PERFORMANCE ANALYSIS OF ELECTRICAL RICKSHAW

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in partial fulfillment of the requirements for the degree of
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2024

DECLARATION

I declare that this thesis entitled "PERFORMANCE ANALYSIS OF ELECTRICAL RICKSHAW is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled " PERFORMANCE ANALYSIS OF ELECTRICAL RICKSHAW ", and in my opinion, this thesis fulfills the partial requirement to be awarded the degree of Bachelor of Mechatronics Engineering with Honours

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Date	:	23/06/2024

DEDICATIONS

To my dear parents and family: This final year project 1 report is dedicated to everyone who has taken part in this trip.

First and foremost, I'd want to convey my heartfelt thanks to my project supervisor, Encik Mohd Bazli Bin Bahar, whose competence, understanding, and patience greatly enhanced my project experience. I appreciate their extensive knowledge and talents in a variety of fields, as well as their support with this study.

I am also very thankful to my parents and family for their unwavering support, encouragement, and love during my academic years, as well as throughout the research and preparation of this report. This success would not have been possible without them.

Thank You.

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ABSTRACT

The electric rickshaw serves as a crucial mode of transport for seamless connectivity in numerous urban areas. Most vehicles in developing nations contribute to noise and air pollution, except for those powered by humans. However, commercially operated human-powered vehicles require substantial physical exertion to operate. An electric rickshaw, powered by a battery and assisted by a motor, can offer a comparatively comfortable, quiet, and pollution-free transportation solution. This electric rickshaw has seen significant alterations in passenger capacity compared to the widely prevalent existing rickshaw. This study's main emphasis was evaluating the performance of electric rickshaw. The time series of electric rickshaw observed at Lapang Sasar Memanah UTeM Road Route and Faculty Technology and Engineering Electric (FTKE) Road Route. The performance test validated through real-world testing showed that the electric rickshaw delivers results in increased load variance, speed, acceleration, and power consumption. This facilitates simpler motion control and offers a good opportunity to adjust the balance between human effort and motor power. This study provides valuable data and insights that can be used to optimize the performance and energy efficiency of electric rickshaw. It also contributes to the broader goal of promoting sustainable transportation solutions.

ABSTRAK

Beca elektrik berfungsi sebagai mod pengangkutan penting untuk ketersambungan yang lancar di banyak kawasan bandar. Kebanyakan kenderaan di negara membangun menyumbang kepada pencemaran bunyi dan udara, kecuali kenderaan yang dikuasakan oleh manusia. Walau bagaimanapun, kenderaan berkuasa manusia yang dikendalikan secara komersial memerlukan usaha fizikal yang banyak untuk beroperasi. Beca elektrik, dikuasakan oleh bateri dan dibantu oleh motor, boleh menawarkan penyelesaian pengangkutan yang agak selesa, senyap dan bebas pencemaran. Beca elektrik ini telah menyaksikan perubahan ketara dalam kapasiti penumpang berbanding beca sedia ada yang berleluasa. Penekanan utama kajian ini adalah menilai prestasi beca elektrik. Siri masa beca elektrik yang dicerap di Laluan Jalan Raya Lapang Sasar Memanah UTeM dan Laluan Jalan Fakulti Teknologi dan Kejuruteraan Elektrik (FTKE). Ujian prestasi yang disahkan melalui ujian dunia sebenar menunjukkan bahawa beca elektrik memberikan hasil dalam peningkatan varians beban, kelajuan, pecutan dan penggunaan kuasa. Ini memudahkan kawalan pergerakan yang lebih mudah dan menawarkan peluang yang baik untuk melaraskan keseimbangan antara usaha manusia dan kuasa motor. Kajian ini menyediakan data dan pandangan berharga yang boleh digunakan untuk mengoptimumkan prestasi dan kecekapan tenaga beca elektrik. Ia juga menyumbang kepada matlamat yang lebih luas untuk mempromosikan penyelesaian pengangkutan yang mampan.

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LIST OF SYMBOLS AND ABBREVIATIONS

EV	-	Electrice vehicles
BLDC	-	Brushless DC Motor

CHAPTER 1

INTRODUCTION

1.1 Motivation

The motivation for electrical rickshaws has sparked significant interest and debate in recent years. "Performance Analysis of Electrical Rickshaw" It is motivated by a rising interest in sustainable transportation systems, namely the design and performance characteristics of electric rickshaws. The author [1] emphasize the importance of sustainable transportation and the elements that influence rickshaw operators' desire to embrace battery-powered rickshaws in India. Figure 1-1 shown the Indian's electric rickshaw. These studies collectively highlight the significance of sustainable and efficient transportation solutions, which serve as the foundation for the performance analysis of electrical rickshaws.

Figure 1-1 Indian's electric rickshaw

Moreover, the challenges and future works related to charging infrastructure for commercial electric vehicles, as presented by [2], are relevant to the motivation behind the performance analysis of electrical rickshaws. Understanding the charging infrastructure and its implications is essential for evaluating the overall performance of electric vehicles, including rickshaws.

Therefore, the motivations for the title "Performance Analysis of Electrical Rickshaw" stem from the need for sustainable transportation solutions, the variables influencing the adoption of electric rickshaws, the benchmarking of fuel efficiency, the influence of work motivation on performance, and the engineering aspects of renewable energy-based vehicles.

1.2 Problem Statement

The problem statement for the title "Performance Analysis of Electrical Rickshaw" revolves around the need to address the challenges and opportunities associated with the development and evaluation of electric rickshaw.

The current state of transportation may rely heavily on fossil fuels, contributing to environmental pollution. The goal is to analyze an electric rickshaw that not only reduces reliance on fossil fuels but also integrates an efficient and reliable motorized system for better performance and usability. The performance of the electrical rickshaw is greatly impacted by variable load conditions and terrain adaptability, especially when it comes to speed and acceleration. Maximizing functionality requires thinking about things like energy consumption. This solution should consider factors such as safety, user-friendliness, and environmental impact.

There is an absence of a thorough assessment system capable of accurately evaluating these crucial performance measures in a practical environment. The aim is to establish a solid verification method that can close this gap and guarantee that the performance indicators truly represent conditions in the real world.

The electric rickshaw lacks integrated systems that can deliver comprehensive performance data, which is essential for verifying and enhancing their dependability and efficiency. The lack of a standardised black box-style evaluation system hinders the development of improvements that might result in more dependable and efficient electric rickshaws in addition to making it difficult to validate performance. Furthermore, when damage occurs, the lack of a standardised evaluation system that functions like a black box makes it more difficult to diagnose and fix. It is more difficult to identify the root causes of errors or inefficiencies in the absence of comprehensive performance data, which increases maintenance expenses and downtime.

1.3 Objectives

The objective of the study Performance Analysis of Electrical Rickshaw:

1. Analyze an electric rickshaw with an integrated electric motorized system.

2. Validate the performance of the real-world testing based on speed, acceleration, and power consumption.

By achieving these objectives, the study's goal is to contribute to the improvement of electric rickshaw technology while also providing vital information.

1.4 Scope and Limitations

Scope:

The scope of the study "Performance Analysis of Electrical Rickshaw" encompasses a comprehensive investigation:

1. Analyze an electric rickshaw with an integrated electric motorized system. The study will focus on the technological aspects of designing electric rickshaws using Fusion 360, emphasizing efficiency and load-bearing capacity. The voltage measurements underscore precision and safety.

2. Validate the performance of the real-world testing based on speed, acceleration, and power consumption. These evaluations track the rickshaw's acceleration to show its agility and to optimize the electric rickshaw's performance and energy efficiency.

3. Observing the electric rickshaw over time at two specific routes: Lapang Sasar Memanah UTeM Road Route and Faculty Technology and Engineering Electric (FTKE) Road Route.

Limitations:

1. The study’s scope is restricted to the electric rickshaw's performance on a few chosen routes, which might not account for all potential scenarios the rickshaw might face.

2. The electric rickshaw's performance may alter depending on the weather, which this study does not consider.

3. The study will not delve into a detailed economic analysis of the electric rickshaw's manufacturing costs and market dynamics.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Performance Analysis of Electrical Rickshaw requires to conduct one must possess a profound comprehension of electric rickshaw technology, its integration into contemporary power networks, and the potential benefits of electric rickshaws in emerging nations. Furthermore, the article offers valuable perspectives on the potential of electric rickshaws in developing nations, emphasising the significance of considering economic, ecological, and social issues when designing and evaluating these vehicles.

The review delves into the consumption factors for electricity generation technology [3], electricity demand prediction using statistical, machine learning, and deep learning methods [4], prospects of electricity storage [5], these topics provide a comprehensive understanding of the technological, economic, and environmental factors that influence the performance of electrical rickshaws. Figure 2-1 presents a scheme of analyzed technologies in the paper from different perspectives of electricity storage systems. The authors [6], investigate the socioeconomic attributes of paratransit drivers and their attitudes towards electric three-wheeled rickshaws. Their research provides insights into the market dynamics and public reception of electric rickshaws. The research primarily investigates the impact of gradients on the dynamic performance of three-wheeled vehicle systems. This analysis is crucial for comprehending the stability and performance of electric rickshaws on different terrains [7].

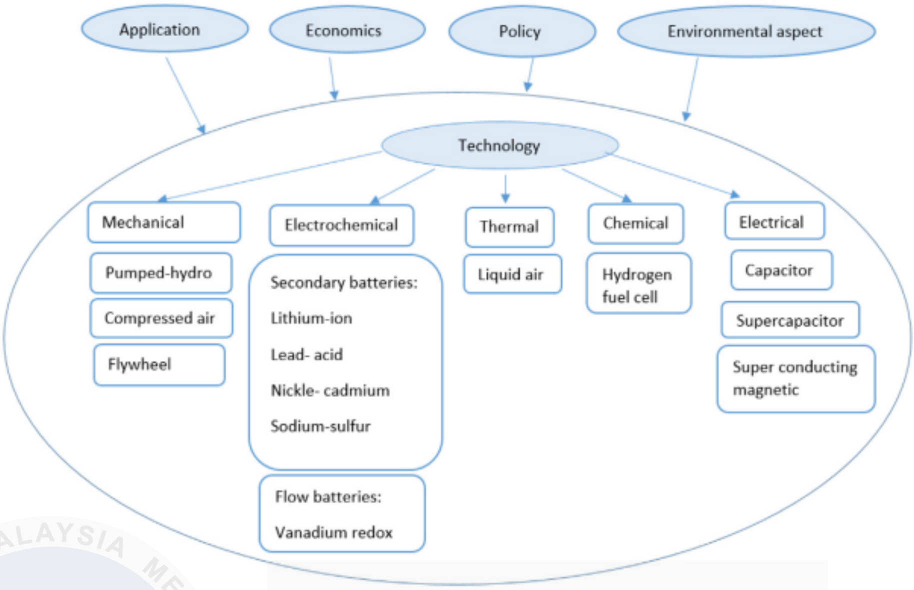


Figure 2-1 Selected energy storage technologies for electricity considering different perspectives for the analysis.

The literature study consolidates these issues to provide a comprehensive understanding of the diverse factors that influence the efficacy of electric rickshaws. This review aims to comprehensively evaluate the performance of electrical rickshaws by analysing the latest advancements in electricity storage, solar-powered vehicles, and electric heating. It also considers the economic and environmental impacts of sustainable transportation.

2.1.1 Environmental and economic benefits of Electrical Rickshaw

The environmental and economic benefits of electrical rickshaws are evident from the literature. [8] highlight the environmental friendless of e-rickshaw, emphasizing their ability to reduce carbon footprint. Furthermore, [9] examine the large decrease in air pollution levels caused by rickshaw electrification, emphasizing their environmental benefits provided light on the real-world emissions and the effect of three-wheeler electric auto-rickshaws in India. In addition, research conducted in India on the evaluation of propulsion systems for three-wheeled electric-powered rickshaws highlights their potential to reduce carbon emissions and address pollution concerns, further confirming their environmental benefits.

The literature strongly supports the environmental benefits of electrical rickshaws, highlighting them as a sustainable and eco-friendly mode of transportation that can help preserve the environment and enhance public health. Additional research that emphasises economic evaluations and cost-effectiveness would provide a more comprehensive understanding of the financial benefits associated with electric rickshaws.

2.2 Fabrication of Electrical Rickshaw

A Conducting a thorough analysis of electrical rickshaw performance involves evaluating various factors such as structural design, battery performance, control schemes, environmental impact, affordability, and engine combinations. The existing literature provides valuable insights into different aspects, offering a comprehensive understanding of the challenges and opportunities in this field. Key considerations in the design and analysis of electric rickshaws revolve around their impact on the environment and the potential improvements they can bring to people's lives [10]. Similarly, [11] examines the use of digital fabrication technologies in education to facilitate sustainable design and prototyping. The application of digital fabrication tools in the manufacturing process of electrical rickshaws is highly relevant, with a strong focus on sustainability and design education. Figure 2-2 shown Proposed framework for digital fabrication based sustainable design and prototyping. The use of digital fabrication tools is essential in the design and prototype of automotive components, enabling accurate and efficient production procedures.

In addition, [12] conducted a study on the tribological properties of magnesium matrix nanocomposites. The study examines the impact of various fabrication methods, including stir casting (SC), ultrasonic treatment casting (UST), disintegrated melt deposition (DMD), and friction stir processing (FSP), on the wear and friction behavior of these materials. While the primary emphasis is on materials science, it is crucial to comprehend how fabrication techniques affect the wear and friction characteristics of materials to develop and manufacture components for electric vehicles that provide maximum performance and durability.

