then be pushed slowly towards the speed bump until the detection and alerting system works.

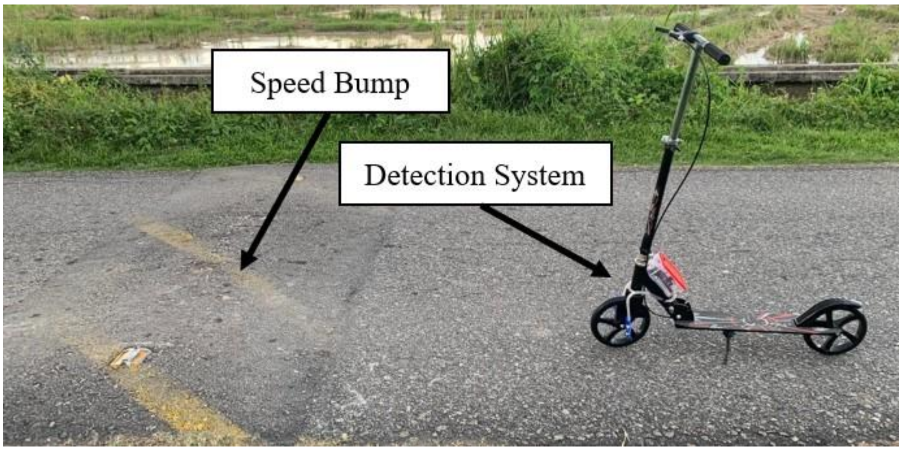


Figure 37 Speed Bump Test Setup

Figure 37 and Figure 38 will show the testing results where the detection system detects the speed bump with the aid of decibel meter. A decibel meter will show a reading of how loud a sound it detects. In Figure 37, the decibel meter shows a low sound reading meaning that the buzzer is not producing sound indicating no speed bump is detected. In Figure 38, the decibel meter shows higher reading meaning that the buzzer is producing sound indicating a speed bump is detected.

Figure 38 Before Speed Bump Detection

Figure 39 During Speed Bump Detection

4.4.2 Pothole On-Road Test

Figure 39 shows the test setup for pothole detection where the children's scooter with the detection system is placed near a pothole. The children's scooter will then be pushed slowly towards the speed bump until the detection and alerting system works.

