Research Progress in Mechanical and Manufacturing Engineering Vol. 3 No. 1 (2022) 988-997

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Design of Mobile Scooter to Increase Flexibility and User Friendliness

Goh Zong Wei[1], Nik Hisyamudin Muhd Nor[1]*

[1]Faculty of Mechanical and Manufacturing Engineering,
University Tun Hussein Onn Malaysia(UTHM), 86400, Parit Raja, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2022.03.01.104
Received 01 Dec 2021; Accepted 01 April 2022; Available online 30 July 2022

Abstract: Mobile scooter is a light-weight transportation device that is specially designed for short distance travel. Due to the size and less flexibility characteristic of existing product in the market, the mobile scooter is not easy to be store and carry. Hence, the objective of this project is to design a flexible and user-friendly mobile scooter that can be carried easily. The general idea of the mobile scooter is typically based on customer's expectation and requirement. The design process method introduced by George E. Dieter is referred to as the guideline of this project including conceptual design, embodiment design and detail design. The analysis by formula calculation and SolidWorks software are done to ensure the specification and quality of mobile scooter reach the customer requirement. The final design expected to be more flexible and user friendly. The power rating of mobile scooter is 500W with maximum speed of 25km/hr. The dimension of mobile scooter before folding is 1124mm(L) x 464mm (W) x 1200mm(H) and the height reduce to 360mm after folded. The estimated weight of mobile scooter is 12.8kg including motor and battery. The objective had been achieved in aspect of flexibility and user friendliness.

Keywords: Mobile Scooter, Engineering Design, Solidworks

1. Introduction

Micro-mobility is a new mode of travel category that uses personal transportation devices which is known as micro-mobility vehicles to travel a short distance[1]. The micro-mobility vehicle is a light-weight transportation that is specially designed for personal used to allow the rider travel in a faster and more convenient way from one place to another within a short distance[2]. The usage of micro-mobility vehicle has gone up over the years as it can provide quick and convenient rides[3]. According to research, more than 50% of car trips are shorter than 5 miles in United State and the micro-mobility vehicle became the favourite choice of people as it can be travel faster and more convenient in a short distance[4]. File mile/last mile is to describe as the passenger need to travel for getting to or from rail and bus stops which is normally under a short distance[5]. Therefore, micro-mobility vehicle service is one of the suggested solutions to solve the first mile/last mile issue and the gaps between public transport.

*Corresponding author: nhisyam@uthm.edu.my

The upcoming problem for micro-mobility vehicle is how and where the vehicle to be store or keep. Some of the micro-mobility vehicle is not flexible and their size is big[2]. The convenience and practicality depend on the level of difficulty to bring the vehicle around and using it on our daily basis. Therefore, flexibility and user-friendliness of vehicle is crucial to develop so it can be easier to carry and store in a small compartment. In this project will discussed about the engineering design process of mobile scooter which is under the category of micro-mobility vehicle.

1.1 Objective

The main objective of this project is to design a flexible and user-friendly mobile scooter that can be carried easily.

1.2 Expectation of Study

The expectation of this project is to develop a mobile scooter to improve the flexibility and user friendliness. The flexibility and reasonable weight of the mobile scooter design allows the perfect storing in a smaller compartment and easier to carry around. The project drawing of the mobile scooter can be design using SolidWorks. By using SolidWorks, the simulation of component and weight of the mobile scooter can be evaluated to achieve the customer's requirement.

2. Literature Review

Literature review is important to gather information to determine the mechanism, design structure, specification, and the function of existing machine. This helps to generate new idea and solution to improve the existing product. This can be done by patent search and studies on the existing product.

2.1 Studies on Type of Micro-Mobility Scooter

There are a few types of micro-mobility scooter that used in difference of operation such as kick scooter. electric scooter and foldable scooter. Kick scooter is a human energy powered device that operates by rider swinging his leg in a kicking motion to push off the scooter and move forward[6]. Electric scooter is the one operates by using electric motor, normally a DC electric motor is use as its operation[2]. Foldable scooter can be transformed into a small compact unit that can be store in a small compartment.

2.2 Patents Search

Several patents are reviewed and compared in collecting information of existing design to develop the design concept. Table 1 shows the list of patents selected to be reviewed and compared.