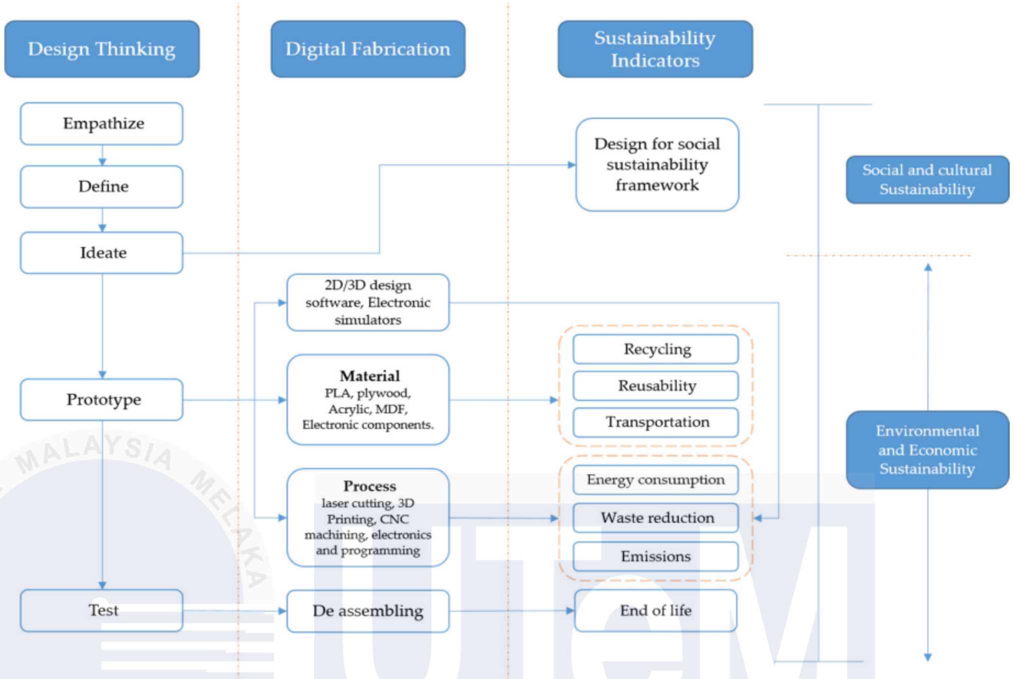


Figure 2-2 Proposed framework for digital fabrication based sustainable design and prototyping.

According to [13], there is also a major influence from the market share and total cost of ownership for hybrid and electric vehicles when deciding whether or not an automobile is feasible and accepted. The Total Cost of Ownership was calculated using the following formula:

$$TCO_C = \sum_{t=1}^{3} \frac{(I_C) - (S_C) - (I_C) - (S_C) * d_c^t + f_{ct} * m_c * e + a_{ct} + n_{ct} + x_{ct})}{(1 + r_c)^{\square}} \qquad (2\text{-}1)$$

where I = Initial Price,

d = depreciation rate,

t = time (yr. of ownership),

f = annual fuel price,

m = annual mileage (miles),

e = vehicle fuel efficiency (liter/mile),

a = annual maintenance inclusive of vehicle testing,

n = annual insurance,

x = annual tax,

s = annual subsidy,

r = discount rate for geographic region c

Research on state of charge estimation and battery life prediction using machine learning algorithms and artificial intelligence helps to improve the performance and reliability of electric vehicle batteries, which is a crucial component of electric vehicles [14]. For instance, [15] a comprehensive review was conducted on various sources that delve into the design, performance, and benefits of utilising brushless DC (BLDC) motors in electric vehicles. These motors offer advantages such as improved efficiency, reduced maintenance requirements, and enhanced torque control. The authors also discuss certain obstacles and drawbacks associated with BLDC motors, including high expenses, intricate control systems, and electromagnetic interference.

In summary, electrical rickshaws involve sustainability, materials science, market realities, battery efficiency, motor selections, control algorithms, and powertrain optimisation. Though more study is needed to make electric vehicles practicable, current research sheds light on each of these factors. Four-seater designs need to be optimised, motor and powertrain combinations need to be assessed, advanced control algorithms need to be used for efficiency and safety, and economical and sustainable production techniques need to be investigated. We can create electric vehicles that are aesthetically pleasing, environmentally friendly, function well, and help create a more sustainable road future by carefully examining these intricate components.

2.3 Energy of Electrical Rickshaw

2.3.1 Energy Stored in a Lithium-ion (Li-on) Battery.

To create and evaluate electrical rickshaw efficiency, researchers must address the battery system, specifically the lithium-ion battery. Li-ion batteries are popular due to their high energy density, long cycle life, and wide operating temperature range [16]. Electric vehicles rely on them because of their exceptional performance, which includes a high operating voltage and lightweight properties [16]. Moreover, Lithium insertion or intercalation recharges Li-ion batteries, making them ideal for long-term electric vehicles use [17].

Their mechanical characteristics, thermal safety, and electrochemical performance have all been thoroughly investigated; they are crucial elements for the design and performance evaluation of an electric vehicle [18]. In addition, research has been done on the creation of simulation models for electrochemical impedance spectroscopy and the synthesis of novel anode materials, which has led to an understanding of the possible developments in Li-ion battery technology for electric vehicles [19]. The temperature management of Li-ion batteries is crucial in the context of electric vehicles. Maximizing the use of batteries in electric vehicles requires ensuring that they run within an optimal temperature range[20]. Characteristics of the lithium titanate oxide lithium-ion battery are demonstrated in Figure 2-3. Besides, ensuring the safety of Li-ion batteries is of utmost importance, especially in the context of electric vehicles. Research studies have mostly concentrated on developing early monitoring and warning systems to detect thermal runaway in Li-ion batteries. This is of utmost importance in guaranteeing the safety of electric vehicles [21]. The inducement analysis of thermal runaway is shown in Figure 2-4.

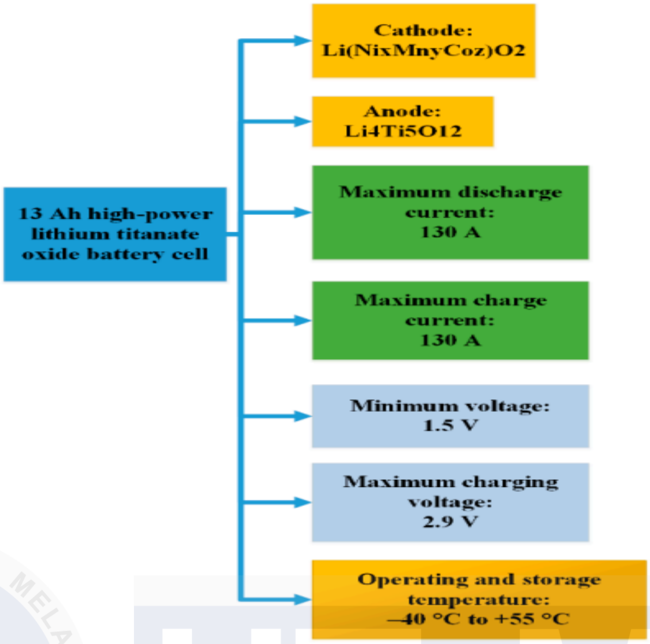


Figure 2-3 Characteristics of the lithium titanate oxide lithium-ion battery.

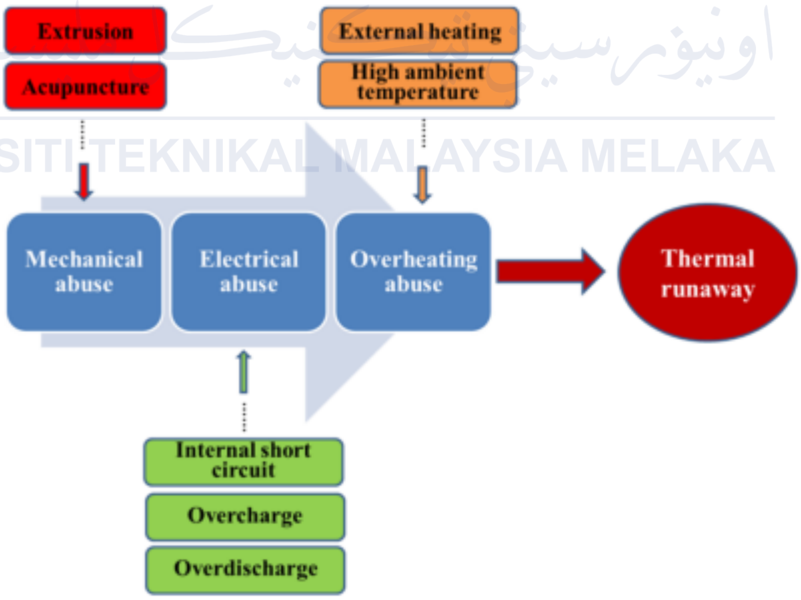


Figure 2-4 Inducement analysis of thermal runaway.

This emphasizes the need to tailor the Li-ion battery design to meet the specific needs of a four-seater electric vehicle, considering aspects such as energy density and charge/discharge rates. Moreover, the use of light to improve the efficiency of energy storage systems, such as Li-ion batteries, has been successfully shown [22]. To improve Li-ion battery efficiency in electric vehicles, photo-accelerated quick charging may be worth investigating. Li-ion battery mechanical integrity and safety boundary analysis have been studied, emphasising the necessity of mechanical strength and safety in electric car battery module design [23], [24], [25]

To summarize, electrical rickshaw design and performance evaluation require a solid understanding of Li-ion batteries. The literature emphasises lithium-ion (Li-ion) batteries' importance. These components' electrochemical behaviour, mechanical properties, and thermal safety are studied to optimise design and operational analysis due to their role in vehicle performance. Safety drives the development of early warning systems and the safe use of Li-ion batteries in electric vehiclesIt is necessary to customise batteries to match the energy density, charging speeds, and safety requirements of these vehicles. Li-ion battery efficiency can be enhanced by the utilisation of simulation models, novel materials, and light-based approaches. The essay proposes exploring the enhancement of Li-ion battery performance and safety in electric car technology through the investigation of photo-accelerated quick charging and mechanical strength.

2.3.2 Plug-in charging design

The power design of a new electric vehicle, which considers many operational, technological, and environmental concerns, is an essential element. The study examined the management and effects of electric vehicle (EV) charging on electric power systems. It focused on the positive impacts of controlled EV charging and discharging, including the provision of electrical services such as frequency regulation, voltage regulation, reactive power compensation, congestion management, and enhancement power quality [26]. This research offers provides vital insights on the impact of electric car charging on power systems, which are crucial for understanding the integration of electric vehicles into the power grid.

The authors [27] provided a valuable tool for assessing the potential value of battery swapping stations (BSS) resources in future distribution systems. They proposed a comprehensive and efficient method to evaluate the reliability advantages of electric vehicles (BSS), considering the specific characteristics of BSS. This study contributes to our understanding of the effects of electric car infrastructure, namely battery swapping stations, on the reliability of distribution systems. The importance of safety in the design and operation of electric car charging infrastructure is in addressing electrical safety concerns in large-scale charging stations. The power architecture of electric vehicle (EV) infrastructure is heavily reliant on the insights provided by this research regarding the safety characteristics of high-capacity charging stations for EVs. By creating a reference document that evaluates the impact of electric vehicles on the local power grid and provides policy recommendations to the government. This is done by estimating the charging demand of electric vehicles in different distribution network locations [28]. Planning and management of the electrical system to the understanding of the grid's planning and management by providing insights into the distribution of electric vehicle charging demand and its impact on the electrical system.

All these sources offer a comprehensive literature review on the power design of electrical rickshaws, covering themes such as reliability issues, safety measures, grid load modelling, and the impact of electric vehicle charging on power systems.

2.4 Design Structure of Electrical Rickshaw

The design characteristics of four-seater electric vehicle involve a wide variety of concerns that are critical for their performance, efficiency, and general functioning. The literature provides valuable insights into these design aspects. The authors in [29] emphasize the significance of combination of analytical calculations and simulation software (ANSYS) to design and analyze the chassis of a four-seater electric vehicle. The design approach considers varied materials and cross sections for the chassis elements, such as rectangular, square, tube, and C-channel. Furthermore, [30] provides insights into the Mimuro plot a graphical tool that uses four parameters derived from the bicycle model to evaluate the handling performance of the vehicle. The parameters are steady state yaw rate gain, natural frequency of yaw rate response, damping ratio of yaw rate response, and phase delay of lateral acceleration response at 1 Hz3. The plot forms a rhombus whose area and shape are correlated with the vehicle handling quality and stability. The gap in the literature on the comparison of handling performance between conventional and hybrid vehicles, and the need to consider the changes in mass and mass distribution due to the hybrid powertrain components.

Additionally, existing electronic stability control (ESC) strategies for four in-wheel-motor independent-drive electric vehicles (4MIDEVs), highlighting their limitations such as neglecting the influence of road adhesion coefficient and the difficulty of torque allocation under varying adhesion conditions [31]. It proposes a new hierarchical ESC strategy adaptive to the road adhesion coefficient, consisting of a reference model level, an upper-level controller, and a two-hierarchy lower-level controller. The paper claims that this strategy improves the steering stability and maneuverability of the 4MIDEV under varying road conditions and supports this claim with simulation and experimental results.

Similarly, [32] these findings highlight a combination of laboratory tests, numerical simulations, and design solutions to investigate the application of light metal alloy EN AW 6063 to vehicle frame construction with an innovated steering mechanism. The authors used metallographic analysis to look at the alloy's microstructure from various angles and after various heat treatments. Further, they performed fatigue tests to evaluate the fatigue life of the alloy and the welded joints when subjected to cyclic loading. They also conducted static tension tests to measure the tensile strength of both the alloy and the welded joints. Furthermore, numerical simulations were carried out to analyse the heat conductivity, deformations, and residual stresses in the welded material. Ultimately, they developed an innovative, eco-friendly tricycle equipped with a revamped front wheel steering mechanism. The drivetrain was comprised of an electric motor equipped with permanent magnets and a frame made of an aluminium alloy, namely EN AW 6063.T66.