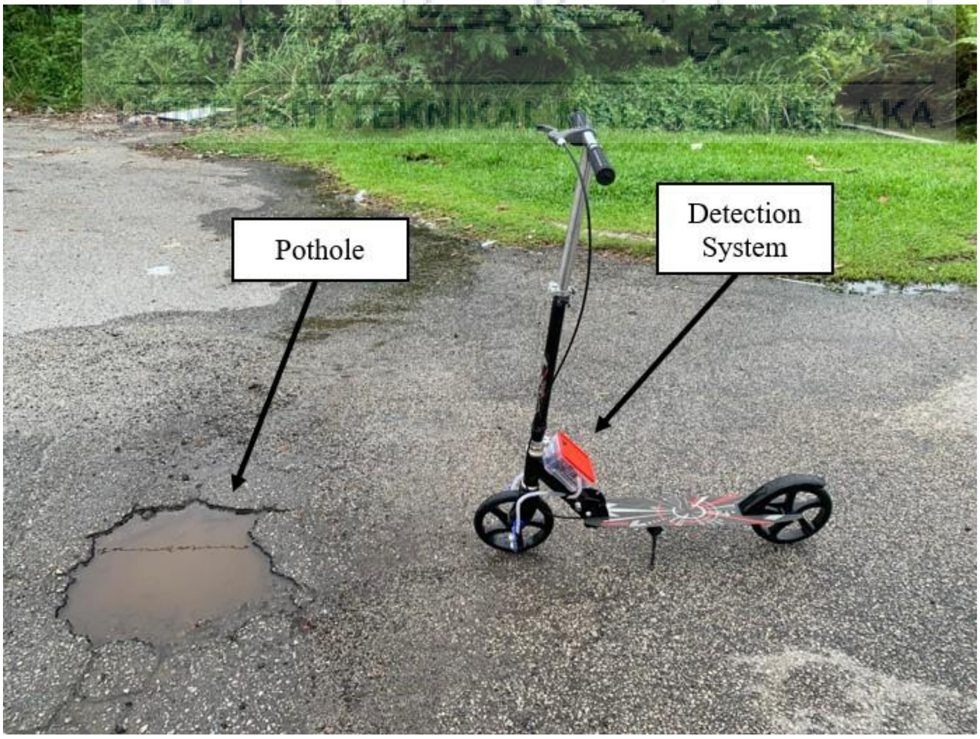


Figure 40 Pothole Test Setup

Figure 40 and Figure 41 will show the testing results where the detection system detects the pothole with the aid of decibel meter. A decibel meter will show a reading of how loud a sound it detects. In Figure 37, the decibel meter shows a low sound reading meaning that the buzzer is not producing sound indicating no pothole is detected. In Figure 38, the decibel meter shows higher reading meaning that the buzzer is producing sound indicating a pothole is detected.

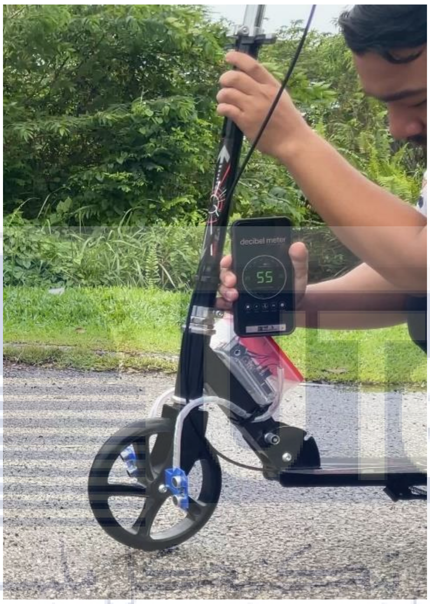


Figure 41 Before Pothole Detection

Figure 42 During Pothole Detection

4.5 Discussion

This project's main objective is to greatly increase scooter rider safety by identifying and warning scooter users about possible risks like potholes and speed bumps. This proactive strategy seeks to reduce the possibility of accidents and falls, particularly for scooter riders who could be more vulnerable during scooter riding activities.

Unexpected road hazards can significantly lower the chance of accidents when using the real-time detection and alerting system. This is especially important in places where there may not be as much road maintenance, since potholes and speed bumps can catch scooter riders by surprise and resulting in potentially sustaining heavy injuries.

This system can assist in preventing injuries from unexpected shocks or falls brought on by running over a speed bump or pothole by sending out timely notifications. This feature is crucial for the safety of scooter riders and can help reduce injuries sustained during scooter riding activities, making the riding environment safer.

Making scooter riders aware of possible risks is one way that this effort indirectly tackles the problem of poor road infrastructure. In the long term, this greater knowledge may raise public awareness and fuel demands for improved road maintenance and repairs, which will benefit both scooter riders and other road users.

In summary, the detection and warning system for potholes and speed bumps has the potential to significantly improve rider safety, road infrastructure awareness, and the overall urban mobility environment. This project clear the path for a safer and more effective future on the roads as technology plays a vital role in transportation.

4.6 Summary

This chapter explains the results related to designing and fabricating the detection and alerting system which also includes the results of the overall function of the detection and alerting system. The on-road testing results for the detection and alerting system shows that the system works because it detects the speed bump and pothole but not very accurate because the alerting system produce a sound even though a speed bump and a pothole is not in front of it. All in all, the detection and alerting system for children's scooter function as intended because it detects the presence of the speed bump and pothole but require improvements on the detection part to increase the accuracy of detection for this system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter will present the conclusion and recommendations for the pothole and speed bump detection and alerting system for children's scooter. The conclusion and recommendations will be based on the overall result of the project and the potential of the project to perform better in detecting speed bumps and potholes also in alerting.

5.2 Conclusion

In conclusion, injuries sustained from accidents involving falling from a scooter mostly happen because of the person riding the scooter does not notice the speed bumps or potholes. This is due to some factors, one of the factors is that the person riding the scooter is distracted or not aware of the hazards on the road. Second factor is that some of those hazards that is speed bumps and pothole are difficult to spot. Some speed bumps have lost their indication lines and that makes them hard to spot with human eyes. For potholes, it is hard to see them because most potholes are dark and this acts as camouflage since the color of the road is black.