Table 1: List of Patents Selected

No.	Patent Name and Number
1	Electric Scooter (Patent No: CN202863656U)
2	Three-wheeled electric scooter (Patent No: US 9592876B2)
3	Powered Foldable Scooter (Patent No: US8162090B2)
4	Foldable Scooter (Patent No: CN205554463U)
5	Foldable Scooter (Patent No: US7134677B2)

2.3 Benchmarking

Benchmarking is a tool used to figure out the best performance being achieved in a company, a competitor or by a totally different section of industry[7]. Benchmarking is important for the designer to compare the specification of the existing product in the engineering design process. Table 2 shows the comparison of available product.

Table 2: The Comparison of Available Product

Product	Glion Balto Electric Scooter	Uberscoot 1000W Electric Scooter	Razor A5 Lux Kick Scooter
Figure			
Manufacturer	Glion	EvoPowerboard	Razor
Power Source	Electric Motor	Electric Motor	Foot power (manual)
Power	750 W	1000 W	-
Weight	17 kg	34 kg	3.81 kg
Dimension,mm (L*W*H)	1220*300*670	1250*250*1100	860*457*980
Portability	Medium	Low	High
Maximum load	115 kg	120 kg	100 kg
Maximum Speed	27 km/h	34km/h	Depend on rider
Type of tires	12” pneumatic tires	11” pneumatic tires	8” urethane tires
Braking system	Rear disc brake	Disc brake for front and rear wheel	Rear fender brake
Foldability	Yes	Yes	Yes
Features	-Removable seat -Swappable battery -Detachable storage basket	-Powerful motor -Better braking system -Dual coil spring suspension	-High portability -Easy to fold -Simple design structure

3. Project Flow

3.1 Flow Chart

The design process method is the basis for directing the design process steps and creating engineering techniques and systematic approaches that allow the engineer or designer to obtain a better solution in developing and designing a product[8]. Engineers can use the series of design process steps to get the initial ideas and further development of the product to meet desired needs. Based on the design process proposed by George E. Dieter, the design process model consists of three main phases of design process which is conceptual design, embodiment design and detail design [9]. These three main phases of design are further divided into eight stages of activities. Figure 1 shows the flow chart of design process.

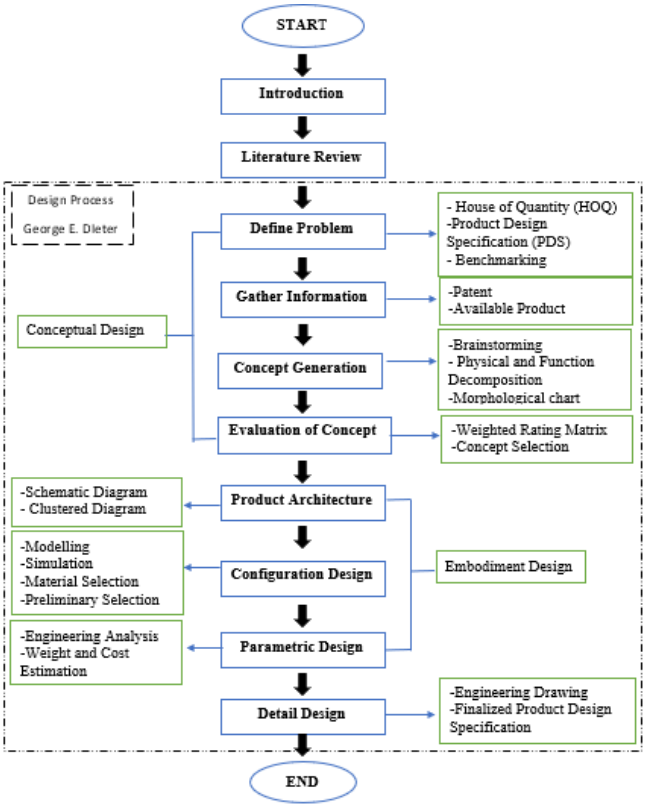

Figure 1: Flow Chart of Design Process

3.2 Objective Tree

Figure 2 shows the Objective Tree of Mobile Scooter. The requirements such as function, design, price, safety, and sustainability listed followed by sub-criteria.