Research on the electrical rickshaw highlights the value of using simulation software in conjunction with analytical calculations to get the best possible chassis design and the Mimuro plot as a tool for assessing handling performance. However, research gaps exist in comparing handling performance between conventional and hybrid vehicles and in adaptive ESC strategies for varying road conditions. For vehicle chassis, light metal alloys have great promise. One such example is EN AW 6063, which is used in a cutting-edge three-wheeled electric vehicle that features an inventive steering system. Further research is needed on handling performance comparison and improved ESC strategies, while innovative materials and engineering solutions hold promise for efficient, safe, and sustainable Electrical Rickshaw.

2.5 The Electric Rickshaw

The electric rickshaw has gained significant attention due to the rising need for environmentally friendly and effective urban transportation. Multiple investigations have concentrated on different facets pertaining to electric rickshaws, encompassing their construction, efficiency, charging infrastructure, and social ramifications.

In their study, [33] conducted research on the design of an electric rickshaw intended for usage in Kolkata, India. The objective was to improve upon the limitations of the existing cycle rickshaw and investigate the feasibility of using solar electricity. This study offers useful information about the design concerns and prospective applications of renewable energy sources for electric rickshaws. In addition, [34] did research examining the socioeconomic attributes of paratransit drivers and their attitudes towards electric three-wheeled rickshaws in Delhi, India. This study illuminates the drivers' perspectives and attitudes, which are vital elements in the effective acceptance and incorporation of electric rickshaws into the current transportation system.

Moreover, [35] examined the capacity of electric rickshaw charging stations to function as decentralized energy storage systems for incorporating intermittent renewable energy sources. An example of this novel approach is shown in Figure 5, in terms of an energy system in rural areas. The author emphasized the significance of infrastructure and energy management in facilitating the extensive adoption of electric rickshaws. Furthermore, [36] conducted a detailed analysis of the economic and technological aspects of solar-powered electric auto-rickshaws. Their study shed light on the practicality and long-term viability of solar-powered solutions for electric rickshaws in India.

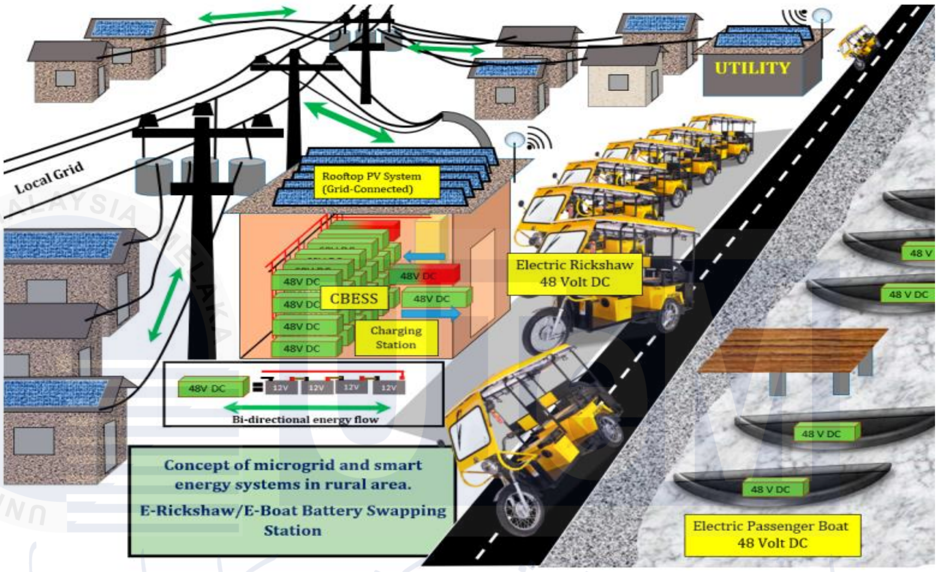


Figure 2-5 The concept of rural smart energy systems using a BSCS for e-rickshaws. Major components

These studies jointly enhance our comprehension of the design, functionality, and consequences of electric rickshaws, covering several topics including design considerations, socioeconomic variables, charging infrastructure, and integration of renewable energy.

2.6 Performance of Electric Rickshaw

The analysis of electric rickshaws has been a subject of interest in various studies. Through an experimental investigation, [37] investigated the performance of lead-acid battery-powered E-rickshaws augmented with a capacitor bank. Moreover, [38] highlighted efficiency and safety when discussing machine learning-based lithium-ion battery health prediction in hybrid automobiles. The authors [39] conducted thorough simulations and comparative studies of the electric propulsion motor for a solar/battery electric auto-rickshaw three-wheeler to shed light on propulsion systems. Affordability was identified by [40] as a critical factor driving the adoption of battery-operated rickshaws. Furthermore, [41] contributed by developing a benchmark fuel economy for hybrid electric rickshaws, comparing different control systems for optimal performance.

The study [42] delves into the integration of solar photovoltaic (PV) arrays with battery systems, presenting a model that employs voltage source inverters (VSI) and brushless direct current (BLDC) motors to power the rickshaws. This configuration not only bolsters energy efficiency but also contributes to the overall improvement of the vehicle's performance metrics. Moreover [43] , the development and analysis of switched reluctance motors specifically for e-rickshaws have been explored, which are instrumental in determining the speed and range capabilities of these vehicles.

These studies emphasise the need for a comprehensive approach to analyse and improve the performance of electric rickshaws. This approach should cover several aspects such as energy consumption, efficiency, speed, range, and regulatory factors.

2.7 Conclusion

The literature study on electrical rickshaw presents a captivating storyline: Although there is a growing need for electric rickshaw as an environmentally friendly and cost-effective mode of transportation, their extensive implementation is still impeded by many significant concerns. The literature indicates that the growth of these entities is hindered by a complicated interaction between inadequate infrastructure, technological constraints, and regulatory obstacles.

The performance analysis of electric rickshaws is a multifaceted domain encompassing various aspects such as design, economic viability, environmental benefits, battery technology, and overall system efficiency. Studies emphasise the need to optimise electric rickshaw design to address traditional model shortcomings and suit user needs. Electric rickshaws greatly reduce air pollution and carbon footprint. However, detailed economic evaluations are lacking, suggesting further research is needed to properly comprehend these vehicles' cost-effectiveness and economic benefits. Battery systems, especially lithium-ion ones, determine electric rickshaw efficiency and performance. These batteries are popular for their energy density, cycle life, and efficiency. Ensuring appropriate temperature management and safety and developing innovator improving methods to improve battery performance. Chassis materials, handling performance, and road stability are important while designing electric rickshaws. This rickshaw can be more efficient, safe, and sustainable with light metal alloys and advanced engineering. Studies aim to improve electric rickshaw propulsion, energy efficiency, and performance. Overall, the performance analysis of electric rickshaws requires a comprehensive approach that includes optimizing design, leveraging advanced battery technologies, understanding environmental and economic impacts, and improving overall system efficiency. Continued research and innovation in these areas will enhance the viability and sustainability of electric rickshaws as a key component of urban transportation.

CHAPTER 3

METHODOLOGY

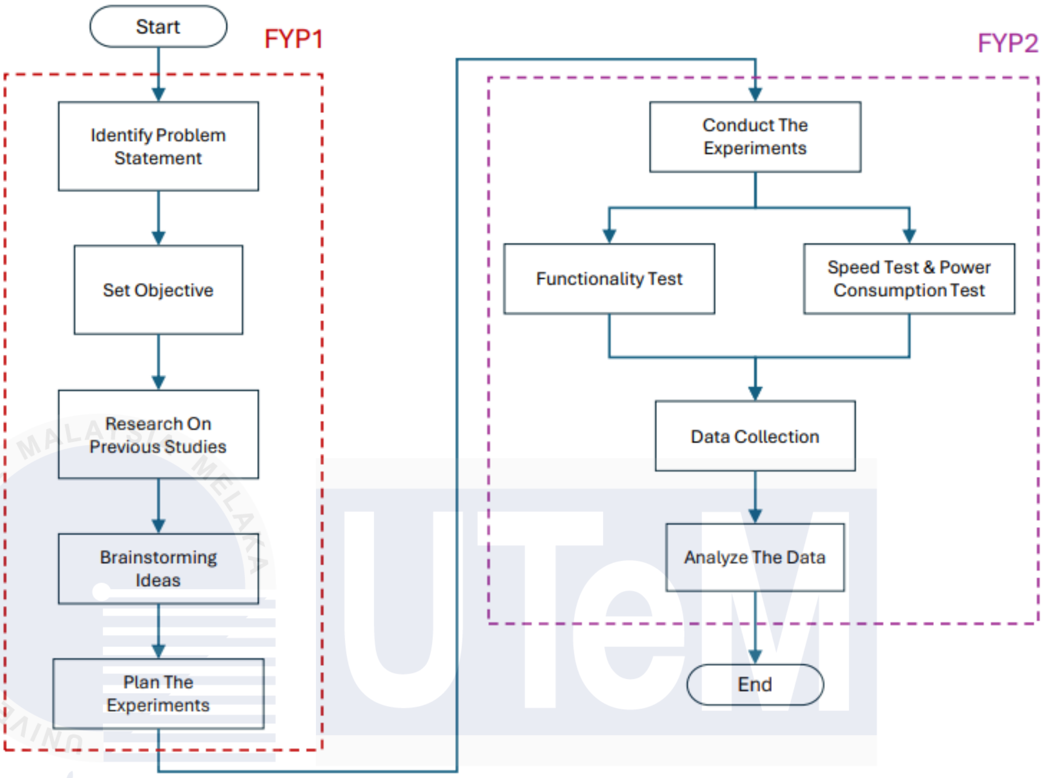
3.1 Introduction to the Methodology

A comprehensive technique is required for the performance analysis of electrical rickshaws. This methodology should encompass all aspects of sustainable transportation, including rickshaw technology and powertrain optimisation. The development of electric rickshaws has been influenced by factors such as market control, total cost of ownership, and the focus on eco-friendly transportation. Moreover, enhancing the electric drive trains and power trains has been a primary objective in enhancing the performance and efficiency of commercial fleets. Furthermore, the utilisation of modelling, simulation, and validation techniques has been crucial in resolving the shortcomings in research methodologies for the rapid development and validation of high-performance electric rickshaw powertrains

In addition, the investigated techniques to enhance the powertrain efficiency of electric rickshaw for certain routes and have also studied reliability-based design optimization methods to address vehicle vibrations. The complex nature of electric vehicle design and performance analysis. The present condition and future potential of electric motor utilization in electric rickshaw, together with the swift and efficient design of hybrid electric vehicle transmissions have played a significant role in the progress of electric rickshaw technology and technique.

To summarize, the process of the performance analysis of electric rickshaw involves several factors such as optimizing the powertrain, prioritizing sustainable transportation, incorporating hybrid technology, and conducting dynamic performance study. These approaches are essential for guaranteeing the effectiveness, dependability, and eco-friendliness of electric rickshaw, hence facilitating the advancement of sustainable transportation options.

3.1.1 Flow Chart Overview



3.2 Electrical Design

Electrical design consists of two parts: electrical components and electrical connection diagram. An overview of electrical components including its technical data or specifications was presented. The connection of the overall electrical components will be presented as well. Note that some of the components will not be introduced since they are not significant in this performance analysis.

3.2.1 Electrical Components

Electrical components includes the battery, motor and LED controller, regulator as well other devices.

Rechargeable Battery 48V Lithium Ion

Lithium is an active material in lithium batteries, which are a type of reusable battery. Because they have a higher energy density than other rechargeable batteries like nickel-cadmium or lead-acid batteries, they can store more energy per unit weight and volume, which has led to their widespread popularity. Lithium batteries come in different varieties, such as Li-ion (Li-ion), Li-polymer (LiPo), Lithium iron phosphate (LiFePO4), and others. Due to their large energy capacity and lightweight design, they are utilized in a wide range of gadgets, including laptops, electric cars, and renewable energy storage systems. However, it can have some drawbacks and safety issues such as the possibility of overheating and fires if they are damaged or handled incorrectly, despite their many benefits. Thus, using lithium batteries requires careful handling and attention.

Table 3-1 Technical Data of Rechargeable Battery

Battery Model	ES-48100
Battery Technology	LiFePO4
Nominal Voltage	48V
Nominal Capacity	100Ah
Nominal Energy	4.8KWh

Dimension (WxDxH)	483x500x177mm
Weight	50.8Kg
Boost Charge Voltage	54V
Discharge Cut-off Voltage	38-40.5V
Max Charge Current	100A
Recom. Charge Current	50A
Max Discharge Current	100A
Working Temperature Range	Discharge: -20°C to +60°C Charge: 0°C to +60°C Storage: -20°C to +60°C
Cycle Life	≥3000 Cycles @ 100% DOD @ 25°C
Communication	None
Safety Standard	CE, UN38.3
Design life	15+ years @25°C
Protection	Short circuit, over charge, over discharge, under charge, under discharge, over/under temperature etc.

Miniature Circuit Breaker (MCB)

The purpose of miniature circuit breakers (MCBs) is to safeguard electrical circuits against short circuits and overcurrents. Their amperage ratings, shown by the numerals 63A and 12A, indicate the maximum current that they can safely take. The term "63A MCB" describes a small circuit breaker that has a rated current of sixty-three amperes. It indicates that, in order to guard against overcurrents, this specific MCB is made to withstand currents of up to 63 amps before tripping and cutting the circuit. For bigger appliances or circuits that need more power, these higher-rated MCBs are frequently utilized. Similarly, the term “20A MCB” indicate that it has a rated current of 12 amps. It is intended for lesser current-drawing circuits or devices. Smaller appliances, lighting circuits, or circuits with reduced power requirements might make use of these compared to those that would require a “63A MCB”.

