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DESIGN IMPROVEMENT OF A MODULAR MOBILITY WATER FILTRATION SYSTEM

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Faculty of Industrial and Manufacturing Technology and Engineering

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Mohamad Idzrul Bin Kamalruddin

Bachelor of Manufacturing Engineering Technology (Product Design) with Honours

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MOHAMAD IDZRUL BIN KAMALRUDDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Product Design) with Honours

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TAJUK: Design Improvement of A Modular Mobility Water Filtration System

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

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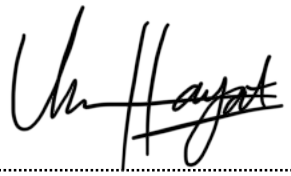
Signature : 

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DEDICATION

I dedicated this research to every person that has involved during the making of this research directly or indirectly and that has helped me during the preparation of this report and while this research is running.

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ABSTRACT

Previously, an invention of a modular mobility water filtration system for flood victims has been invented to help people which does not have access to clean water supply during flood disaster. The idea of the filtration system is to be carried by people to nearest water resources. the main objectives of previous project is focusing on the development of the filtration system which is the mechanism of the product. After finishing, some lacks are found on the design which leaves discomfort to the consumer. So through this project, some improvement will be make towards the design of the product to make the product more efficient, user friendly and ergonomics. In order to achieve the objectives, certain aspects is emphasized in this research to help improve the design which is ergonomics aspects. Ergonomics aspects is used to focused on the comfort of the design to the human body. It is an analysis help to reduce the constrain given by the products to the consumer. One of tools that are used in ergonomics aspect is RULA assessment tools. The RULA analysis help to analyze any posture that are used by the consumer of the product during using it. It is to help reduce any awkward position that may give health impacts towards the consumer. Plus, the improvement also will come be evaluated also using Boothroyd Dewhurst evaluation in order to increade the design efficiency of the product.

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ABSTRAK

Sebelum ini, ciptaan sistem penapisan air mobiliti modular untuk mangsa banjir telah dicipta untuk membantu orang ramai yang tidak mendapat bekalan air bersih semasa bencana banjir. Idea sistem penapisan adalah untuk dibawa oleh orang ramai ke sumber air yang terdekat. objektif utama projek sebelum ini adalah memberi tumpuan kepada pembangunan sistem penapisan yang merupakan mekanisme produk. Selepas selesai, beberapa kekurangan ditemui pada reka bentuk yang menyebabkan ketidakselesaan kepada pengguna. Jadi melalui projek ini, beberapa penambahbaikan akan dilakukan terhadap reka bentuk produk untuk menjadikan produk lebih cekap, mesra pengguna dan ergonomik. Bagi mencapai objektif, beberapa aspek ditekankan dalam penyelidikan ini bagi membantu menambah baik reka bentuk iaitu aspek ergonomik. Aspek ergonomik digunakan untuk memberi tumpuan kepada keselesaan reka bentuk kepada tubuh manusia. Ia adalah bantuan analisis untuk mengurangkan kekangan yang diberikan oleh produk kepada pengguna. Salah satu alat yang digunakan dalam aspek ergonomik ialah alat penilaian RULA. Analisis RULA membantu menganalisis sebarang postur yang digunakan oleh pengguna produk semasa menggunakannya. Ia adalah untuk membantu mengurangkan sebarang kedudukan janggal yang boleh memberi kesan kesihatan terhadap pengguna. Selain itu, penambahbaikan juga akan dinilai juga menggunakan penilaian Boothroyd Dewhurst untuk meningkatkan kecekapan reka bentuk produk.

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LIST OF SYMBOLS AND ABBREVIATIONS

C_a	-	Total assembly cost
T_a	-	Total assembly time
N	-	Total theoritical minimum number of parts
E	-	Design efficiency

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CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is a country in a tropical region that only have two seasons throughout the year which is dry and wet season. It is the reason Malaysia receive equal hot and rainfall through the year. Malaysia also can receive rainfall rate at 200 mm/hour and the rate can exceed the value.(Shayea et al., 2018). Especially during wet season, Malaysia are often receive excessive rainfall rate that cannot be accomodate by the land and rain catchment area that are available which can cause the water to overflow and causing flood disaster.

Flood that occur will cause a lot of casualties towards the area in terms of soul, mental and also properties. Properties damage is the most significant that occur every year. One of the properties damage that affect the most towards the area is the cut off supply of clean water. (Zubaidah, 2022). Water is one of the most important basic things in daily life. Lost of water supply can disturb daily routine for people. Since the disaster has hit malaysia every year, the authorities has prepared with emergencies water supply for the victims.(Shahrul Hassan, 2018)

Eventhough authorities has prepared, issues about insufficient clean water supply occur every year. To overcome this problem, an idea of providing a mobility modular water filter for flood victims is made to help ease their problems. This idea will enable

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the victims to easily filter water from any available water resource reachable during the time needed.(ROSLAN, 2023)

The development of the ideas has reached near perfection where the mechanism of the idea has been developed completely and functioning. For any product, the development of the mechanism is not only the aspect that need to be concerned. Other factors such as design and the capabilities of the product to be use repeated time is important especially a product that are needed to help during disaster. Worst situation are often to be expected during a disaster and the product must not only depends like usual situation.

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1.2 Problem Statement

When a product interacts with human body, it will give impacts towards it. The current design of the product is said to have given discomfort towards the user when they are using it. The discomfort experienced by the consumer certainly coming from the design language of the product itself and the components concept used in the product. To improve the design, an analysis is needed,

1.3 Research Objective

The main objectives of this projects are as follows:

a) To design a product that conforms to the ergonomics analysis.

b) To simplify the assembly process using Design For Assembly (DFA) principles.

1.4 Scope of Research

The scope of this research are as follows:

a) Designing a product that are ergonomics to human body according to RULA assessments by using manikin model in CATIA v5 software.

b) Simplifying the assembly process according to the DFA principles using Boothroyd Dewhurst method

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Product design is one of the important aspects that need to emphasize by manufacturer before doing a mass production of the product. Design take place in the early stage of new product development (NPD) process. It is crucial because unsuitable design with the product objectives can hinder the performance of the product and even will not get attention from the consumer. A suitable and good design is important to ensure the survival of the product in market. Plus, every design that are chose and used in any product are not simply just take and use but there are explanation and reason for what the design is being used. The reason can be from to lower the production cost or as the uniqueness of the product. Sometimes design is chosen according to the function or objectives of the product. Lightweight design and compact design are an example of design that are used for a product that need to achieve the mobility or portable. The selection of design are very subjective looks into what the product id design for. Many other factors that still need to be considered before determined the final sketching of the product. One of the famous example design of products used nowadays is ergonomics. This is because some product are working closely related to human and manufacturer wanted the product be more user friendly with the ergonomics factor.

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2.2 Ergonomics

The word of ergonomics are taken from Greek word which is “ergons” which means works and “nomos” which means law. It is a field of study of human’s works and the environments to improve occupational safety of workers and their

productivity.(Ogedengbe et al., 2023). Ergonomics is a popular field of study and involves the process of creating tools and workplaces to suit the human resources that utilise them.(Christy & Duraisamy, 2020) The aim of ergonomics is to maximise the interaction between people with the environment to improving productivity, comfort, safety, and general wellbeing. In ergonomics, there are 3 types of ergonomics:

1. Physical ergonomics
2. Cognitive ergonomics
3. Organizational ergonomics

The most significant ergonomics that are used in a product design is the physical ergonomics. Physical ergonomics studies how the body reacts to physiological and physical stress. It considers the anatomy, physiology, and biomechanics of the human body as they relate to physical exercise. (WU, 1982). The physical ergonomics help to reduce constrain produced by the design toward human body which make the design into user safety and user friendly.

However, there is certain factors that are also emphasized in ergonomics that make it more comfortable for human which is known as the ergonomics risk factors (ERF).

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2.2.1 Ergonomics Risk Factors (ERF)

Risk factors are characterized as behaviors or situations that raise the possibility of musculoskeletal injuries. (Keyserling W, 1992). A limited number of physical risk factors are recognized by applied ergonomics literature as being common to many different jobs and work environments. The connection between exposures to risk factors thus it is difficult to determine the degree of risk for musculoskeletal injuries. Even though, physical risk factors are in addition to significant primary risk factors, other likely variables include

organizational and psychological elements that could cause a problem or have an indirect impact on how physical risk factors work.

Ergonomics Risk Factors (ERF) is a situation that can occur intentionally or unintentionally, can contribute to a result that is opposite with the philosophy of ergonomics. The result obtained can be harmful to the well-being of the user or worker during or after work. So, it is important to understand and be aware of the effect of the ergonomics risk factors (ERF) in order to find a countermeasure. There are 7 risk factors that are listed in ergonomics philosophy which is:

1. Awkward posture
2. Force
3. Repetition
4. Vibration
5. Static loading
6. Contact pressure
7. Temperature

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Among all of the factors that are listed, the most factors that will be touched in this research is awkward posture and contact pressure.

2.2.2 Awkward posture

Awkward posture factors are coming from the terms posture which is related with the position of our body. Our muscles, tendons, and ligaments must be exerted to a force when we do any posture body. (Kolgiri S, 2019). Extra force may be exerted to the muscles, tendons, and ligaments when an awkward posture is done to our body. Awkward posture can occur when we try to do a posture in which we bend our body and joint more than the

comfortable range of motion. Prolonged or repetitive awkward posture can increase the risk or result in fatigue, pain, and injury. Some of the awkward posture examples includes in:

a) Twisting
b) Bending
c) Reaching
d) Kneeling / squat
e) Excessive wrist extension or flexion
f) Raised or lowered arms

Another term that is familiar in posture is a static posture. Static posture is a posture that is maintained for a longer time. Postural stress often occurs when the body part is extended at or near the normal range of motion. For every particular body part and joint, there are neutral zones of motion for the joint that can be extended. (Kolgiri S, 2019). In this range, every motion or posture is considered as low risk of injury. But when the motion or posture is extended at or near the range, the risk of injury will likely to be increased.

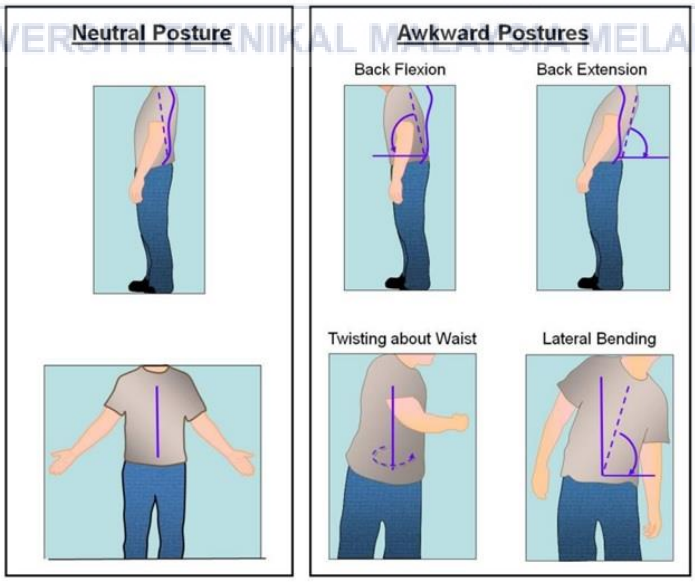

Figure 2.1 Normal posture VS awkward posture

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Since posture is common to the human body, it has become one of the main causes of the musculoskeletal disorders (MSD) that are always faced by workers. It is because for some people, they will think posture will not give any serious harm to their body. But turns out, every posture done by humans will have an impact and effect towards their body without noticing.

