DESIGN AND PROTOTYPING OF MOTORCYCLE RACKS FOR FOOD DELIVERY BAGS

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Tarikh: 12/1/2024

Tarikh: 09/02/2024

DECLARATION

I declare that this project entitled "Design and Prototyping of Motorcycle Racks for Food Delivery Bags " is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : Sharveen A/L Anandaraja

Date : 19/1/2024

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 with Honours.

Signature :

Supervisor Name : Dr. Fadhilah Binti Shikh Anuar

Date : 09/02/2024

DEDICATION

To my beloved parents,

Anandaraja A/L Kumarasamy and Punithavathy A/P Kanniah

Thank you for all of the support, belief in my abilities,

and countless sacrifices.

To my honourd supervisor,

Dr. Fadhilah Binti Shikh Anuar and all UTeM lecturers and staffs

Thank you for all of your guidance, expertise and encouragement

To help me complete this project thesis.

ABSTRACT

The food delivery industry's rapid growth has prompted the development of efficient and secure transportation systems to ensure the safe delivery of food products. The design and prototype of motorcycle racks particularly designed to safely safeguard food delivery bags during transportation. The study focuses on the difficulties that food delivery riders experience when securing and safeguarding food bags while riding motorbikes. A design strategy is offered based on a thorough examination of existing solutions and an understanding the needs of food delivery riders. The thesis project presents systematic design process, starting with conceptualization and finalizing with the fabrication of actual working prototypes. Many factors, including capacity for weight, stability, and ergonomic issues, were considered during the design phases. Finite Element Analysis (FEA) simulations were used to assess the structural integrity and endurance of the rack designs. Prototypes were created using materials and production procedures. A thorough testing methods were used to evaluate the performance of the motorcycle racks in relation to load-bearing capabilities, vibration resistance, and overall stability. A comparison analysis with current solutions and feedback from food delivery riders were used to examine the efficacy and practicality of the proposed design. In accordance with the findings, the proposed motorcycle racks offers a safe and reliable manner of transporting food delivery bags. Furthermore, they facilitate access to the bags and limit the possibility of leaking or damage during transit. The current problems for the existing racks are that most of the designs in the market do not have a movability design in order for accessing the refueling area below the seat compartment and majority of motorcycle racks on the market currently are not made with protection and security purposes in mind which can lead to accidental damage to the food delivery bag. The study's findings have significant implications for improving the effectiveness and reliability of food delivery firms, which will benefit both riders and consumers in the long run. Market survey results highlight challenges faced by food delivery riders, emphasizing the need for secure and durable rack solutions. Design A emerges as the preferred choice. Technical drawings, load distribution tests, Finite Element Analysis, and user testing validate the structural integrity and functionality of the prototype. Positive feedback on features like easy bag securing and a sliding mechanism for refueling indicates significant improvements in rider comfort and operational efficiency. The study sets the stage for future enhancements in motorcycle rack design for food delivery logistics.

ABSTRAK

Pertumbuhan pesat industri penghantaran makanan telah mendorong perkembangan sistem pengangkutan yang efisien dan selamat untuk memastikan penghantaran makanan dilakukan dengan selamat. Reka bentuk dan prototaip rak motosikal khusus direka untuk menjaga keselamatan beg penghantaran makanan semasa pengangkutan. Kajian ini memberi tumpuan kepada kesukaran yang dihadapi oleh pemandu penghantaran makanan dalam mengikat dan menjaga keselamatan beg makanan semasa menunggang motosikal. Strategi reka bentuk ditawarkan berdasarkan pemeriksaan terperinci terhadap penyelesaian sedia ada dan pemahaman terhadap keperluan pemandu penghantaran makanan. Projek tesis ini menyajikan proses reka bentuk sistematik, bermula dengan pemkonsepsian dan diakhiri dengan pembuatan prototaip berfungsi sebenar. Banyak faktor, termasuk kapasiti berat, kestabilan, dan isu ergonomik, dipertimbangkan semasa fasa reka bentuk. Simulasi Analisis Elemen Terhingga (FEA) digunakan untuk menilai integriti struktur dan ketahanan rekabentuk rak. Prototaip dibuat menggunakan bahan dan prosedur pengeluaran. Kaedah pengujian menyeluruh digunakan untuk menilai prestasi rak motosikal berhubung dengan keupayaan menanggung beban, rintangan getaran, dan keseluruhan kestabilan. Analisis perbandingan dengan penyelesaian semasa dan maklum balas daripada pemandu penghantaran makanan digunakan untuk mengkaji keberkesanan dan kepraktisan reka bentuk yang dicadangkan. Berdasarkan dapatan, rak motosikal yang dicadangkan menawarkan cara pengangkutan beg penghantaran makanan yang selamat dan boleh dipercayai. Selain itu, ia memudahkan akses kepada beg dan mengurangkan kemungkinan kebocoran atau kerosakan semasa pengangkutan. Masalah semasa bagi rekabentuk rak yang sedia ada adalah kebanyakan rekabentuk yang ada di pasaran tidak mempunyai reka bentuk boleh bergerak untuk mengakses kawasan pengisi bahan bakar di bawah kompartmen tempat duduk dan kebanyakan rak motosikal yang ada di pasaran pada masa ini tidak dibuat dengan tujuan perlindungan dan keselamatan yang boleh menyebabkan kerosakan tidak sengaja kepada beg penghantaran makanan. Dapatan kajian ini mempunyai implikasi yang signifikan untuk meningkatkan keberkesanan dan kebolehpercayaan syarikat penghantaran makanan, yang akan memberi manfaat kepada kedua-dua pemandu dan pengguna dalam jangka panjang. Hasil kajian pasaran menunjukkan cabaran yang dihadapi oleh pemandu penghantaran makanan, menekankan keperluan untuk penyelesaian rak yang selamat dan tahan lama. Reka Bentuk A muncul sebagai pilihan utama. Lukisan teknikal, ujian taburan beban, Analisis Elemen Terhingga, dan ujian pengguna mengesahkan integriti struktur dan fungsi prototaip. Maklum balas positif terhadap ciri-ciri seperti pengunci beg mudah dan mekanisme geseran untuk isian petrol menunjukkan peningkatan yang signifikan dalam keselesaan pemandu dan kecekapan operasi. Kajian ini menetapkan landasan untuk penambahbaikan masa depan dalam reka bentuk rak motosikal untuk logistik penghantaran makanan.

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LIST OF SYMBOLS AND ABBREVIATIONS

MIG	-	Metal Inert Gas
TIG	-	Tungsten Inert Gas
UTS	-	Ultimate Tensile Strength
A	-	Ampere
kN	-	Kilonewtons
mm	-	Millimetre
cm	-	Centimetre
h	-	Height
l	-	Length
w	-	Width
kg	-	Kilogram
m/s	-	Metre per second
W	-	Weight
N	-	Newton
m	-	Mass
a	-	Acceleration
F	-	Force
Pa	-	Pascal
RM	-	Malaysian ringgit

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CHAPTER 1

INTRODUCTION

1.1 Background

The services for delivering food through online platforms have significantly risen over the years and has revolutionized the way people receive their food. As the demand for food to be delivered quickly and efficiently through delivery services proliferated, motorcycles are the only form of transportation option for delivery riders to deliver food on time and effectively to their customers especially considering the heavy traffics in the cities. However, deliveries made on a motorcycle can be difficult at times, especially when there is a lack of practical and secure storing options for their food delivery bags.

At the moment, majority of foodpanda and grabfood riders only attach their food delivery bags temporarily onto the motorcycle body which can lead to recurring accidents of the bag losing balance and falling causing the contents in the food delivery bag to spill during transit. This will not only delay and cause inconvenience for the food delivery riders but also affect the quality of the services caused by the food getting damaged.

Acknowledging the necessity for an effective and reliable solution, this project aims to design a motorcycle rack prototype which can securely protect food delivery bags during deliveries. The main objective is not only to build a strong and practical motorcycle rack, but also to consider the convenience of the rider, specifically for refueling the motorcycle in between deliveries.

The primary objective of the design of the motorcycle rack is to include the strength, and also the foldability aspects. The rack must be strong enough to withstand the weight of food delivery bags with food contents filled inside and stable enough during high speeds without losing any balance for a much secure transportation of the delivery bags. Additionally, considering the refueling process for riders, the rack must also be able to fold easily so that riders and access the refueling area below the seat compartment without and difficulty or hindrance.

This project aims to include a comprehensive background on the design and prototyping of the motorcycle where stages such as research, analysis and development are considered to creating a rack plus with the discussion of the material selection, manufacturing process and also the structural considerations to construct the final design. The effective construction of a functional and reliable motorcycle rack can provide a significant benefit to the whole food delivery sector.

1.2 Problem Statement

Food delivery bags are usually large in size and fragile in design which can be difficult for food delivery riders necessitating for diligence handling and as well as protection. The primary problem that food delivery riders face is the lack of a secure and reliable method of delivering food orders because food delivery bags can be subjected to accidental damage during transit. The majority of motorcycle racks on the market currently are not made with protection and security purposes in mind which can lead to accidental damage to the food delivery bag.

Considering the key objectives which is developing a motorcycle rack that is strong and has a foldable mechanism for refueling process, the first issue that needs attention is the strength of the motorcycle rack. Taking into consideration of the rough rides in the cities and sudden movements plus with the various size of riders and their ages, the motorcycle rack must be suited to coping with the dynamic forces encountered during the riding operations, making sure that the delivery bags are securely held in position.

Moreover, the motorcycle rack must also implement a folding design in order for accessing the refueling area below the seat compartment much easier and simpler so that the riders can refuel their motorcycle quickly without and interruptions and continue with their delivery. Through resolving these mentioned issues, the proposed design of the motorcycle rack offers to provide an efficient and practical solution to securely protect food delivery bags. Problems such as food spillage, bag falling off accidentally can be avoided and enhance the overall convenience of the delivery process for the riders.

This project will mainly focus on the development of an efficient and practical motorcycle rack which can resolve the current limitations of food delivery bag storage compartments through research, analysis and using the right design principles and manufacturing processes.

1.3 Research Objective

The main focus of this project is to offer food delivery riders with an effective and dependable method to safely deliver food orders where the motorcycle rack must be built to keep the food delivery bag in place without any movement during transits, accidental falling or getting damaged during deliveries. Precisely, the objectives are as follows:

- To design a motorcycle rack that is semi automatic and securely protect food delivery bags.
- To fabricate a prototype of the motorcycle rack using suitable materials that are durable and compatibility with the design requirements.
- To test the motorcycle rack under real-world conditions to ensure it is semi automatic and can securely protect food delivery bags.

1.4 Scope of Research

The scope of this project are as follows:

- Design the motorcycle rack for food delivery bags using SolidWorks.
- Fabricate using steel for the motorcycle rack to ensure the rack is durable and compatibility with the design requirements.
- Develop the design of the motorcycle rack specifically for moped motorcycles with two direction of movement which are forward and backward motion.
- Ensure that the motorcycle rack safely secures and safeguards food delivery bags during transit by taking into account the special requirements of food delivery riders.
- Test run the motorcycle rack to make sure it can effectively hold and protect the food delivery bags.
- Keep aware of the constraints imposed by the money, time, and manpower constraints as well as other resources.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The increasing popularity of food delivery services has contributed to the need for secure and safer transportation of food using food delivery bags. Motorcycles have currently become a popular option for food deliveries because of their practicality, efficiency and also speed. Nevertheless, bringing food delivery bags securely on a motorcycle may prove to be challenging considering the prevention of food spillage and the overall safety of the food delivery bag. A proper and well-designed motorcycle rack that has been tested can provide a solution to these issues.

2.2 Types of Designs for Motorcycle Racks

Motorcycle racks are available in various kinds of design to accommodate the variety of shapes, sizes, and quantities for bags and also luggage. One of the example is referring to Figure 2.1 which is the "method of mounting storage units on a motorcycle" patent by James W. Mann (2021), which describes a cantilevered mounting component with a mounting plate is fastened onto the chassis of the vehicular apparatus as part of a method of installing a storage compartment to a vehicle, such as a motorbike. The mounting plate can be used to attach a storage device, which will help to stabilize it while the vehicle is moving. In a preferred implementation, the foot peg mount bracket where the mounting component is attached is exposed by removing the foot peg from the motorcycle. Whether another form of storage is employed or not, the mounting plate attached to the mounting component can be used to secure items being transported by the vehicle equipment.

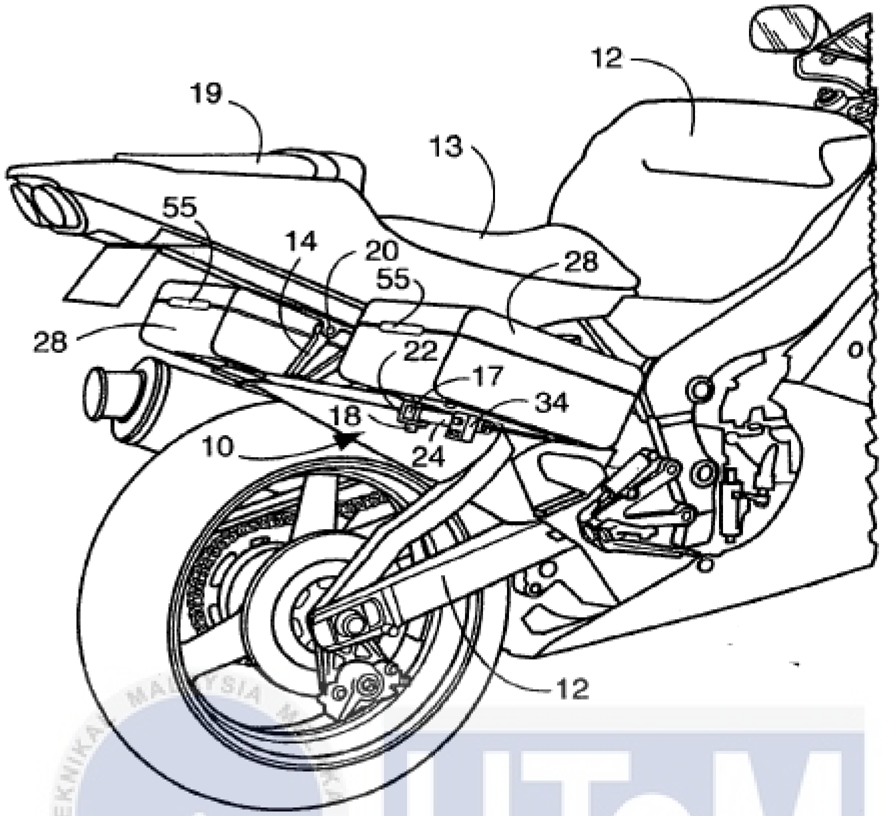


Figure 2.1 Single cantilevered support member removably and non-rotationally rack (James W. Mann, 2021)

Referring to Figure 2.2, a different type of motorcycle rack is the “motorcycle accessory rack” patent by Loren D. Van Wyk (2011), which describes that there is a motorcycle attachment rack that consists of two separate brackets that are spaced apart from one another and have several support rods attached to them and extending between them. The initial and subsequent brackets can be fastened to a wall or other sturdy surface. To make room for accessories from various motorcycle models, the rods can be moved within the slots or apertures that correspond to them or to different slots or openings. At the ends of the rack, there are also available jacket and helmet hangers. A motorcycle windscreen can be fastened onto a pair of upright supports that are fixed on a couple of support rods.

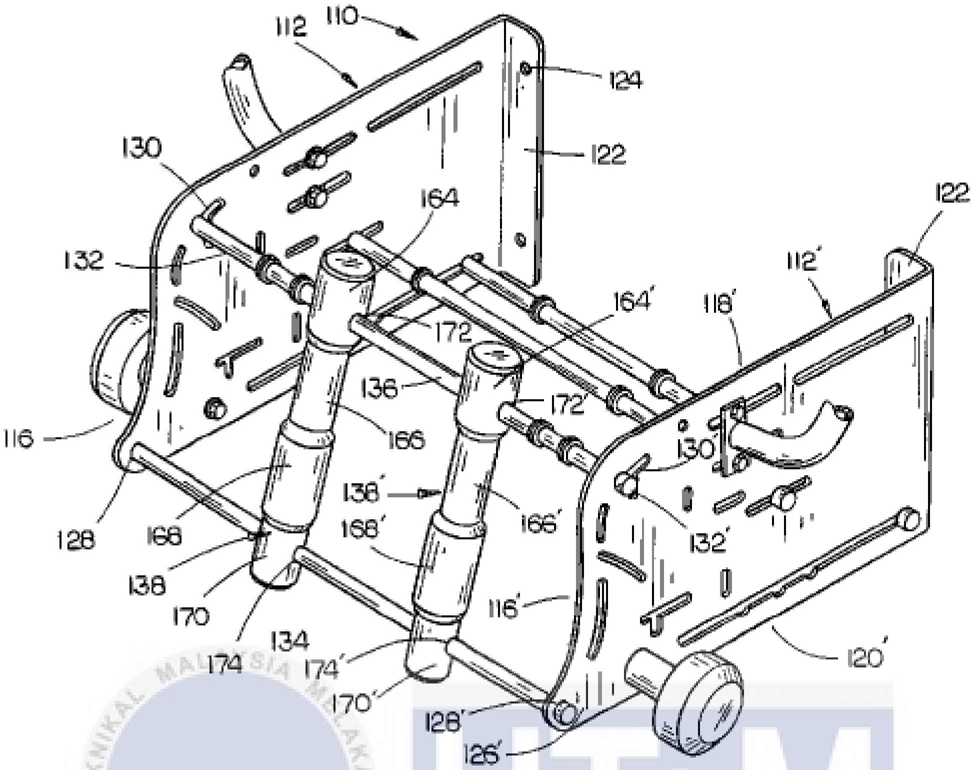


Figure 2.2 Motorcycle accessory rack (Loren D. Van Wyk, 2011)

Referring to Figure 2.3, the next type of motorcycle rack is the “front luggage rack for a motorcycle with load-bearing shell” patent by Francesco Maffe (2020), which describes a motorbike with a load bearing shell that has a front shell component and a shell part that is functionally facing downwards. There is a luggage rack body with at least single anchoring element attached to the luggage rack's body in the luggage rack. A rigid anchoring of the luggage rack component in at least one position of the front shell component is made possible by the configuration of its at last one anchoring element. The luggage rack body features the third and fourth anchored components that are connected to the initial and second anchoring arms, respectively, and two anchoring arms that can be attached to the shell part pointing downwards.