Table 3-2 Technical Data of MCB

Type	DC MCB
Rated working voltage	DC12-240V
Rated current [In]	6A/10 A / 16 A / 20 A / 25 A / 32 A / 40 A / 50 A / 63 A (optional)
Two levels	2 P
Release technology	Thermomagnetic
Curve code	C
Breaking capacity	4 kA Ics=Icu
Uimp	4 kV
Mechanical durability	10000 cycles
Electrical life	2000 cycles
Operating temperature	-13°F(-25°C) ~ 140°F(60°C)
Mounting bracket	35 mm DIN rail
Tightening torque	2.5 N.m
Standard	IEC60898-2
Dimensions LxWxH	1.42 x 2.95 x 3.15 inches
Tightening torque	2.5 N.m
Standard	IEC60898-2
Dimensions LxWxH	1.42 x 2.95 x 3.15 inches

DC-DC Converter 36 - 96V to 12V 20A

An electronic circuit or device known as a DC-to-DC converter is used to change a direct current (DC) source from one voltage level to another. It can do this by bucking, bucking down, or changing the level using different topologies like buck, boost, buck-boost, or isolated converters. In many situations, where the input voltage has to be adjusted to meet the specifications of certain systems or devices, these converters are essential. By converting DC power from one voltage level to another, they are widely used in industrial equipment, renewable energy systems, portable electronics, and automobile electronics to effectively manage and regulate power delivery and ensure that different devices or system components operate as intended. The parameters of a DC-to-DC converter, including its input voltage range, output voltage, and current capacity, are described in the description "DC-DC Converter 36V - 96V to 12V 20A". The converter can produce a consistent 12V/20A output while accepting a broad range of input voltages, especially between 36V and 96V.

Table 3-3 Technical Data of DC-DC Converter

Input voltage	36-96V
Output voltage	12V
Output current	10A
Features	With short circuit, overcurrent, overvoltage protection and many other functions, to prevent damage during use.
Wiring	Red --input - Battery + 12V (output --LED +) Black - ground (sharing a common thread - Battery -)

RGB Control Box 12V

An RGB (Red, Green, and Blue) LED lighting arrangement that runs at a voltage of 12 volts is controlled by an RGB Control Box 12V. Users may usually adjust RGB LED strips or lights' colour, brightness, and occasionally their patterns or effects with this control box. It frequently has a number of features including the ability to be controlled by a remote, a variety of colour possibilities, several modes (such strobe, fade, or static hues), and perhaps even the ability to sync with sound or music. The control box’s operating voltage is indicated by the 12V specification. It may be used with 12 volts RGB LED lighting systems, which are widely utilized in accent lighting for automobiles, gaming settings, home decoration, and other applications where multi-coloured lighting that can be customized is needed.

Table 3-4 Technical Data of RGB Control Box

Working temperature	-20 °C to 60 °C
Power supply voltage	DC 12V
Output	3*2A
Function mode	20 mode
Dimensions LxWxH	62 x 35 x 23 mm
Static power consumption	<1W
Maximum load current	2A per way
Output power	12V <72W

DC Motor Controller by Lithium Battery

An electrical device called a DC motor controller controls the direction, speed, and power sent to a direct current motor. By controlling voltage and current, it works as a bridge between the power source and the motor, adjusting the motor's speed, torque, and direction of rotation. The complexity of these controllers ranges from simple resistors that change speed to more complicated systems like microcontroller-based setups or pulse-width modulation (PWM) controllers. Their capabilities include accurate speed control, reversal of direction, and torque management, which are useful for a variety of robots, industrial machinery, electric vehicle, and automation system applications. In addition to controlling speed and direction, these controllers frequently include protections against overcurrent and overvoltage to avoid damage to the motor and controller itself. This ensures reliable and secure motor operation under a wide range of conditions.

Table 3-5 Technical Data of Motor Controller

Controller	48V 1500W
Voltage	DC 36/48V
Rated Current	35±1A
Max Current	60±1A
Speed Set	1.1-4.2V Dual Model
Brake Input	Low Level
Booster	1 : 1

Twist Throttle

Twist throttle devices are seen on several electric motorcycles. By twisting the handlebar grip, riders can control the electric motor's speed and power. The electric bike motor receives a signal when the throttle is twisted. The engine powers up without pedaling using this signal. This function allows users to operate the motor and accelerate the electric bicycle without pedaling. Twist throttles help the riders start from a stop or climb steep parts without pedalling. This applies especially when the cyclist has to accelerate quickly.

Speaker Fidelity FT-204

The speaker which transforms electrical impulses into audible sound waves is a crucial part of audio systems. Speakers are used in many different settings and devices, such as public address systems, professional sound installations, home entertainment systems, and personal electronics like laptops and smartphones. They come in a variety of sizes and designs that are perfect for different audio needs and settings. It works by converting electrical information into mechanical vibrations that produce sound. It is made up of components like a voice coil, a magnet, and a diaphragm. Sound waves are produced when the diaphragm vibrates due to an electrical current flowing through the voice coil and interacting with the magnetic field created by the magnet. Because enclosures and cabinets can affect how sound waves are dispersed, they can improve the quality of sound produced by some speakers.

Table 3-6 Technical Data of Speaker

Model	FT-204
Rated Power	20W
Voltage Input	110V
Impedance	8Ω
Sensitivity	92dB
Frequency Response	60-18kHz
Dimensions L x W x H	250 x 140 x 130mm

Amplifier Wiring Kit

An amplifier wiring kit is needed to install an aftermarket amplifier in a rickshaw's audio system. The grounding wire ensures a stable, interference-free electrical connection for better amplifier performance. Safety is improved by the fuse and holder in the package, which prevents spikes in electricity. The high-quality signal wires deliver audio signals from the head unit to the amplifier with consistency. Overall, the wiring kit protects the rickshaw's electrical components and gives the amplifier power, signal, and grounding connections for reliable and amazing sound.

3.3 Development Drawing Design

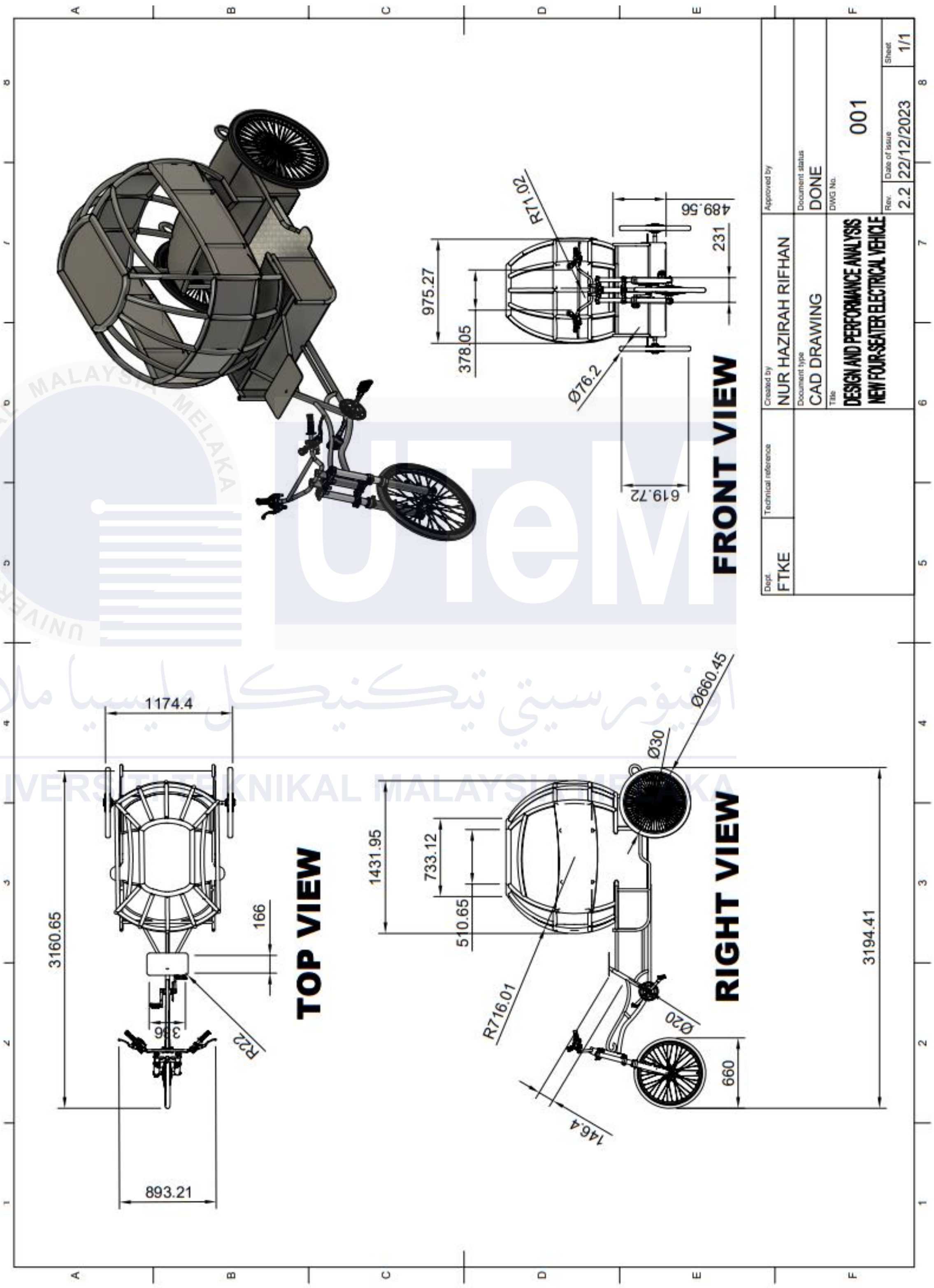


Figure 3-1 Drawing Design of Electric Rickshaw using Fusion 360

Figure 3-1 shows the technical drawing design for Electric Rickshaw. The design presents several views of the rickshaw, including the top, right, and front views accompanied by dimensions.

3.4 Experimental setup

To comprehensively test and evaluate the proposed Performance Analysis of Electrical Rickshaw, a robust experimental setup was designed and implemented. This experimental setup consisted of a variety of components, each fulfilling a specific role in the system.

3.4.1 Experimental 1: Analyze an electric rickshaw with an integrated electric motorized system.

The experiment configuration functions as the fundamental element that supports the entire investigative procedure, determining the precision and dependability of the acquired outcomes. Analyzing an electric rickshaw's system entails doing thorough design specifications, and testing the functionalities of the component's voltage measurement through a series of procedures to ensure the proper functioning of all components and that the rickshaw operates safely.

Design specifications:

Apparatus:

- Fusion 360 software.

Procedure for design specifications:

1. Applying Fusion 360 for the purpose of designing an electric rickshaw.

2. Determine the dimensions, proportions, and maximum load-bearing capability of the rickshaw to ensure optimal comfort for passengers.

Validating for the functionalities of the component's voltage measurement

Equipment:

- Digital Multimeter
- Voltage calibrator
- Clamp meter
- Battery 48v
- Battery 12v
- Smart brushless controller
- BLDC motor
- RGB LED
- Constant current LED
- Reverse Camera
- Android player
- Speaker

Procedure for voltage measurement:

1. Setup the multimeter:

    - Turn on the multimeter and set it to the voltage measuring mode. Choose the suitable voltage range for the anticipated measurements.

    - Connect the multimeter's probes: Red to the positive terminal (+) and Black to the negative terminal (-).

2. Repeat procedure no 1 to measure the voltage on each device.

    - Read the voltage displayed on the multimeter.

- Note down the voltage measurements for each device. Make sure to label them accordingly for reference.

3. Safety Precautions.

   - Upon completion of measurements, power off the device and safely disconnect any connections established with the multimeter.

3.4.2 Experimental 2: Validate the performance of the real-world testing based on speed, acceleration, and power consumption.

The experiment aims to thoroughly examine the performance of an electric rickshaw, concentrating on key parameters such as acceleration, speed, and power consumption. The weight of the driver is 45 kg in this experiment.

The real-world testing based on speed and acceleration:

Equipment:

- Clamp Meter
- Digital Multimeter
- Speedometers
- Speed sensor wireless
- Cruise Control Throttle Lock

Apparatus:

- Strava Application
- Google Earth Pro Cruise

Use of Cruise Control Throttle Lock:

To guarantee that the rickshaw keeps a steady speed during the experiment, the cruise control throttle lock is a crucial component. The speed may be adjusted by pressing the unlock button (N) and the lock button (Y). By locking the throttle at a fixed position, can eliminate variations in speed that might arise from manual throttle control, leading to more precise measurements of speed, acceleration, and power consumption.

Figure 3-2 Cruise Control Throttle Lock

Throttle Turn Percentage:

Throttle input is measured in percentage, which indicates the degree to which the throttle is engaged. For my setup, a 15% throttle turn means speed 1, 40% throttle turn means speed 2 and 100% throttle turn means speed 3. This percentage allows precise control over rickshaw speed. The rickshaw's operating speed is standardised for every test run by setting the throttle turn to a specific percentage. The maximum twist distance is 2cm, speed 1 twist distance is 0.3cm, speed 2 twist distance is 0.8cm, and speed 3 twist distance is 2cm.