2.2.3 Contact Pressure

In a simple physics, any surface that interact or having contact with another surface will exert pressure towards the contact area. This is called contact pressure. The pressure that has been exerted towards the area is normally based on the the area of the surface and the force that exerted toward the area. The smaller the area of the contact surface, the higher the pressure will be exerted towards the contact area.

Similarly to the contact pressure in ergonomics risk factors, contact stress happened when any surface is touching and making contact with human body or precisely skin. Additional in contact stress for ergonomics, area is not the only factor that take into account. Other factors such as surface sharpness, roughness, and hardness also will give impact to the ergonomics. Since in ergonomics aspect is emphasizing the interaction between the product with human body, the surface condition is important in order to make the product ergonomics. According to OSHA, continuous contact of hard or sharp object surface with body sensitive tissue is the result of contact stress in ergonomics. (Kolgiri S, 2019). This can cause concentrate pressure for a small area of the body which can inhibit blood,nerve function, or movements of tendons and muscles.

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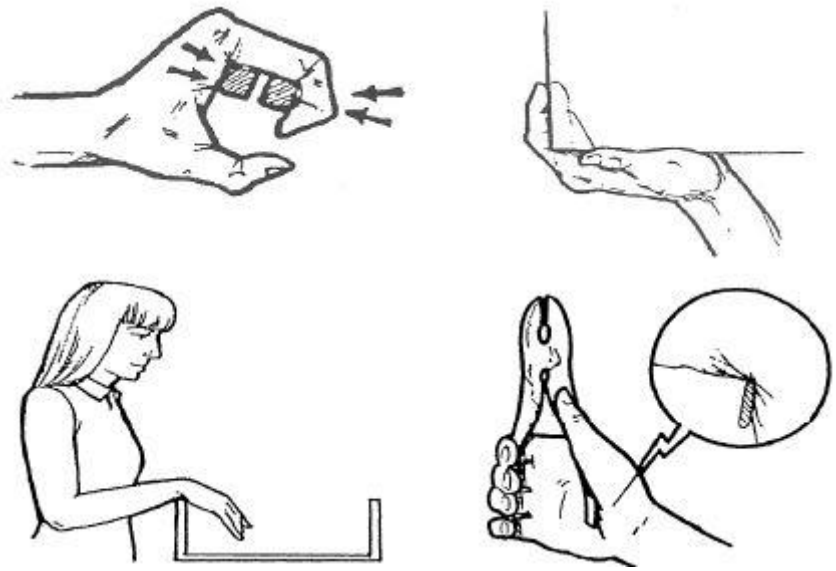

Figure 2.2 Example of high risk contact pressure

2.3 Musculoskeletal Disorders (MSD)

Musculoskeletal disorders (MSD) are injuries or illnesses that impact the musculoskeletal system of the human and the movement of human body. A worker starts to get fatigued when they are exposed to MSD risk factors. A musculoskeletal imbalance acquired when their level of fatigue exceeds their body's capacity to heal. A musculoskeletal disease develops over time when tiredness keeps getting in the way of healing and the musculoskeletal imbalance endures.(Middlesworth, 2023). There are so many musculoskeletal disorders such as carpal tunnel syndrome, muscle strain, ligament sprain, tendonitis, degenerative disc disease, and many more.

2.4 RULA Assessments

Rapid Upper Limb Assessment or RULA is an ergonomic evaluation method of human posture and the risk of working posture. It is a tool that specialized to assessed human body posture and evaluating the posture based on focuses body part which is neck, trunk,

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and the upper limbs. (Bridger, 2003). The body posture is accessed during a working cycle at a specific moment where the posture is giving the highest impact on the workers body. The RULA tool consist of 7 question sections which refers to the main affected body part when doing a posture upper arm, lower arm, wrist, wrist twist, neck, trunk and leg. Each section will be scored according or referring to a worksheet before the evaluation of the grand score.

2.4.1 Evaluation Method in RULA Assessments

The following working flow are showing the step or process needed when scoring or recording the posture:

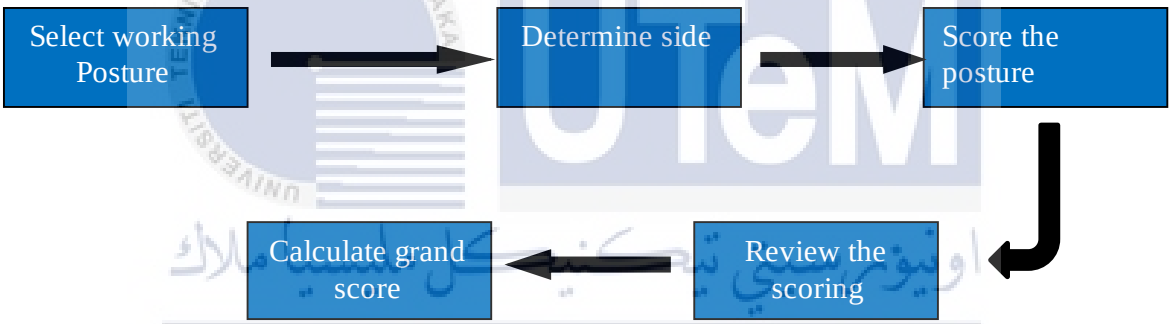

Figure 2.3 RULA Evaluation Process

Selection of posture depends or based on the working posture that need to be evaluated and determine the side of evaluation. It could be single side or both sides. Scoring the posture by using RULA Employee Assessment worksheet. Review the scoring for accuracy or better adjustment. Then calculate the final grand score using sheet or software.

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Table 2.1 MSD Risk Level Indicator

Score	Level of MSD Risk
1-2	Negligible risk, no action required
3-4	Low risk, change may be need
5-6	Medium risk, further investigation, change soon
6+	Very high risk, implement change now

The table above shows the action level list of the final grand score. Every level has different action that need to be take and its indicates the level of MSDs of the posture.

2.4.2 Significance Of RULA Assessments

RULA was implemented to help reduce the risk of getting injured during working especially a long-term working posture. It works as an indicator for the musculoskeletal disorders (MSD) level to avoid wrong posture. The impact of doing posture is a long-term effect which it is cannot be seen by the moment the posture is done. Even though the posture only be done in few minutes, but repeated movement or implementation of body posture can give the wear and tear effect towards our bone and muscle. Plus, the involvement of load during lifting will give a great impact towards the erector spinae muscles. The function of the muscles is to straighten or bend humans back. Every time lifting is done using a stood lifting posture, this muscle must produce a greater counter force to lift the load.

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Figure 2.4 Erector Spinae Muscles

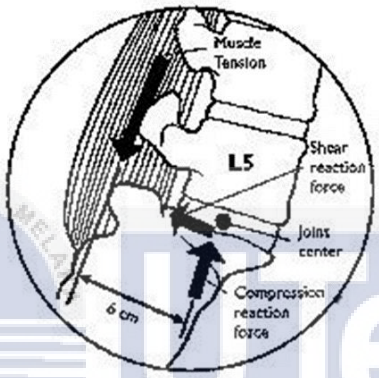

Figure 2.5 Applied Force During Lifting

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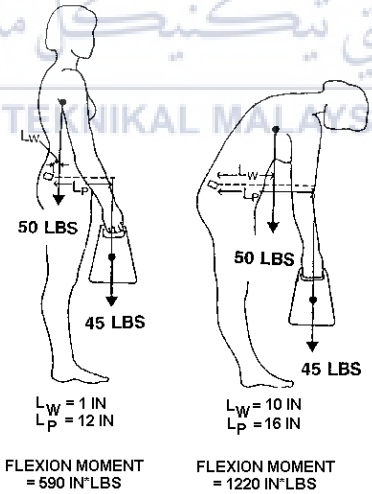

Figure 2.6 Force Needed To Lift Certain Weights

The effect of producing great amount of load in the spine muscle can cause lower back pain to the user against time. Every posture done by human have an impact towards the body, it is inevitable, and the effect will come by time. It cannot be avoided totally but only can be reduce to a certain level to lower the risk.

2.5 Design for Assembly (DfA)

In the manufacturing industry, assembly process and installation factors of a product could be the determinant of the process costing for the manufacturer. Assembly process that has a complex procedure can cause the cost to go high either for the labor expenses or facilities expenses due to the time taken. Different sight from the consumer, complex assembly procedure can cause the consumer to not be able to understand the product assembly procedure well enough that may affect the maintenance of the product.

Many design approaches have been developed lately to help optimize the design of the product and also the final cost. One of the approaches is Design for Assembly (DfA) which was improved by Boothroyd and Dewhurst. The DfA approaches is derived from the first methodologies developed by the same person which is Design for Excellence (DfX). (Remirez et al., 2019). The DfA approach is applied in the design phase. It is to reduce the assembly time and cost by reducing the total number of components in the product. (Favi et al., 2016). On order to achieve the objectives, certain guidelines are highlighted and some of the guidelines is (Velling, 2021):

a) Minimize part count.

b) The use of self-locating and self-fastener in the design

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c) Emphasized to the part symmetry.

d) Optimize tolerances.

e) Self-aligning features to reduce incorrect assembly chances.