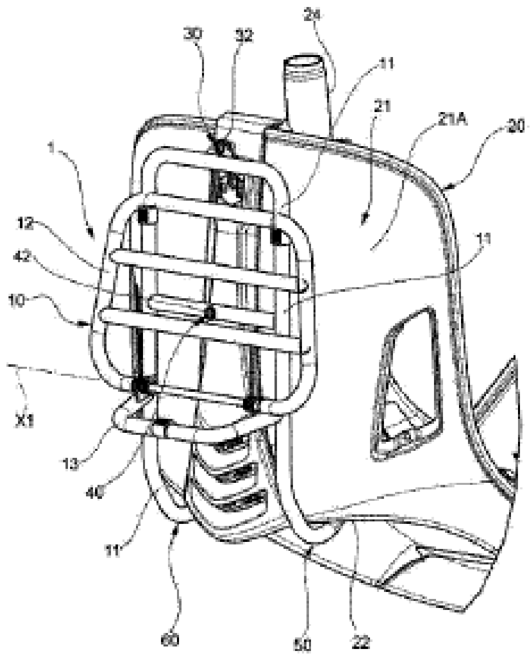


Figure 2.3 Front luggage rack with load-bearing shell (Francesco Maffe, 2020)

Referring to Figure 2.4, another type of motorcycle rack is the "luggage rack for securing an item of luggage on a motorcycle" patent by Tim Krych, et al. (2022), which describes a converter plate to which the piece of cargo may be fastened is included in a baggage rack for mounting luggage to a motorbike or a scooter. The adapter plate has a displacement device with a lever and an engagement component that work together to lock as well as release the mounting plate off the motorbike or motor scooter while the lever is moved within the open and a closed position, causing the locking element to shift into or out of engagement with an attachment point on the motorcycle.

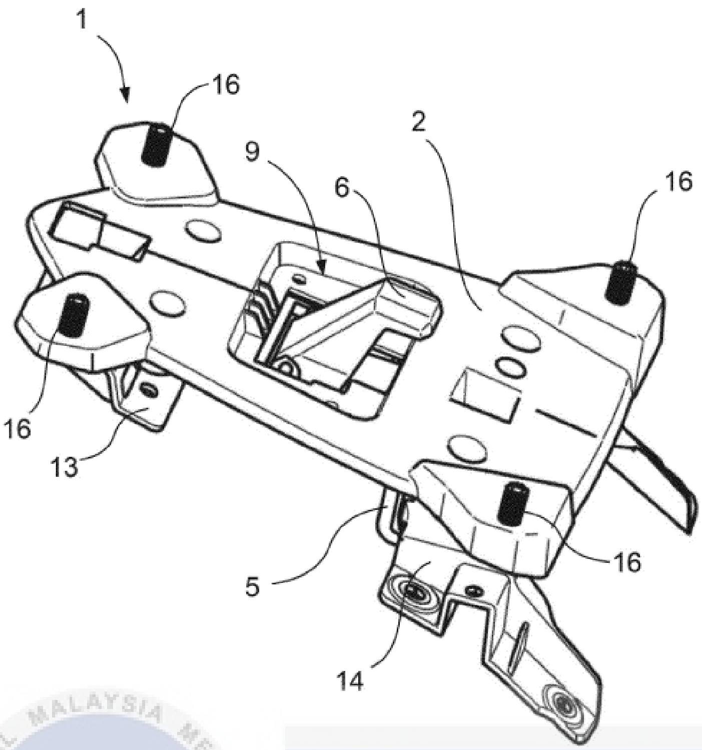


Figure 2.4 Luggage rack with an adapter plate (Tim Krych, et al., 2022)

Referring to Figure 2.5, yet another type of motorcycle rack is the "system for fixing and transporting storage bags for motorcycles" patent by Giuseppe Visenzi (2020), which describe a carriage and a support frame that are fixed to the motorcycle serve as the fixing and transportation components of a storage bag system. The carriage consists of two shells: a lower shell with a support surface that is essentially flat and a first set of coupling devices for removably connecting to the support frame; and an upper shell with a support surface that is essentially flat and an additional set of linking devices for removably linking to the storage bag. A fourth group of coupling methods are provided in the storage bag for removably attaching to the support surface of the upper shell, whereas the support frame is equipped with another set of coupling devices for removably linking to the supporting surface of the lower shell.

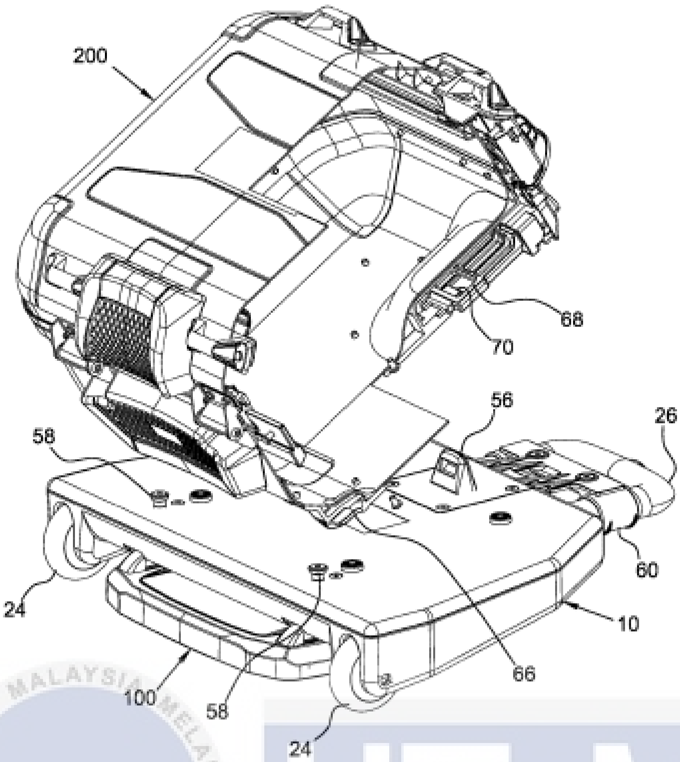


Figure 2.5 System for fixing and transporting a storage bag for motorcycles including a support frame (Giuseppe Visenzi, 2020)

Referring to Figure 2.6, the next type of motorcycle rack is the "combined second seat, backrest and luggage rack for a motorcycle" patent by James E. Grove (2007), which describes that there is a motorcycle accessory that combines a second seat, backrest and baggage rack includes a frame made of two mirror images of each other's tubular members that are connected by an adjusting link to allow for adjustable side member spacing. One plate is not mounted on the frame but is movable between being in opposition with the plate that is fixed on the frame and being transverse to the plate that is attached on the frame. A hinge plate assembly comprising a pair of plates that are pivotally linked together is attached on the frame. This transverse plate will have a cushion mounted on it. When the cushion is placed next to the plate that is attached on the frame, the unit can be used as a second seat for a motorcycle and the transverse plate can be utilized as a backrest for a motorcycle operator when it is in its opposite position. The frame also functions as a luggage rack when the plate positioned transverse.

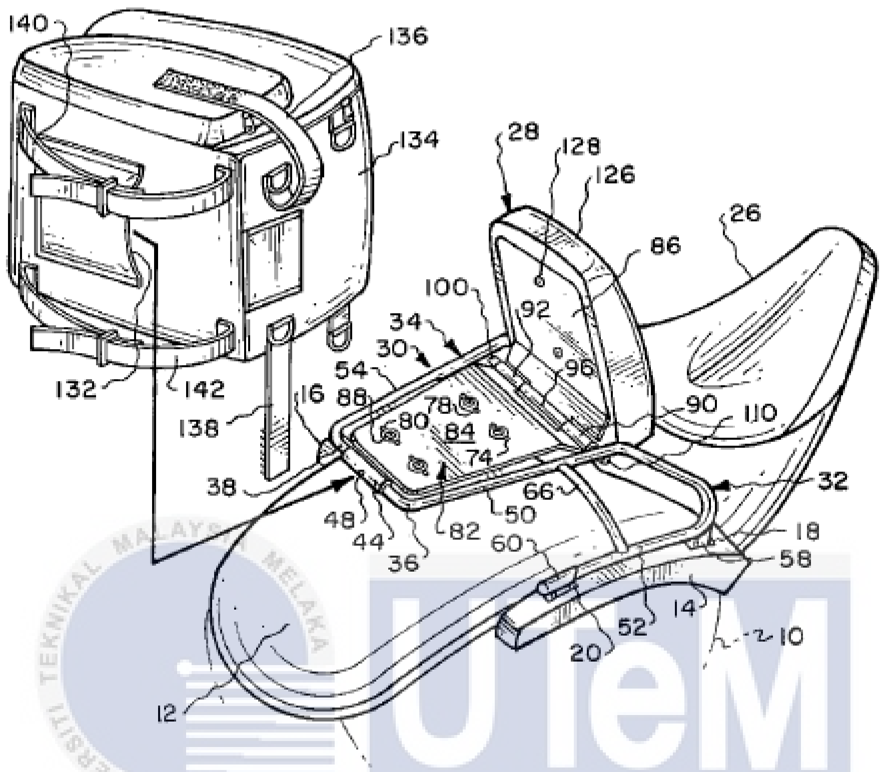


Figure 2.6 Combined second seat, backrest, and luggage rack for a motorcycle

(James E. Grove, 2007)

Referring to Figure 2.7, a another type of the motorcycle rack is the “collapsible motorcycle luggage rack” patent by John Willard, et al. (2010), which describe a folding luggage rack made to attach quickly to the "sissy bar" or backrest of a motorcycle. Using already existing holes that also hold the rear seat to the motorcycle, the luggage rack is made to attach to the motorcycle. The baggage rack may be mounted on a range of motorcycles thanks to a pair of movable mounting brackets. The luggage rack has a number of panels that may be rotated to any desired position and then fastened in a variety of settings by simply pulling a lever. The luggage rack is thus flexible to securely fastening a wide range of loads relying on the operator's needs and the panel configuration.

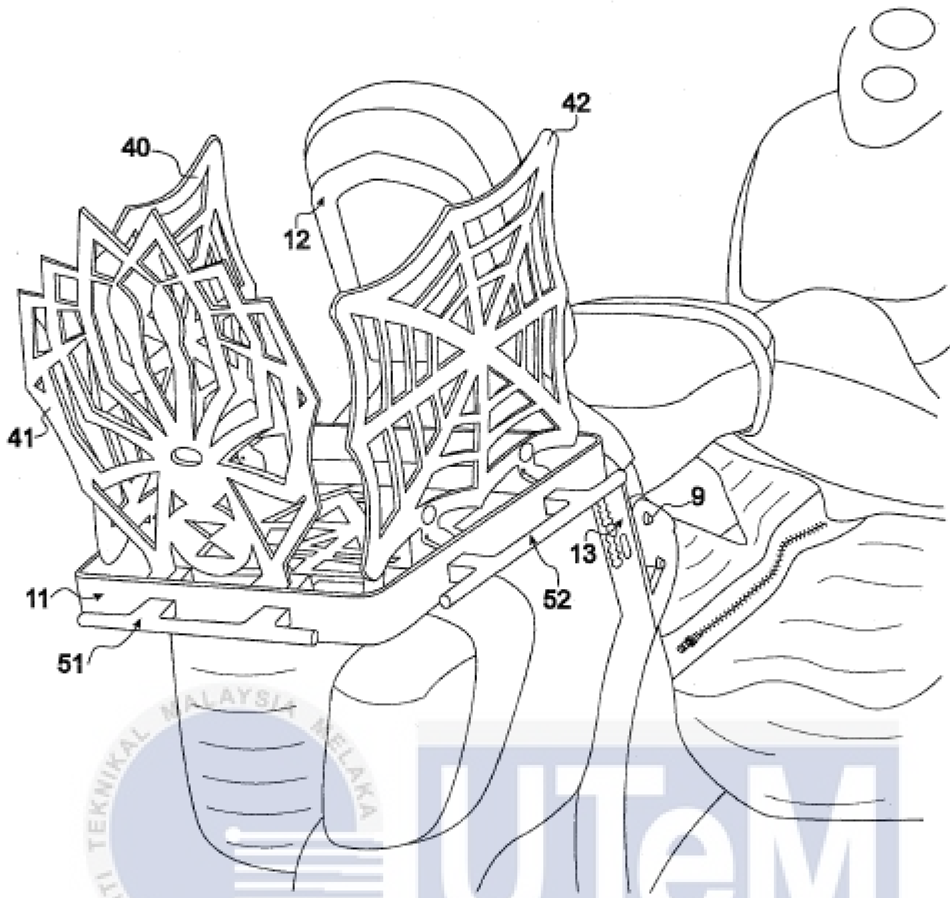


Figure 2.7 Collapsible motorcycle luggage rack (John Willard, et al., 2010)

2.3 Types of Materials used and Fabrication Processes for Motorcycle Racks

Motorcycle racks play an important role in transporting bags and luggage securely and safely, while the materials that are used for their building process have a significant impact on the performance of the rack overall. Due to aspects such as durability, weight, strength, and cost, selecting the right materials for motorcycle racks is very crucial. The materials used must be able to withstand the pressures of transportation and also ensure the rider's and the motorcycle's safety. Added to that, material selection for the rack influences the overall longevity and performance of the rack.

While selecting the fabrication process for motorcycle racks, durability and strength must be considered. Fabrication procedures such as brazing and welding can offer great strength and stiffness which makes them suitable for heavy-duty applications. These types of processes can form a strong bonding between the materials while maintaining the overall structural integrity of the motorcycle rack when it is under heavy load. However, distortion or weakening can be caused by localized heat during brazing and welding of the material near the joints.

On the other hand, procedures like mechanical fastening and adhesive bonding give an equal distribution of stress, reducing the risk of localized failure. The choice of material and joint design is very critical for ensuring the motorcycle rack's endurance. To add on, cost also plays a significant role because processes such as brazing and welding need specialized equipment, post welding processes such as polishing and grinding, and skilled labor which can contribute to higher production costs.

This section of the literature review aims to investigate and explore the various types of materials widely and commonly used for motorcycle racks reviewing their properties, advantages and also the limitations of materials itself and also the types of fabrication process that are involved in building the motorcycle racks. To add on, the commonly used materials that are found in the market for motorcycle racks are steel, stainless steel and aluminum.

2.3.1 Steel

Steel is one of the popular material selection for motorcycle racks because of its excellent strength, broad availability and also durability. These characteristics makes it an excellent choice for securing and supporting motorcycles during transit. Steel is recognised for its amazing rigidity, which is important for motorcycle racks overall built because a motorcycle can weigh several hundred kilogrammes, so the rack must be securely and safely support this weight. Steel's great tensile strength helps it to handle huge loads from the food delivery bags without any deformation or bending, ensuring the motorcycle remain well-supported and stable during transit.

According to Callister, et al. (2013), in their book "Materials Science and Engineering: An Introduction" (9th edition), it is stated that the ultimate tensile strength for steel ranges around 380 MPa to 400 Mpa. As for the durability, variety of stresses such as accidents, vibrations and also weather exposure are subjected to motorcycle racks. Steel is extremely resistant to deterioration making it a durable material choice for rack construction.

Without compromising the structural integrity from repeated usage, collisions, accidental bumps and also harsh weather conditions, this durability assures that the motorcycle rack is functional and dependable for an extended period of time. Steel's low cost and accessibility has lead to widespread use in motorcycle industry and readily accessible for manufacturing process.

Steel is also highly adaptable, allowing for wide design options. Motorcycle rack made out of steel can be tailored to meet specific requirements such as adjustable features and extra mounting options. Steel racks may be further treated or coated to improve corrosion resistance, which is very important considering the exposure to environmental factos such as moisture during transits. Protective coatings including galvanization and powder coating can be used to increase the racks's lifespan and keeping its visual appeal.

2.3.2 304 Stainless steel

304 Stainless steel is a favored material for building motorcycle racks and is commonly used in the market due to its multiple advantages. An alloy comprising high content of nickel, chromium and other constituents imparts onto it an inherent capability for

withstanding corrosion and high endurance. The utilization of this metal entails numerous gains like superior robustness, protection against rusting as well as aesthetic charm. Given these advantages, manufacturers find using this metal ideal to create secure motorcycle racks that can endure tough outdoor conditions while providing unwavering support (Almeida et al., 2021).

304 Stainless steel offers impressive durability in creating sturdy motorcycle racks. It possesses fantastic mechanical properties such as high tensile strength and impact resistance that are vital for ensuring its remarkable performance even with substantial bike weight plus added loads like baggage or accessories placed on it. 304 Stainless-steel ability provides an excellent guarantee for strengthening a rack's structure, which significantly minimizes the risk of deformities and failures during strenuous circumstances (Huang et al., 2020).

Another advantage of 304 stainless steel is its resistance to corrosion because when it is exposed to oxygen, the chromium in this metal, which is around 18% to 20% by weight forms a passive oxide layer on the surface. This acts as a coating shielding and preventing corrosion and rusting. Since motorcycle racks are exposed to various environmental factors such as humidity and rain, 304 stainless steel would be able to keep its aesthetic and also structural integrity in the long term (Li et al., 2019).

304 Stainless steel is also attractive in appearance and is strong and resistant to corrosion. The 304 stainless steel's brilliant and shiny surface provides motorbike racks with a sleek, contemporary look. For motorcycle consumers who respect both utility and flair, this aesthetic quality is appealing. Motorcycle racks constructed of this metal are more appealing overall because of their capacity to keep looking good even after extensive usage and exposure to the environment (Zhang et al., 2018).

2.3.3 Aluminium

Aluminium is very well-known for its superior lightweight properties which makes it a material with great adaptability and notable advantages in various sectors. Having lower density compared to other metals, aluminium weighs only around one-third the weight of steel. Aluminum's inherent lightweight feature provides various advantages, including lower transportation fuel consumption, enhanced energy efficiency, and higher payload capacity. Aluminum's application in the automotive and aerospace sectors, for example, has resulted in significant weight reductions without sacrificing structural integrity (Abdulrahman et al., 2021).

Corrosion resistance is also one of the advantages of aluminium because it is able to produce a thin oxide layer naturally which can protect from oxygen, moisture, aggressive chemicals, and other environmental factors. Aluminium's corrosion resistance is especially useful in the rainy season where moisture and humidity are common. Aluminium also makes for a good choice for demanding applications because of its excellent mechanical strength and high-performances characteristics.

Aluminium also can be tailored to specific designs after achieving specific strength requirements from engineered aluminium alloys. Aluminium-based alloys are an excellent choice for purposes in which minimizing weight is crucial because of the high strength-to-weight ratio, making it possible for the development of lightweight constructions despite not compromising durability (Razavi et al., 2020). Likewise, aluminium is also an excellent selection for high-performance applications which includes electrical conductors, heat exchangers, and automotive parts because of its more accurate and effective electrical and thermal insulation plus simplicity of machining and shaping (Khan et al., 2021).

2.3.4 Carbon Fiber Reinforced Polymers

Carbon fiber reinforced polymers have attracted significant interest in various sectors because of their extremely light weight but exceptional strength. Carbon fibers are incorporated into polymer matrix which creates these great mechanical properties in terms of high tensile strength and overall stiffness, coupled with the flexibility of polymers gives unique benefits for a range of applications (Baucom et al., 2019).

Carbon fiber reinforced polymers have an excellent weight reduction because of their low density, which is a critical consideration in various sectors, particularly in automotive sectors because of the demand for better fuel economy and overall performance is high. With the incorporation of carbon fiber reinforced polymers in the structural design and components, huge amounts of weight can be reduced, plus having better fuel efficiency and enhanced payload capacity (Buljak et al., 2018).