Table 3-7 Table of Twist of the Throttle

Speed	Twist of the throttle
Speed 1	$\frac{0.3\text{cm}}{2\text{cm}} \times 100\% = 15\%$
Speed 2	$\frac{0.8\text{cm}}{2\text{cm}} \times 100\% = 40\%$
Speed 3	$\frac{2\text{cm}}{2\text{cm}} \times 100\% = 100\%$

The real-world testing based on speed and acceleration:

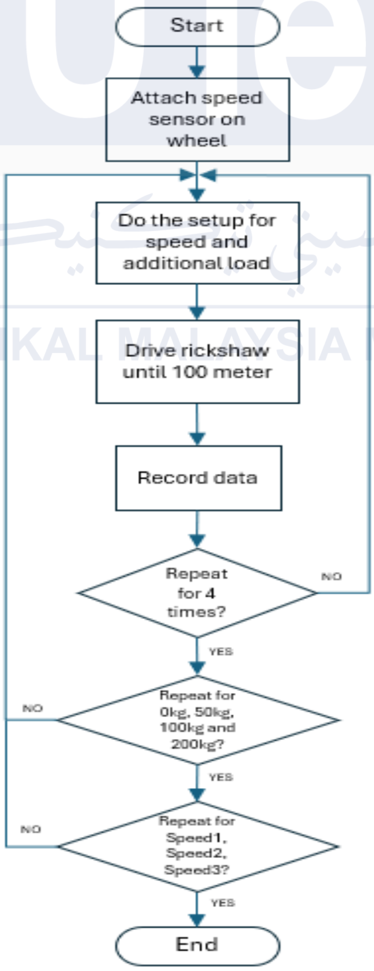


Figure 3-3 The real-world testing based on speed and acceleration

Procedure:

1. To begin the experiment, calibrate a speedometer. For real-time data tracking, install the wireless speed sensor, and link it to the Strava app.

2. Place the electric rickshaw on a test track that is horizontal. The first test with weight no load (0kg) commenced, 15% throttle turn was applied to achieve speed 1. To guarantee precise distance measurement, reset the speedometer's trip mete to zero.

3. The rickshaw was loaded with the specified weights for each test condition: No load (0kg), 50kg, 100kg and 200kg.

4. Start the rickshaw and gradually accelerate to the desired test speed. Upon reaching the desired velocity, use the cruise control throttle lock to sustain this pace steadily for the duration of the experiment.

5. After completing the first test run, the process was repeated three more times for load 1 with speed

6. The test continued with speeds 2 and 3 with a throttle of 40% and 100% turn was applied. The same procedure was followed for loads 50kg, 100kg and 200kg and 4 test runs were conducted for each load.

7. The data collected during the test was carefully documented. The average speed, the maximum speed and the total time taken for each test condition were recorded in the Strava application.

8. Consistency checks, conduct multiple acceleration and speed tests to ensure consistency and reliability of the recorded times.

9. Performance validation, compare the obtained results against design specifications and industry standards to validate the rickshaw's performance.

The real-world testing based on power consumption:

There are three parts: Three different cases of terrain, three different angles of inclination, and ride a rickshaw around the FTKE's building. Each of the parts are deduced different set of results and conclusions.

Equipment:

- Clamp Meter
- Digital Multimeter
- Speedometers
- Cruise Control Throttle Lock

Apparatus:

- Strava Application
- Google Earth Pro Cruise

Part 1: Three different cases of terrain (horizontal, uphill, downhill):

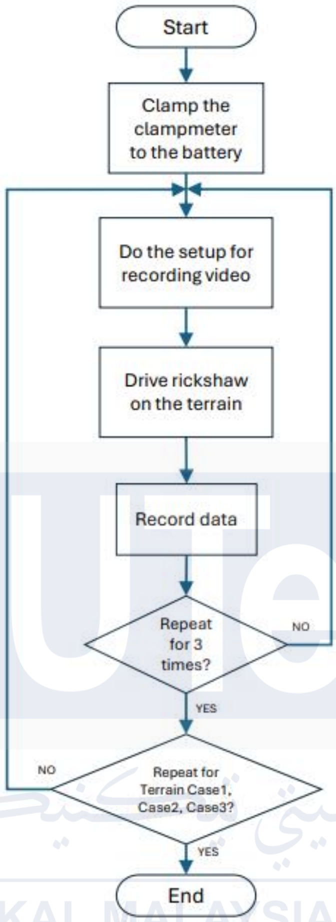


Figure 3-4 The real-world testing based on power consumption Part 1

Procedure:

1. Choose three different cases of terrain (horizontal, uphill, and downhill) with the same time constant for the power consumption tests. The starting point of the inclination is marked.

2. 30 meters distance is measured using measure tape from the beginning inclination and the ending point of measurement is marked as in the figure below.

Figure 3-5 Measuring 30 meter using measure tape

3. The clamp meter is set to DC current measurement, and the wire that is connected to the positive terminal of battery is clamped. The setup to record the video of changing currents is set as figure below.

Figure 3-6 Setup to record the video of changing currents

4. The video recorder starts to record as soon as the rickshaw starts to move and stops to record when reaches the ending point. Start recording using a speedometer connected to the Strava application after the initial 5 meters to ensure a consistent speed is achieved.

5. Apply 100% twist of the throttle when starting to move up each terrain.

6. The data of the currents is documented from the recording video.

7. Step 4 to Step 6 is repeated three times.

8. Step 7 also is repeated until all the different types of terrains such as horizontal terrain, uphill and downhill cases are done.

9. All the recorded data is re-organized and discussed.

10. Consistency checks, conduct multiple current tests to ensure consistency and reliability of the recorded times.

11. Performance validation, compare the obtained results against design specifications and industry standards to validate the rickshaw's performance.

12. Compare the power consumption across the three different cases of terrain based on the recorded.

Part 2: Three different angles of inclinations ($\theta = 2.25°, 3.15°, 6.10°$)

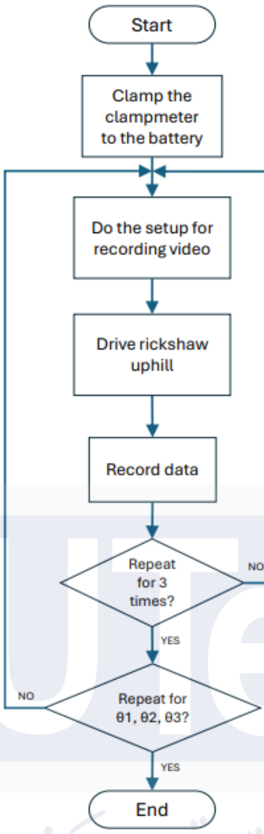


Figure 3-7 The real-world testing based on power consumption Part 2

Procedure:

1. Choose three different hills with varying inclines for the power consumption tests. By using the Google Earth Pro, the angle of the terrain is determined by calculation as below:

a. Angle of Lapang Sasar Memanah UTeM Road Route

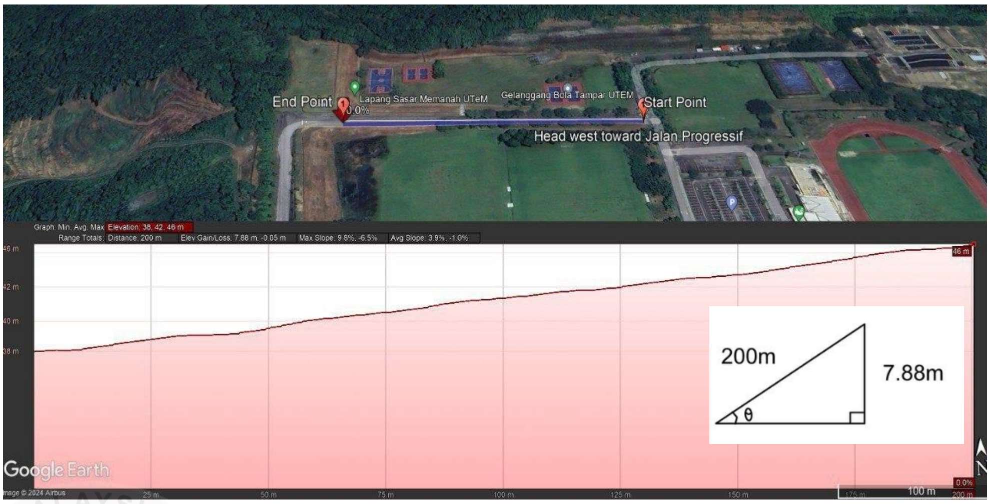


Figure 3-8 Roadway for angle 1 use Google Earth Pro

Elevation Gain = 7.88m

$$\sin\theta = \frac{7.88}{200}$$

$$= 2.25°$$

b. Angle of next to the Café FTKE building

Figure 3-9 Roadway for angle 2 use Google Earth Pro

Elevation Gain =1.65m

$$\sin\theta = \frac{1.65}{30}$$

$$= 3.15°$$

c. Angle of next to FTKE block D building

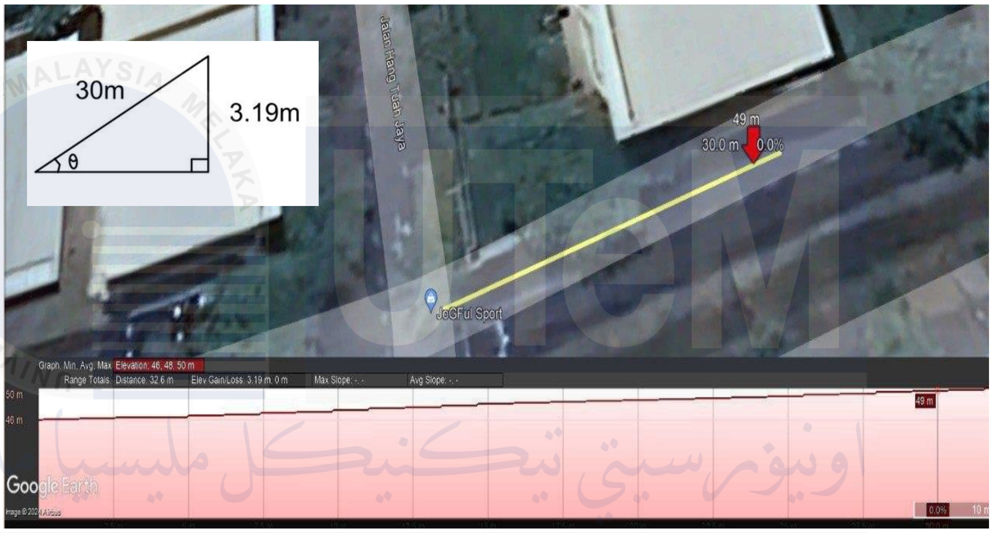


Figure 3-10 Roadway for angle 3 use Google Earth Pro

Elevation Gain = 3m

$$\sin\theta = \frac{3.19}{30}$$

$$= 6.10°$$

2. 30 meters distance is measured using measure tape from the beginning inclination and the ending point of measurement is marked.

3. The clamp meter is set to DC current measurement, and the wire that is connected to the positive terminal of battery is clamped. The setup to record the video of changing currents.

4. The video recorder starts to record as soon as the rickshaw starts to move and stops to record when reaches the ending point. Start recording using a speedometer connected to the Strava application after the initial 5 meters to ensure a consistent speed is achieved.

5. Apply 100% twist of the throttle when starting to move up each hill.

6. All the recorded data is re-organized and discussed.

7. Step 4 to Step 6 is repeated three times.

8. Step 7 also is repeated until all the three different angles of inclinations are done.

9. Consistency checks, conduct multiple current and tests to ensure consistency and reliability of the recorded times.

10. Performance validation, compare the obtained results against design specifications and industry standards to validate the rickshaw's performance.

11. Compare the power consumption across different angles of inclinations based on the recorded.

Part 3: Travel around the FTKE's building

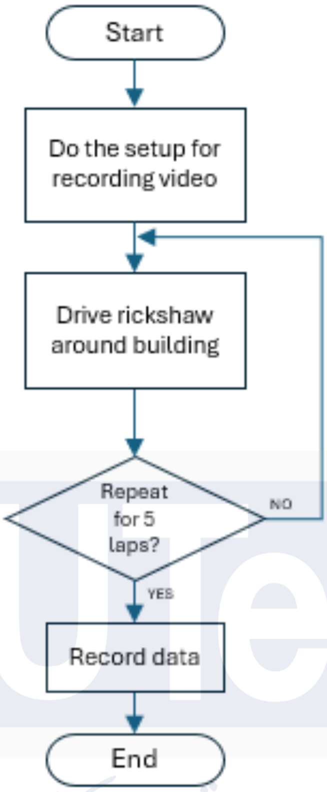


Figure 3-11 The real-world testing based on power consumption Part 3

Procedure:

1. The starting and ending point of this experiment is decided as shows in figure below:

Figure 3-12 Route of Road near FTKE's Building

2. Connect a multimeter in parallel and the wire that is connected to the positive terminal of battery. Record the initial voltage reading. The setup to record the video of changing voltage.

3. The video recorder starts to record as soon as the rickshaw starts to move and stops to record when reaches the ending point. Start recording using a speedometer connected to the Strava application after the initial 5 meters to ensure a consistent speed is achieved.

4. The rickshaw is driven for 5 consecutive laps, around the FTKE's building. Video recorders are stopped to record when the rickshaw has fulfilled the 5 consecutive laps and reached the ending point.

5. Then, the voltages of the rickshaw throughout the consecutive laps are documented with intervals of 15 seconds for the total of 12 minutes 35 seconds.
6. The voltage behavior is discussed.

7. Consistency checks, conduct multiple current tests to ensure consistency and reliability of the recorded times.

8. Performance validation, compare the obtained results against design specifications and industry standards to validate the rickshaw's performance.

3.5 Reliability of data

The reliability of the experimental setup for the Performance Analysis of Electrical Rickshaw is ensured through meticulous design and thorough validation procedures. The all-encompassing strategy includes several parts and distinct functions inside the system, ensuring precision and uniformity in the outcomes. The initial experiment involved meticulous consideration of size, dimensions, and load-bearing capacity when creating the electric rickshaw's specifications using Fusion 360 software. A comprehensive validation method was carried out to ensure the proper and safe functioning of every component of the voltage measurement apparatus, including a voltage calibrator, digital multimeter, and other critical tools. Conducting many repetitions of each test aids in detecting any discrepancies or irregularities in the data, enabling a more thorough validation of the rickshaw's performance. The second experiment involved conducting real-world tests to validate the performance of acceleration, speed, and power consumption under different loads and topographical conditions. In order to guarantee the precision of the collected data, multiple tests were conducted, and consistency checks were performed. In order to validate the efficiency and security of the rickshaw, its performance was assessed based on predetermined design standards and established industry benchmarks. The implementation of a systematic and thorough methodology in both studies guarantees a high level of dependability and precision in the evaluation of the electrical rickshaw's performance.