2.5.1 Boothroyd Dewhurst Method

Boothroyd Dewhurst method is developed in University Massachusetts by Geoffrey Boothroyd 1970. It is used as an analysis for the DFA methodologies. The applications of this method by reducing the components number or facilitating the assembly process. The Boothroyd Dewhurst method could be analyse by using software or manual method. The manual evaluation method using a worksheet provided for indicators which is assembly time, assembly cost, minimum number of components and design efficiency. (Ezpeleta et al., 2019)

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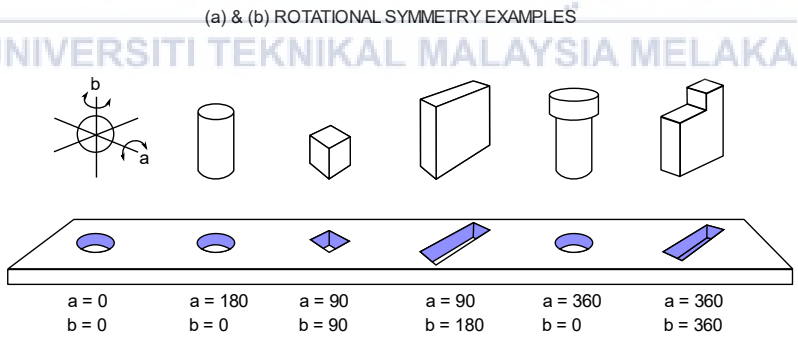

Figure 2.7 Rotational symmetry

Table 2.2 Boothroyd Dewhurst worksheet

Design A											
α	β	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
											(Part name)

TOTAL	T	C	N	**Design Efficiency** (E) = 3N/T =

Legends:

a. α and β: Based on the rotational symmetry
b. C1: Parts number.
c. C2: Parts quantity.
d. C3: Based on rotational symmetry and thickness from manual handling chart.
e. C4: Time taken based on manual handling chart.
f. C5: Based on insertion characteristics from manual insertion charts.
g. C6: Time taken based on manual insertion chart.
h. C7: Total time taken, (C4+C6)
i. C8: Assembly cost, (C7 * 0.4)
j. C9: Theoretical minimum number of parts, part can be reduced=0, part cannot be reduced=1
k. C10: Part name

2.6 CATIA

Catia which stands for Computer Aided Three-Dimensional Interactive Application is a software that has three software package or functions which is Computer Aided Design (CAD), Computer Aided Engineering (CAE) and Computer Aided Maanufacture (CAM). (Patel, 2023). The CAE functions in Catia helps to simulate and analyze a design which commonly used is Finite Element Analysis (FEA), Computational Dynamics Fluid (CFD) and Multibody Dynamics (MBD). Another functions that are also embedded inside the Catia software for human modelling which is Human Builder (HB) functions with 3 add ons Human Measurement Editor, Human Posture Analysis, and Human Activity Analysis. With the help of these three functions can simplify the analysis of ergonomics assessments towards human body. (Muñoz, 2008)

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2.7 Quality Function Development

Quality Function Deployment (QFD) is a tool or method that used to translating the customer requirement or customer statement to a technical specification in a product development process. It is a tool that is used to facilitate any organization in carrying out the analysis of the desired specification given by the customers. The QFD helps improving product quality by involving the voice of the customer in the design development so that the product developed is relevant in the market. (Madu, 2020). QFD helping in product development process, and it contains 4 phases with different matrix individually which is design, details, process and production. Even so the QFD help to increase the quality of the design and product, certain weakness cannot be avoided from this method which is the importance value is not clearly stated and also it negative numbers and relation are also included in the relationship matrix. (Kulcsar et al., 2021)

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2.7.1 House of Quality

House of Quality (HoQ) is a tool in a form of a house matrix used in quality function development early stage of design phase. (Robecca & Putra, 2019). The concept of this tools is to prioritize the design processes and parameters based on the customer need before proceed into conceptual sketches and so on. Customer feedback is subjective surveys where all the answer obtained are based on the customer experienced and varieties of factors. It is why the HoQ is used to rearrange the specification gathered from the customer according to prioritization to optimize the design because it is near impossible to follow every customer taste for the product.

2.8 Summary

In summary, this chapter helps to determine what is needed in this project. It helps to clear the vision by gathering information through research from internet, books, and articles journey which then helps to facilitate in the next chapter, methodologies. The information gathered from this chapter is including ergonomics aspects which divided into two subcategories which is RULA assessments and anthropometry data and the DFA methods that can help to improve the design.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

Certain approaches or method need to be used in order to make a good and high-quality product. Since this project is about making improvement towards an existing product, several factors need to be focused on and review from the previous product development. Plus, the voice of the customer giving feedbacks towards the product also need to give more attention to avoid the same mistakes. Priorities towards the improvement factors must be sort accordingly so that it is clearer about the project goals. So the product planning must be strong starting with mission statement and then identifying the customer feedback using the need statement to gather the information first and also consists of design specification. Then the design parameters must be determined by using axiomatic design. House of quality (HoQ) to evaluate and ranking the priorities for every improvement parameter before listing available concept and sketching.

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3.2 Project Flow Chart

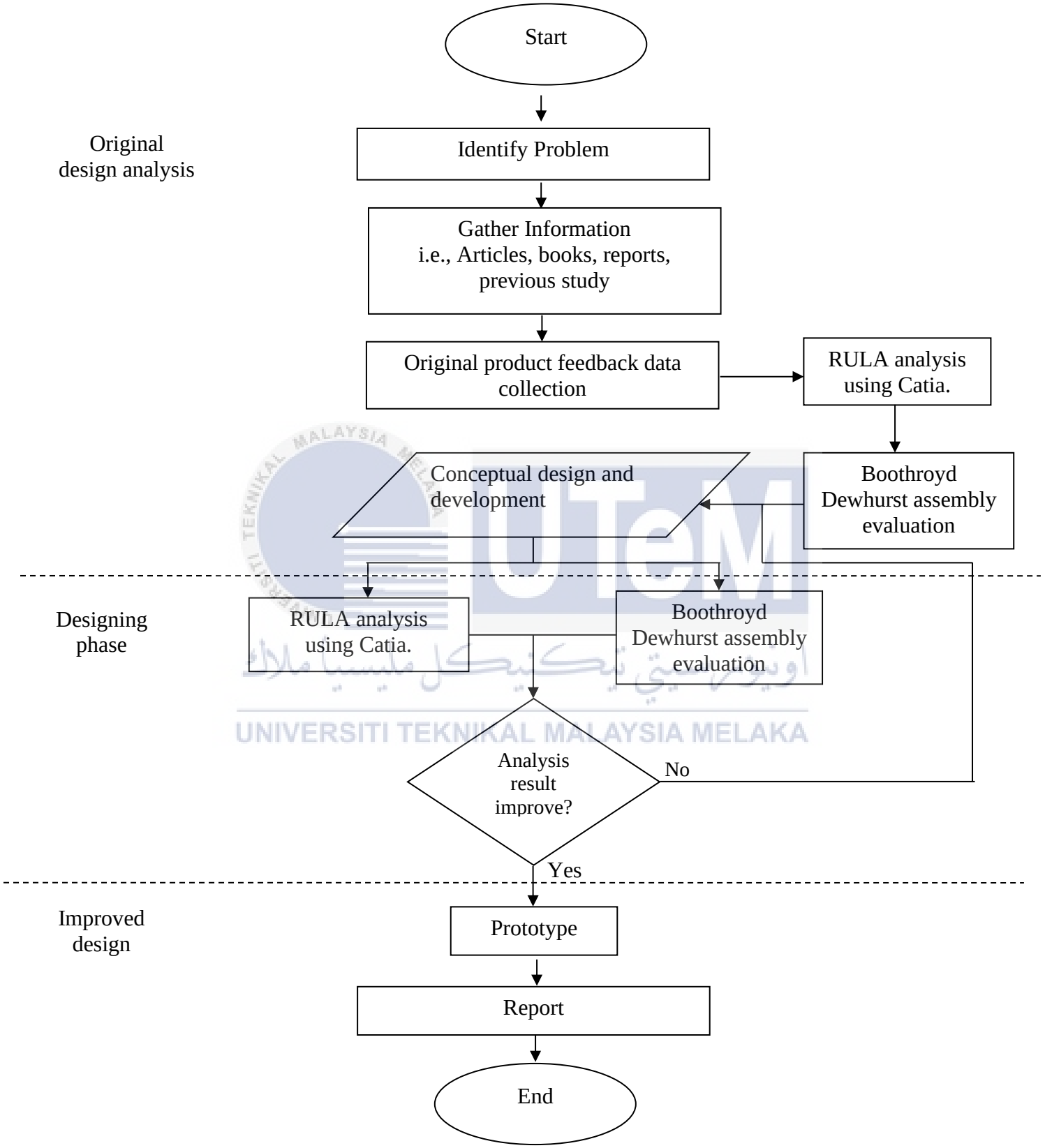

Figure 3.1 Project Flow Chart

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3.3 Product Planning

Product planning is a strategy or planning used to help in defining and determining the design, features, functions and specifications of a new product from a customer requirement or need. This product planning is including mission statement, need statement, house of quality (HoQ), morpholigical chart, conceptual sketching, concept selection and the final sketching.

Tools :

1. Need statement / customer statement
2. House of Quality (HoQ)
3. Morphological chart
4. Conceptual sketching
5. Weighted rating evaluation method (conceptual selection)
6. Final sketch

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3.4 Original Product Analysis

Since this project is to make a design improvement, it is important to get customer feedback on the original product to have a clear vission on the improvement needed for the product.

3.4.1 Customer Feedback

An interview session is made with customer to get the response about the product. About 30 customer will be asked to try wear the water filtration product. Feedback focused on this testing is only on ergonomics aspects of the product and also the assembly process of major components of the product. After trying,customer will try to disassemble and assemble the product without instructions first and the instructions will be given if they asked.

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Equipment and tools:

1. 30 respondents

2. Modular mobility water filtration system device

3. Survey questionnaire

3.5 RULA Analysis

The RULA analysis is done to checked the saftey level of the posture for original product and improved product. The analysis is done using two method which is through simulation using manikin modelling in Catia v5 software and a manual RULA assessments using RULA employee worksheet assessments for more accurate and as a prove to the result.

3.5.1 Manikin Modelling

Manikin modelling in CATIA v5 software are using a model as a medium to imitate the posture of the human for analysis. The posture modeled in the Catia might be slightly inaccurate with the original posture due to the remodelling process which only observed roughly and certain postition of the body parts is slightly inaccurate. RULA analysis in the software will generate the result based on the manikin model posture.

Equipments and tools:

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1. CATIA v5 software

2. Working posture

3.5.2 RULA Employee Worksheet Assessments

RULA employee worksheet assessments is the manual evaluation method for the RULA analysis. The posture is evaluate and scored in 7 sections based on the table to get the grand score of the posture. The score is then compared with the MsD level. This analysis is to support the manikin model result as the evaluation is made by human experienced.

Equipment and tools:

1. RULA employee worksheet assessment

2. Working posture

3.6 Boothroyd Dewhurst Assembly Evaluation

Boothroyd Dewhurst assembly evaluation is make to check and evaluate the assembly process of the design. This evaluation is involving all the components of the product. The scoring method for this evaluation method are based on the assmbly procedure of the product and the difficulties of the assembly procedure. From this evaluation, there is 4 result that can be obtain which is total time for assembly, total assembly cost for production, minimum number of components and the design efficiency. Since the aim for this methodology section is only focused on consumer, only 2 result that is focused on this evaluation which is total assembly time and design efficiency.

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Equipment and tools:

1. Modular mobility water filtration system components

2. Boothroyd Dewhurst evaluation method

3. Manual handling chart

4. Manual insertion chart

3.7 Summary

This chapter is about the process and procedure need to be done in order for the project can be completed. All step stated in this chapter played a crucial points that can effect the design phase of the product. Starting with product planning as the master mind of the whole process and original product analsys to detect the problem on the original design to all analysis needed in order to make improvement such as RULA assessments, anthropomery data collection and also the DFA Boothroyd Dewhurst method evaluation for the assembly process.