Carbon fiber reinforced polymers also have high stiffness and tensile strength which makes them capable of enduring structural stresses and heavy loads. Due to their enhanced strength, carbon fiber reinforced polymers are used in demanding applications such as aircraft structures, automotive components, and also sporting goods (Poursartip et al., 2018).

Furthermore, carbon fiber reinforced polymers composites also provide design freedom and adaptability because they can be easily molded into complex geometries and structures (Neto et al., 2020).

2.3.5 Welding Processes in Motorcycle Rack Fabrication

Welding procedures play a very important role in fabricating a motorcycle rack because they can provide reliable and strong joints between the components of the motorcycle rack. This section of the literature review aims to study the uses of welding processes for motorcycle racks, including metal inert gas welding and tungsten inert gas welding. Advantages and limitations of each of the welding processes will be reviewed with specific focuses on adaptability, quality, joint strength and also simplicity if the operation is done.

Metal inert gas welding, also known as gas metal arc welding, is widely popular used welding process for the fabrication of motorcycle racks. The process involves argon or a mixture of argon and carbon dioxide acts as inert gas combining with a consumable electrode wire where the gas shields the weld pool from ambient contamination.

Metal inert gas welding has a few advantages such as having excellent joint strength, high deposition rates and also has the ability to weld variety ranges of metals with different thickness. The learning process is also easier which makes it suitable for novice welders. The downside to metal inert gas welding is that it can generate a larger heat-affected zone compared to other welding processes which can compromise the motorcycle rack's structural integrity (Zhang et al., 2019).

Tungsten inert gas welding, also known as gas tungsten arc welding, is another popular and commonly used welding process in motorcycle rack fabrication. The process involves having a non- consumable tungsten electrode combining with inert gas shield, commonly argon, to safeguard to protect the weld pool.

Tungsten inert gas welding has several advantages, which includes higher weld quality and better aesthetics compared to metal inert gas welding and also precision of heat control. Without creating any distortion or spatter, Tungsten inert gas welding creates smooth, clean, and strong welding where this welding process can be used for fragile and thin materials.

Tungsten inert gas welding is highly versatile where it can be used to join metals, including stainless steel, titanium, and aluminium. But tungsten inert gas has a disadvantage compared to metal inert gas welding because it is relatively a slower process and demands highly skilled labor (Wang et al., 2018).

Metals like steel, stainless steel, and aluminium, which are frequently used in the building of motorcycle racks, are appropriate for welding using MIG welding and also TIG welding. The base metal being connected determines the type of filler material to use during MIG welding. Stainless steel filler wire is used for welding stainless steel components, while mild steel or carbon steel filler wire is commonly used for welding steel. An aluminium filler wire is used for aluminium.

Additionally, same as the MIG welding, the base metal being connected determines the type of filler material used in TIG welding. Steel components are welded using mild steel filler rods. For connecting stainless steel pieces, filler rods made of stainless steel are used. Aluminium components are welded using aluminium filler rods.

A stainless-steel filler wire is utilized in MIG welding to guarantee optimum corrosion resistance in the weld junction. The welding pool is shielded from air contamination while the welding gun feeds the consumable wire electrode while emitting an inert gas barrier. TIG welding is a good choice for welding motorbike racks made of stainless steel. An inert gas barrier and stainless-steel filler rods are utilized to avoid oxidation. TIG welding maintains the corrosion resistance of stainless steel by offering precise control and high-quality welds.

Table 2.1 Pros and cons of MIG and TIG welding processes (Matt Mcledd, 2017)

	MIG	TIG
Learning curve	4	1
Suitability to weld different thickness materials (up to 6mm)	5	5

	MIG	TIG
Suitability to weld stainless steel	3	5

Based on Table 2.1, the suitability to weld stainless steel for metal inert gas welding has a rating of 3 while tungsten inert gas welding's suitability to weld stainless steel together is 5. This shows that tungsten inert gas welding is the best option for welding stainless steel compared to metal inert gas welding. As for the suitability to weld different thickness ranging to 6mm for both MIG welding and TIG welding has the same rating. The only downside of TIG welding is the learning curve compared to MIG welding which is much easier to master (Matt Mcledd, 2017).

Table 2.2 The peak force values obtained from tensile test for 304 stainless steel (Aysha Sh. Hasan , et al., 2018)

Type of welding	Type of joint	Peak Force (kN)	
		70A	140A
MIG	Butt	39.370	45.590
	Lap	18.620	83.490
TIG	Butt	16.100	71.37
	Lap	15.620	52.11

Based on Table 2.2, the type of welding and the type of joint with different amounts of current supplied can have an effect on the strength and ductility of the 304 stainless steel. If the values are compared between MIG and TIG welding for the butt type of joint where 140A of current is used, TIG welding has the highest amount of peak force from the tensile test compared to MIG welding which are 71.37kN and 45.590kN respectively. As for the lap joint, MIG welding has the highest amount of peak force from the tensile test compared TIG welding which are 83.490kN and 52.11kN respectively.

Based on this data obtained, the type of joint and current used has a significant amount of effect on the types of welding used to weld 304 stainless steel together. Given the importance of joint type and current on the welding process, selecting the optimal welding procedure for each joint design is critical in motorcycle rack manufacturing. To identify the best welding procedure, the rack's design and construction must consider the individual joint requirements, load circumstances, and material attributes. Motorcycle rack fabricators may assure optimal strength, durability, and performance of the welded joints in the final product by carefully selecting the welding process based on joint type and current.

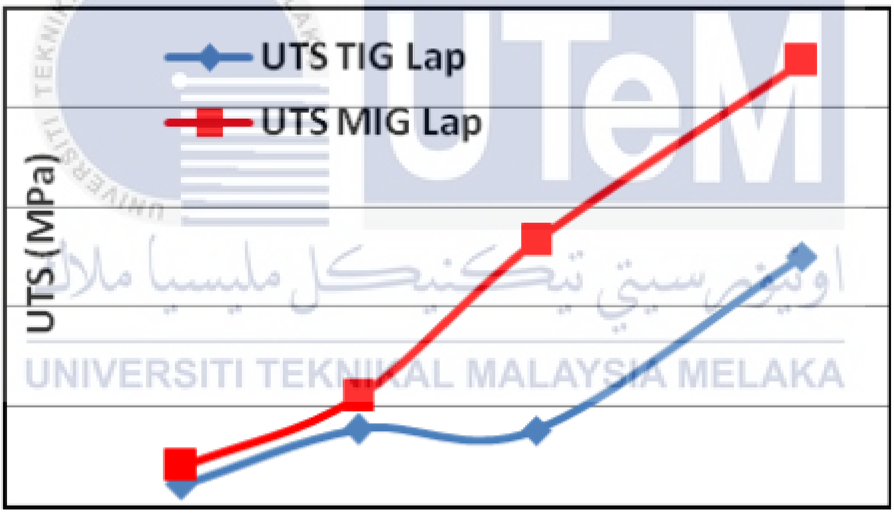


Figure 2.8 Ultimate tensile strength graph for MIG and TIG lap joint welding (Wang Q , et al., 2011)

Figure 2.8 shows that both TIG and MIG lap joint welding procedures have increasing values for the ultimate tensile strength as a result of current. The maximum ultimate tensile strength for TIG lap joint specimens was at the current value of 140A, and lowest ultimate tensile strength value was at the current value of 70A. The specimens that had been welded with a MIG lap joint, however, had the same behavior. When compared to lap joint weldments welded with the MIG technique, the ultimate tensile strength of lap joint weldments welded with the TIG method was generally lower.

A greater ultimate tensile strength is desired in the context of motorcycle rack fabrication since it assures the rack's capacity to bear applied loads and stresses during usage. Based on the data supplied, MIG welding may be recommended over TIG welding if the motorcycle rack design includes lap joint weldments. MIG welding would offer a stronger and more robust junction due to its typically greater ultimate tensile strength for lap joint weldments. This is especially critical for motorcycle racks, which must sustain the weight of the motorbike as well as withstand different shocks and impacts when riding.

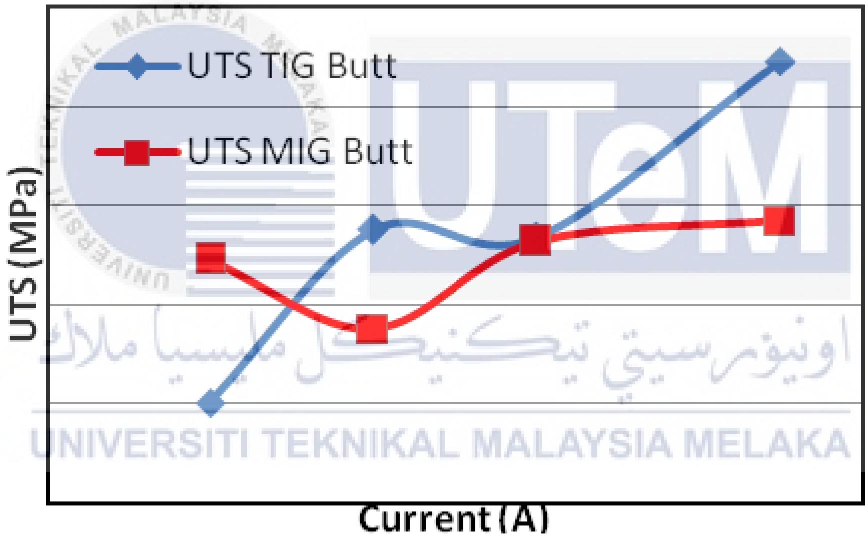


Figure 2.9 Ultimate tensile strength graph for MIG and TIG butt joint welding (Wang Q , et al., 2011)

Figure 2.9 depicts how the ultimate tensile strength values for the TIG and MIG butt joint welding processes varied with current for both welding methods. The greatest ultimate tensile strength value for TIG butt joint specimens was at the current 140A, while the lowest ultimate tensile strength value was at the current 70A. Meanwhile, the specimens were welded by MIG butt joint with a maximum ultimate tensile strength of 140A and a minimum ultimate tensile strength of 70A.In general, the ultimate tensile strength values for TIG weldments were greater than those for MIG weldments for all specimen's butt type joints except at current 70A.

Based on the data given, TIG welding may be recommended over MIG welding if the motorbike rack design includes butt joint weldments. TIG welding produces butt joint weldments with increased ultimate tensile strength, especially at higher current levels. TIG welds can produce stronger and more durable connections for the motorbike rack, improving its overall structural integrity and load-bearing capability.

2.3.6 Machining Processes in Motorcycle Rack Fabrication

To achieve exact dimensions, shapes, and surface finishes, machining methods are required. The purpose of this literature review is to go through how machining processes like milling and turning are employed in the production of motorcycle rack components. The accuracy and efficiency of these processes, as well as their ability to generate exact cuts, detailed patterns, and remarkable surface quality, will be highlighted in the evaluation.

Milling is a fabrication procedure used to enhance component shape and standards in motorcycle rack manufacturing. It entails removing material from a workpiece by rotating a cutting tool, usually a multi-toothed cutter. Milling allows for precise material removal control and the creation of complex shapes, curves, and surface finishes.

It's incredibly versatile and can work with a variety of materials, including metals and polymers. Because of its great dimensional precision and repeatability, milling is perfect for mass producing motorbike rack components. Vertical milling machinery and Computer Numerical Control milling machines, among others, can be utilized to finish the process, providing versatility and automation for efficient manufacture (Mannan et al., 2020).

Turning is a machining process that is commonly used in the production of motorcycle racks to produce cylindrical components like axles or mounting brackets. It comprises rotating a workpiece while employing a cutting tool to remove material from the surface. With excellent accuracy and efficiency, turning delivers perfect dimensions and clean surface finishes. It is suitable for a wide range of materials, particularly metals and polymers.

Turning may create components with a variety of forms, including straight, tapered, or curved profiles. It has good concentricity and dimensional control, making it appropriate for tight tolerances. Furthermore, turning may be done on both manual and CNC lathe machines, providing for greater component manufacturing flexibility (Kumar et al., 2018).

2.4 Motorcycle Rider Comfort, Safety and Ergonomic Design

Comfortability, safety, and ergonomic design of the rider is important in motorcycle rack design since it aims to optimize the interaction between the rider, motorbike, and rack system. This overview of the literature investigates the premise of comfortability and safety plus the ergonomic design and its application to motorcycle rack design. It dives into the fundamental ergonomic aspects for motorcycle racks, taking rider comfort, safety, and practicality into mind.

The science of designing and arranging items and processes that improve human well-being, efficiency, and safety is known as ergonomics. Comfortability and safety in motorcycle rack design concentrates on building a rack system that smoothly incorporates with the motorbike while maintaining rider comfort, effective load management, and simplicity of use. Designs may improve the whole riding experience, reduce rider exhaustion, and increase safety while transporting by dealing with the ergonomics of motorcycle racks.

2.4.1 Visibility and Lighting

Visibility is critical for ensuring the security of the rider and other drivers. The motorbike rack should not restrict the rider's field of view or reduce sight of critical road cues. Designers may minimize blind spots and give clear views for the rider by optimizing the rack's shape, height, and location, encouraging situational awareness, and lowering the risk of accidents (Blanchard & Pearce, 2017).

Incorporating bright materials and high-visibility markers into the motorbike rack design is critical for increasing the rack's visibility. Reflective materials strategically positioned on the rack improve visibility in low-light or at night, making it simpler for other road users to recognize the presence and size of the motorbike with the rack attached. Reflective tape or bright colors, for example, can improve the visibility of the rack and raise the rider's overall conspicuity (Gopinath & Babu, 2018).

Motorcycle rack lighting is critical, especially while riding in low-light or nighttime circumstances. To achieve enough illumination, ergonomic considerations include including lighting systems into the design. This might involve placing LED lights on the rack, such as brake lights or turn signals, to improve visibility and efficiently convey intentions to other road users. Furthermore, the lighting system should be designed to reduce glare and offer adequate illumination without distracting or inconveniencing the rider (Li et al., 2019).

Given the prolonged exposure of motorcycle racks to varied weather conditions, it is critical to select weather-resistant and long-lasting lighting components. The lighting system should be built to endure dampness, vibrations, and temperature changes in order to provide constant performance and lifespan. Using high-quality, weather-sealed lighting components decreases the danger of failure, maintains excellent visibility, and improves the motorbike rack system's dependability (Blanchard & Pearce, 2017).

2.4.2 Load Capacity and Weight Distribution

The maximum weight that a motorcycle's rack may securely carry without affecting stability and safety is referred to as load capacity. Motorcycle racks should be constructed with enough load capacity to handle the intended cargo, considering elements such as item weight, extra attachments, and the rack itself. Overloading can occur when the load capacity is insufficient, impacting the motorcycle's balance, steering control, and braking effectiveness. It may also increase the likelihood of ride instability, loss of control, and accidents (Seif & Fard, 2021).

Another important factor of ergonomic concern in motorcycle rack design is weight distribution. Proper weight distribution aids in the maintenance of balance and equilibrium during rides. To provide excellent handling qualities, the weight should be equally distributed across the front and back of the motorbike. Factors like bag location and closeness to the motorcycle's axis of gravity should be addressed while building the rack. An uneven or incorrectly distributed load can impair the handling of the motorbike, potentially producing instability, decreased maneuverability, and greater wear on suspension components (Blanchard & Pearce, 2017).

Motorcycle rack load capacity and weight distribution have significant consequences for rider safety and comfort. Excessive load can put undue pressure on the motorcycle's frame, suspension, and tires, affecting its performance and lifetime. Overloading can potentially cause premature wear and failure of vital components, putting the rider's safety at risk. Furthermore, unequal weight transfer while braking, acceleration, or turning can result in unpredictable handling characteristics and lost rider confidence. This can lead to rider fatigue, decreased comfort, and an increased chance of an accident (Gopinath & Babu, 2018).

2.4.3 Mounting and Securement

The motorbike rack must be properly mounted and secured to avoid movement, vibrations, and potential separation during transit. To maintain stability and reduce the danger of accidents caused by the rack moving or breaking free, the rack should be securely fastened to the motorcycle frame or approved mounting points. Adequate mounting and securement procedures are crucial for keeping the integrity of the rack and minimizing dangers such as objects falling off during rides (Seif & Fard, 2021).

Functional design issues in motorcycle rack design include the inclusion of user-friendly attachment mechanisms that assist installation and removal procedures. Quick-release mechanisms, adjustable mounting brackets, with tool-free mechanisms for locking can all help to increase user convenience. These features enable riders to easily connect and uninstall the rack as needed, boosting motorbike versatility and diversity (Blanchard & Pearce, 2017).

The motorbike rack's stability and vibration dampening capabilities may have a significant influence on rider comfort and safety. The design should have features that reduce vibrations and restrict vibrations and shocks transfer from the road's pavement to the rack and motorcycle frame. Damping components or vibration-absorbing devices, including rubber covers or isolation mounts, can help minimize vibrations, reducing rider discomfort and the possibility of damage to the rack or motorcycle components (Gopinath & Babu, 2018).

Securement mechanisms are required to ensure that the items on the motorcycle rack remain firmly in place during travel. Adjustable straps, tie-down points, or integrated cargo nets that assist the secure attachment of things are all ergonomic concerns. These devices should be designed to fit a wide range of cargo sizes and shapes while providing sufficient restraint to prevent cargo movement while also assuring rider safety and stability (Li et al., 2019).

The design should allow for easy loading and unloading of freight while minimizing the rider's exertion. Considerations like the height and positioning of the rack, as well as the accessibility of storage compartments or other amenities, all contribute to the motorcycle rack's overall usability and usefulness (Seif & Fard, 2021).

2.4.4 Aerodynamics and Wind Resistance

Aerodynamic design is critical in lowering wind resistance and enhancing overall motorcycle economy. When a rack is mounted to a motorbike, it may interfere with the engine's normal airflow and generate drag. Proper considerations when designing can aid in reducing the frontal area, streamlining the form, and improving airflow around the motorbike and rack system. The motorbike becomes more stable, encounters less turbulence, and takes a smaller effort from the rider to retain control by lowering wind resistance (Blanchard & Pearce, 2017).

The motorbike rack's design and profile are critical for reducing aerodynamic drag. The airflow is smoother and wind resistance is decreased with optimized profiles that closely match the curves of the motorbike. Integration of the rack into the design of the motorbike, such as putting it near to the back end or integrating it into the overall body work, can improve aerodynamic performance while reducing the influence on stability and fuel economy (Gopinath & Babu, 2018).

Aerodynamics performance for motorcycle rack designs can be enhanced by using computational fluid dynamics (CFD) models and wind tunnel testing. Designers can employ these tools to analyze and optimize airflow patterns, detect locations of excessive drag, and make appropriate changes to increase aerodynamic efficiency.