This project aim is to reduce the accident rate for scooter riders who ride scooters on paved road especially children riders because children riders are more prone to fall from scooters because children have lower awareness than teenagers or adults. The results from the on-road testing shows that the detection system works but to a certain extent when detecting speed bumps and pothole. When tested with the purpose of detecting a speed bump, the detection system shows inconsistent results where when faced with shorter speed bump, the system does not detect the speed and when faced with a taller speed bump, the detection system can detect the speed bump. This result happens because of the distance between detection sensor and the surface of the road is not close enough. Next, when tested with the purpose of detecting a pothole, the detection system will sometime indicate that it detects a pothole and sometime it does not detect the presence of a pothole.

With the outcome and results shown by this project, it is safe to say that the project works as intended but the detection system is not very accurate. The aim of the project is to detect speed bumps and potholes, and the product perform well but the accuracy of the detection system needs to be improved so that the success rate of detecting those road hazards can be increased. The solution to those inaccuracy is to use a different detection sensor that is more accurate. If the same detection sensor is to be used, then the solution is to further refine the Arduino coding and do an extended amount of on-road testing to gain a data on the accuracy rate of the detection system.

With the improvement of this project, the goal of reducing accidents involving scooter riders sustaining injury due to falling off from a scooter because of not noticing speed bumps and potholes can be achieved.

5.3 Recommendations

For the recommendation, this project can be further improved in terms of functionality, system, design and hardware. When these aspects are to be studied more, it can bring up the potential of this project such as:

i) The design can be changed or improved depends on the idea so that the system is more hidden in the children's scooter.

ii) The system can be redesign or upgraded so that the detection and alerting system can perform better than the previous system.

iii) In terms of hardware, the project can perform better when using more accurate sensor for the detection part and a louder alerting device for the alerting part.

iv) The project can also be upgraded to do more tasks such as automatically slows the scooter down when a speed bump or pothole are detected.

v) A lot more idea can be implemented into this project if an electric scooter is used or the current scooter is fitted with an electric motor.

vi) This system also can be implemented onto a bicycle or motorcycle because this can reduce the fatality rate of bicycle and motorcycle riders.

REFERENCES

Abouelela, M., Chaniotakis, E., & Antoniou, C. (2023). Understanding the landscape of shared-e-scooters in North America; Spatiotemporal analysis and policy insights. *Transportation Research Part A: Policy and Practice*, *169*(January), 103602. https://doi.org/10.1016/j.tra.2023.103602

Azam, A., Ahmed, A., Hayat, N., Ali, S., Khan, A. S., Murtaza, G., & Aslam, T. (2021). Design, fabrication, modelling and analyses of a movable speed bump-based mechanical energy harvester (MEH) for application on road. *Energy*, *214*, 118894. https://doi.org/10.1016/j.energy.2020.118894

Chen, C. F., & Lee, C. H. (2023). Investigating shared e-scooter users' customer value co-creation behaviors and their antecedents: Perceived service quality and perceived value. *Transport Policy*, *136*(November 2022), 147–154. https://doi.org/10.1016/j.tranpol.2023.03.015

Dib, J., Sirlantzis, K., & Howells, G. (2023). An annotated water-filled, and dry potholes dataset for deep learning applications. *Data in Brief*, *48*. https://doi.org/10.1016/j.dib.2023.109206

Egaji, O. A., Evans, G., Griffiths, M. G., & Islas, G. (2021). Real-time machine learning-based approach for pothole detection. *Expert Systems with Applications*, *184*, 115562. https://doi.org/10.1016/j.eswa.2021.115562

Félix, R., Orozco-Fontalvo, M., & Moura, F. (2023). Socio-economic assessment of shared e-scooters: do the benefits overcome the externalities? *Transportation Research Part D: Transport and Environment*, *118*(November 2022), 103714. https://doi.org/10.1016/j.trd.2023.103714