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CHAPTER 4

FINDING & RESULT

4.1 Introduction

This chapter presents the preliminary findings from this project. The result present in this chapter is including from the first stage of the NPD process until the final and finished product that is gain and produced through this project. This chapter is divided into two main finding of this project which is the preliminary findings and also the final result. The preliminary findings are including the early stage of designing phase which is starting from the customer feedback until concept selection. While the result from this chapter consist of the development of the product from idea that has been generated in the early stage. This chapter will clearly shows about the problem that faced by the modular mobility water filtration system that need to be improved and how the problem detection is done. Only then all procedure will take place to help improved the water filtration system.

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4.2 Product Planning

Product planning is an approach used to obtain a clear path for the project. It helps to determine the journey of the product before it can fully develop and improve.

4.2.1 Mission Statement

Table 4.1 Mission Statement

Mission statement	
Vision	- Ease people in need
Product description	- Ergonomics - User-friendly
Key business goals	- Body comfort - Easy assembly procedure - Easy to carry
Primary market	- Flood evacuation centre
Secondary market	- Camper or community
Assumptions and constrains	Assumptions - A design of water filtration system that is easy to carry during disaster and not causing fatigue or injuries towards body. - Simple setup without involving spine major movement. - Easy to reach by hands. Constrains - Bigger size of water filter to meet the capacities.
Stake holder	- National Disaster Management Agency (NADMA) - Non-Governmental Organization (NGO) - Communities

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4.2.2 Customer Feedback

An interview session is held to gather customer feedback towards the product. Response given by opinions of 15 respondents towards the product is recorded and certain components from the product are mentioned repeated times by the respondents.

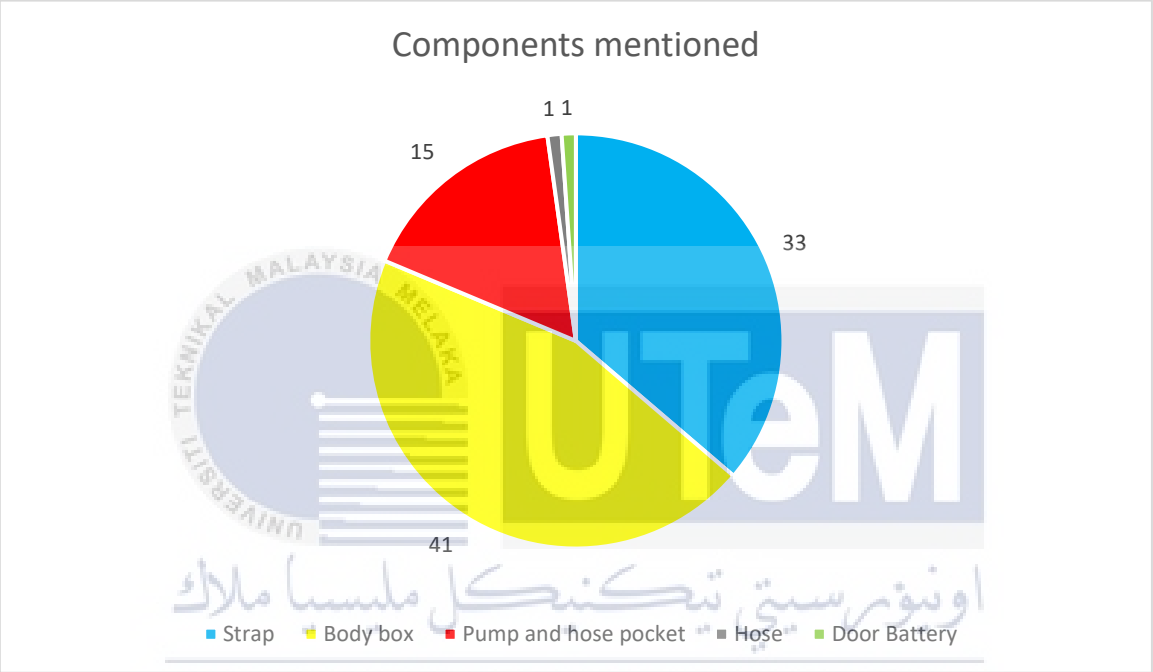
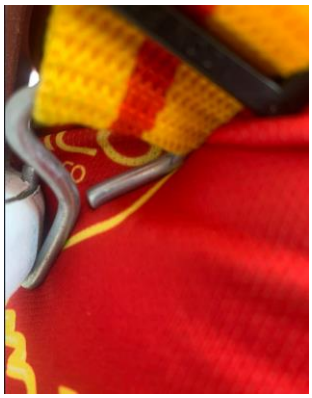


Figure 4.1 Components mentioned in customer feedback

The data in the pie chart shows the frequency of the components mentioned by the respondents in their response. Of a total of 51 response gathered from respondents, 21 of them is about the product strap, 20 response is about the body box, 8 response is about the pump pocket and hose pocket, and 1 response to each hose and door battery.

Table 4.2 Customer feedback analysis on the product

Components analysis			
No	Original product	Customer feedback	Product trial
1	 Body box	- Heavy - The bottom edge of the body box is pressing on the waist which causes pain. - Loose during walking	
2	 Strap	- Strap giving too much pressure on shoulder.	
		- The harness stabbing user body.	

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		- Difficult to wear	
3.	Pump pocket and hose pocket  	- Too low clearance for the slot.	

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4.2.3 Posture Analysis

Original design posture analysis is to analyse any posture that developed and used on the product for setup or any kind of product usage that made any body posture.

Figure 4.2 Setup posture

Picture above shows or demonstrate on a posture that made by user to setup the product. Since the product only have compartment to store the tube and not to hold them while it is already attached to the product, it requires user to setup the product every time they want to use and after using. This posture will be repeated several times just in one time of use of the product.

A RULA assessments is made towards the posture to evaluate about the risk of the posture towards human body. In order to evaluate the posture, a manikin model is developed by using Catia V5 Software and imitated the same posture.

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Figure 4.3 Manikin modelling in Catia V5

The result of the assessments is generated by Catia software using RULA analysis functions. The posture frequency is set to intermittent because it is repeated in an irregular interval. The load is set to 0kg because of the posture is only for setup.

Figure 4.4 Catia generated RULA analysis result for the left side

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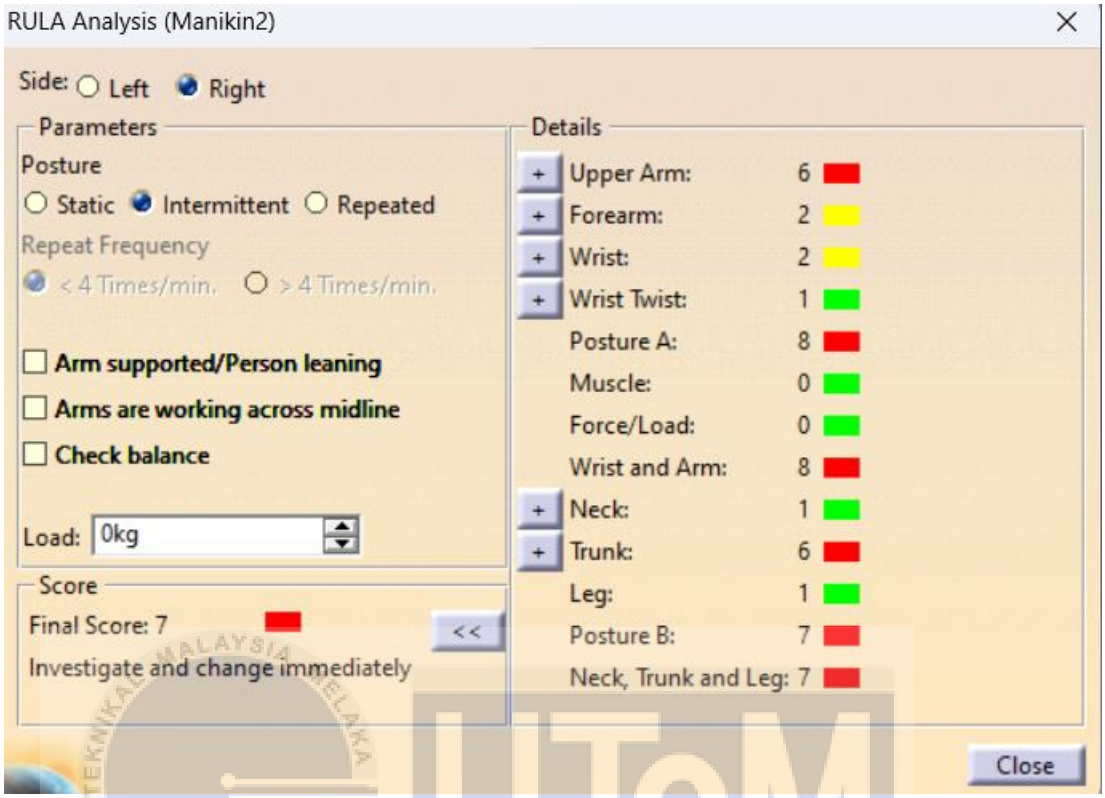

Figure 4.5 Catia generated RULA analysis result for right side

Based on the result generated by the Catia, it shows that the posture is rated to a value of 7 for both sides. Since the model is develop in software, it might have a chance that the position of any body part is not accurate. So to support the result, a manual RULA assessment is made by using the RULA employee worksheet.

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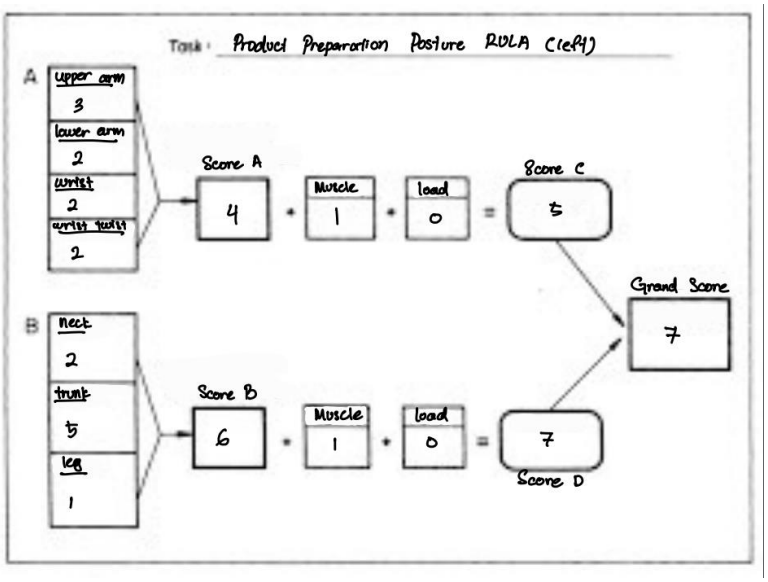