Aerodynamic problems with motorcycle rack design have a direct effect on the motorbike's balance and handling qualities. Appropriate aerodynamic design decreases crosswind force, reduces buffeting, and improves the motorcycle's capability to sustain a stable direction at high speeds.

The materials utilized by the motorcycle rack design can have an effect on its aerodynamic effectiveness. Lighter materials, such as aluminium or carbon fiber, might lower the overall mass of the rack system, reducing additional drag and enhancing the aerodynamic performance of the motorbike. In order to guarantee that weight decrease does not impair the rack's strength and practicality, the structural integrity and resilience of the materials should be carefully considered (Blanchard & Pearce, 2017).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes in full the methodology employed in this research task. A methodology chart is shown to illustrate the whole design process of a semi-automatic motorbike rack that securely protects food delivery bags. This research project required data collection, test results, and prototype creation. Each chapter contained detailed information on each step. The objective, problem description, and scope of work of the project proposal are all covered.

The whole process began with the accumulation of data and information. The data was gathered from dependable resources such as reference books, journals, and internet sites. In the research process, every component of information is critical. This section went through the strategy and methods that were used to complete this project. It provided the prototype's design, which was examined in a real-world situation. A number of tests were required to determine the greatest probable outcome.

3.2 Process Flowchart

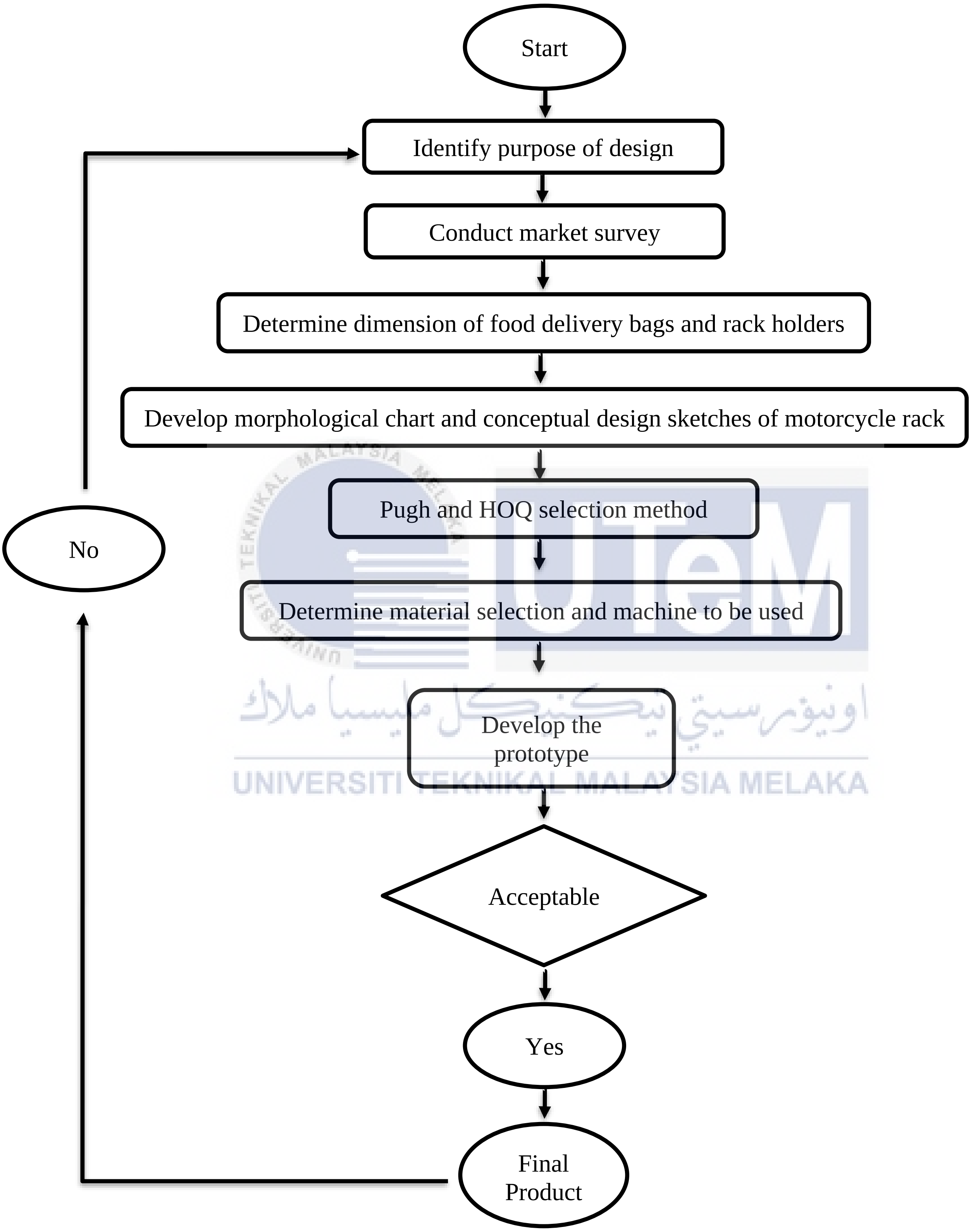


Figure 3.1 Flowchart for the prototype production

3.3 Market Survey

The findings of a detailed market study that was done among food delivery riders to understand the issues connected with the existing design of motorcycle racks and the protection of food delivery bags were presented in this part. The online survey collected important feedback and recommendations from riders in order to improve the efficiency and efficacy of the meal delivery procedure.

The major goal of this study was to identify the major issues and limits experienced by food delivery riders in terms of present motorcycle rack design and food delivery bag protection. The survey attempted to investigate issues such as bag leakage, stability concerns, and refueling convenience, with the ultimate goal of optimizing the delivery process.

Each question in the poll served a unique goal in understanding riders' experiences and thoughts on existing motorcycle rack systems and the protection of food delivery bags. The study began by asking if motorcyclists employed a rack mechanism to mount their food delivery bags to their motorcycles. This question created a baseline and offered context for the subsequent questions. It enabled the survey to target those who have actually used motorcycle racks for food delivery.

The poll asked riders to indicate the type of motorbike they used for food deliveries with a rack system mounted in order to acquire a better knowledge of the individual bikes utilized. This information assisted in identifying any specific factors associated with various motorbike models, allowing the survey to capture a varied variety of experiences.

One critical part of the survey was determining the significance of safe food delivery bag protection. Riders described how important this feature was to them by rating it on a scale of 1 to 5. This grade indicated how much priority riders placed on the secure security of their food delivery bags during transportation.

Understanding the degree of problems encountered by riders was critical for assessing current motorcycle rack designs. As a result, the poll inquired about the prevalence of issues that resulted in food delivery bags collapsing or spilling their contents. This inquiry tried to identify possible areas for improvement as well as to address any concerns about dependability or safety.

In addition, the survey investigated the significance of strength and durability in motorcycle rack design. The poll looked into riders' expectations for durable and long-lasting rack systems by asking them to rank the importance of these aspects. Furthermore, the survey investigated the significance of mobility in motorcycle rack design, with a particular emphasis on ease of refueling. The study assessed the feasibility and convenience of having a mobile rack system that gives simple access to the motorcycle's tank by questioning about the frequency of refueling during food delivery shifts.

The poll asked riders how they generally mounted their food delivery bags onto the rack system in order to better understand the attachment procedure. This data gave light on the existing installation techniques employed by riders and aided in the identification of prospective enhancements or alternative options. The poll went on to look at the frequency of problems observed while attaching or removing food delivery bags from existing motorbike racks. The survey gathered insights into the usability and efficiency of present rack systems by gathering comments on these difficulties, highlighting areas that may require attention or adjustment.

The ease of installation was a critical factor in motorcycle rack design. The study asked users to judge how easy it was to install the rack system on their motorcycles. This inquiry was intended to assess the installation procedure and indicate any potential issues or areas for improvement. Similarly, the survey investigated the significance of simple installation and removal of food delivery bags from the rack system. The poll evaluated the importance of user-friendly systems that permitted swift and hassle-free attachment and detachment by inquiring about riders' preferences in this respect.

Another critical factor covered by the poll was general satisfaction with existing motorcycle rack designs. By asking passengers to score their level of satisfaction, the survey allowed respondents to communicate their ideas and experiences, emphasizing areas where modifications or additions may be required. The poll also took into account any ergonomic considerations by asking riders if they had suffered any back discomfort while carrying the food delivery bag on their motorcycles with the rack attached. This question recognized the significance of rider comfort and well-being throughout delivery shifts.

Furthermore, the poll explored the influence of weight and balance on riders' performance by asking if they believed the weight of the rack system and the linked food delivery bag had an impact on their riding performance. This question focused on stability, handling, and the overall riding experience, recognizing the importance of proper weight distribution and balance.

Finally, the poll allowed riders to submit any further thoughts or ideas they had on the design of motorbike racks for securely securing food delivery bags. This open-ended question allowed respondents to add insights, ideas, or recommendations that were not covered by the preceding questions, ensuring that all relevant viewpoints were recorded.

3.4 Dimensions

Dimension was critical inside the design technique due to the fact it provided a detailed and particular depiction of the final layout. By including measurements into the layout, it provided a demonstration for the shape, length, and proportionality of the various components, ensuring that the final product fit the necessary requirements and functional needs.

3.4.1 Food Delivery Bag

Figure 3.2 Foodpanda bag dimension are 44 cm (h) x 48 cm (l) x 48 cm (w)

Before considering the dimensions of the motorcycle rack that was to be built, the dimensions of the delivery bag were taken. Figure 3.2 depicted the dimensions of the foodpanda bag, which were 44 cm in height, 48 cm in length, and 48 cm in width. The dimensions of the motorcycle rack had to be 1 cm to 2 cm bigger compared to the dimensions of the foodpanda delivery bag so that the foodpanda delivery bag could snugly be kept in place, reducing the possibility of it sliding or dropping during usage.

Figure 3.3 Grabfood bag dimensions are 45 cm (h) x 47 cm (l) x 47 cm (w)

Figure 3.3 depicted the dimensions of the grabfood bag, which were 44 cm in height, 48 cm in length, and 48 cm in width. Taking into the same consideration as for the foodpanda delivery bag, the dimensions of the motorcycle rack had to be 1 cm to 2 cm bigger compared to the dimensions of the grabfood delivery bag so that the grabfood delivery bag could be properly kept in place, reducing the possibility of any sliding during transit.

3.4.2 Rack Holder

Figure 3.4 Rack holder dimensions for Y15ZR are 30cm(w) x 20cm(w) x 38cm(l)

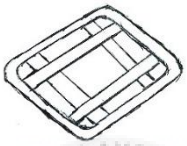
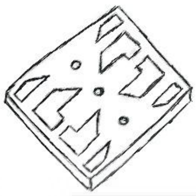
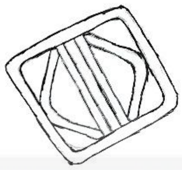
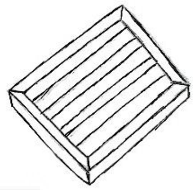
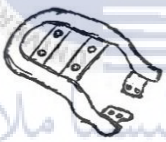
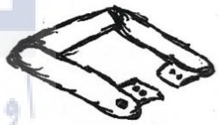
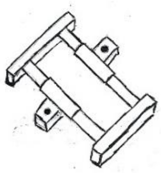
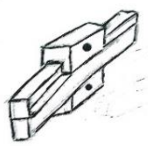
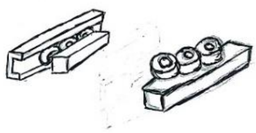
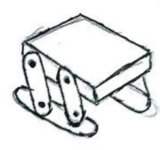
Figure 3.4 depicted the dimensions of the rack holder for Y15ZR, which were 30 cm in width at the spoilers' area, 38 cm in length, and 20 cm in width at the topmost portion of the rack holder. The Y15ZR motorcycle model was chosen as the specific choice because of its popularity in Malaysia. Taking these dimensions into consideration, the rack holder was designed to specifically fit the Y15ZR model.

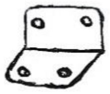
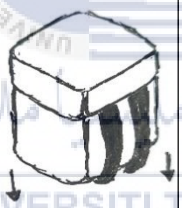
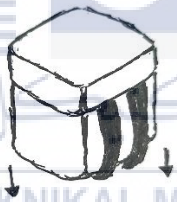
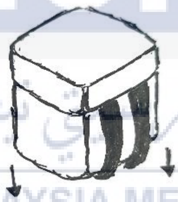
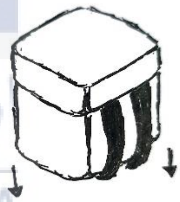
3.5 Morphological Chart

By incorporating several fundamental design factors and variables, the morphological chart was used to investigate and develop a large range of design choices. The goal of this section was to demonstrate the full creation of the morphological chart, highlighting the important design aspects and variables that had been recognized as crucial to the operation and performance of the motorbike rack.

To develop numerous design configurations, the morphological chart was generated by methodically altering and combining these design factors. Each combination of design components represented a distinct design approach for the motorbike rack, with varying benefits and trade-offs. Table 3.2 showed the morphology chart for the motorcycle rack.

Table 3.2 Differences between design A, design B, design C and design D

Design	A	B	C	D
Base of the rack				
Rack Holder				
Sliding mechanism of the rack				

Design	A	B	C	D
Brackets to attach the rack				
Hex bolts	 M5 x 25mm	 M5 x 20mm	 M5 x 25mm	 M5 x 16mm
Stainless stell nuts				
Food delivery bag placement				

3.6 Conceptual Design Sketching of the Motorcycle Rack

Concept design was critical in the development of visual user interfaces because it assisted product understanding and utilization by building a consistent and user-centered foundation. This section covered the importance of concept design in the building of user interfaces and highlighted the advantages of a clearly defined conceptual design that correctly represented the intended usage and constraints of a product.

The significance of concept design came from its capacity to serve as a solid basis for user interface design. A well-executed concept design guaranteed that a product is in line with customer expectations, thereby making it easier for consumers to comprehend and use its features. Concept design improved usability, user fulfilment, and in general product success by addressing user demands and using a user-centered approach. Two different ideas have been sketched down on paper. For each concept, there are combination based on the base of the rack, edge of the base of the rack, sliding mechanism of the rack and the cover to protect the food delivery bag that are incorporated from the morphological charts.

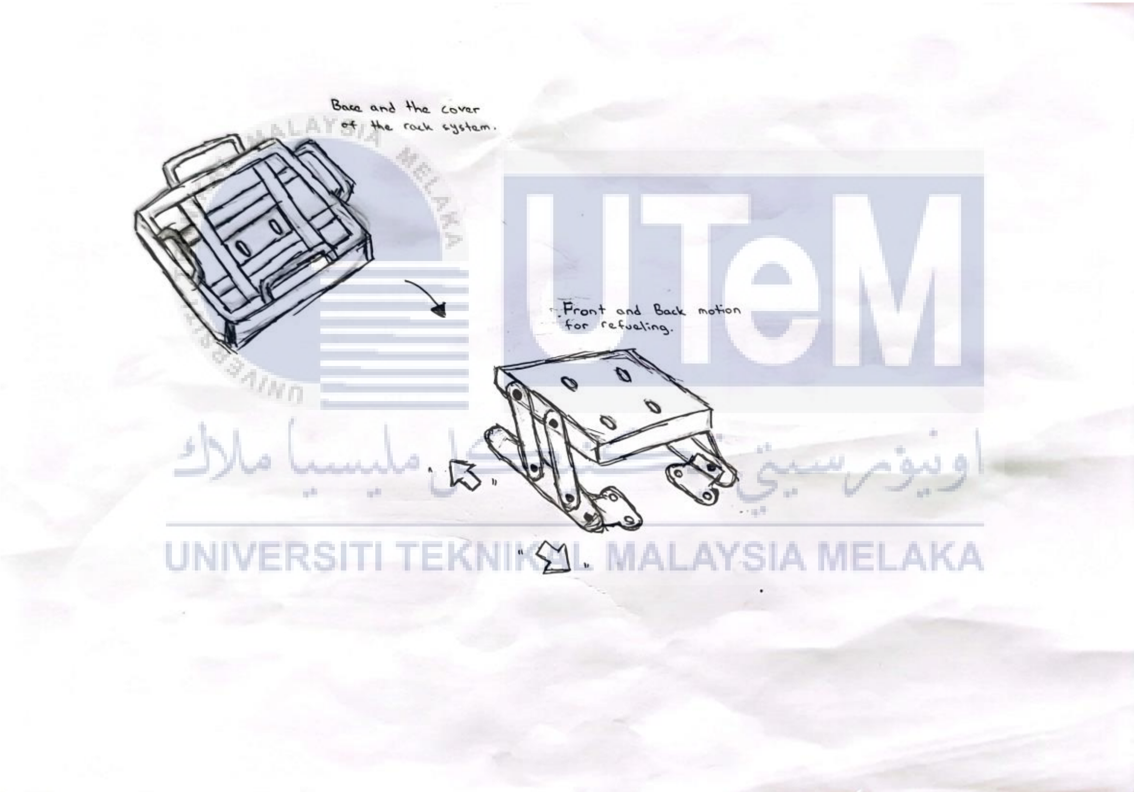


Figure 3.5 Concept design 1

Based on the Figure 3.5, the concept design 1 was developed and sketched where the refueling and light weight aspect of the motorcycle rack was focused on more rather than the overall protection of the food delivery bag. The proposed design provided a creative method to meet the refueling needs of motorbikes while being transported. The rack design enabled for simple access to the motorcycle's petrol tank without having to remove it totally from the rack by having a front and back motion.

This innovation avoided the time-consuming and inconvenient procedure of removing the motorbike from the rack, allowing for quick and simple refueling at rest stops or refueling stations. By including this function, the design assured that the user's travelling experience is uninterrupted. Weight reduction was an important design aspect to improve the overall efficiency and functionality of the motorbike rack.

By reducing the overall size of the cover to protect the food delivery bag, the design achieved a lightweight structure for greater maneuverability during transits. Furthermore, the lightweight design made loading and unloading the motorbike onto the rack a breeze. It decreased the user's physical effort, keeping the process more comfortable and user-friendly. Furthermore, the lightweight nature of the rack helped the vehicle's overall aerodynamic efficiency, further optimizing fuel usage during transportation.