Fisher, N. D., Nwakoby, E., Hernandez, H., & McLaurin, T. M. (2023). Electric scooter injuries: Incidence and injury patterns at a level I trauma center. *Chinese Journal of Traumatology*, *xxxx*, 0–4. https://doi.org/10.1016/j.cjtee.2023.02.003

Gong, F., Cheng, X., Fang, B., Cheng, C., Liu, Y., & You, Z. (2023). Prospect of 3D printing technologies in maintenance of asphalt pavement cracks and potholes. *Journal of Cleaner Production*, *397*(December 2022), 136551. https://doi.org/10.1016/j.jclepro.2023.136551

Guo, Y., & Zhang, Y. (2021). Understanding factors influencing shared e-scooter usage and its impact on auto mode substitution. *Transportation Research Part D: Transport and Environment*, *99*(August), 102991. https://doi.org/10.1016/j.trd.2021.102991

Kazemzadeh, K., Haghani, M., & Sprei, F. (2023). Electric scooter safety: An integrative review of evidence from transport and medical research domains. *Sustainable Cities and Society*, *89*(November 2022), 104313. https://doi.org/10.1016/j.scs.2022.104313

Kiran, K. R., Kumar, M., & Abhinay, B. (2020). Critical Analysis of Speed Hump and Speed Bump and Geometric Design of Curved Speed Hump. *Transportation Research Procedia*, *48*(2018), 1211–1226. https://doi.org/10.1016/j.trpro.2020.08.144

Kortmann, F., Fassmeyer, P., Funk, B., & Drews, P. (2022). Watch out, pothole! featuring road damage detection in an end-to-end system for autonomous driving. *Data and Knowledge Engineering*, *142*(October 2021), 102091. https://doi.org/10.1016/j.datak.2022.102091

Kosakowska, K. (2022). Evaluation of the impact of speed bumps on the safety of residents - selected aspects. *Transportation Research Procedia*, *60*(2021), 418–423. https://doi.org/10.1016/j.trpro.2021.12.054

Kumar, V., Subramanian, S. C., & Rajamani, R. (2022). A novel algorithm to track closely spaced road vehicles using a low density flash lidar. *Signal Processing*, *191*, 108360. https://doi.org/10.1016/j.sigpro.2021.108360

Lav, A. H., Bilgin, E., & Lav, A. H. (2018). A fundamental experimental approach for optimal design of speed bumps. *Accident Analysis and Prevention*, *116*(February 2017), 53–68. https://doi.org/10.1016/j.aap.2017.05.022

Lee, S. Y., Le, T. H. M., & Kim, Y. M. (2023). Prediction and detection of potholes in urban roads: Machine learning and deep learning based image segmentation approaches. *Developments in the Built Environment*, *13*(October 2022), 100109. https://doi.org/10.1016/j.dibe.2022.100109

Li, N., Zhao, Y., Pan, Q., Kong, S. G., & Chan, J. C. W. (2021). Illumination-invariant road detection and tracking using LWIR polarization characteristics. *ISPRS Journal of Photogrammetry and Remote Sensing*, *180*(September), 357–369. https://doi.org/10.1016/j.isprsjprs.2021.08.022

Lin, C., Wang, Y., Gong, B., & Liu, H. (2023). Vehicle detection and tracking using low-channel roadside LiDAR. *Measurement*, *218*(April), 113159. https://doi.org/10.1016/j.measurement.2023.113159

Moscoso Thompson, E., Ranieri, A., Biasotti, S., Chicchon, M., Sipiran, I., Pham, M. K., Nguyen-Ho, T. L., Nguyen, H. D., & Tran, M. T. (2022). SHREC 2022: Pothole and crack detection in the road pavement using images and RGB-D data. *Computers and Graphics (Pergamon)*, *107*, 161–171. https://doi.org/10.1016/j.cag.2022.07.018

Mouratidis, K. (2022). Bike-sharing, car-sharing, e-scooters, and Uber: Who are the shared mobility users and where do they live? *Sustainable Cities and Society*, *86*(June), 104161. https://doi.org/10.1016/j.scs.2022.104161