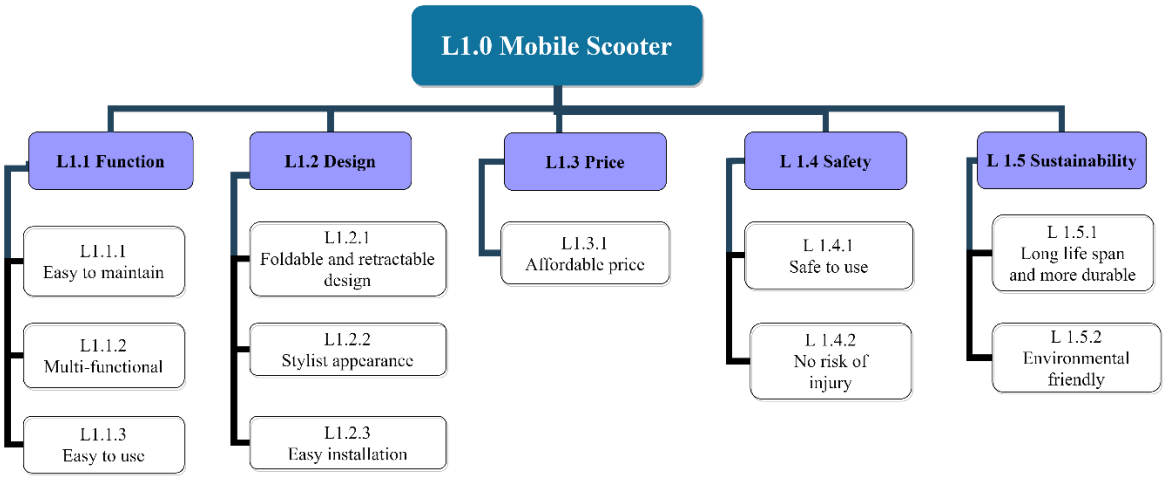

Figure 2: Clarifying Objectives Tree of Mobile Scooter

3.3 Product Design Specification

Product design specification is a crucial tool to guide the designer to develop the design specification of the mobile scooter based on the information obtained from the survey and HOQ to achieve the requirement from the customer. Table 3 shows the detail of engineering design specification for the mobile scooter.

Table 3: Product Design Specification for the Mobile Scooter

Introduction	
Title	Mobile Scooter
Design Problem	Scooter in the current market is not flexible and the size is too big. Problem in portability and storing.
Intended Purpose	To improve the flexibility and user friendliness.
Project Requirement	
Function Performance	• The scooter able to travel in a maximum speed between 20-30km/hr • Can be function in power and non-power mode of travel. • Removable seat to fit the usage of customer whether they need to travel in standing or sitting.
Operating Environment	• Suitable to use in rural and urban area. • Not suitable to use in aggressive terrain such as off-road travel.
Economic	• The selling price of the scooter must be affordable. • Low maintenance cost.
Geometric Limitation	• The total weight of mobile scooter should be less than 15kg. • The scooter able to fit in most of the sedan and MPV in the market after completely folded.
Maintenance, Repair, Retirement	• The scooter should be easy to change the battery and easy maintenance on the power transmission of scooter.
Safety	• No sharp edge that can cause any damage or danger to the rider.
Ergonomics	• The height of the handlebar and saddle tube are adjustable according to the height of the customer.

3.4 Full Assembly of the machine

Function structure is represented in a graphical order based on function decomposition that consists of the input and output of mobile scooter. The Figure 3 shows the black box of mobi

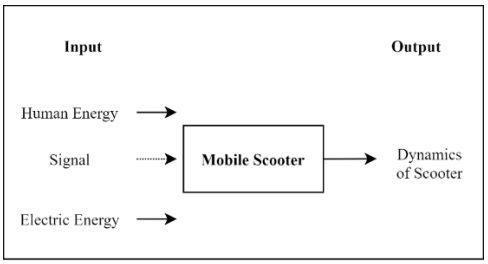

Figure 3: Black Box Function Structure for Mobile Scooter

Morphological chart is a tool for generating and analysis of different combinations of components in a table that help designer to select the most appropriate combination that satisfy the common functionality required in a new product. Evaluation of combination can be done by weighted decision matrix which rank all the alternative combinations to meet the design goal. Figure 4 shows the highest rated weighted of the concept design are selected.