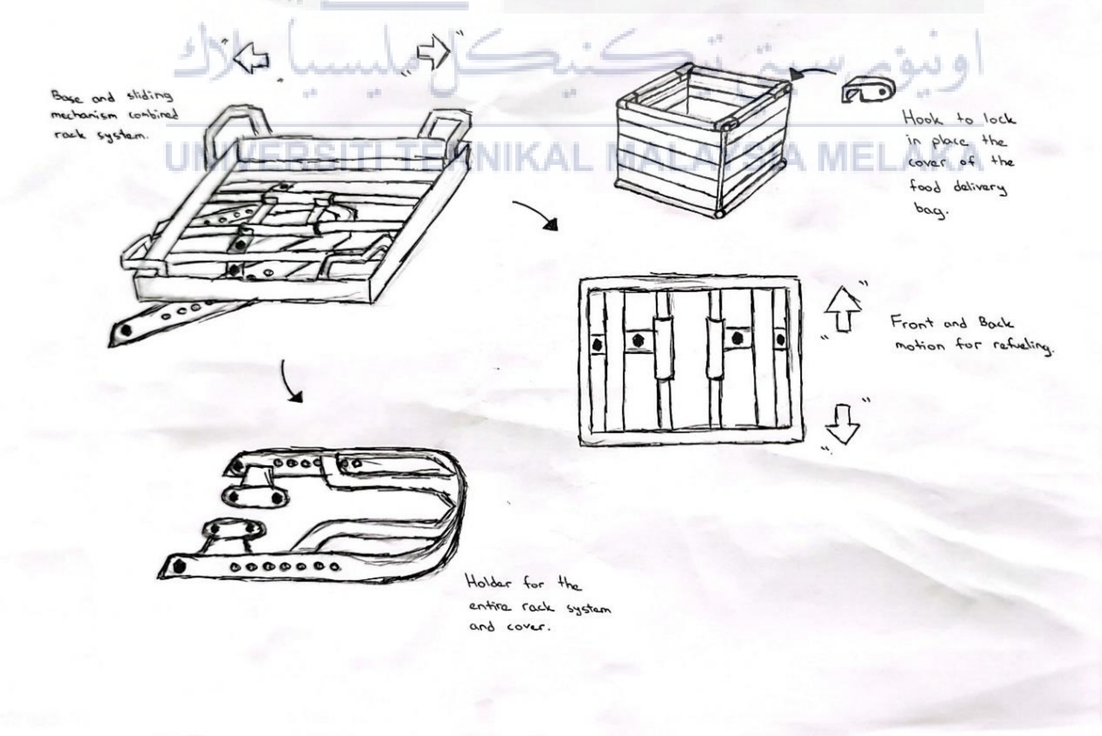


Figure 3.6 Concept design 2

Based on Figure 3.6, concept design 2 was developed and sketched, where the focus was on the refueling and protection aspect of the food delivery bag rather than the lightweight aspect of the overall rack system. This concept's design, like the first one, contained a mechanism that allowed for quick refueling of the motorbike while it was still mounted on the rack with front and back motion.

The design guaranteed that the refueling operation could be completed without removing the motorbike or the food delivery bag from the rack. This function permitted efficient refueling throughout delivery routes, saving delivery employees time and effort. Recognizing the necessity of food delivery bag protection, this idea design incorporated specialized compartments or enclosures inside the rack structure.

These chambers were intended to securely store and protect the food delivery bag from external influences such as weather or potential impact during transit. The possible weight increase of the overall rack system related to the installation of protective enclosures or compartments for the food delivery bag was a difficulty in this concept design.

This concept design intended to improve the efficiency, convenience, and safety of motorcycle-based food delivery services by concentrating on the refueling element and overall protection of the food delivery bag. While tackling the weight issue was critical, finding inventive methods to reduce the increased weight while guaranteeing appropriate protection was critical to the design's success.

3.7 Final Concept Design with SolidWorks 2023

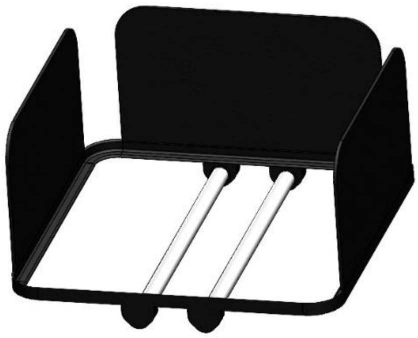


Figure 3.7 Frame of the motorcycle rack designed in SolidWorks 2023

Based on Figure 3.7, the frame of the motorcycle rack was designed using SolidWorks 2023 software where the design idea was taken from the existing market, combined with one's own ideas.

Figure 3.8 Sliding mechanism of the rack designed in SolidWorks 2023

Based on Figure 3.8, the sliding mechanism of the motorcycle rack was also designed using SolidWorks 2023 software, where the design idea was taken from the existing mechanism, combined with one's own ideas.

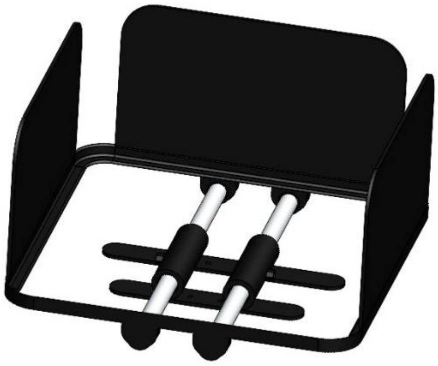


Figure 3.9 Final assembly of all parts of the rack in SolidWorks 2023

Based on Figure 3.9, all of the parts were combined and assembled into the semi-automatic motorcycle rack that was used for the fabrication process and built as the final prototype. The goal of this project was to automate the modeling of motorcycle racks by incorporating knowledge-based engineering methodologies into the early design phases once the design process had been finished, and the necessary data had been gathered.

In order to acquire a thorough grasp of the complete manufacturing process and precisely estimate the cost of the finished product, this included using real-world technical information. Any possible rack structural problems might have resulted in huge monetary losses. Focusing efforts on improving the design stage would have been useful in order to reduce costs related to motorbike rack development.

3.8 Calculation for Motorcycle Rack Weight

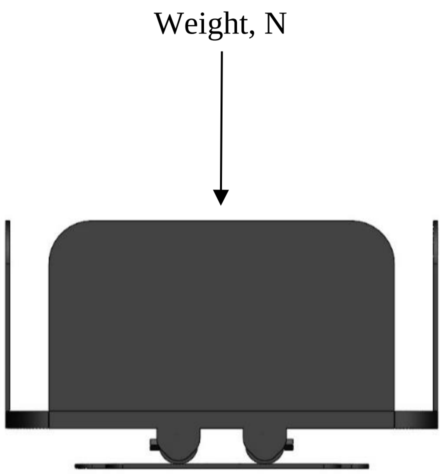


Figure 3.10 Semi-automatic motorcycle rack

$$Force, F = mass\ (kg)\ \times acceleration\ (ms^{-1}\ )$$

$$F = m\ \times a$$

a = gravitational force = 9.81 ms^{-1}

m = camera weight, Kg

The weight of a motorbike rack was explained using the equation W = mg. In this application, weight referred to the gravitational pull exerted by the motorbike rack. The variable m represented the mass of the motorbike rack and related to the amount of matter it held. The gravitational acceleration, g, represented the gravitational field's strength. The weight of the motorcycle rack (W) was obtained by multiplying the mass of the motorbike rack (m) by the rate of the acceleration caused by gravity (g).

3.8.1 Materials Selection

Table 3.3 Material selection

Figure	Description
L Shaped Steel Frame 	Used for the main frame and support structure of the motorcycle rack.
Steel Plates 	Used as the protective cover for the bag.
Hex Bolts 	Used to secure the various components together.

Figure	Description
Washers 	Used to keep the screw from loosening and to distribute the load from the nut.
Stainless Steel Nuts 	Used to tighten and hold hex bolts into place.
Sliding Hollow Stainless-Steel Tubes 	Acts as a slider with forward and backward movement.
Spray paint 	Used as a protective finish to enhance the appearance and corrosion resistance of the rack.

3.8.2 List of Machine Used

Table 3.4 List of machines used

Figure	Description
MIG Welding Machine 	Used to join the L shaped Stainless-Steel Frame and Sliding Hollow Stainless-Steel Tubes together.
Metal Cutting Saw 	Used to cut the tubing and L shaped steel and steel plates to the desired lengths.
Drill and Drill Bits 	Used for creating holes in the tubing and brackets for inserting fasteners.

Figure	Description
Measuring Tape and Vernier Caliper  	Used to ensure accurate measurements for cutting and positioning components.

3.8.3 FEA Parameter

Table 3.5 FEA parameter for hardware components (stainless steel)

Property	Value	Unit
Density	7750	kg m^{-3}
Coefficient of thermal expansion	0.1	c^{-1}
Derive from:	Young modulus and Poisson's ratio	
Young modulus	1.93 x 10^{11}	Pa
Poisson's ratio	0.31	
Bulk modulus	1.693 x 10^{11}	Pa
Shear modulus	7.3664 x 10^{11}	Pa
Tensile yield strength	2.07 x 10^{8}	Pa

Property	Value	Unit
Compressive yield strength	2.07×10^{8}	Pa
Tensile ultimate strength	5.86×10^{8}	Pa
Compressive ultimate strength	0	Pa

3.9 Concept Selection

3.9.1 Pugh Selection Method

The first part addressed the Pugh selection method and its significance in evaluating design options. The purposes and selection criteria for motorcycle rack design were provided. The criteria for selection that were utilized to evaluate the concept designs were described in this section. Each criterion had been set and classified as either positive (+), neutral (0), or negative (-) based on its significance and impact on the performance as a whole of the design. Among the criteria were size, protection, lightweight, cost, durability, ease of operation, and comfortability.

By summing the individual evaluations for each idea design, the net scores were calculated. The scores were classed as positive (+), neutral (0), or negative (-) based on their sum. The net scores provided a measurable evaluation of each design's overall performance. Based on their net scores, the idea designs were ranked from best to worst. The rating indicated the design that most closely matched the selection criteria and performed the best overall. The study provided a final grade, emphasizing the design with the highest net score as the best motorcycle rack choice.

The size criterion for evaluating motorcycle rack designs was concerned with the rack's compactness and space efficiency. A smaller-sized rack was preferable since it reduced unnecessary bulkiness during transit. The small dimension of the rack avoided it from impeding the rider's movement or providing additional hurdles along delivery routes. By reducing the size, the design could increase maneuverability and overall efficiency.

The protection requirements were critical in assessing how well the structure safeguarded the food delivery bag. The rack needed to offer a high level of security to protect the contents from outside influences and injury during traveling. This could be done by incorporating protective cages or compartments within the rack structure, as well as the use of strong and weather-resistant materials. A design that prioritized security fostered trust in the delivery process and maintained the integrity of the delivered items.

The lightweight requirement considered the weight of the motorcycle rack system. A lighter design offered several advantages, including improved maneuverability, higher fuel efficiency, and easier installation and removal. A lightweight rack reduced the load on both the motorcycle and the individual riding it, resulting in improved effectiveness and effortless transport operations. It also lessened the impact on the overall efficiency of the motorcycle and ensured that the extra weight of the bike rack did not jeopardize the motorcycle's stability.

The cost criterion evaluated the financial implications of the motorcycle rack design. While designing an efficient and high-performing rack system was vital, it was also critical to keep costs low without losing functionality and performance. Consideration of cost-effective materials, manufacturing processes, and design optimizations increased the rack's overall affordability. Achieving a cost-performance balance guaranteed that the rack design remained economically feasible for food delivery services.

Durability was an important factor in determining the strength and lifespan of a motorbike rack. The design had to be strong enough to resist the harsh conditions and demands of motorbike transportation over time. High-quality materials, strengthened structural parts, and extensive testing assured the rack's durability to varied environmental conditions and potential impacts. A sturdy rack design reduced the need for frequent repairs or replacements, lowered maintenance costs, and assured reliability over the lifetime of the rack.

The ease of operation criterion was concerned with the user-friendliness and simplicity of the motorbike rack's functioning. A simple design allowed for quick loading, unloading, and secure latching of the motorbike onto the rack. Installation and removal processes that were quick and easy added to the productivity and convenience of food delivery staff. The design guaranteed that users with varied degrees of expertise could easily operate the rack by taking into account intuitive mechanics, ergonomic features, and clear directions.

The comfortability criteria assessed the amount of comfort supplied to the rider while on the road. A design that reduced vibrations, impacts, and pain improved the user experience. The rack design could improve rider comfort by using shock-absorbing materials, ergonomic sitting configurations, and vibration dampening devices. Comfortable transportation made delivery operations go more smoothly and lowered rider fatigue, resulting in enhanced efficiency and work satisfaction.

3.9.2 House of Quality, HOQ

The House of Quality (HOQ) was an important instrument in the product development process for matching client expectations to design characteristics. This section contained a thorough House of Quality analysis for the motorbike rack design project. The HOQ matrix allowed for an assessment of how effectively the design met client needs, supporting a customer-centric approach and boosting the overall success of the end result.

The HOQ analysis emphasized the need to balance budget restrictions and functional objectives by recognizing the high relative impact of cost and material choices. This guaranteed that the motorcycle rack design not only fit consumer expectations in terms of protection, size, convenience of operation, and other elements but also stayed economically viable for manufacturing.

3.10 Fabrication process and making

The fabrication process and manufacturing phases are critical in developing the conceptual design into a physical and practical product in the development of the motorcycle rack. This complex procedure includes a number of precise procedures, including material selection, cutting, shape, welding, and assembly. This section goes into the fabrication process in detail, offering insight on the methodology used, quality control measures put in place, and the smooth integration of different components.

3.10.1 Main frame

The first stage in the construction of the motorcycle rack was to create a base for the main frame. As shown in Figure 3.11, 4 pieces of L shaped steel frame was used to build the base of the main frame following the proper size that was measured accordingly to the size of the food delivery bags which was 49 cm in length.

Figure 3.11 L shaped steel frame

The middle part of the L shaped steel frames was measured and marked to cut it and bend it into 90-degree angle so that the corners of all 4 base are bent to prevent sharp edges as shown in Figure 3.12.

Figure 3.12 90-degree angle bended corners of L shaped steel frames

Next, the bent L shaped steel frames were then cut using an angle grinder according to the measurement of the technical drawing which were 49 cm in equal length and joined together using MIG (Metal Inert Gas) welding as shown in Figure 3.13 to form the base.

Figure 3.13 Joint and welded L shaped steel frames

After finishing the base, the next stage was to create 4 holders for the sliding hollow stainless steel pipes where a thicker 0.5 mm hollow steel pipe was cut into 4 pieces including with 8 small plates to be welded to together bellow the base of the frame as shown in Figure 3.14.

Figure 3.14 4 pieces of 0.5 cm thickness hollow steel pipe and 8 pieces of small plates

Next, the 0.5cm thickness hollow steel pipe and smal pieces of plates were then welded together on all 4 sides to act as the holder for the 2 sliding hollow stainless steel pipes that will play a crucial role in the sliding mechanism as shown in Figure 3.15.

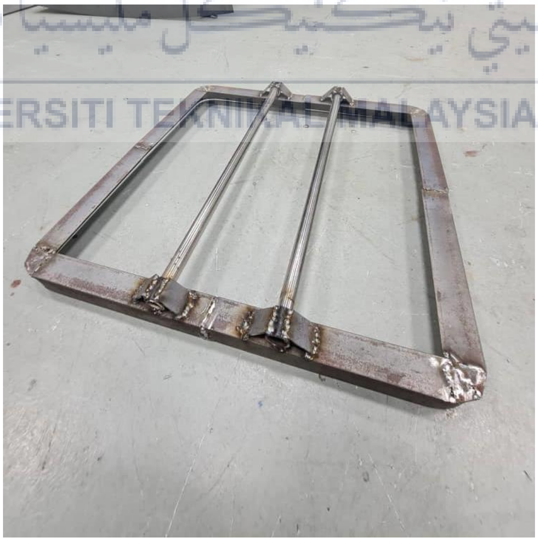


Figure 3.15 Completed base of the main frame

After the base was completed, the next stage of making the protective cover around the base was done where a few thick steel plates were cut according to the height of the technical drawing which was 20cm and 38 cm in length. The thick plates were then welded onto to base of the frame and grinder machine was used to blunt the sharp edges of the steel plates to prevent any injury or cut as shown in Figure 3.16.

Figure 3.16 Welded steel plates acting as cover for the main frame

3.10.2 Sliding mechanism

As for the sliding mechnasim, 2 thick 0.5 cm hollow steel pipe was cut with the length of 15 cm each and a 2 cm hole was drilled in the middle between both the steel pipes as shown in Figure 3.17. The holes functions as to hold the whole motorcycle rack into desired position and lock it into one place using bolts and nuts.

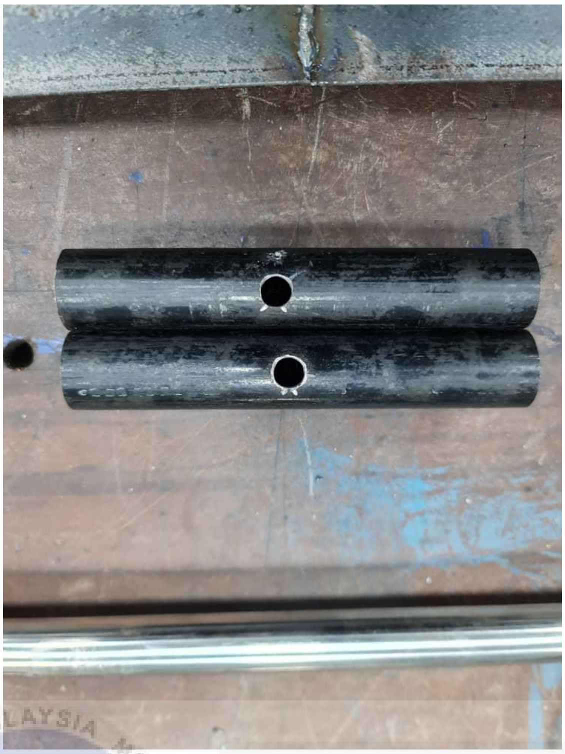


Figure 3.17 Hollow steel pipe with 0.5 cm thickness with 2 cm drilled hole

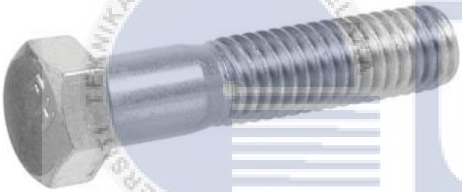
As for the base of the sliding mechanism, 2 steel plates were cut with the length consisting of 30 cm and 36 cm respectively and welded together with the 2 0.5cm hollow steel pipe to complete the sliding mechanism as shown in Figure 3.18.

Figure 3.18 2 pieces 0.5 cm hollow steel pipe welded together with 2 steel plates

3.11 Bill of Material

Table 3.6 Bill of Material

No.	Material/Components	Quantity	Price (RM)
1.	L Shaped Steel Frame 	7	210

No.	Material/Components	Quantity	Price (RM)
2.	Steel Plates 	1	24
3.	Hex Bolts 	20	10
4.	Washers 	20	14

No.	Material/Components	Quantity	Price (RM)
5.	Stainless Steel Nuts 	20	2
6.	Sliding Hollow Stainless-Steel 	4	56

No.	Material/Components	Quantity	Price (RM)
7.	Spray Paint 	1	10
Total			326

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

After conducting a thorough market assessment, the Pugh Selection Method and the House of Quality were implemented to assist with design decisions aligned with market demands. This approach ensured that the design process was informed by a comprehensive understanding of the market, allowing for a more targeted and customer-centric development of the motorcycle rack. The chapter thoroughly analyses technical drawings, the complex structure of load distribution, and the specifics of the selected design. The durability and reliability of the finished product is confirmed by an extensive analysis of the Factor of Safety (FOS) evaluations and Finite Element Analysis (FEA) results.