3.6 Ethics and Safety of Method

When analysing the performance of an electrical rickshaw, it is important to consider many ethical considerations such as safety, environmental impact, social equity, and cultural sensitivity. Prioritising the safety of passengers, pedestrians, and other individuals on the road is of paramount significance, and safety is given the highest priority. To accomplish this, it is necessary to evaluate the reliability of the rickshaw, the effectiveness of its safety mechanisms, and its adherence to regulations governing its design and operation. Devoting oneself to safety yields two advantages: protecting lives and fulfilling the ethical responsibility to preserve human well-being.

Ensuring safety is of utmost importance when conducting tests on electrical rickshaws, which involves doing a thorough evaluation of potential risks and implementing appropriate measures to minimise those risks. A malfunction or breakdown of a rickshaw could result in accidents or loss of control. Regular maintenance inspections should identify and rectify potential malfunctions to prevent this from occurring. Implementing backup vehicles and emergency shutdown methods can mitigate the consequences of unexpected failures, hence enhancing the safety of experiments. Weather is another factor that poses a risk to the safety of the experiment. Inclement weather conditions such as rainfall or powerful gusts of wind can undermine the stability and control of a rickshaw. Monitor meteorological predictions and adjust study schedules in the event of unfavourable weather conditions to mitigate this potential hazard. In addition, enhancing drivers' safety by providing them with appropriate protective attire and ensuring that the rickshaw's tyres and brakes are suitable for wet or slippery surfaces can enhance safety during unfavourable weather conditions.

Researchers can conduct thorough assessments of electric rickshaw performance while minimising risks to all parties involved by systematically addressing these ethical and safety considerations throughout the experimental phase. Promoting a prioritisation of safety not only upholds ethical norms but also enhances the credibility and reliability of the research findings, thereby contributing to the responsible and sustainable advancement of transportation technology.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results and Discussions

4.1.1 Experimental 1: Analyze an electric rickshaw with an integrated electric motorized system

The result of analyzing an electric rickshaw's system entails doing thorough design specifications and testing the functionalities of the component's voltage measurement.

Drawing Design Specification:

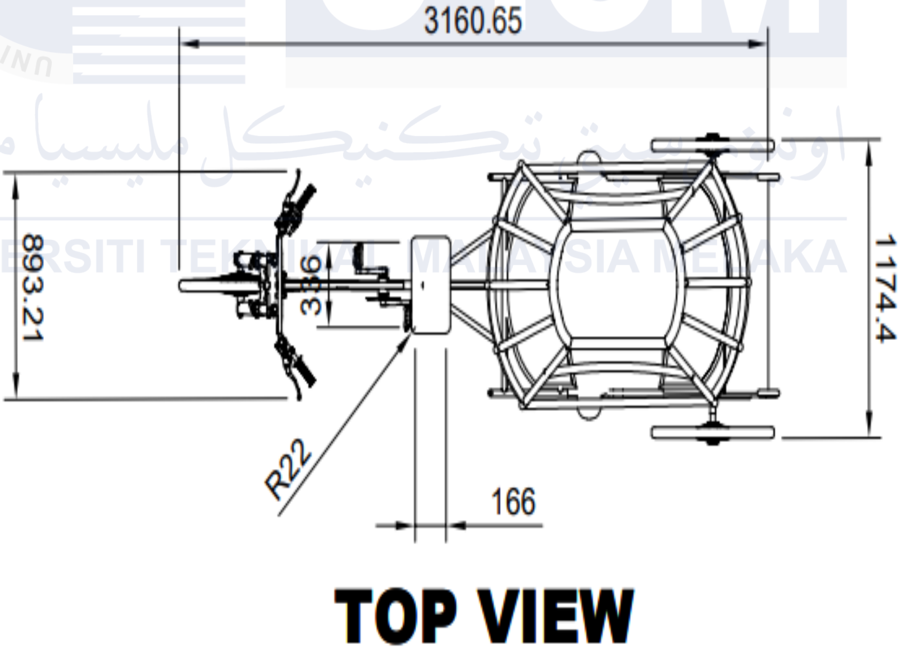


Figure 4-1 Top View of Electrical Rickshaw by using Fusion 360

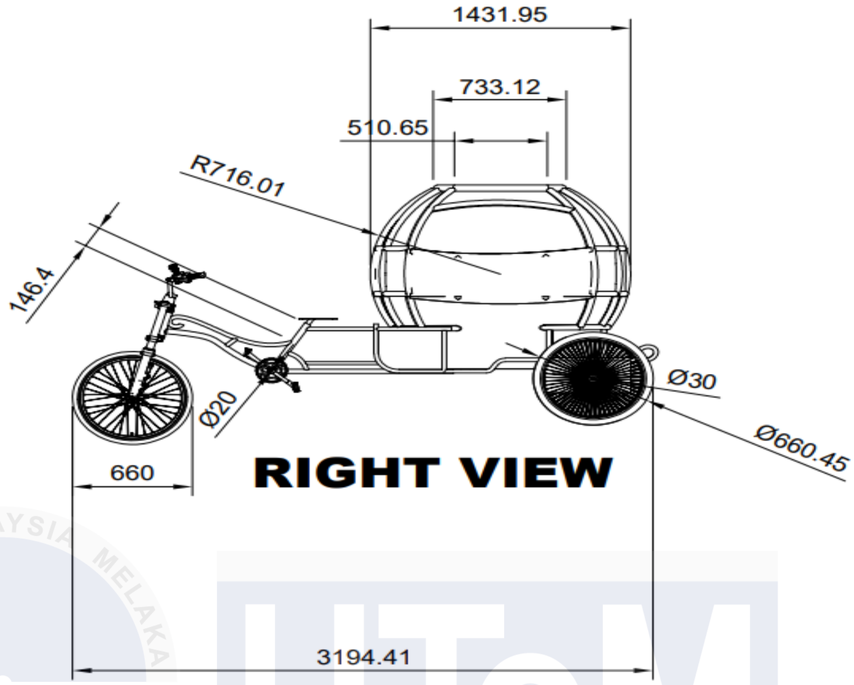


Figure 4-2 Right View of Electrical Rickshaw by using Fusion 360

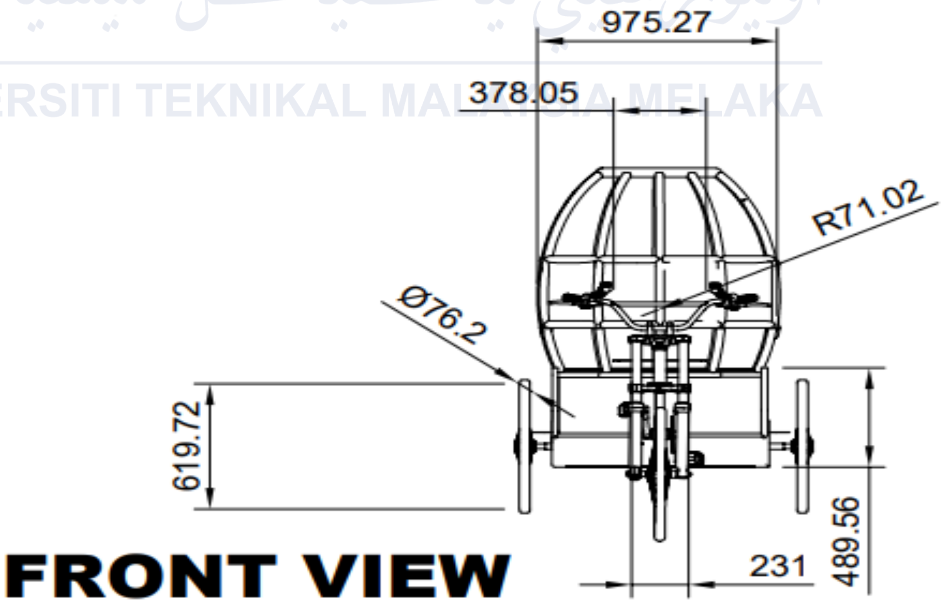


Figure 4-3 Front View of Electrical Rickshaw by using Fusion 360

The component's voltage measurement:

a. Lead-acid battery power supply 12V and 48V.

Figure 4-4 Lead-acid battery power supply 12V and 48V

The specifications of the Lead-acid battery power supply 12V and 48V used in the experimental setup are presented in the table below:

Table 4-1 The specifications of the Lead-acid Battery Power Supply

Features	12V Battery	48V Battery
Nominal Voltage	12V	48V
AH Capacity	80AH	625AH
Rechargeable	Yes	Yes

b. Stream brushless controller

Figure 4-5 Stream brushless controller

The specifications of the Stream Brushless Controller used in the experimental setup are presented in the table below:

Table 4-2 Specification of Stream Brushless Controller

Features	Specification
Item type	Smart Dual Mode Electric Vehicle Controller
Material	Aluminum
Rated Power	800W
Rated Voltage	41V/52V±0.5V
Limit Current	37A

c. Brushless Motor

Figure 4-6 The Electric Rickshaw Conversion Motor

Calculations are performed, battery weight 8kg, human maximum weight 3+4-person total weight 200kg, driver weight (45kg), and standstill or initial velocity of electric 0 and maximum velocity: 23.8km/h.

Parameter for calculation: I = 22A, V = 48v, P = 900W, N = 2700 RPM, Pole = 8.

Torque:

$$Torque, T = \frac{P(60)}{2\pi N}$$

$$Torque, T = \frac{900(60)}{2\pi(2700)}$$

$$T = 3.18Nm$$

Output power:

$$W = \frac{2\pi N}{60}$$

$$W = 282\ rad/sec$$

$$Pout = T\ x\ W$$

$$Pout = 896.76W$$

Efficiency:

$$\text{Pin} = \text{V x I}$$

$$\text{Pin} = 48 \text{ x } 22$$

$$\text{Pin} = 1056\text{W}$$

Efficiency:

$$\%\ n = \frac{Pout}{Pin}\ x\ 100$$

$$\%\ n = \frac{896.76}{1056}\ x\ 100$$

$$\%\ n = 84.92\%$$

Based on efficiency, motor power should now be larger than 700W. The present BLDC motor to propose the controller for the same and the specification for the existing motor as follows:

- Voltages: 48Vdc
- Rated power: 800W

- Speed: 2700 rpm
- Rated torque: 10Nm
- Peak torque: 25Nm
- Efficiency: > 85%

The specifications of the Electric Rickshaw Conversion Motor used in the experimental setup are presented in the table below:

Table 4-3 The Electric Rickshaw Conversion Motor

Features	Specification
Rated Voltage	48V
Rated Power	800W
Rated current	21A
Work system	S2 60min

d. LED

Figure 4-7 RGB LED

Figure 4-8 Single-color LED

The specifications of the LED used in the experimental setup are presented in the table below:

Table 4-4 Specifications of the LED

Product name	RGB LED	Single-color LED
Power	60W	6.2W
Input voltage	12V	24V
Emitting Color	RGB	2200K-6500K
Ingress Protection Rating (IP)	IP65	IP20/IP67

e. Reverse Camera

Figure 4-9 Reverse Camera

The specifications of the Reverse Camera used in the experimental setup are presented in the table below:

Table 4-5 Specifications of the Reverse Camera

Features	Specifications
Operating voltage	12V
Effective pixels	648 (H) x 448(V)
Operating Temperature	20º - 70º
View Angle	Diagonal viewing angle 170-degree, horizontal viewing angle 110 degree

f. Android Player

Figure 4-10 Android Player

The specifications of the speaker used in the experimental setup are presented in the table below:

Table 4-6 The specifications of the Android player

Features	Specification
Rated Voltage	12V
Output Power	180W

g. Speaker

Figure 4-11 Speaker

The specifications of the speaker used in the experimental setup are presented in the table below:

Table 4-7 The specifications of the Speaker

Features	Specifications
Rated power	20W
Line Voltage	110V
Sensitivity	89dB

Measuring the voltage of the device:

Table 4-8 Parameter Reading

Components	Parameter Reading
48V battery	48V
12V battery	12V
RGB LED	2V – 3.3V
Single-color LED	1.8V – 3.6V
Android Player	11.56 Watt
Reverse camera	1.6 Watt
Speaker	4 Ohm

The Electrical Rickshaw:

Figure 4-12 Right View of Electrical Rickshaw

Figure 4-13 Front View of Electrical Rickshaw

Figure 4-14 Back View of Electrical Rickshaw

4.2 Conclusion

Base on experimental analysis of an electric rickshaw with an integrated electric motorized system. Design standards, including Fusion 360 top, right, and front views, analyse a well-structured approach to adding components. Lead-acid batteries with 12V and 48V power supply offer enough energy for the rickshaw. Stream Brushless Controller, with 800W power and 41V/52V voltage, regulates and controls power for rickshaw performance. Critical components like the brushless motor transform electrical energy into mechanical energy with low losses at 84.92% efficiency. This efficiency with the motor's 48V rated voltage, 800W power, and 2700 RPM speed provides optimal performance under diverse conditions. With 3.18Nm of torque and 896.76W of output power, the motor meets the rickshaw's needs. This study helps optimize electric rickshaw operation for better performance, efficiency, and battery life in real-world applications.

Validate the performance of the real-world testing based on speed and acceleration, the measurement of acceleration in relation to load revealed a constant decrease in acceleration as the load grew, suggesting that the motor's capacity to achieve higher accelerations diminishes when subjected to bigger loads. The Speed 3 with the highest beginning accelerations also showed the most substantial decrease, highlighting that higher speeds are more negatively impacted by greater loads. The examination of power consumption in various terrains demonstrated that uphill travel necessitates the largest current, as it involves expending more energy to oppose gravity. Conversely, downhill travel requires much less current due to the help of gravitational forces. There was a direct relationship between power consumption and angle of inclination, meaning that steeper inclines required more power to be used.