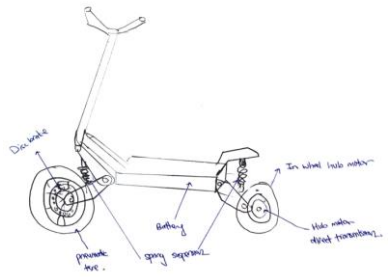

Figure 4: Project Sketch

The design of the mobile scooter is created in SolidWorks. Figure 5 shows the three-dimension overview of the mobile sooter when folded and unfolded.

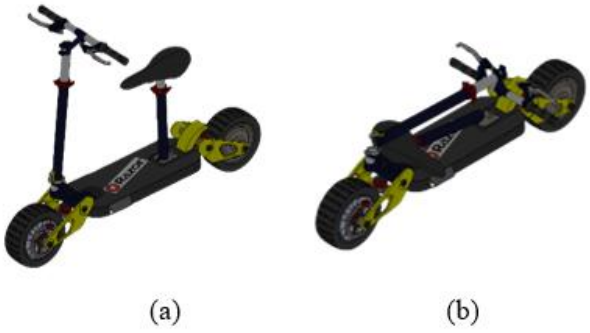

Figure 5: Isometric view (a) unfolded (b) folded

3.5 Simulation

Simulation was conducted on deck, brake disc and wheel. Static analysis was conducted on deck and wheel while thermal analysis was conduct on brake disc. Figure 6 and 7 show the static analysis on deck and wheel respectively. Figure 8 shows the thermal analysis of brake disc.