Testing and fitting is also done under real world conditions to ensure the motorcycle rack functions according to the design and mechnasim. A systematic procedure is also included to assemble the motorcycle rack onto a motorcycle where all this findings and discussions demonstrates the effectiveness of designing and developing the motorcycle rack and also lays a framework for future development and modifications for a better and optimized motorcycle rack.

4.2 Market Survey Result

The findings of a detailed market study done among food delivery riders to understand the issues connected with the existing design of motorcycle racks and the protection of food delivery bags were presented in this part. The online survey collected important feedback and recommendations from riders in order to improve the efficiency and efficacy of the meal delivery procedure.

The major goal of this study was to identify the major issues and limits experienced by food delivery riders in terms of present motorcycle rack design and food delivery bag protection. The survey attempted to investigate issues such as bag leakage, stability concerns, and refueling convenience, with the ultimate goal of optimizing the delivery process.

Based on Appendix C, there were a total of 53 responses from local food delivery riders working around the central Melaka district that answered the online Google survey form, which consisted of 16 questions. Based on Figure 4.1, it was discovered that 100% of the riders polled used a rack system to put their food delivery bags onto their bikes, highlighting the importance of these systems in the food delivery sector.

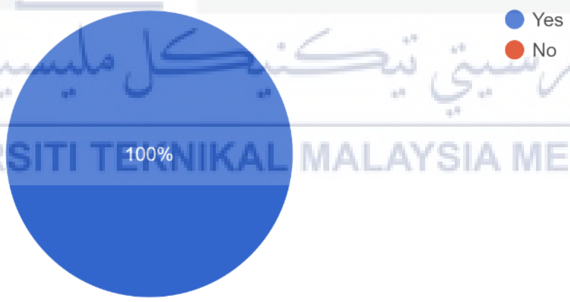


Figure 4.1 Amount of responded that used a rack system

The poll found that the riders rode a wide variety of motorcycle models, including 18 (34%) Y15ZR, 14 (26.4%) Honda RS150R, 5 (9.4%) SYM VF3i 185, 3 (5.7%) Suzuki Raider R150 Fi, and 13 (24.5%) Yamaha LC 135 based on Figure 4.2. This showed that there was no one-size-fits-all strategy for the selection of motorcycles for food deliveries, and riders had preferences depending on aspects like performance, durability, and compatibility with rack systems.

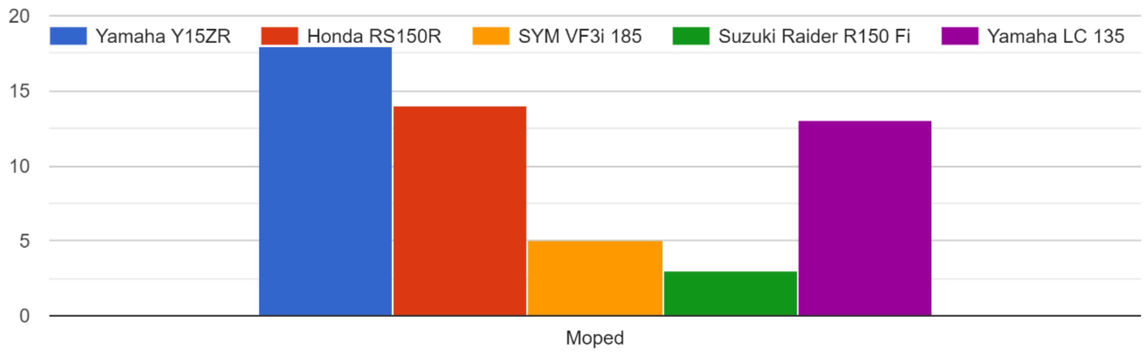


Figure 4.2 Types of motorcycle used for food deliveries with a rack system attached

One of the noteworthy results was that the majority of respondents (92.5%) believed that having a motorbike rack that securely covered food delivery bags was extremely or very vital based on Figure 4.3. This demonstrated the riders' care for the safety and protection of the supplied food while in transit. This showed that developing durable and secure rack solutions that could avoid food spills or damage during shipment was extremely important.

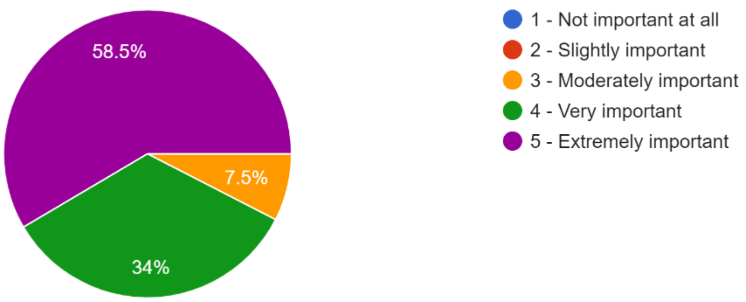


Figure 4.3 Importance of motorcycle rack that securely protects food delivery bags

The survey also revealed a number of issues with current motorbike racks. A sizable proportion of respondents (69.8%) reported regular or very frequent problems with the present rack systems, which resulted in food delivery bags collapsing or spilling their contents based on Figure 4.4. This suggested that the design and functioning of these racks should be improved to offer greater stability and security during transit.

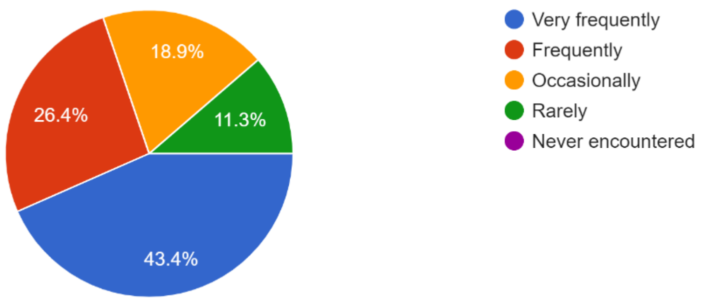


Figure 4.4 Experienced issues with existing motorcycle racks that result in food delivery bags falling and spilling their contents

As it came to the essential characteristics of motorbike racks, respondents stated distinct preferences. The majority of riders (88.7%) stressed the need for having a sturdy and long-lasting rack that could handle the pressures of regular food delivery operations based on Figure 4.5.

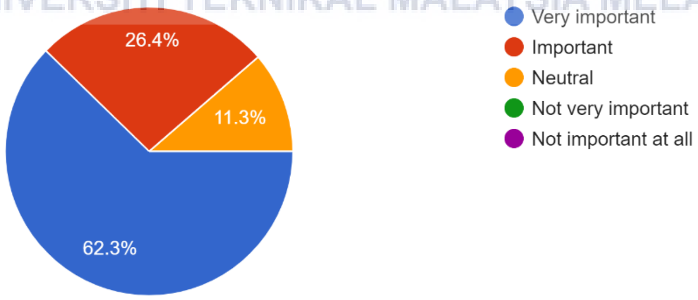


Figure 4.5 Strong and durable motorcycle rack

Furthermore, a sizable proportion of responders (84.0%) emphasized the need for a mobile design that allowed for quick refueling, allowing riders to properly control their fuel use during their delivery shifts based on Figure 4.6.

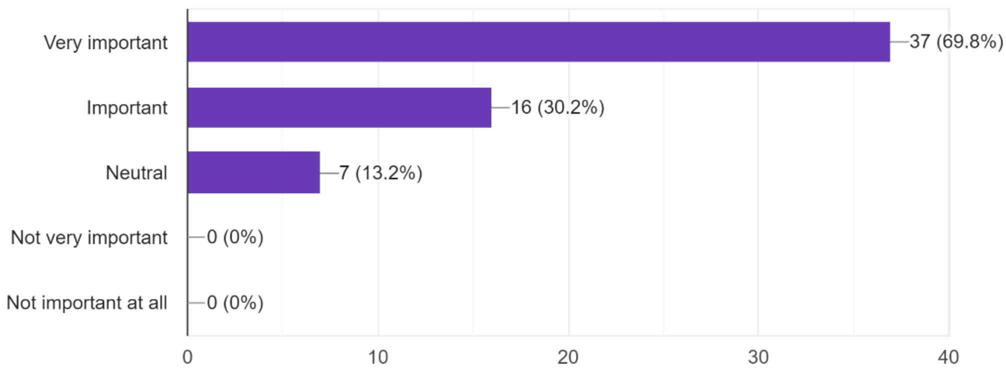


Figure 4.6 Importance to have the designed motorcycle rack to be movable for easy refueling

The poll also revealed some of the difficulties that the riders experienced. The vast majority (71.7%) of respondents experienced back discomfort when carrying the food delivery bag on their motorcycles with the rack attached based on Figure 4.7. This highlighted the need of ergonomic considerations in rack system design in order to reduce physical strain on riders and ensure their well-being.

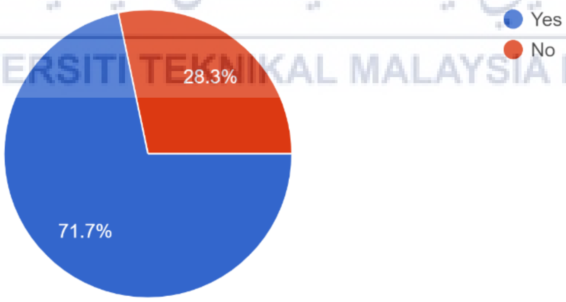


Figure 4.7 Food delivery riders facing back pain while carrying the food delivery bag on the motorcycle with the rack installed

Additionally, the mass and balance of the rack system were discovered to affect the responders' riding performance. The weight as well as the balance of the rack system with the food delivery bag connected had a substantial influence on their riding ability, according to the majority (56.6%) based on Figure 4.8. This emphasized the need of developing rack systems that maintained ideal balance while minimizing any detrimental influence on rider handling and maneuverability.

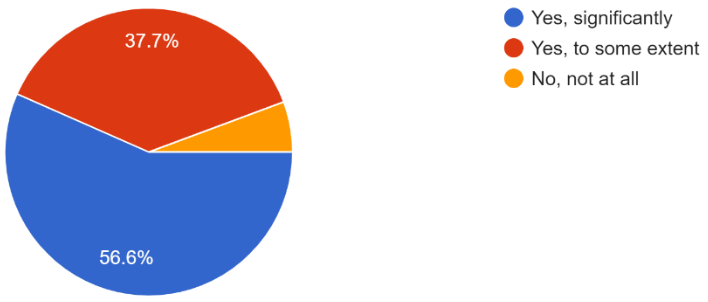


Figure 4.8 Felt the weight and balance of the rack system with food delivery bag attached on affecting the riding performance

Based on the feedback received, it was clear that there was potential for enhancements to the design of motorcycle racks for food delivery bags. Riders indicated a wish for readily moveable racks, coverings to protect food delivery bags from outside elements, stronger and and improved durability and quality.

Finally, the survey results emphasized the importance of rack systems in the food delivery sector and the need for changes in their design and performance. The responses of the polled riders gave vital information for future developments in motorcycle rack systems, eventually improving the efficiency and efficacy of food delivery operations.

4.3 Pugh Selection Method Result

Table 4.1 Criteria selection between four design using pugh selection method result

Selection Criteria	A	B	C	D
Size	+	0	0	0
Protection	–	+	+	+
Lightweight	+	–	–	0
Cost	0	–	–	–
Durability	–	+	+	+
Ease of operation	+	+	+	+
Comfortability	+	–	–	0
Sum +	4	3	3	3
Sum 0	1	1	1	3
Sum -	2	3	3	1
Net score	2	0	0	2
Rank	1	3	4	2

Based on table 4.1, the ideas for the designs were sorted from best to worst based on their net ratings. Design A had the highest net score, suggesting that it performed well overall. Design D and B were in second and third place, respectively, with Design C in fourth place. The rankings influenced the final decision process, with Design A being the suggested motorcycle rack option.

4.4 House of Quality, HOQ Result

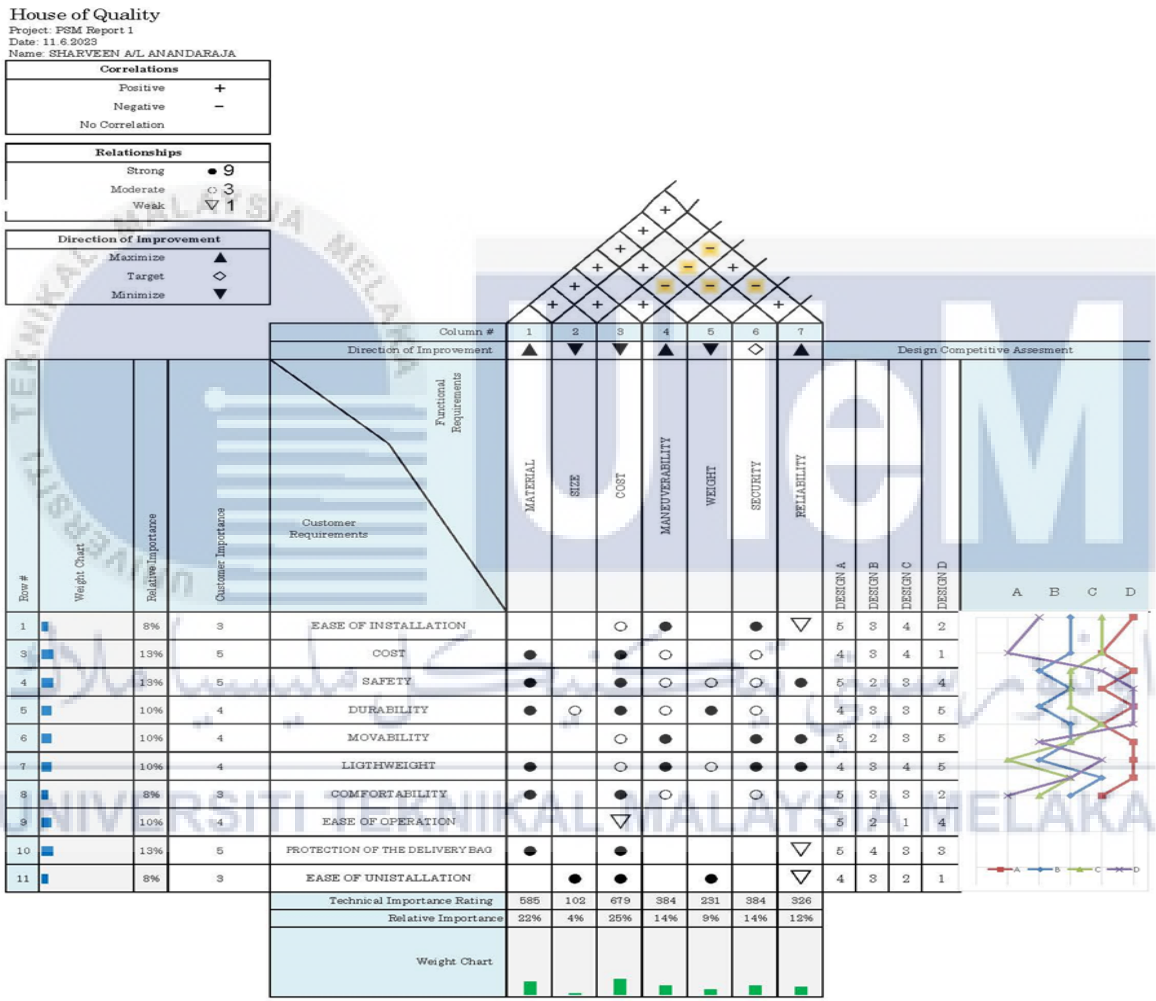


Figure 4.9 House Of Quality, HOQ for the motorcycle rack design resul

Based on Figure 4.9, cost had the highest relative importance, which was 25%, followed by the type of material from the functional requirements of the motorcycle rack design. The relevance of budget constraints in the motorbike rack design project was shown in the high relative emphasis attributed to cost. The cost of manufacturing was a critical factor in assessing the feasibility and economic viability of any product development project. The study recognized the necessity to build a design that was not only functional and aesthetic but also cost-effective to manufacture by providing a significant weightage to cost.

Bearing the cost implications considerations during the design process helped to guarantee that the final product could be created within the budget constraints. This entailed making strategic judgments about material selection, manufacturing techniques, and component selection in order to reduce production costs while maintaining the motorbike rack's performance and quality.

As for the material type chosen for the motorcycle rack design was also very important where it could have a significant impact on the motorcycle rack's durability, longevity, and also the weight which could affect the performance in general. Keeping in mind several aspects such as strength to weight ratio, cost-effectiveness, and resistance to corrosion was crucial in selecting a proper material for the motorcycle rack.

Steel was considered an excellent option due to its durability and corrosion resistance as well as being relatively cheaper as an option. The selection of the best material helped to reduce production costs, improve overall performance and lifespan of the motorbike rack, and ultimately satisfied customer expectations.

4.5 Technical Drawing

The top, front, and side perspectives of an object are given orthographically. A 45-degree angled piece of paper, on the other hand, reveals the object's 3D shape. Orthographic images are excellent in revealing the object's size and scale. An exploded view, also known as a technical drawing, on the other hand, shows how the many elements of an object relate to one another.