Figure 4.6 Manual RULA assessment for the left side

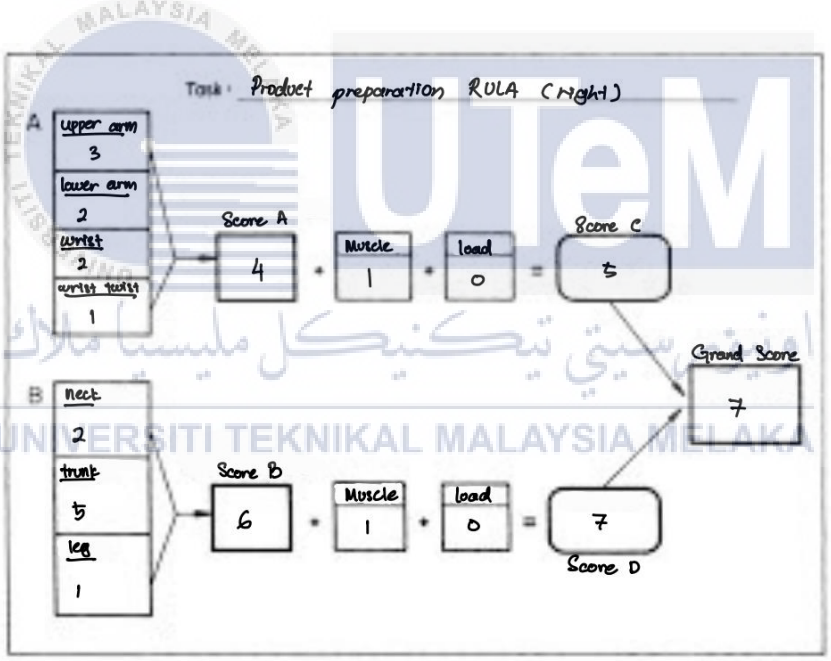
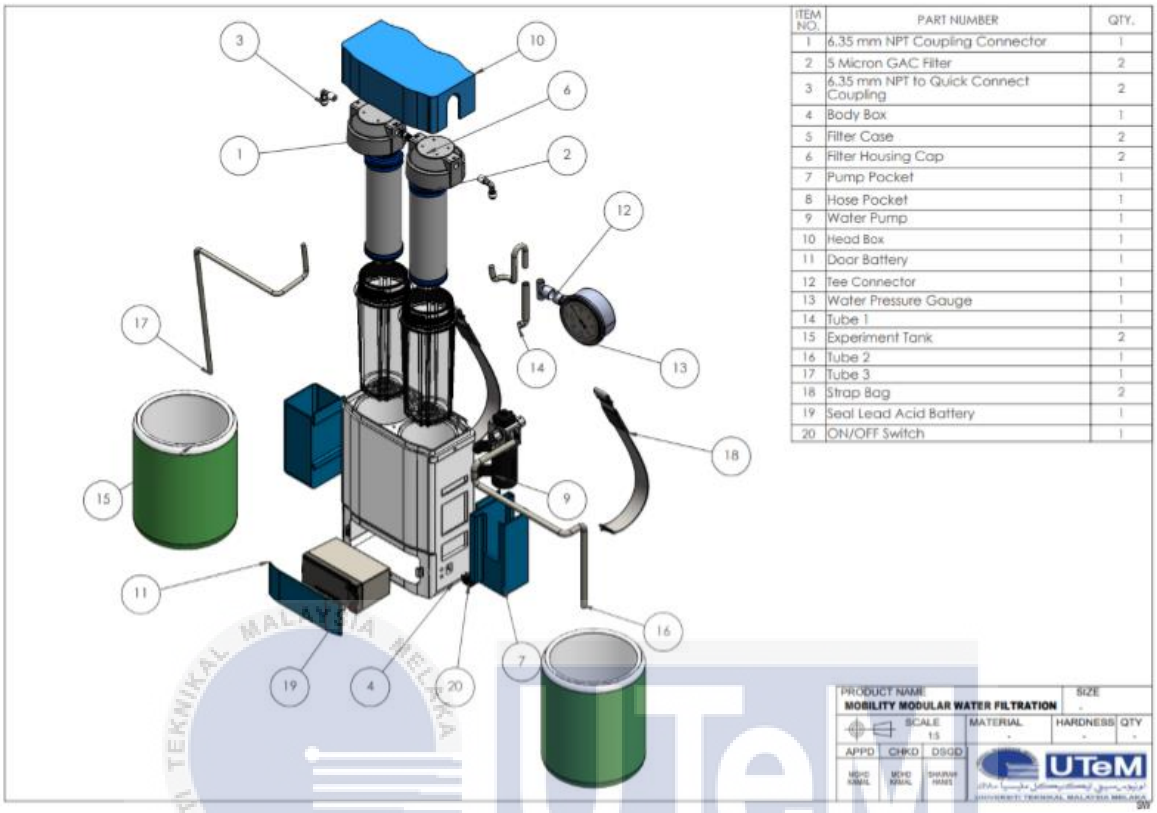


Figure 4.7 Manual RULA assessment for right side

Based on the manual assessment of the RULA, it also shows that the posture has the same value as the result in Catia which is 7. This indicates that the posture need to be investigate and change immediately based on the MSD level table.

4.2.4 DFA Boothroyd Dewhurst evaluation



ITEM NO.	PART NUMBER	QTY.
1	6.35 mm NPT Coupling Connector	1
2	5 Micron GAC Filter	2
3	6.35 mm NPT to Quick Connect Coupling	2
4	Body Box	1
5	Filter Case	2
6	Filter Housing Cap	2
7	Pump Pocket	1
8	Hose Pocket	1
9	Water Pump	1
10	Head Box	1
11	Door Battery	1
12	Tee Connector	1
13	Water Pressure Gauge	1
14	Tube 1	1
15	Experiment Tank	2
16	Tube 2	1
17	Tube 3	1
18	Strap Bag	2
19	Seal Lead Acid Battery	1
20	ON/OFF Switch	1

Figure 4.8 Exploded view of the water filtration system

The figure above are showing the original components of the water filtration system taken from the previous product development. According to the bill of materials (BOM), the product consists of 20 components in total, but since the assembly process focused in this research is only for customer ease, the main components that will frequent to be assemble and disassemble is the body box, water filter, seal lead acid battery, door battery, water pump, pump pocket, hose pocket, head box, tube and strap bag.

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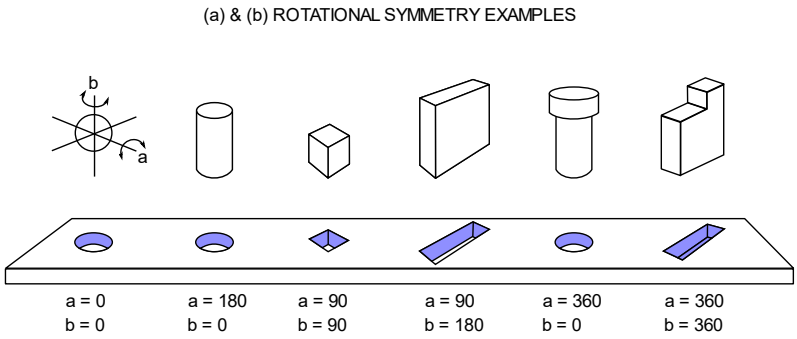

Table 4.3 Original design modular mobility water filtration system assembly evaluation

Original design											
α	β	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
360	360	4	1	30	1.95	00	1.5	3.45	$1.38	1	Body box
360	180	5	1	20	1.8	30	2	3.8	$1.52	1	Water filter
360	180	19	1	20	1.8	00	1.5	3.3	$1.32	1	Seal lead acid battery
360	360	11	1	33	2.51	30	2	4.51	$1.8	1	Door battery
360	360	9	1	30	1.95	40	4.5	6.45	$2.58	1	Water pump
360	360	7	1	30	1.95	34	6	7.95	$3.18	0	Pump pocket
360	360	8	1	30	1.95	34	6	7.95	$3.18	0	Hose pocket
360	360	10	1	30	1.95	30	2	3.95	$1.58	0	Head box
180	0	14	3	01	1.43	32	4	5.43	$2.17	1	Tube/hose
360	360	18	2	33	2.51	30	2	4.51	$1.8	1	Strap bag
TOTAL								51.3	$20.51	7	**Design Efficiency**
								T_a	C_a	N	(E) = 3N/T = 3(7)/51.3 =0.409

From the table, it is clear that the original design of the product needs approximately to 51.3 seconds to be fully assembled and has a design efficiency of 0.409 or 40.9% which is still can be improve to a better design. Plus, assembly concept introduce at pump pocket and hose pocket is inefficient because it has showing tear effect after few times of repeated assemble and disassemble process.

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4.2.5 Need Statement

Table 4.4 Need statement

No.	Customer Feedback	Specification	Components for improvement	Improvement requirement	Weightage
1.	The current design is quite loose and always moving during walking.	Strap that prevents the casing from movement.	Strap	Ergonomics	4
2.	I love the carrying concept, but it would be better if the body are not pressing our waist.	Body box dimensioning and sizing	Body box	User friendly	5
3.	I would like if the water filtration system were more lightweight.	Minimize design of the body box.	Body box	Ergonomics	4
4.	It is better if the strap not pressuring our shoulder too much.	Larger surface area and comfortable material	Strap	Ergonomics	4
5.	I would prefer if the harness of the strap not stabbing our body.	Hiding harness design	Harness / strap	User friendly	5
6.	I hope that the pocket can be assemble easier	Self-fastener concept for pocket	Pump pocket and hose pocket	Modular	3
7.	I wish the battery cover can avoid any water from entering the battery.	A waterproof design for the battery cover	Battery cover / body box	User friendly	5
8.	I would love if it were easier to wear	adjustable strap width	Strap	User friendly	5

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9.	I hope the design of the box is not restricted our body	Small dimension of the body box	Body box	Ergonomics	4
10.	It would be better if the hose can filter any foreign object from entering	Strainer on the hose	Hose	Usability	3