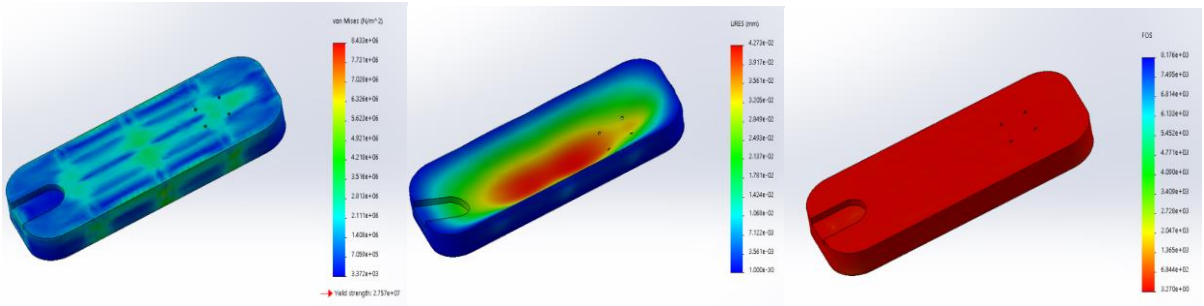

Figure 6: Simulation of Deck

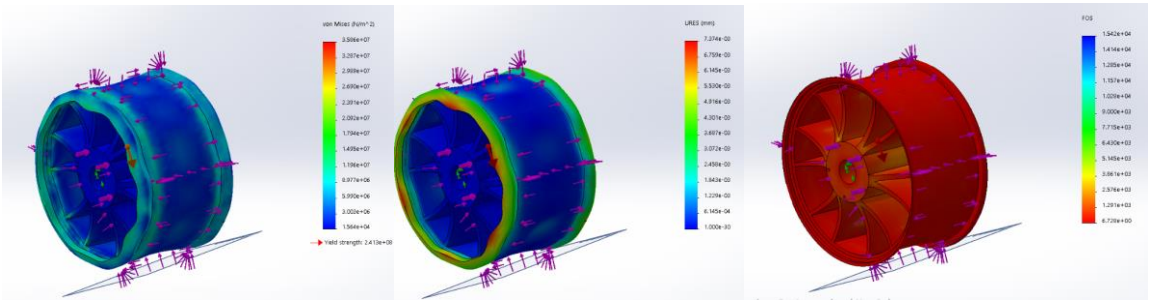

Figure 7: Simulation of Wheel

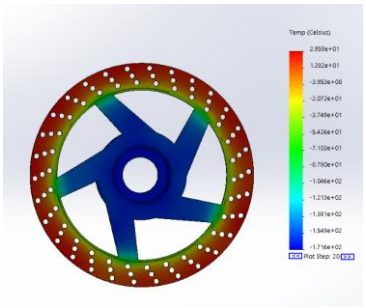

Figure 8: Simulation of Brake Disc

3.6 Engineering Analysis

Engineering analysis was analyzed to generate the details specification of the mobile scooter.

i. Fundamental Analysis in the In-Wheel Hub Motor

In-Wheel Hub Motor is a synchronous electric motor which is powered by direct current (DC). From the catalogues and the specification of the In-Wheel Hub Motor available in the market, the motor selected in this project is 36V;500W. By considering suggested speed of micro-mobility vehicle in different countries, the maximum speed of mobile scooter was limited to 25km/hr in this project. In verifying the capability of motor, the scooter dynamics such as rolling resistance, gradient resistance and aerodynamic drag will be considered.

$$F_{rolling} = C_{rr} * M * g \quad Eq.1$$
$$= 0.0025(112)(9.81)$$
$$= 2.7468N$$

$$F_{gradient} = Mgsin\theta \quad Eq.2$$
$$= 112(9.81)\sin(1.72)$$
$$= 32.98\text{N}$$

$$F_{aerodynamicdrag} = 0.5C_D A_f \rho v^2 \quad Eq.3$$
$$= 0.5(0.5)(0.7)(1.1644)(6.9444)^2$$
$$= 9.826\ \text{N}$$

$$F_{total} = F_{rolling} + F_{gradient} + F_{aerodynamicdrag} \quad Eq.4$$
$$F_{total} = 2.7468 + 32.92 + 9.826$$
$$= 45.5528\text{N}$$

$$\text{Power required for the motor} = F_{total} * v \quad Eq.5$$
$$= 45.5528(6.9444)$$
$$= 316.34\ \text{W}$$

The power required for the motor is 316.34W which do not exceed the power rated of the hub motor selected (500W). Therefore, the motor is safe to use.

ii. Thermal Analysis of Brake Disc

The mobile scooter can be slow down or stop by applying the friction to the brake disc to reduce the speed of the rotating disc. The heat power and heat flux generated of the brake disc and be calculated and the result can be further simulate by using SolidWorks to evaluation the thermal distribution of the disc. The table 4 shows the parameters of Mobile Scooter.

Table 4: Parameters of Mobile Scooter

Mass of Mobile Scooter, m	112Kg	Stopping Distance Time, t	2 sec
Initial Velocity	6.9444 m/s	Brake Disc Inner Diameter, d	98mm
Vehicle Speed After Brakes, u	0 m/s	Acceleration due to gravity, g	9.81m/s
Brake Disc Outer Diameter, D	125mm	Static Coefficient of Friction	0.4

$$KE = \frac{1}{2}mv^2 \quad Eq.6$$
$$= \frac{1}{2}(112)(6.9444)^2$$
$$= 2700.58\ \text{J}$$

$$Heat\ Power\ Generated, P = \frac{KE}{t} \quad Eq.7$$
$$= 2700/2$$
$$= 1350.29\ \text{W}$$

$$Stopping\ distance = \frac{v^2}{2\mu g} \quad Eq.8$$
$$= \frac{6.9444^2}{2(0.4)(9.81)}$$
$$6.145\ \text{m}$$

$$Heat\ Flux\ Generated = \frac{4P}{pi(D^2 - d^2)} \quad Eq.9$$
$$= \frac{4(1350.29)}{3.14159(0.125^2 - 0.098^2)}$$
$$= 285541.04\frac{W}{m^2}$$

3.7 Engineering Drawing

Engineering drawing of the mobile scooter will be generated by using SolidWorks. The details of the component such as material and dimension of the mobile sooter will be stated in the engineering drawing. Figure 9 shows full assembly for the overview design of the mobile scooter. Figure 10 shows the exploded view of the mobile scooter.