Overall, the electric rickshaw's performance is heavily influenced by load and terrain. The findings underscore the importance of optimizing design and operational parameters to enhance efficiency and battery life. By understanding the power demands associated with different driving conditions, the rickshaw's usability can be significantly improved, ensuring reliable and efficient operation in real-world scenarios.

4.2.1 Experimental 2: Validate the performance of the real-world testing based on speed, acceleration, and power consumption.

4.2.1.1 The real-world testing based on speed and acceleration

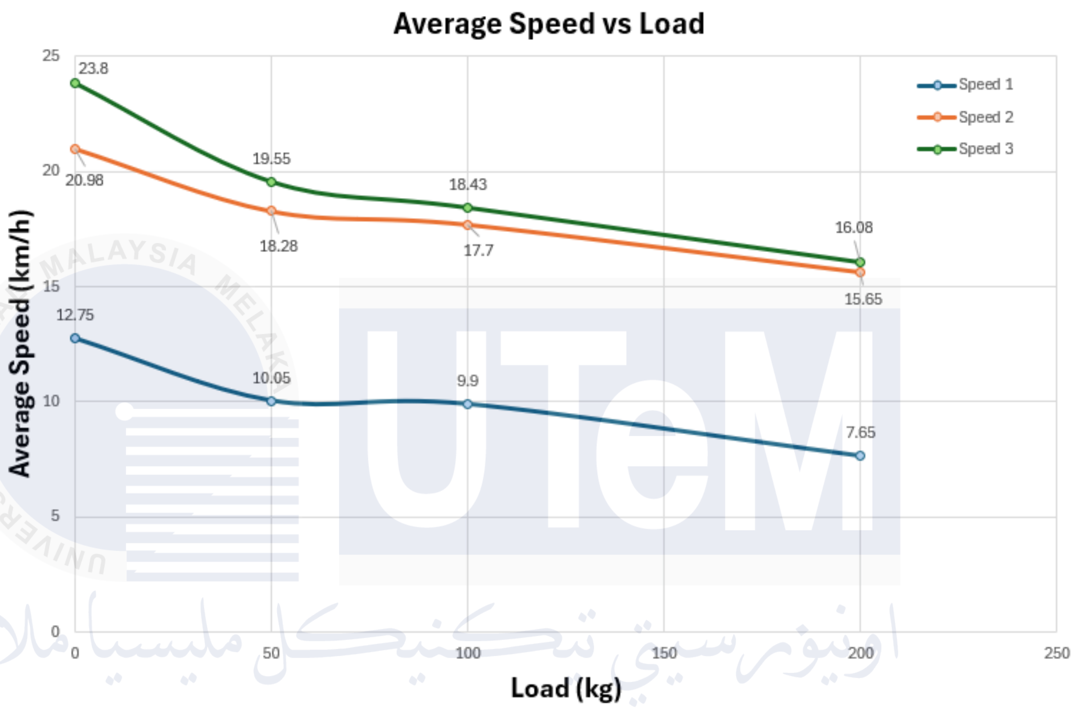


Figure 4-15 Graph of Average Speed vs Load

The graph that shows the relationship between average speed and load reveals that there is a clear decline in average speed as the load increases across all three speeds. The average speed drops from 12.75 km/h when there is no load to 7.65 km/h with load is 200kg. The speed reduces from 20.98 km/h to 15.65 km/h for Speed 2, and it decreases from 23.8 km/h to 16.08 km/h for Speed 3. As the load on the rickshaw increases, this pattern indicates that the motor's capacity to maintain higher speeds decreases. This is most likely due to the increasing power consumption that is required to overcome the additional load. Correspondingly, the Acceleration vs. Load graph below that compares acceleration to load demonstrates that the acceleration decreases in the same way as the load increases.

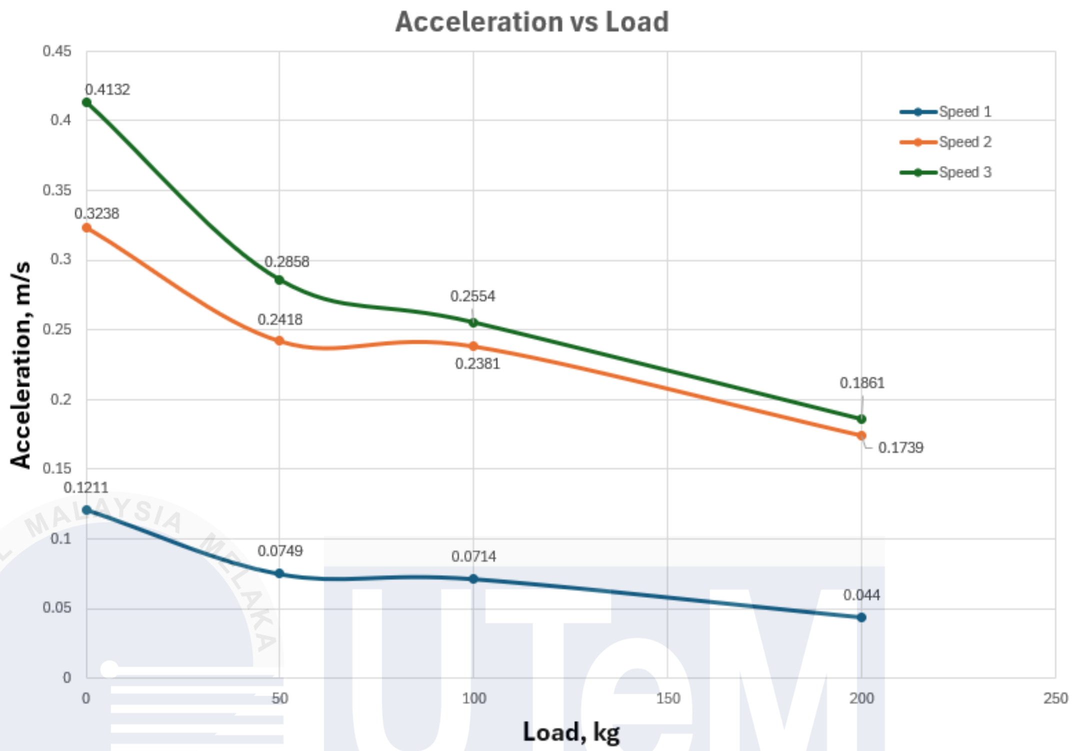


Figure 4-16 Graph of Acceleration vs Load

Experiments conducted to analyze the performance of electric rickshaws revealed several findings. Figure Graph of Acceleration vs Load discusses how acceleration and load relate to one another at various speeds. These tests involved a driver weighing 45kg and four different loads were measured on the electric rickshaw 0 kg, 50 kg, 100 kg, and 200 kg and three different speeds 1,2, 3.

Speed 1 consistently decreased as the load increased, starting from 0.1211 m/s^2 at 0 kg load to 0.044 m/s^2 at 200 kg load. This indicates a significant reduction in acceleration capability under heavier loads. Acceleration for Speed 2 decreases from 0.3238 m/s^2 at 0 kg to 0.1739 m/s^2 at 200 kg. The decrease is less pronounced than at Speed 1. In acceleration, 0.2418 m/s^2 at 50 kg to 0.2381 m/s^2 at 100kg shows only a slight decrease of 0.0037 m/s^2. However, it still shows a marginal decline in performance with added load. Speed 3 displayed the highest initial acceleration but underwent a significant decrease as the load increased from 50kg to 200kg. Initially, the acceleration was 0.4132 m/s² at 0 kg, but it dropped to 0.1861 m/s² at 200 kg. This indicates that higher speeds are noticeably affected by increased loads.

Overall, the performance of the electric rickshaw is heavily reliant on speed. Higher speeds result in better acceleration. The graph illustrates a consistent pattern of decreasing acceleration as the load increases at all speeds. This understanding is crucial for identifying constraints and enhancing the efficiency and performance of electric rickshaws.

4.2.1.2 The real-world testing based on power consumption

Part 1: Three different cases of terrain (horizontal, uphill, downhill)

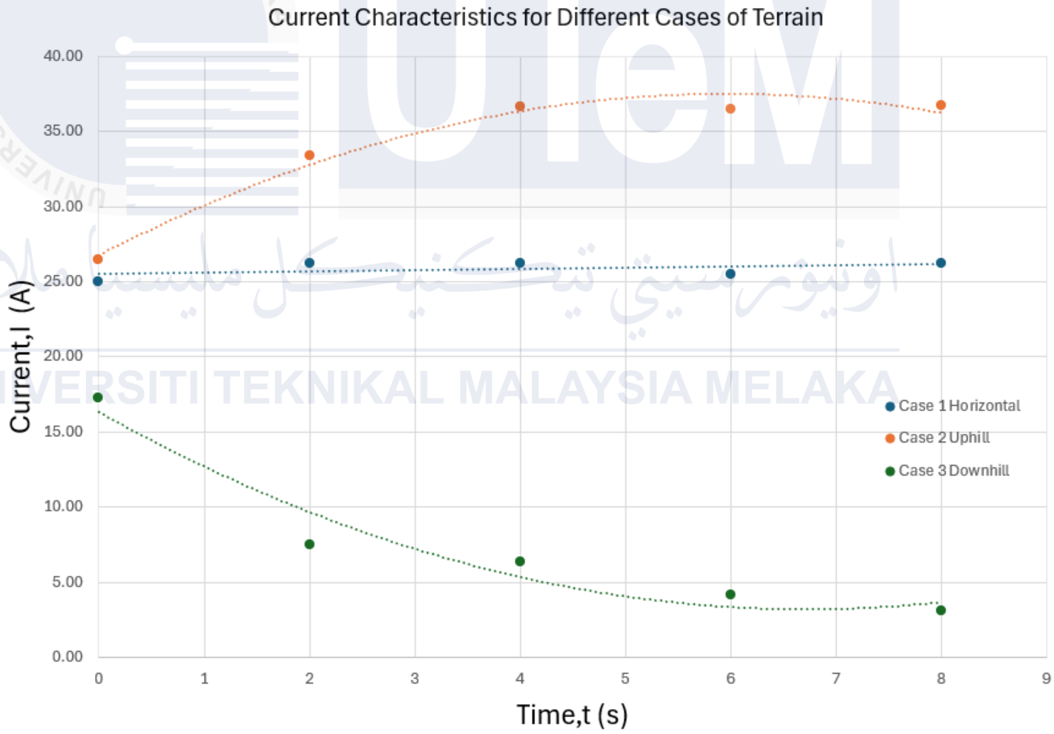


Figure 4-17 Graph of Current Characteristics for Different Cases of Terrain

Throughout the test, the recorded video records the current changes at intervals of 1 second every 10 seconds. Consequently, for every scenario with a standardized timeline, the average of the currents is computed through time.

The Graph of Current Characteristics for Different Cases of Terrain shows how different terrains impact the current required to move the rickshaw. The graph illustrates the current required by a rickshaw over time for three different terrains: flat or horizontal terrain (Case 1), uphill (Case 2), and downhill (Case 3). Initially, the uphill scenario demands the highest current which is around 36.7A, while the horizontal scenarios require moderate at around 25.8A and and downhill scenarios lower currents at around 7.6A respectively.

This pattern for the horizontal terrain shows that, to overcome inertia and start motion, the motor first needs a substantial amount of electric current on a horizontally flat surface. As the system reaches a stable state and remains in operation, the resistance and friction gradually reduce, resulting in a slight decrease in the amount of current being drawn. This indicates that after the initial time of starting up, the motor reaches a steady condition in which it operates as efficiently as possible with lower power demands.

Furthermore, when the road is going uphill, the initial current is the most out of the three situations, beginning at roughly 26.4A and gradually increasing to about 36.7A at the end of the specified time. The sustained high current indicates the motor's need to overcome gravity forces when traveling uphill due to higher demand. The gradual decline over time may be explained by little calibrates as the motor adjusts to a steadier operation. However, in general, the current level remains somewhat elevated due to the continuous requirement to counterbalance the inclination. This proves that maintaining motion against the force of gravity requires a higher energy consumption.

For downhill case, due to the aid of gravity, the motor need far less power to travel downward in a downhill scenario. The motor can frequently be set to operate in no-load or regenerative braking mode, which significantly lowers the amount of current it uses. Because the system uses gravitational forces to keep moving, not much energy is used.

Overall, by comparing different types of terrain, uphill slopes require the greatest and most constant flow of current, which indicates the extra power required to resist the force of gravity. The presence of a horizontal terrain indicates a consistent and modest consumption of energy, suggesting a state of equilibrium between overcoming resistance and ensuring optimal performance. This analysis highlights the differing power consumption patterns based on terrain, with uphill travel demanding more power and downhill travel requiring significantly less, which is crucial for optimizing battery usage and managing energy efficiency in electric rickshaw operations.