4.2.6 Improvement Requirements

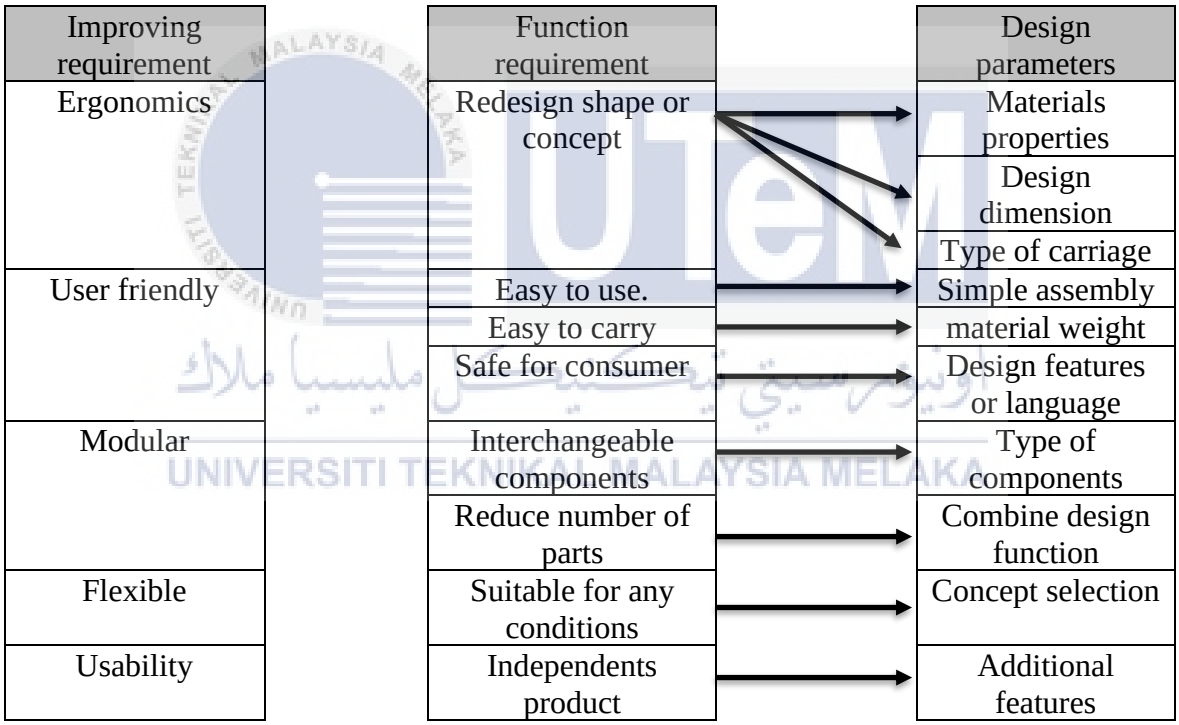

Figure 4.9 Design Parameters using axiomatic design

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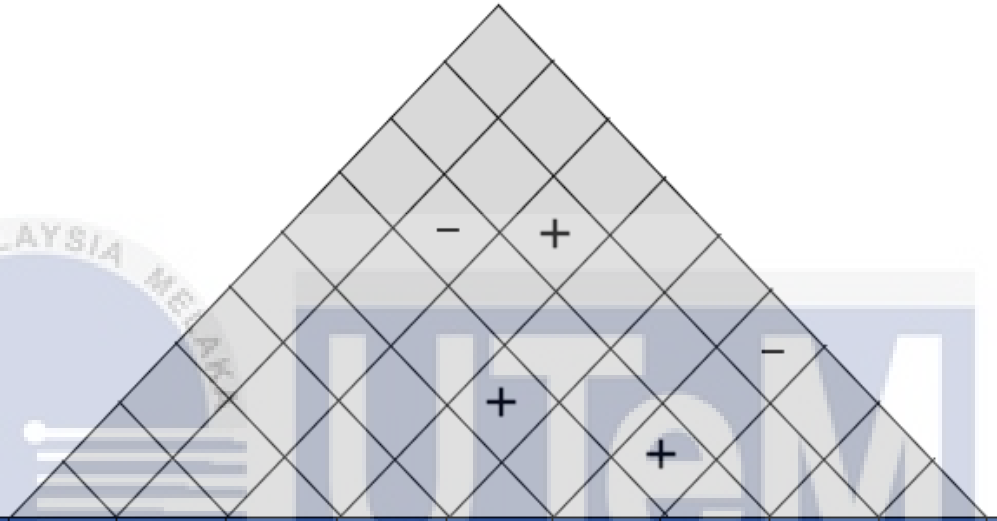
4.2.7 House Of Quality (HoQ)

Correlations	
Positive	+
Negative	−
Relationship	
Strong=5	●
Fair=3	○
Weak=1	△



	Column	1	2	3	4	5	6	7	8	9	
	Direction of improvement	↓	↓	↑	↓	↑	↓	↑	◇	↑	
Weightage	Improving requirement \ Design parameters	Material properties	Design dimension	Type of carriage	Simple assembly	Design features / languages	Number of components	Design combination function	Concept reselection	Additional features	
5	User friendly		●	●	●	○					
4	Ergonomics	●	●			○			●		
3	Modular				●		●				
3	Flexible							●	●		
3	Usability								△	●	
Absolute score		20	45	25	40	27	15	15	38	15	
Priorities		6	1	5	2	4	7	9	3	8	

Table 4.5 House of quality

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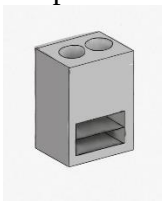
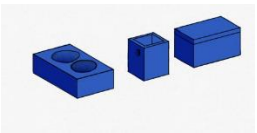
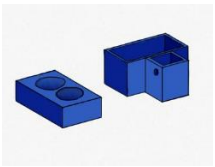
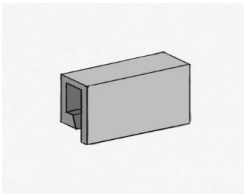
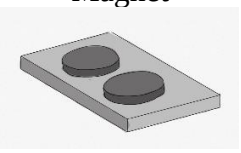
Table 4.6 Improvement listing

No.	Design parameters for improvement	Components involved
1	Design dimension	1. Body box
2	Simple assembly procedure	1. All components
3	Concept reselection	1. Strap 2. Body box
4	Design features/languages	1. Body box
5	Type of carriage	1. Strap
6	Material properties	1. Body box 2. Strap
7	Number of components	1. All components
8	Additional features: - Alternatives power source - Strainer	1. Body box 2. Hose
9.	Design combination features	1. All components

4.2.8 Morphological Charts

Table 4.7 Morphological chart

	1	2	3	4
Strap	Elastic chest strap 	Belt 	3-way carrier strap 	School begs strap. 
Components compartment	Single box compartment 	Particular box compartment 	Combined box compartment 	
Compartment joint	Clip 	Hook slot in 	Press fit 	Magnet 

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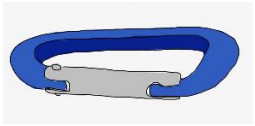
Strap joint	Buckle joint 	Hook joint 		

4.2.9 Concept Combination

Table 4.8 Concept combination

1	Elastic chest strap	Single box compartment	Clip	Buckle joint
2	Elastic chest strap	Single box compartment	Clip	Hook joint
3	Elastic chest strap	Single box compartment	Hook slot in	Buckle joint
4	Elastic chest strap	Single box compartment	Hook slot in	Hook joint
5	Elastic chest strap	Single box compartment	Press fit	Buckle joint
6	Elastic chest strap	Single box compartment	Press fit	Hook joint
7	Elastic chest strap	Single box compartment	Magnet	Buckle joint
8	Elastic chest strap	Single box compartment	Magnet	Hook joint
9	Elastic chest strap	Particular box compartment	Clip	Buckle joint
10	Elastic chest strap	Particular box compartment	Clip	Hook joint
11	Elastic chest strap	Particular box compartment	Hook slot in	Buckle joint
12	Elastic chest strap	Particular box compartment	Hook slot in	Hook joint
13	Elastic chest strap	Particular box compartment	Press fit	Buckle joint
14	Elastic chest strap	Particular box compartment	Press fit	Hook joint
15	Elastic chest strap	Particular box compartment	Magnet	Buckle joint
16	Elastic chest strap	Particular box compartment	Magnet	Hook joint

1st Concept

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17	Elastic chest strap	Combined box compartment	Clip	Buckle joint
18	Elastic chest strap	Combined box compartment	Clip	Hook joint
19	Elastic chest strap	Combined box compartment	Hook slot in	Buckle joint
20	Elastic chest strap	Combined box compartment	Hook slot in	Hook joint
21	Elastic chest strap	Combined box compartment	Press fit	Buckle joint
22	Elastic chest strap	Combined box compartment	Press fit	Hook joint
23	Elastic chest strap	Combined box compartment	Magnet	Buckle joint
24	Elastic chest strap	Combined box compartment	Magnet	Hook joint
25	Belt	Single box compartment	Clip	Buckle joint
26	Belt	Single box compartment	Clip	Hook joint
27	Belt	Single box compartment	Hook slot in	Buckle joint
28	Belt	Single box compartment	Hook slot in	Hook joint
29	Belt	Single box compartment	Press fit	Buckle joint
30	Belt	Single box compartment	Press fit	Hook joint
31	Belt	Single box compartment	Magnet	Buckle joint
32	Belt	Single box compartment	Magnet	Hook joint
33	Belt	Particular box compartment	Clip	Buckle joint
34	Belt	Particular box compartment	Clip	Hook joint
35	Belt	Particular box compartment	Hook slot in	Buckle joint
36	Belt	Particular box compartment	Hook slot in	Hook joint
37	Belt	Particular box compartment	Press fit	Buckle joint
38	Belt	Particular box compartment	Press fit	Hook joint
39	Belt	Particular box compartment	Magnet	Buckle joint
40	Belt	Particular box compartment	Magnet	Hook joint

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41	Belt	Combined box compartment	Clip	Buckle joint
42	Belt	Combined box compartment	Clip	Hook joint
43	Belt	Combined box compartment	Hook slot in	Buckle joint
44	Belt	Combined box compartment	Hook slot in	Hook joint
45	Belt	Combined box compartment	Press fit	Buckle joint
46	Belt	Combined box compartment	Press fit	Hook joint
47	Belt	Combined box compartment	Magnet	Buckle joint
48	Belt	Combined box compartment	Magnet	Hook joint
49	3-way carrier strap	Single box compartment	Clip	Buckle joint
50	3-way carrier strap	Single box compartment	Clip	Hook joint
51	3-way carrier strap	Single box compartment	Hook slot in	Buckle joint
52	3-way carrier strap	Single box compartment	Hook slot in	Hook joint
53	3-way carrier strap	Single box compartment	Press fit	Buckle joint
54	3-way carrier strap	Single box compartment	Press fit	Hook joint
55	3-way carrier strap	Single box compartment	Magnet	Buckle joint
56	3-way carrier strap	Single box compartment	Magnet	Hook joint
57	3-way carrier strap	Particular box compartment	Clip	Buckle joint
58	3-way carrier strap	Particular box compartment	Clip	Hook joint
59	3-way carrier strap	Particular box compartment	Hook slot in	Buckle joint
60	3-way carrier strap	Particular box compartment	Hook slot in	Hook joint
61	3-way carrier strap	Particular box compartment	Press fit	Buckle joint
62	3-way carrier strap	Particular box compartment	Press fit	Hook joint
63	3-way carrier strap	Particular box compartment	Magnet	Buckle joint
64	3-way carrier strap	Particular box compartment	Magnet	Hook joint