4.5.1 Orthographic View

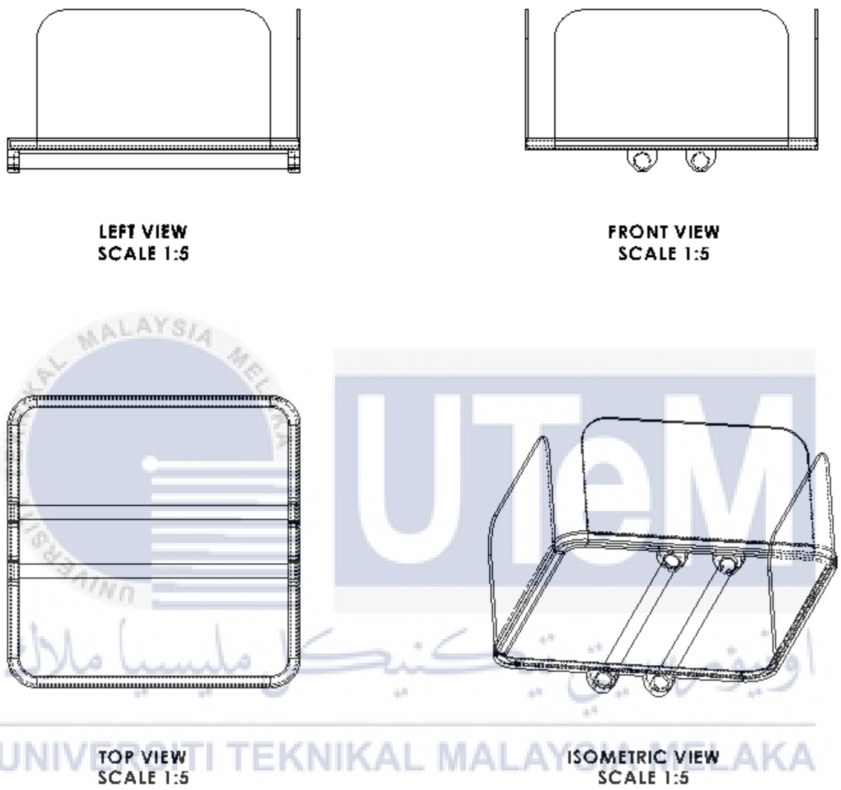


Figure 4.10 2D drawing of the main frame

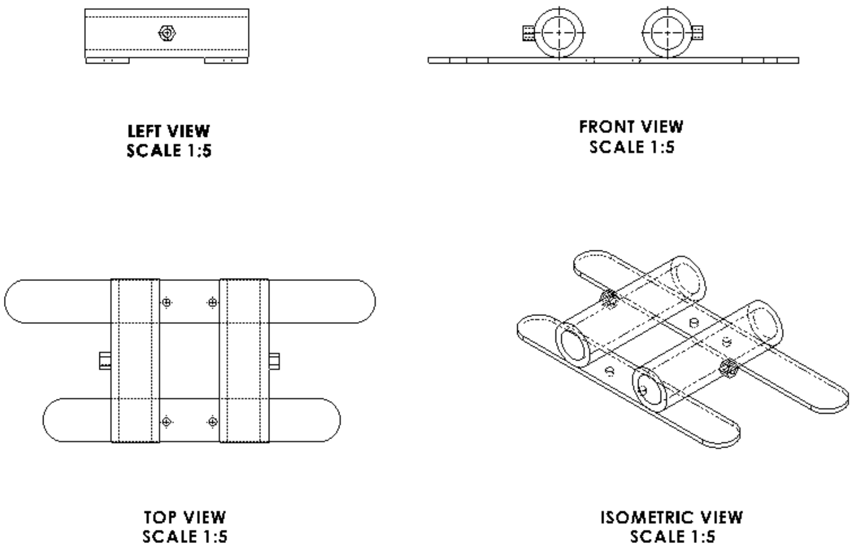


Figure 4.11 2D drawing of the sliding frame

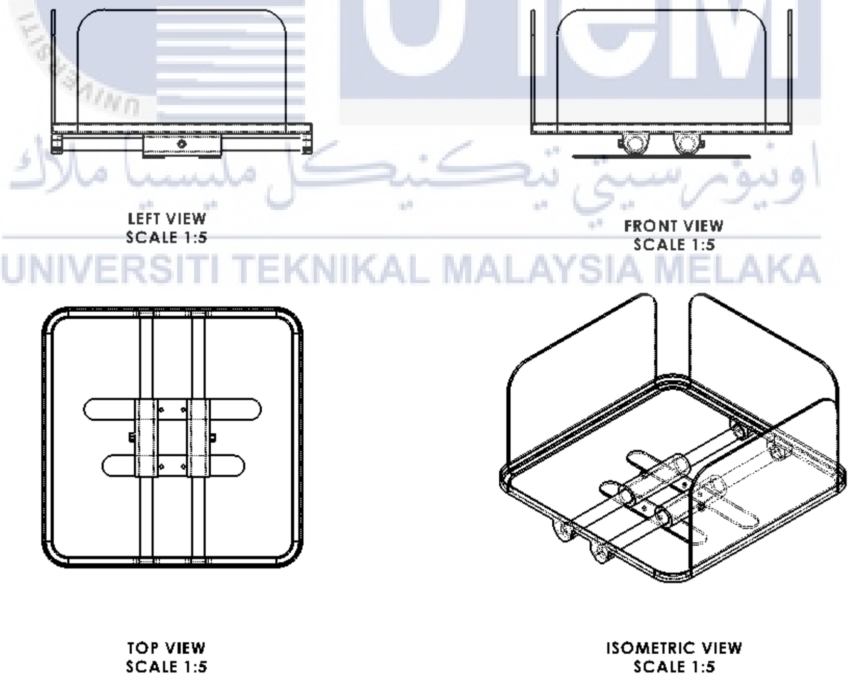


Figure 4.12 2D drawing of the motorcycle rack

Considering the parameters of the project, the 2D drawings has several orthographic perspective that serves as showcasing the main frame, sliding mechanism, and the motorcycle rack in effort to make these components sizes and forms much simpler to understand. These visual method is important for presenting complicated design details and enabling an proper and in-depth analysis of the geometries.

4.6 Load distribution

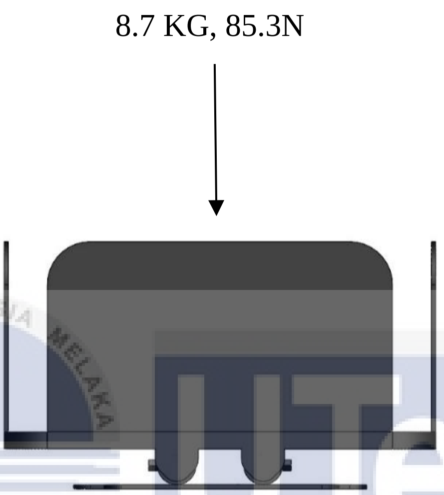


Figure 4.13 Distribution of force of the motorcycle rack

Prior to doing an in-depth examination on each part of the motorcycle rack design, a load distribution test on the handle components is required. This test is critical for determining where the majority of the force is centred when sustaining the weight of the motorcycle rack. Static construction is then subjected to simulation to acquire the relevant data. As a result, it is determined that the motorcycle rack with delivery bag weighs 85.3 N.

4.6.1 Load distribution data of motorcycle rack

Table 4.2 Mass of all parts

Parts	Quantity	Mass (kg)
Main frame	1	4.1
Sliding mechanism	1	2.4
Food delivery bag	1	2.2

4.7 FEA analysis

The analysis of structural integrity by Finite Element Analysis (FEA) is a vital stage in the design evaluation of the motorcycle rack. Before getting into the deep examination of each design part, FEA simulations of the structure are required. This stage is critical for gaining a thorough understanding of how the motorcycle rack reacts to various weights and pressures.

FEA is used in this context to examine the structural behavior and possible stress areas in the design. The FEA study explains how the components distribute and sustain the applied forces by applying a simulated load equal to the weight of the motorcycle rack with the delivery food bag on, which is 85.3 N.

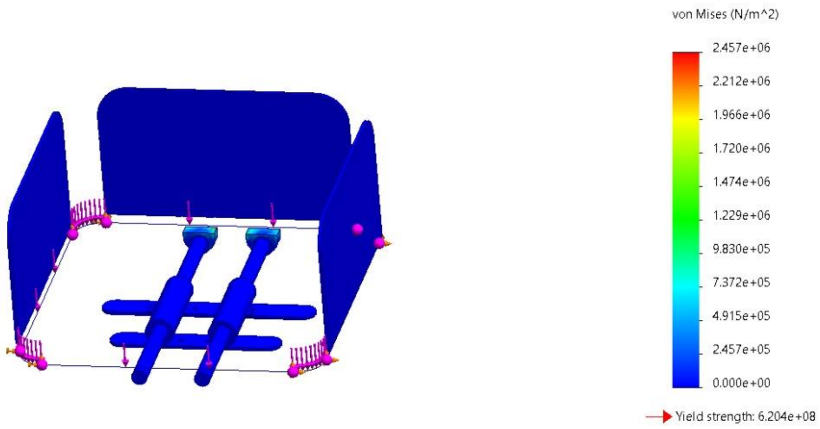


Figure 4.14 Von Mises Stress of the main frame

The Von Mises stress analysis of the primary frame of the motorcycle rack is critical in determining its structural integrity under an 85.3 N load. The maximum stress observed in the study is 2.457e+06 N/m^2, which represents the main frame's peak stress. This stress level is crucial for identifying possible failure areas and ensuring that the main structure can resist the force exerted. Minimum stress, estimated at 0.000e+00 N/m^2, indicates locations with lower stress concentrations. These Von Mises stress analysis findings are critical in refining the design, optimizing material consumption, and guaranteeing that the motorbike rack shows strong structural performance under the given load circumstances.

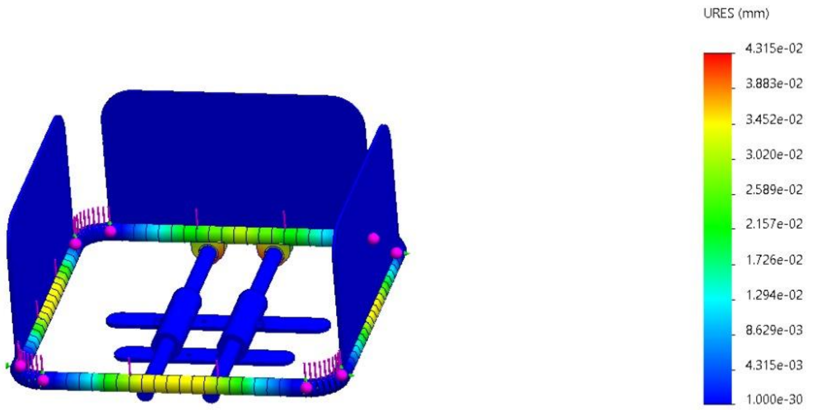


Figure 4.15 Displacement of the main frame

The displacement study of the motorcycle rack's main frame under a load of 85.3 N gives important insights into its structural response. The maximum displacement measured in the study is 4.315e-02 mm, showing the main frame's maximum degree of deformation under the imposed load. This maximum displacement number is useful for identifying possible areas of concern and refining the design to handle these deformations within acceptable bounds. The minimum displacement, measured at 1.000e-30 mm, on the other hand, depicts locations with little deformation. Understanding this range of displacements is critical for ensuring that the primary frame's structural integrity is maintained while tolerating the imposed force.

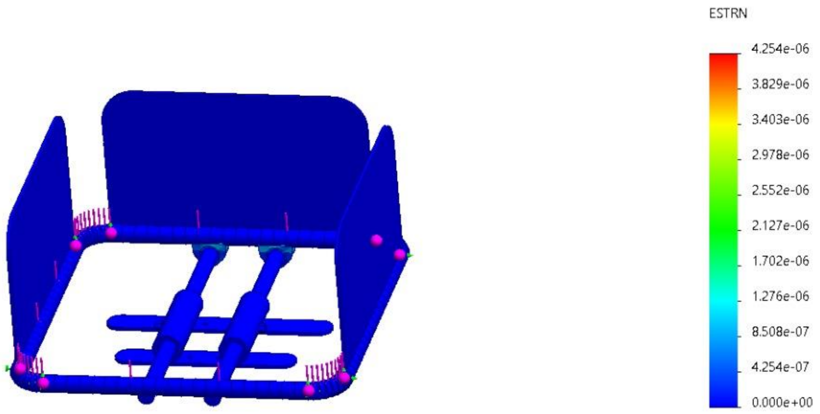


Figure 4.16 Strain of the main frame

The strain study of the motorbike rack's main frame, performed under an 85.3 N stress, gives important insights into the material deform properties. The maximum strain measured in the study is 4.254e-06, which represents the maximum amount of material deformation observed in the main frame under the imposed load. This maximum strain value is important for identifying possible trouble spots and ensuring that the material stays within permitted deformation limits. Minimum strain, measured at 0.000e+00, denotes locations with little deformation. The strain study results provide useful information for the refining of the main frame, assuring its structural reliability and efficacy in real-world applications.

4.8 Factor of safety (FOS)

The safety factor is a direct measure for assessing design safety, assisting designers in determining the acceptability of their generated or manufactured designs for user application. It is a critical indication of design safety and is sometimes referred to as a simple factor. The main goal of design analysis is to create a secure design. A design flaw can endanger human life and result in significant financial losses. The safety factor is calculated by using the formula presented below.

$$\text{Factor of safety, FOS} = \frac{\text{Ultimate stress}}{\text{Material strength}}$$

Table 4.3 Result of Safety Factor

Force applied : 85.3 N	Material strength (Pa)	Ultimate stress (Pa)	Factor of Safety
Main frame	2.567e+06	2.457e+06	1.35

4.9 Testing and fitting results

Figure 4.17 The food delivery bag fitted into the motorcycle rack

After assembling the motorcycle rack and fixing it onto the motorcycle, the bag is fitted into the motorcycle rack and tested to see if the bag fitted properly and the motorcycle rack prototype worked as it was intended based on Figure 4.17. The rack is then tested where it was pulled back until the maximum distance it can go and tried to open the seat fully for refueling proposes which worked as intended without any difficulty as shown in Figure 4.18.

Figure 4.18 Opening the seat after pulling back the motorcycle rack fully

The next test was done to see if the motocycle rack is pulled to the front until the maximum distance and check if the motorcycle rack properly fixed behind the pillion seat but not obstract the sitting position of the rider and make it uncomfortable. It was also tested to see if the whole rack did not obstract and block the back brake light of the motorcycle which is shown as in Figure 4.19.

Figure 4.19 Positioning the motorcycle rack fully to the front

As for the locking mechanism for the sliding hollow steel pipe, it was tested to see if the sliding mechanism can be locked into place easily without much effort in prefered position which worked as intended which was shown as in Figure 4.20.

Figure 4.20 Locking mechanism for locking the motorcycle rack in place

4.10 Summary of prototype test results

The prototype functions flawlessly according to with the thoroughly indicated design parameters. Notably, the motorcycle rack has a dynamic feature that allows for flexible forward and backward adjustment via a user-friendly pulling and pushing mechanism that permits secure locking into the chosen configuration. At the same time, a strategically placed surrounding cover serves the dual goal of protecting the food delivery bag and eliminating the need for extra fastening features such as bungee cords or straps.

The protective function of the cover is a substantial improvement, preserving not only the integrity of the delivered goods but also speeding the delivery process by removing the need for additional fastening equipment. This operating efficiency saves the delivery rider significant time and energy. The absence of bungee cords or straps eliminates the complications of bag positioning, resulting in a more efficient and smooth delivery experience.

Furthermore, the design innovation improves its application to include the ease of refuelling for delivery riders. The use of a sliding mechanism allows for the smooth retraction of the motorbike rack. This design element eliminates the need to untangle bungee cords that are generally fastened to the motorbike seat during refuelling activities. This not only saves time but also reduces the possibility of harm to the seat lock mechanism over time.

In summary, the expected results highlight not only the sticking to design purpose, but also the innovative impact of the motorcycle rack prototype on operational efficiency and rider convenience in the field of food delivery logistics.

4.11 Food delivery riders testing and feedback

The participation of 21 food delivery motorcyclists proved crucial in analysing the prototype's real-world performance during a critical stage of the motorcycle rack design process. The extensive user testing session provided a deep knowledge of the design's functionality, user-friendliness, and overall efficacy, creating critical findings for the project.

The prototype's easy bag securing mechanism was one of the main features highlighted by the participating riders. 13 out of 21 participants commended the user-friendly design, highlighting how it enabled for the safe attachment of food delivery bags with no effort, lowering the chance of spilling during travel dramatically. The sliding system, which allows quick access to the motorcycle's fuel tank without removing the entire rack, was much commended. Riders saw this as a time-saving and handy feature at refueling stops, which helped to streamline the whole delivery procedure.

Figure 4.21 Foodpanda rider testing sliding mechanism for fueling purposes

Furthermore, when compared to standard rack systems, 17 participants reported a significant reduction in back discomfort. The ergonomic design and good weight distribution enhanced the riding pleasure, especially during long delivery shifts. 9 riders commended its sturdy build, which ensured the integrity of delivered goods even in harsh conditions.

Figure 4.22 Grabfood rider testing the comfort and overall sturdiness of the motorcycle rack

Despite the positive response, several people were concerned about the locking mechanism's precision. Some users found it difficult to use, leading to concerns about stability while in transportation. Addressing this issue could involve improving the locking system's simplicity without sacrificing security. Compatibility concerns were also reported, particularly for riders riding less popular motorbike types. While the prototype exhibited adaptability, adopting a wider range of bike designs might require additional modifications to assure universal application.

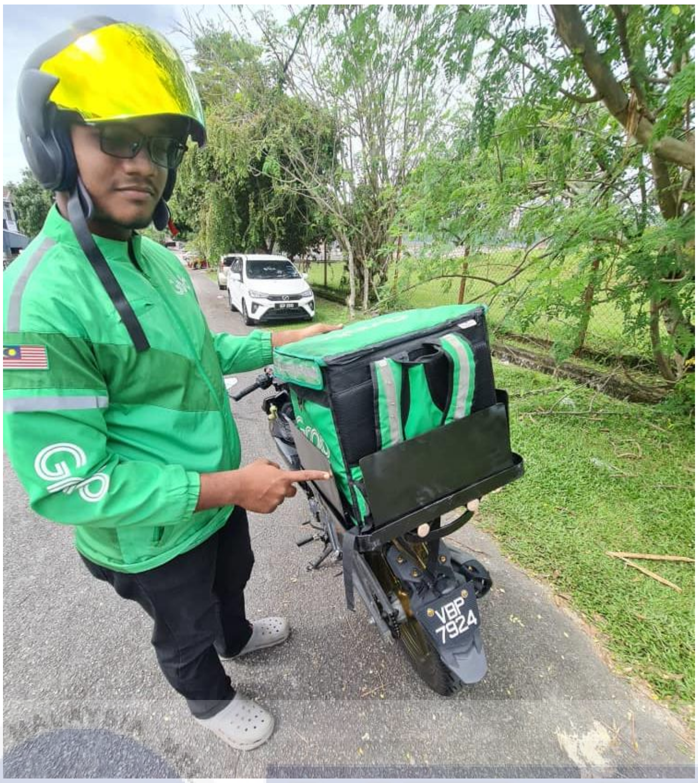


Figure 4.23 Grabfood rider addressing the overall weight of the motorcycle rack compared to the ones found in market

Respondents additionally raised worries about the heaviness of the motorcycle rack while not in use. While it excelled in utility, some riders found it difficult to store, particularly in situations where space was restricted. Taking this negative feedback into account, future design iterations may investigate foldable or space-efficient storage options to improve functionality. Finally, several riders remarked that the protective cover, while sturdy, contributed extra weight to the overall structure, affecting the motorcycle's manoeuvrability, particularly during tight bends.

The varied and informative opinions given by food delivery riders during this user testing phase are crucial for enhancing the prototype to address real-world difficulties. The constructive input is used as a guide for improving user satisfaction, ensuring that the motorcycle rack design not only matches, but surpasses, the actual demands and experiences of delivery motorcyclists in this constantly evolving and demanding profession.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The findings and suggestions for further research are presented in this chapter. In general, a lot of work has been done on developing motorbike rack prototypes using additive manufacturing methods. The goal of this study is to determine the best sample selection strategy for real-world production, taking into account both analytical and manufacturing factors. An overview and a summary of the main findings are presented in the last section, which provides a thorough analysis of the research. The report makes recommendations for the prototype motorbike rack project's further investigation and development.