Part 2:Three different angles of inclinations ($\theta = 2.25°, 3.15°, 6.10°$)

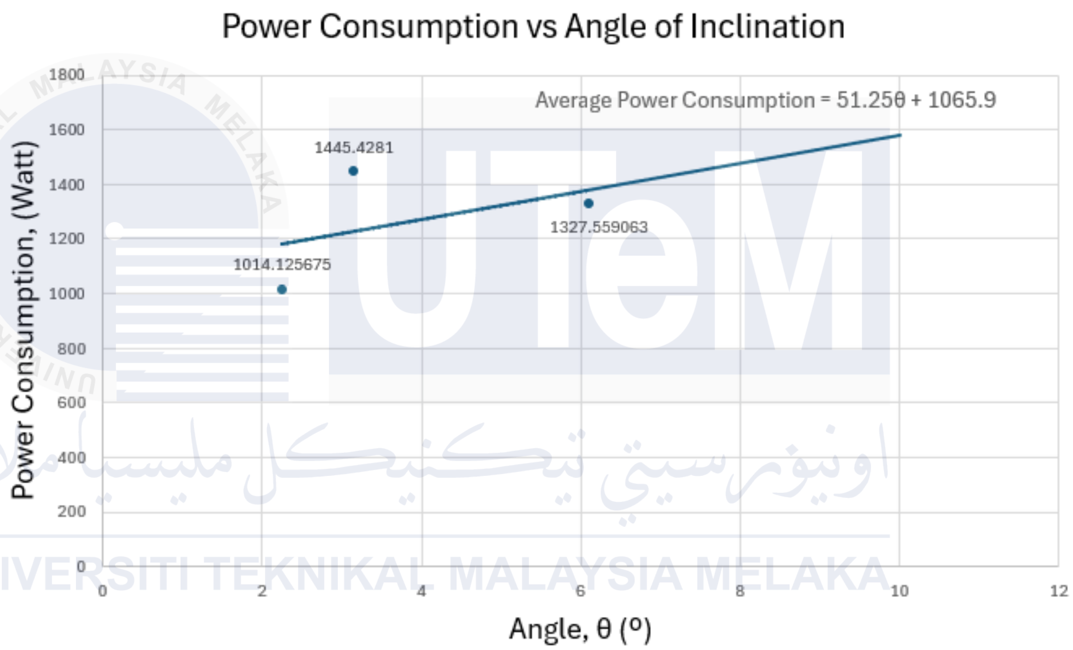


Figure 4-18 Graph of Power Consumption vs Angle of Inclination

Figure Graph of Power Consumption vs Angle of Inclination depicts the relationship between the angle of incline and the power consumption of an electrical rickshaw during real-world performance testing. The graph shows a positive correlation, indicating that as the angle increases, the power consumption also rises. This is quantified by the linear equation.

$$Average\ Power\ Consumption\ = 51.25\theta\ + 1065.9$$

An initial base consumption of 1065.9 watts, there is an approximate rise in power usage of 51.25 watts. This information is crucial for understanding how the rickshaw's energy requirements change with terrain and can be used to optimize its design and operation for energy efficiency and cost-effectiveness. This analysis highlights the impact of terrain inclination on the efficiency and power demands of electrical rickshaws for maximizing battery performance and consumption under a range of driving scenarios.

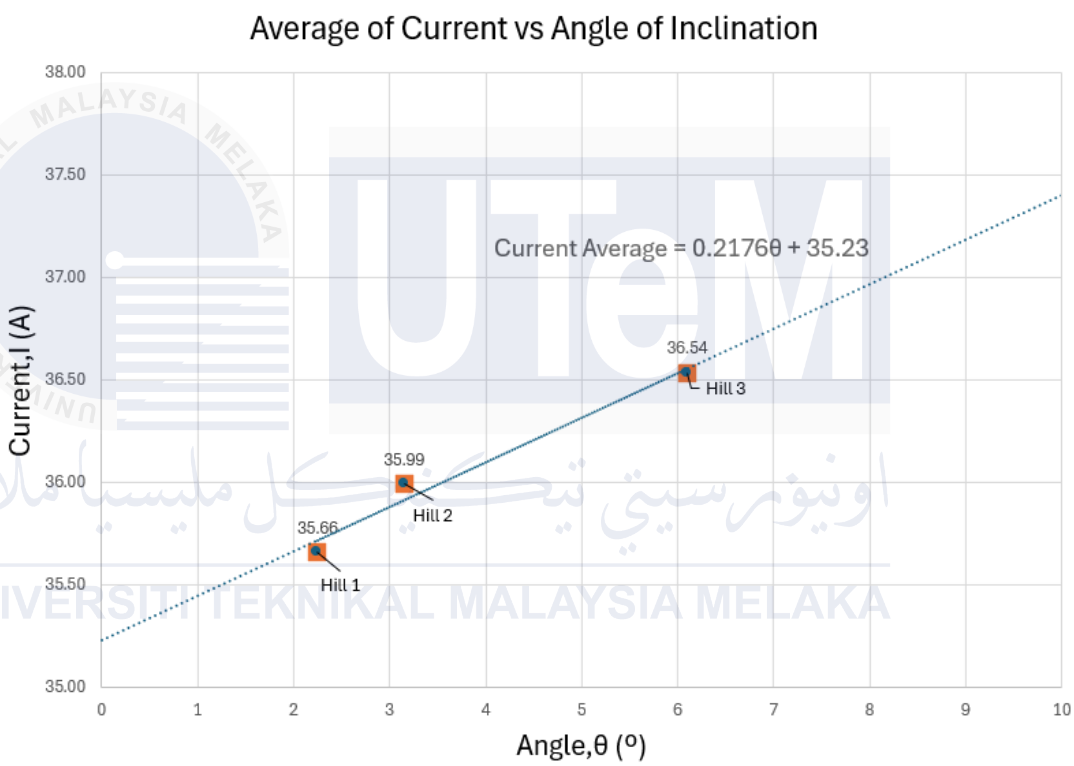


Figure 4-19 Graph of Average of Current vs Angle of Inclination

The current needed by an electrical rickshaw to climb different inclines during real-world testing is shown visually in Figure Graph of Average of Current vs Angle of Inclination. The graph indicates that steeper inclines demand more current because there is a positive link between the current and the hill's angle. The equation's representation of the trend line

$$Current\ Average = 0.2176\theta + 35.23$$

There is a clear positive correlation between the angle of the hill and the average current required. As the angle of the hill increases, the average current needed to move the rickshaw also increases. The steady linear trend demonstrates that both the motor and the system it operates have a reliable and predictable reaction to an increased load caused by steeper inclines. There is no unpredictable or nonlinear behavior because of the motor's efficiency, which is maintained at different inclinations and leads to a proportionate rise in the current draw. Based on the tested views, these results show that the motor operates efficiently, guaranteeing consistent and effective performance.

Given that the DC motor has a rated input current of 37A, using this value as the cut-off current it is estimated that the rickshaw can function up to an angle of inclination of 8.13º with the current increment per degree of inclination is 0.2176A/θ. However, the excessive weight of the structural design makes it difficult to accomplish this maximum angle value.

The motor's internal components would experience significant mechanical strain due to the constant operating at high inclines. The motor's windings, bearings, and other parts are made to withstand stress up to a certain point, which is determined by the rated current. Running at noticeably higher currents accelerates the degradation process, shortening the motor's life and increasing the likelihood of a mechanical failure. The overload structural design is not intended to minimize the long-term effects of continuous high-current operation; rather, it is intended to handle transient overloads.

Moreover, the motor's efficiency decreases while working above its designated current. Moreover, when the motor operates above its specified current, its efficiency drops. Efficiency curves and other design parameters of the motor have been optimised especially for its rated current. Elevated electrical currents cause a greater amount of energy to be lost as heat, which reduces the motor's overall efficiency. Because of this inefficiency, more input power is lost as heat rather than being converted into useful mechanical energy, which causes the overheating issue.

The purpose of the motor's safety mechanisms, such as current limiters and heat cut-offs, is to prevent it from going above safe operating limits. The motor's safety features frequently kick in to keep it safe when it tries to run at steep angles, like 8.13º. Due to these safety mechanisms, the motor would not be able to operate continuously at such high angles since they would periodically switch it off to prevent overheating and damage from excessive current.

Part 3: Travel around the FTKE’s building

The graph of Voltage vs Time for Five Consecutive Laps provides a detailed view of how the voltage varies over time. It displays both the instantaneous voltage measurements and a linear trend line that indicates the overall trend in voltage variation over the full timeline of the laps traveled. By observing the pattern of curve line, the number of laps traveled also can be determine, in this case it is 5 consecutive laps.

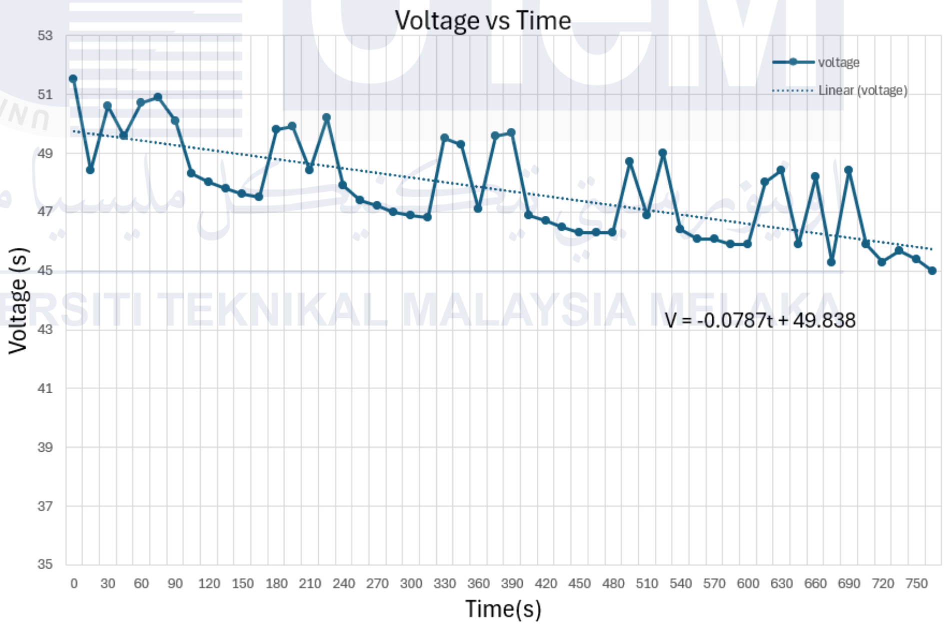


Figure 4-20 Graph of Voltage vs Time for Five Consecutive Laps

Along the graph, there are noticeable variations in voltage, characterized by recurring peaks and troughs. The fluctuations indicate dynamic changes in the power requirements of the system or fluctuations in the effectiveness of the power supplied. As an example, the voltage increases to approximately 51.5V at specific locations and decreases to approximately 45V at other locations. The oscillations may arise due to fluctuations in the system's load, with high-demand periods leading to a decrease in voltage and low-demand or recovery periods allowing for an increase.

Although there are regular changes, the linear trend line exhibits a distinct negative gradient, implying a progressive decline in voltage as time progresses. The overall decrease indicates that the system's power supply is undergoing a deficit in energy. This phenomenon displays the inherent discharge process that occurs as a lithium-ion battery gradually loses its stored energy. Alternatively, if the system is consistently relying on a continuous power supply, it could suggest a rise in inefficiencies or an increase in power requirements that the source cannot sustain permanently.

The graph exhibits significant voltage peaks at specified periods, particularly at around 75 seconds, 225 seconds, 330 seconds, 525 seconds, 630 seconds, 660 seconds and 690 seconds. These peaks indicate instances when the system experiences recharging, lower load circumstances, or receives a surge in power supply. The consistent gaps between these peaks reveal the presence of cyclical activities or actions within the system that momentarily decrease the power demand or increase the power intake, so enabling the voltage to regain its normal level.

Considering the nominal operating voltage of the DC Motor is 48V, can predict that the electrical rickshaw can operate for approximately 13 minutes 15 seconds. This estimation is based on a voltage depletion rate of 0.0787V/s while continuously driving laps around FTKE's building without making any stop for longer duration. The forecast duration is only 13 minutes 15 seconds since the chosen route primarily consists of uphill inclines, which require more strength for handling the load.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this study provides a comprehensive understanding of the operation and assessment of an electric rickshaw. Chapter 1 introduced the concept and reasoning behind the project, emphasising the need for a transport option that is both sustainable and efficient. The problem statement highlighted the challenges related to fuel consumption, pollution, and the performance of traditional rickshaws under various load and terrain conditions. The objectives were set to create an integrated electric motorized system by analyzing its components and validate its performance of the real-world testing based on speed, acceleration, and power consumption.

In Chapter 2, a thorough literature study was conducted on electric rickshaw fabrication, energy, design's structure, performance analysis methodology, and the existing research gap in this field. Based on its practicality and dependability in evaluating performance, the study concluded that the experimental testing approach is the most suitable for this project.

In Chapter 3, the method employed for the project was thoroughly explained. It encompassed analyzing and validating the rickshaw. By evaluating the functionality of electrical components and carrying out experiments to assess performance. The design process encompassed hand sketches, Fusion 360 drawings and was meticulously documented. The electrical components are tested to ensure they meet the specified requirements. For validating the rickshaw's understanding of the power demands associated with different driving conditions, the rickshaw's usability can be significantly improved, ensuring reliable and efficient operation in real-world scenarios.

In Chapter 4, the performance analysis findings were presented. Through the speed test, it became evident that there is a straightforward correlation between the load's mass and the average speed. Heavier loads resulted in reduced speeds. During the power consumption test, it was observed that steeper inclines led to an increase in current usage because of higher power requirements. The electric rickshaw can be predicted with the equation and several considerations. The consideration force that applied on the electric rickshaw is gravitational force, aerodynamic force and rolling force. The path journey also affects the performance of the electric rickshaw, the driving range of electric rickshaw on horizontal path is further than uphill path. This is because, on the uphill path, the electric rickshaw needs higher power consumption. By considering all the specification, the driving range, time of driving range and the power consumption of the car can be predicted. Additionally, different terrains had unique impacts on current consumption.

Finally, the research successfully analysed and validated the electric rickshaw and provided valuable insights into its performance in various situations. The findings highlight key areas for improving power management and efficiency, ensuring the rickshaw's reliability and effectiveness in real-world situations.

5.2 Recommendation

Through the ongoing advancement of electric rickshaw technology, there is a continuous drive to enhance the performance of electric rickshaw through extensive research and development. Here are suggestions for future research on improving the performance of electric rickshaw to obtain more accurate results:

i. The various types of roads that are used.

ii. Implement data logging systems to record various performance metrics such as battery usage, motor efficiency, speed, and load capacity.

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APPENDICES