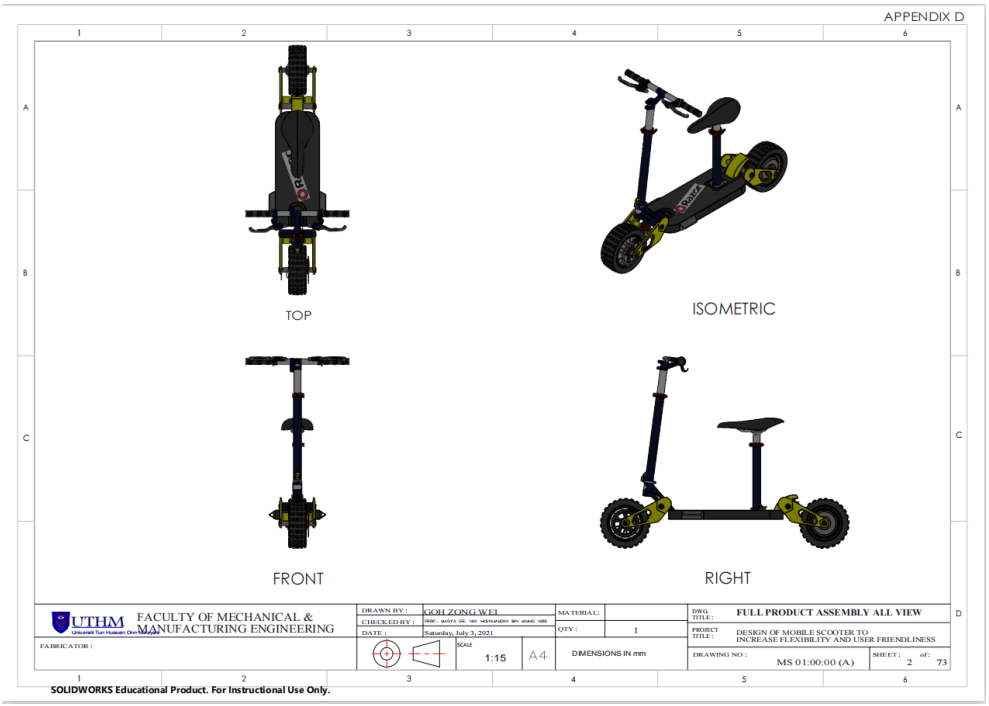

Figure 9: Full Assembly of the Mobile Scooter

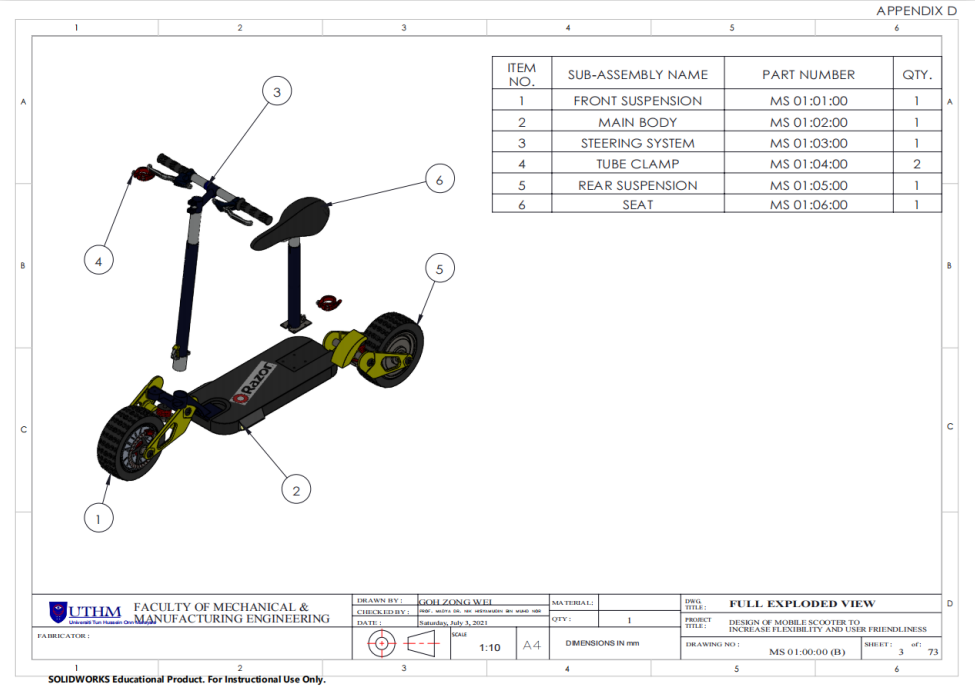

Figure 10: Exploded view of the Mobile Scooter

3.8 Product Specification

The finalize product specification was generated after the detail design and engineering analysis. Table 5 shows the product specification of Mobile Scooter.

Table 7: Product specification

Product Specification	Description
Product Name	Mobile Scooter
Motor Power	500W
Maximum Speed	25km/hr
Overall Weight	12.8 kg
Dimension (unfolded)	1124mm(L) x 464mm(W) x 1200mm(H)
Dimension (folded)	1124mm(L) x 464mm(W) x 360mm(H)
Overall Cost	RM 965.58

4. Conclusion

The objective of this project is to design a flexible and user-friendly mobile scooter that can be carried easily. For micro-mobility transport purposed, the objective had been achieved in aspect of flexibility and user friendliness. In term of flexibility, the mobile scooter design to be fold and retracted into a smaller size which is more convenient for the users to carried around. The designation of folding mechanism in the steering system allows the steering bar to be fold and able to store in smaller compartment such as car boot. The designation of tube clamp in the handlebar tube and seat tube bar allow both tube to be retract. This will minimize the dimension of mobile scooter when folding and the rider can adjust the handlebar tube and seat tube accordingly to the rider's height. In term of user friendliness, a few components were designed to improve the user experience and comfortability. A removable seat was introduced in this project where the rider can choose their way of travel whether they need standing or sitting based to their preference and purpose.