5.2 Conclusion

The motorcycle rack's design and development, as described prior to show a rigorous and user-centered approach to tackling the issues that food delivery motorcycle riders face. The conceptual design phase set the groundwork for a product that takes into account essential issues such as simplicity of refuelling, protection of food delivery bags, and compact construction, all of which aim to improve the overall user experience.

Two separate idea designs were investigated, one prioritising refuelling and lightweight features and the other emphasising food delivery bag safety. This dual-track strategy offers an adaptable solution that caters to a wide range of user needs while demonstrating a sophisticated understanding of the complexities of food delivery logistics.

The use of SolidWorks 2023 in the final design and assembly process displays a dedication to using advanced instruments for precision engineering. The utilisation of 3D models and simulations helps to provide a more accurate depiction of the ultimate product, increasing confidence in the design's viability.

The elaborate production procedure included cutting and welding steel frames, making holders for sliding mechanisms, and attaching protective covers. This hands-on approach emphasises the actual translation of design principles into a physical, manufacturable product, guaranteeing that the desired answer is not only theoretical but also realistically achievable.

A market survey revealed that motorcycle racks play an important part in food delivery, with all questioned riders using them. The study results highlight the necessity of safe and protective designs that address frequent difficulties encountered by riders, connecting market expectations with design aims.

The Pugh Selection Method provided objective evaluation that favoured Design A, emphasising size, protection, lightweight construction, durability, ease of operation, and comfortability. The House of Quality (HOQ) research emphasised the importance of cost in motorcycle rack design, which guides strategic decisions about material selection and production methods.

Technical drawings provided a clear visual depiction of motorcycle rack components, while load distribution analysis revealed force distribution and ensured structural integrity. Finite Element Analysis (FEA) was used to test structural behaviour under load circumstances, and the results demonstrated the motorbike rack's ability to handle real-world forces without compromising safety.

The main frame's determined Factor of Safety (FOS) suggested a design with a safety buffer, ensuring structural reliability. The built motorbike rack was tested in the field, including installing the food delivery bag, adjusting the rack's position and testing the locking mechanism. The anticipated outcomes are consistent with the design objectives, emphasising user ease, security, and operational efficiency.

The impact of innovation may be seen in features such as the sliding mechanism, protective cover, and user-friendly adjustments, which address current difficulties while increasing the efficiency of food delivery operations. Finally, the full design and development approach demonstrated in this information represents a potential solution that satisfies the special needs of food delivery riders while boosting safety, efficiency, and satisfaction with the product. Future improvements to motorcycle-based food delivery systems can be built on this foundation for ongoing improvement.

5.3 Recommendation for future development

This project can always be enhanced with all of the data; here are some ideas on how this project could be improved in the future:

- Implementation of automated forward and back motion of the sliding mechanism for the motorcycle rack using sensors and actuators.
- Use more lighter but durable covers protecting the food delivery bag to reduce the overall weight of the motorcycle rack.
- To obtain extensive feedback, conduct extended user testing with a wide sample of motorcycle riders.
- Consider GPS tracking, temperature control for food delivery, and automated safety alarms.
- Make the rack adaptable to several motorcycle models.
- Allow users to adjust the motorcycle rack to fit various sizes and types of food delivery bags.

- Enhance fuel efficiency by incorporating aerodynamic principles into the structure.
- Develop a folding or collapsible motorbike rack to allow for convenient storage when not in use.
- Make the motorcycle rack simple to maintain and repair.

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APPENDICES

APPENDIX A Process of PSM planning in Gantt chart

Task	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15
Identify problem statement	■														
Identify objectives of project	■														
Identify scopes of project	■														
Conduct researches for literature review		■	■	■											
Produce general methodology		■	■	■											
Design prototype specimen using SolidWorks		■	■	■											
Planning on the motorcycle rack prototype					■	■									
Confirming the materials and parts needed					■	■									
Measuring and cutting process							■	■	■	■	■				
Fabrication and Welding process							■	■	■	■	■				
Modifying components and motorcycle rack prototype											■	■	■		
Testing the motorcycle rack prototype											■	■	■		
Getting feedback from food delivery riders using the motorcycle rack prototype													■	■	■

APPENDIX B Food delivery rider survey

Food Delivery Rider Survey - Challenges with Current Motorcycle Rack Design and Protection of Food Delivery Bags

This survey aims to gather insights and suggestions from food delivery riders regarding the design of motorcycle racks that provide secure and convenient protection for food delivery bags. The goal is to enhance delivery efficiency by addressing challenges related to bag spillage, stability, and refueling. Your feedback will help in designing racks that are strong, durable, and movable, ensuring easy bag attachment and detachment.

* Indicates required question

1. Do you use a rack system to install your food delivery bag onto your motorcycle? *

Mark only one oval.

- Yes
- No

2. What type of motorcycle do you use for food deliveries with a rack system attached? *

Mark only one oval per row.

	Yamaha Y15ZR	Honda RS150R	SYM VF3i 185	Suzuki Raider R150 Fi	Yamaha LC 135
Moped					

3. On a scale of 1 to 5, how important is it for you to have a motorcycle rack that securely protects food delivery bags? *

Mark only one oval.

- 1 - Not important at all
- 2 - Slightly important
- 3 - Moderately important
- 4 - Very important
- 5 - Extremely important

4. How often do you experience issues with existing motorcycle racks that result in food delivery bags falling or spilling their contents? *

Mark only one oval.

- Very frequently
- Frequently
- Occasionally
- Rarely
- Never encountered

5. How important is it for the designed motorcycle rack to be strong and durable? *

Mark only one oval.

- Very important
- Important
- Neutral
- Not very important
- Not important at all

6. How important is it for the designed motorcycle rack to be movable for easy refueling? *

Tick all that apply.

- [ ] Very important
- [ ] Important
- [ ] Neutral
- [ ] Not very important
- [ ] Not important at all

7. On average, how many times do you need to refuel your motorcycle's tank during your food delivery shifts? *

Mark only one oval.

- ( ) Once
- ( ) Twice
- ( ) Three times
- ( ) Four times or more

8. How do you typically install your food delivery bag onto the rack system of your motorcycle? (select all that apply) *

Tick all that apply.

- [ ] Using straps
- [ ] Using bungee cords
- [ ] Using hooks
- [ ] Other: __________

9. How frequently do you encounter difficulties in attaching or detaching food delivery bags to existing motorcycle racks? *

Mark only one oval.

- Very frequently
- Frequently
- Occasionally
- Rarely
- Never encountered

10. How easy is to fix the rack system onto the motorcycle? *

Mark only one oval.

- Very Easy
- Easy
- Neutral
- Difficult
- Very Difficult

11. How important is it for the food delivery bag to be installed and uninstalled onto the rack system easily? *

Mark only one oval.

- Very important
- Somewhat important
- Neither important nor unimportant
- Somewhat unimportant
- Not important at all

12. How satisfied are you with the overall design and functionality of existing motorcycle racks for food delivery bags? *

Mark only one oval.

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

13. Have you faced any back pain while carrying the food delivery bag on your motorcycle with the rack installed? *

Mark only one oval.

- Yes
- No

14. Do you feel that the weight and balance of the rack system with food delivery bag attached on affect your riding performance? *

Mark only one oval.

- Yes, significantly
- Yes, to some extent
- No, not at all

15. What are the most important factors for you while choosing a food delivery bag rack for your motorcycle? (Select all that apply) *

Tick all that apply.

- [ ] Ease of installation and uninstallation
- [ ] Security of the rack to the motorcycle
- [ ] Compatibility with different types of motorcycles
- [ ] Durability and quality of the rack
- [ ] Price of the rack
- [ ] Other: ______________________

16. Do you have any additional opinions or suggestions regarding the design of motorcycle racks for securely protecting food delivery bags? *

____

APPENDIX C Food delivery rider survey results

Food Delivery Rider Survey - Challenges with Current Motorcycle Rack Design and Protection of Food Delivery Bags

53 responses

Publish analytics

Do you use a rack system to install your food delivery bag onto your motorcycle?

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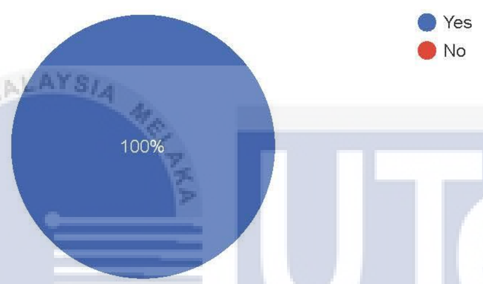
53 responses



What type of motorcycle do you use for food deliveries with a rack system attached?

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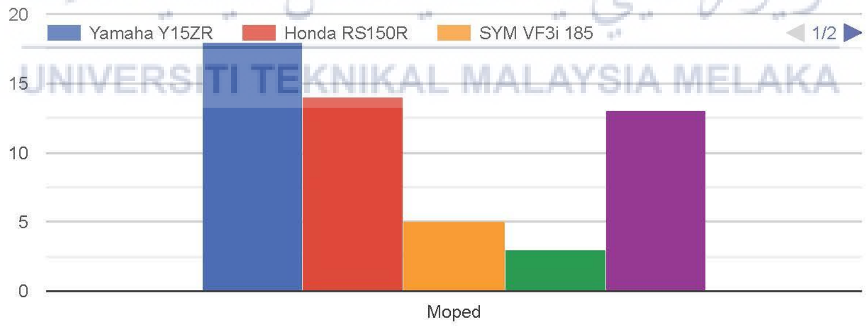

On a scale of 1 to 5, how important is it for you to have a motorcycle rack that securely protects food delivery bags?

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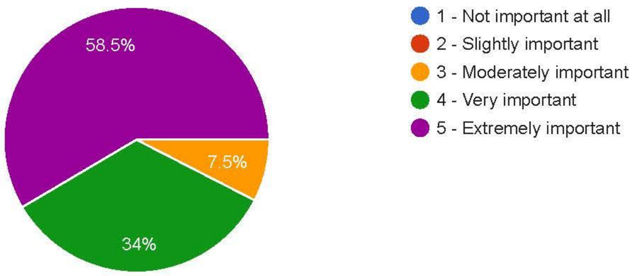
53 responses



How often do you experience issues with existing motorcycle racks that result in food delivery bags falling or spilling their contents?

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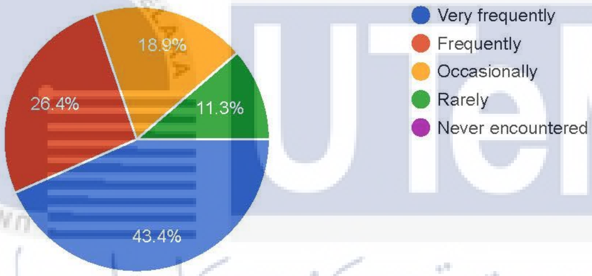
53 responses



How important is it for the designed motorcycle rack to be strong and durable?

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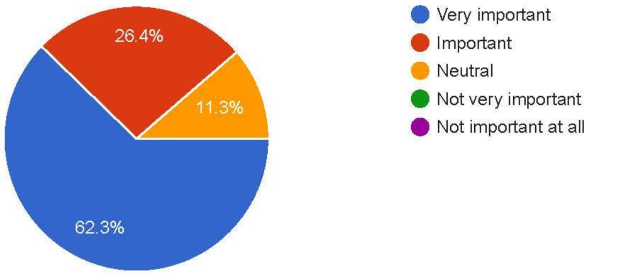
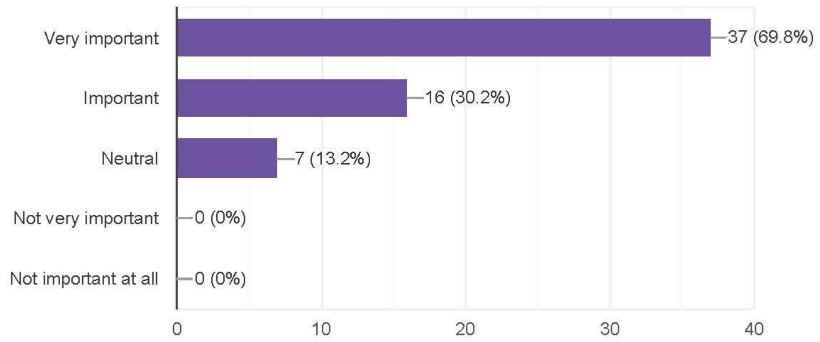


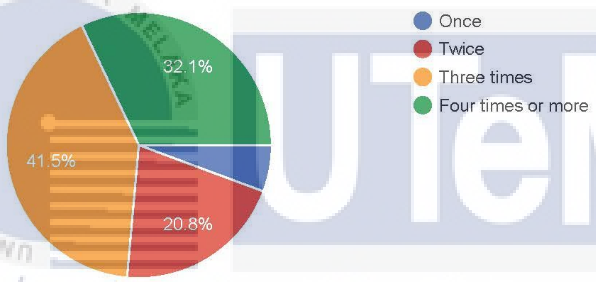
How important is it for the designed motorcycle rack to be movable for easy refueling? Copy

53 responses



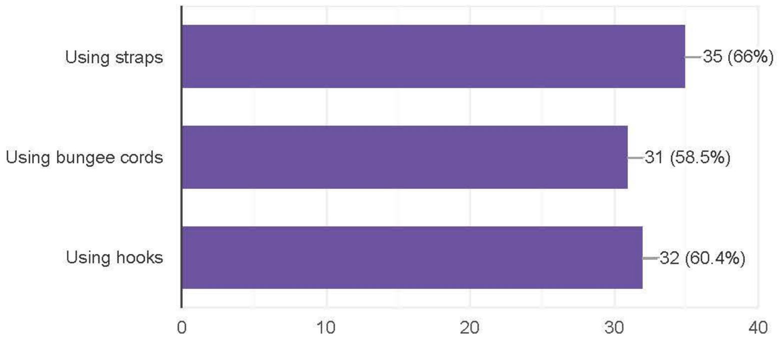
On average, how many times do you need to refuel your motorcycle's tank during your food delivery shifts? Copy

53 responses



How do you typically install your food delivery bag onto the rack system of your motorcycle? (select all that apply) Copy

53 responses



How frequently do you encounter difficulties in attaching or detaching food delivery bags to existing motorcycle racks?

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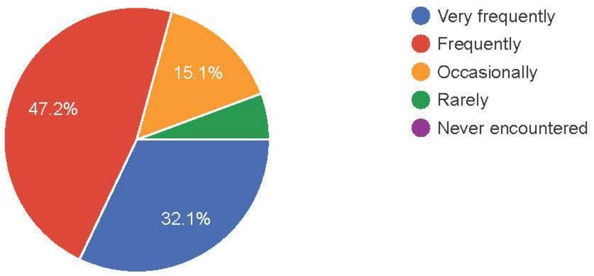

How easy is to fix the rack system onto the motorcycle?

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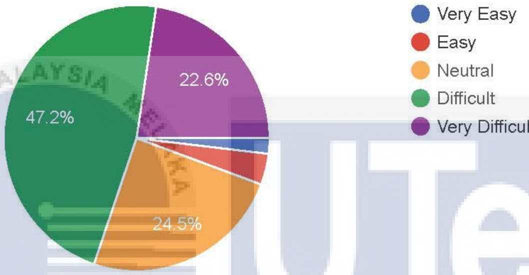
53 responses



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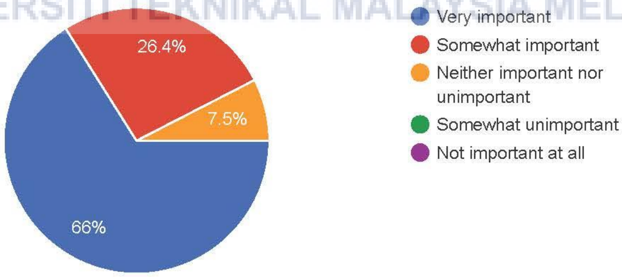
How important is it for the food delivery bag to be installed and uninstalled onto the rack system easily?

53 responses



How satisfied are you with the overall design and functionality of existing motorcycle racks for food delivery bags?

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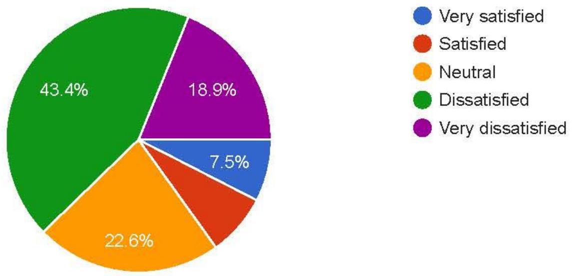
53 responses



Have you faced any back pain while carrying the food delivery bag on your motorcycle with the rack installed?

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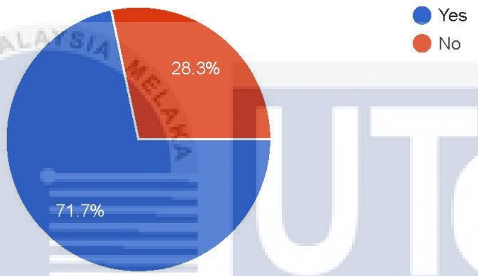
53 responses



Do you feel that the weight and balance of the rack system with food delivery bag attached on affect your riding performance?

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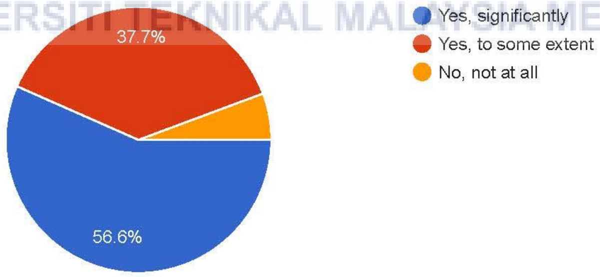
53 responses



What are the most important factors for you while choosing a food delivery bag rack for your motorcycle? (Select all that apply)

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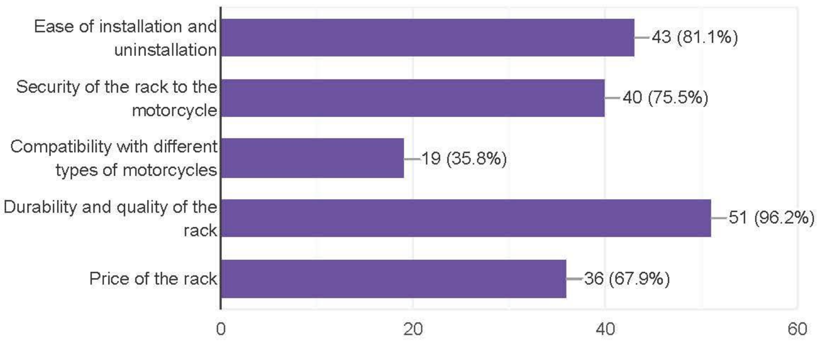
53 responses



Do you have any additional opinions or suggestions regarding the design of motorcycle racks for securely protecting food delivery bags?

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53 responses