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65	3-way carrier strap	Combined box compartment	Clip	Buckle joint
66	3-way carrier strap	Combined box compartment	Clip	Hook joint
67	3-way carrier strap	Combined box compartment	Hook slot in	Buckle joint
68	3-way carrier strap	Combined box compartment	Hook slot in	Hook joint
69	3-way carrier strap	Combined box compartment	Press fit	Buckle joint
70	3-way carrier strap	Combined box compartment	Press fit	Hook joint
71	3-way carrier strap	Combined box compartment	Magnet	Buckle joint
72	3-way carrier strap	Combined box compartment	Magnet	Hook joint
73	School begs strap	Single box compartment	Clip	Buckle joint
74	School begs strap	Single box compartment	Clip	Hook joint
75	School begs strap	Single box compartment	Hook slot in	Buckle joint
76	School begs strap	Single box compartment	Hook slot in	Hook joint
77	School begs strap	Single box compartment	Press fit	Buckle joint
78	School begs strap	Single box compartment	Press fit	Hook joint
79	School begs strap	Single box compartment	Magnet	Buckle joint
80	School begs strap	Single box compartment	Magnet	Hook joint
81	School begs strap	Particular box compartment	Clip	Buckle joint
82	School begs strap	Particular box compartment	Clip	Hook joint
83	School begs strap	Particular box compartment	Hook slot in	Buckle joint
84	School begs strap	Particular box compartment	Hook slot in	Hook joint
85	School begs strap	Particular box compartment	Press fit	Buckle joint
86	School begs strap	Particular box compartment	Press fit	Hook joint
87	School begs strap	Particular box compartment	Magnet	Buckle joint
88	School begs strap	Particular box compartment	Magnet	Hook joint

2nd Concept

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89	School begs strap	Combined box compartment	Clip	Buckle joint
90	School begs strap	Combined box compartment	Clip	Hook joint
91	School begs strap	Combined box compartment	Hook slot in	Buckle joint
92	School begs strap	Combined box compartment	Hook slot in	Hook joint
93	School begs strap	Combined box compartment	Press fit	Buckle joint
94	School begs strap	Combined box compartment	Press fit	Hook joint
95	School begs strap	Combined box compartment	Magnet	Buckle joint
96	School begs strap	Combined box compartment	Magnet	Hook joint

3rd Concept

Table 4.9 Concept explaination

Concept picked	Explanation
Concept 1	Idea to make a concept of product that has the most independent part. Every part can be disassembled very easily without any effort with the usage of magnet because less mechanical structure need for magnet. The concept also is targeted to have great part minimization or reduction by not using any main body that holding other part. So, the concept can be competitive to other concept
Concept 2	This concept is to produce the most comfortable concept by using the 3-way carrier strap because of padding that surround the strap. Has a realistic design and concept. The concept idea also to make the strap that can locate or hold the other part unfixed so that user body does not contact with the hard surface of the component.
Concept 3	This concept is the most similar to the original design. It is chosen to make a reselection for the concept that will be combined to have a better output than the original design. Plus, this concept also viewed as one of the realistic concept.

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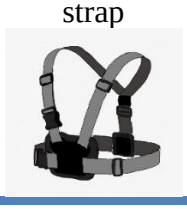
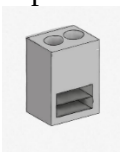
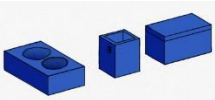
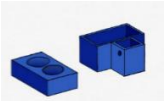
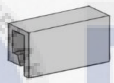
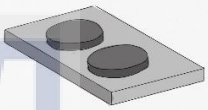
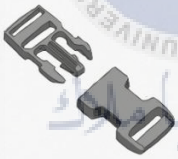
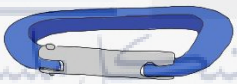
4.2.10 Concept Sketching

1st concept

	1	2	3	4
Strap	Elastic chest strap 	Belt 	3-way carrier strap 	School begs strap. 
Components compartment	Single box compartment 	Particular box compartment 	Combined box compartment 	
Compartment joint	Clip 	Hook slot in 	Press fit 	Magnet 
Strap joint	Buckle joint 	Hook joint 		

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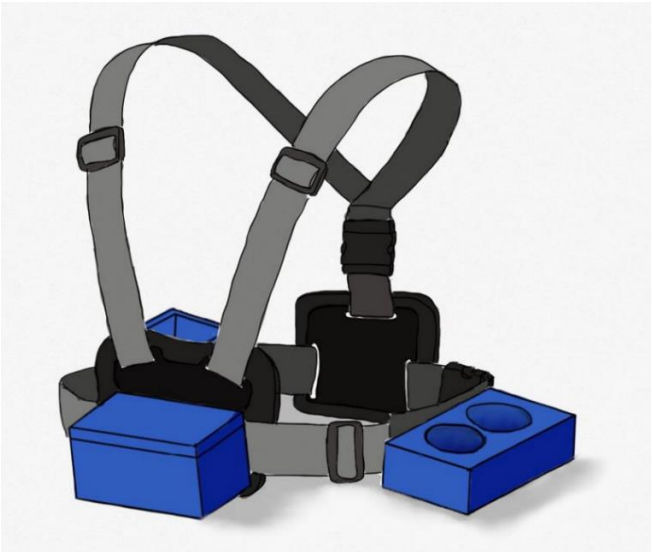
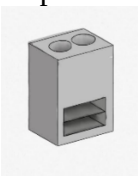
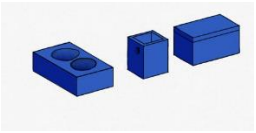
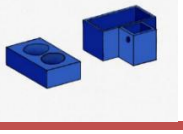
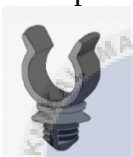
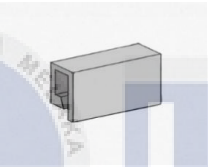
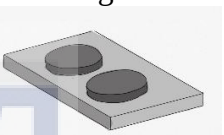
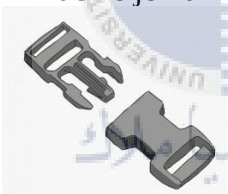


Figure 4.10 1st concept

2nd concept

	1	2	3	4
Strap	Elastic chest strap 	Belt 	3-way carrier strap 	School begs strap. 
Components compartment	Single box compartment 	Particular box compartment 	Combined box compartment 	
Compartment joint	Clip 	Hook slot in 	Press fit 	Magnet 
Strap joint	Buckle joint 	Hook joint 		

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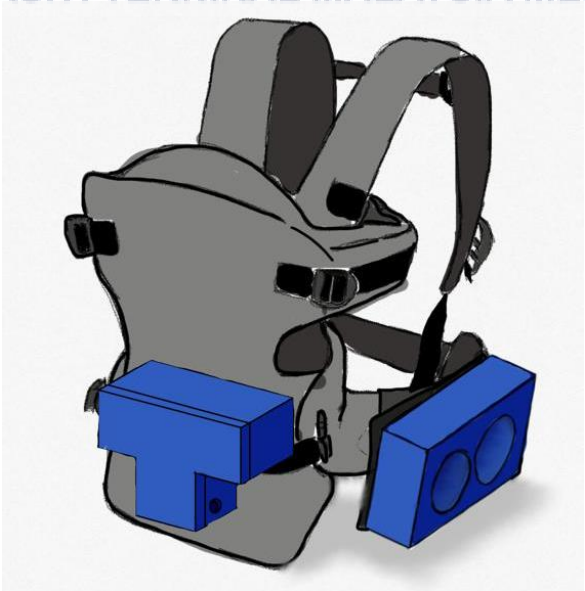
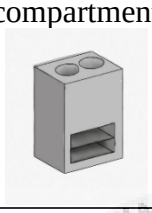
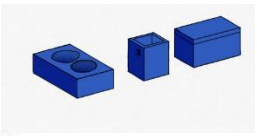
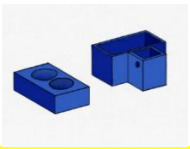
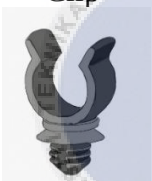
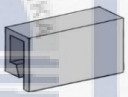
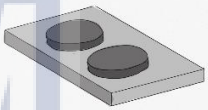


Figure 4.11 2nd concept

3rd concept

	1	2	3	4
Strap	Elastic chest strap 	Belt 	3-way carrier strap 	School begs strap. 
Components compartment	Single box compartment 	Particular box compartment 	Combined box compartment 	
Compartment joint	Clip 	Hook slot in 	Press fit 	Magnet 
Strap joint	Buckle joint 	Hook joint 		

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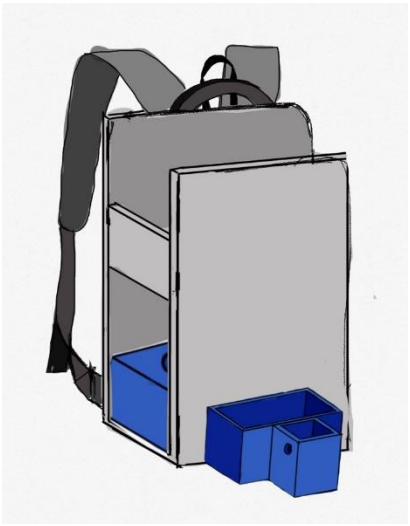
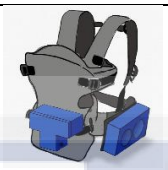


Figure 4.12 3rd concept

4.2.11 Concept Selection

The concept selection is using the weighted rating evaluation method which all the concept will rated in certain criteria. The design with the highest rating will be selected as the final sketch. The same method is used in the second table to select between three alternatives power source to be used in the design.

Table 4.10 Weighted rating evaluating table

Criteria	Weightage	 1st design		 2nd design		 3rd design	
		Rating	R x W	Rating	R x W	Rating	R x W
User friendly	50%	4	2.0	5	2.5	4	2.0
Ergonomics	40%	4	1.6	5	2.0	4	1.6
Modular	30%	5	1.5	4	1.2	5	1.5
Low cost	30%	2	0.6	1	0.3	4	1.2
Usability	30%	4	1.2	4	1.2	4	1.2
Total		N/A	6.9	N/A	7.2	N/A	7.5

The original design as reference for rating

1 = Much Lesser, 2 = Less, 3 = Same, 4 = Better, 5 = Much Better

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4.2.12 Final sketching

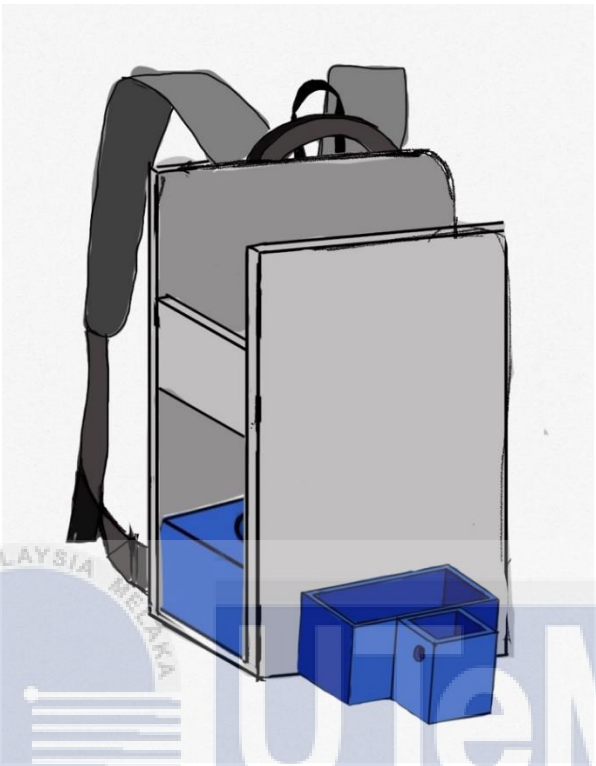

Figure 4.13 Selected concept/design

4.3 CAD Model Adjustment

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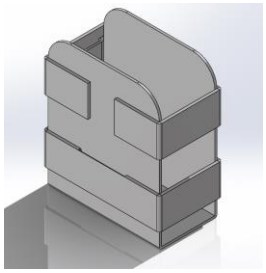
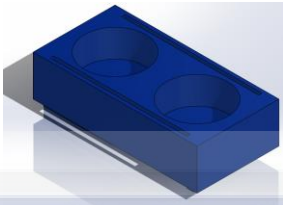
The CAD model development is interpreted from the final sketch that has already been chosen. The development of the CAD model is to ensure that the product has clear vision on the design or detail design of the conceptual sketch. The CAD model also is created and drawn by using SolidWorks.