The final design of mobile scooter can travel in a maximum speed of 25km/hr with a maximum load of 100kg. Overall weight of the mobile scooter is 12.8kg. The dimension of mobile scooter when unfolding is 1124mm length, 1200mm height and 464mm width. When the mobile scooter was folded, the height was reduced to 360mm. In conclusion, this project is giving a good experience in product design and development process to design a micro-mobility vehicle.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] A. Y. Chang, L. Miranda-Moreno, R. Clewlow, and L. Sun, "Trend or Fad? Deciphering the Enablers of Micromobility in the U.S.," *SAE Int.*, no. July, p. 24, 2019.

[2] S. S. Pachbhai, "Design and Fabrication of Power Scooter," no. December 2013, 2014.

[3] A. Hosseinzadeh, M. Algomaiah, R. Kluger, and Z. Li, *E-scooters and Sustainability: Investigating the Relationship between the Density of E-Scooter Trips and Characteristics of Sustainable Urban Development*. Elsevier B.V., 2020.

[4] R. Zarif, D. Pankratz, and B. Kelman, "Small is Beautiful," *Manuf. Eng.*, vol. 69, no. 9, pp. 16–17, 1990, doi: 10.1049/me:19900212.

[5] D. A. King, "WHAT DO WE KNOW ABOUT THE 'FIRST MILE/LAST MILE' PROBLEM FOR TRANSIT?," *Transportist by David Levinson*, 2016.

[6] T. Andy, "What is a kick scooter?," 2020. https://andythousand.com/what-is-a-kick-scooter/ (accessed Jan. 06, 2021).

[7] J. D. Stroud, "UNDERSTANDING THE PURPOSE AND USE OF BENCHMARKING," *ISIXSIGMA*, 2018. https://www.isixsigma.com/methodology/benchmarking/understanding-purpose-and-use-benchmarking/ (accessed Jan. 08, 2021).

[8] J. Cheng, "Product Design Process and Methods," *Prod. Lifecycle Manag. - Terminol. Appl.*, 2018, doi: 10.5772/intechopen.80821.

[9] G. E. Dieter and L. C. Schmidt, *Fifth Edition Engineering Design*. McGraw-Hill, 2012.

[10] Hindustan electric mtoros, "Motoring the Wheels of Success," p. 11, 2020.