Ouma, Y. O., & Hahn, M. (2017). Pothole detection on asphalt pavements from 2D-colour pothole images using fuzzy c-means clustering and morphological reconstruction. *Automation in Construction*, *83*(August), 196–211. https://doi.org/10.1016/j.autcon.2017.08.017

Pandey, A. K., Palade, V., Iqbal, R., Maniak, T., Karyotis, C., & Akuma, S. (2022). Convolution neural networks for pothole detection of critical road infrastructure. *Computers and Electrical Engineering*, *99*(February), 107725. https://doi.org/10.1016/j.compeleceng.2022.107725

Rizzo, M. G., Allegra, P. R., Yakkanti, R., Luxenburg, D., & Dodds, S. D. (2022). Electric scooters as a source of orthopedic injuries at a Level-I trauma center. *Journal of Orthopaedics*, *31*(January), 86–91. https://doi.org/10.1016/j.jor.2022.04.005

Saisree, C., & U, D. K. (2023). Pothole Detection Using Deep Learning Classification Method. *Procedia Computer Science*, *218*, 2143–2152. https://doi.org/10.1016/j.procs.2023.01.190

Shichman, I., Shaked, O., Factor, S., Ashkenazi, I., Elbaz, E., Aviv Mordechai, R., & Khoury, A. (2023). The association between electric scooter riding position and injury characteristics. *Journal of Safety Research*, *84*, 347–352. https://doi.org/10.1016/j.jsr.2022.11.009

Shiva Kumar, G., Jakati, S. S., Sharanagouda, & Ramaraju, H. K. (2023). Developing novel pothole patching mixtures utilizing iron ore waste as substitute to conventional aggregates with anti-stripping agent. *Materials Today: Proceedings*, *xxxx*. https://doi.org/10.1016/j.matpr.2023.03.225

Suttiponpisarn, P., Charnsripinyo, C., Usanavasin, S., & Nakahara, H. (2022). An Enhanced System for Wrong-Way Driving Vehicle Detection with Road Boundary Detection Algorithm. *Procedia Computer Science*, *204*, 164–171. https://doi.org/10.1016/j.procs.2022.08.020

Wang, Y., Zhu, R., Wang, L., Xu, Y., Guo, D., & Gao, S. (2023). Improved VIDAR and machine learning-based road obstacle detection method. *Array*, *18*(February). https://doi.org/10.1016/j.array.2023.100283

White, E., Guo, F., Han, S., Mollenhauer, M., Broaddus, A., Sweeney, T., Robinson, S., Novotny, A., & Buehler, R. (2023). What factors contribute to e-scooter crashes: A first look using a naturalistic riding approach. *Journal of Safety Research*, *xxxx*. https://doi.org/10.1016/j.jsr.2023.02.002

Yan, X., Zhao, X., Broaddus, A., Johnson, J., & Srinivasan, S. (2023). Evaluating shared e-scooters’ potential to enhance public transit and reduce driving. *Transportation Research Part D: Transport and Environment*, *117*(January), 103640. https://doi.org/10.1016/j.trd.2023.103640

Yang, H., Huo, J., Bao, Y., Li, X., Yang, L., & Cherry, C. R. (2021). Impact of e-scooter sharing on bike sharing in Chicago. *Transportation Research Part A: Policy and Practice*, *154*(August), 23–36. https://doi.org/10.1016/j.tra.2021.09.012

APPENDICES

Appendix A Gantt Chart Semester 2 Session 2022/2023.

No.	Subject	WEEK													
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1.	Meeting with Supervisor														
2.	Internet and Library Research														
3.	Thesis Writing														
4.	Thesis Correction														
5.	Submission Date														
6.	PPT Presentation														

Appendix B Gantt Chart Semester 1 Session 2023/2024

No.	**Subject**	**WEEK**													
		W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
1.	**Meeting with Supervisor**														
2.	**Internet and Library Research**														
3.	**Thesis Writing**														
4.	**Project Fabrication**														
5.	**Thesis Correction**														
6.	**Submission Date**														
7.	**PPT Presentation**														

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **SPEED BUMP AND POTHOLE DETECTION FOR CHILDREN'S SCOOTER**

SESI PENGAJIAN: **2023-2024 Semester 1**

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