4.3.1 Adjusted Part CAD Model

Table 4.11 Adjusted part CAD model

No.	Part	CAD model
1.	a. Main body	
2.	Filter stand	
3.	Compartments (pump, battery, and hose)	
4.	Strap	

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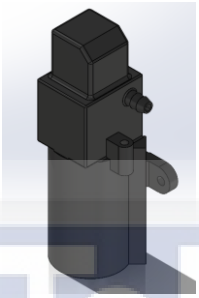
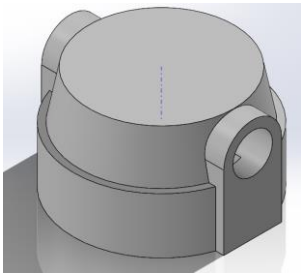
4.3.2 Remain Part CAD Model

Table 4.12 Remain part CAD model

No.	Part	CAD model
1.	Seal lead acid battery	
2.	Diapragm pump	
4.	Filter housing	
5.	Filter cap	

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6.	5 micron filter	
7.	Tubes	

4.3.3 Full Assembly CAD Model and Exploded View

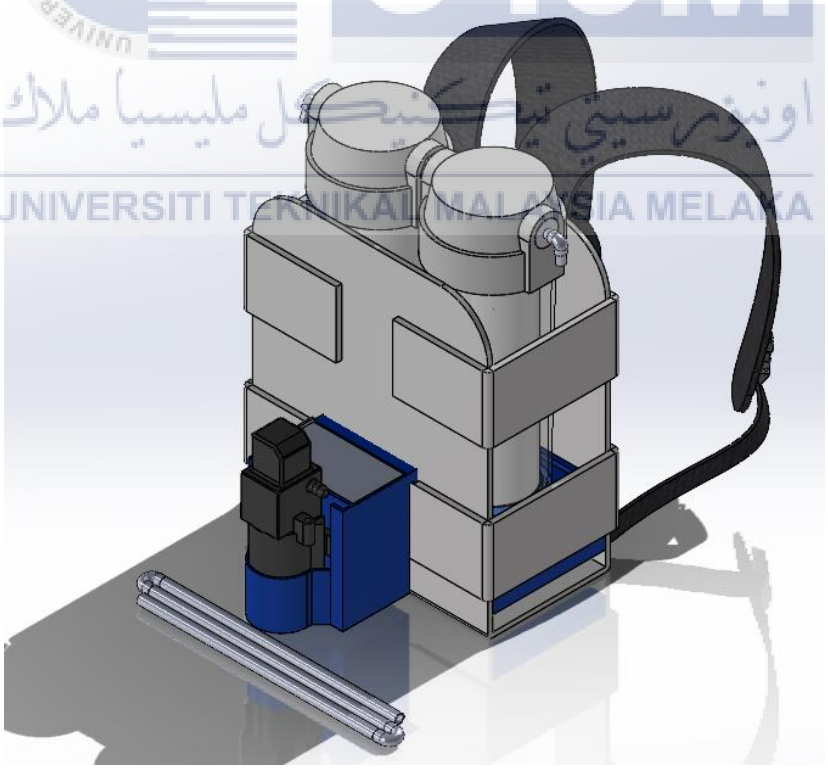

Figure 4.14 Fully assemble CAD

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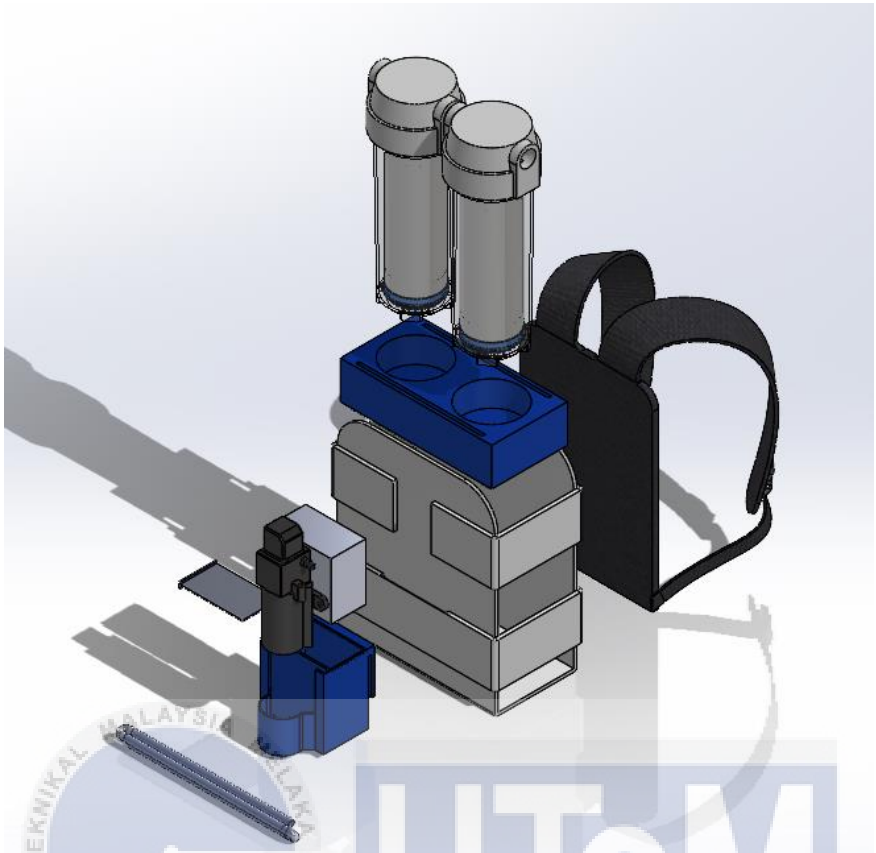

Figure 4.15 Exploded view

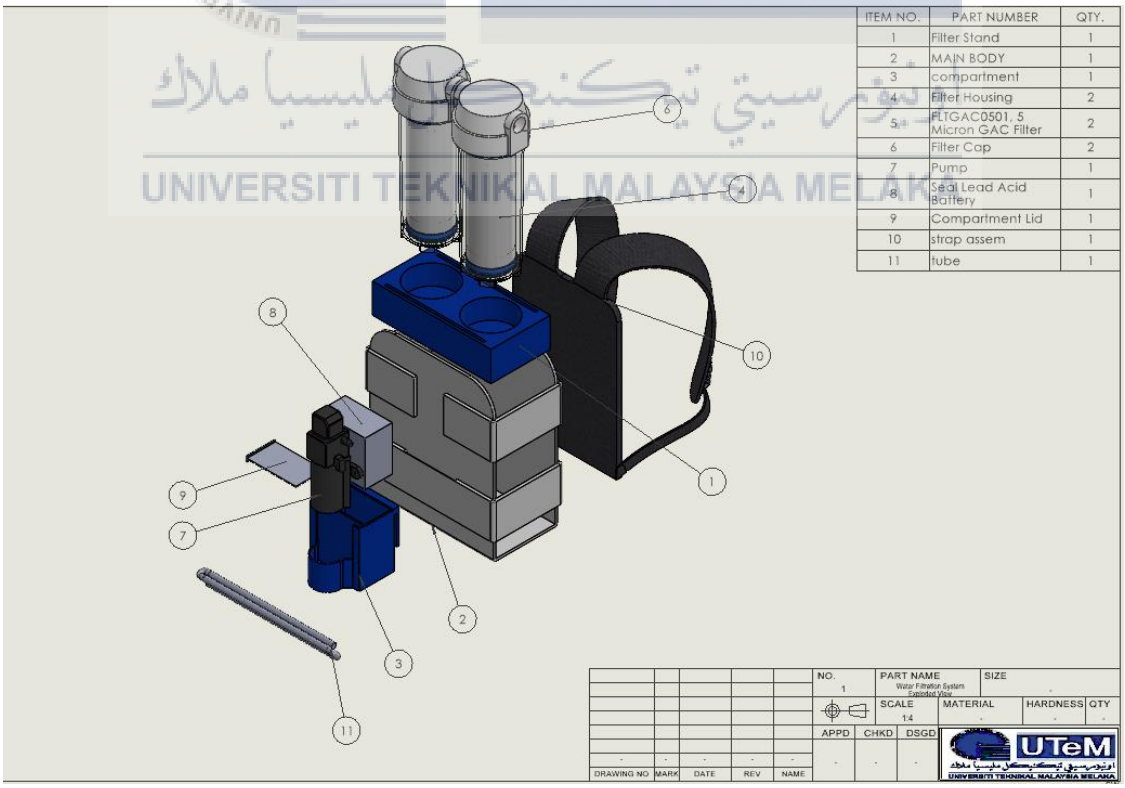

Figure 4.16 Exploded drawing

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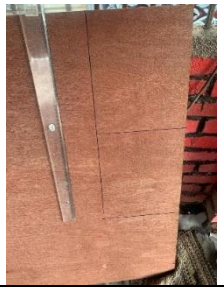
4.4 Fabrication Process

For the fabrication process, 2 different methods has been decided to make the model prototype which is FDM 3D printing process and woodworking process.

No.	Process	Part fabricated	Material	Machine
1	FDM 3D printing process	- Battery and pump compartment - Compartment lid	1.75 mm diameter PLA filament 	- Creality Ender v3-Pro - CreatorPro FlashForge
2	Woodworking process	- Bag - Filter stand	- 297mm x 210mm x 6mm Medium Density Fiberboard (MDF)  - 4ft x 8ft x 9mm plywood 	- Hand grinder machine - Sanding machine - Hand drilling process

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4.4.1 FDM 3D Printing Process

Fused Deposition Modelling (FDM) 3D printing process is a 3D printing process that involves extrusion of the material (filament) from the nozzle on the machine bed in order to fabricate the model.

4.4.1.1 3D Print Machine Preparation

Before starting the printing process using the FDM 3D printing machine, several setup or preparation is done first such as CAD model slicing, machine bed calibration and filament loading.

1. CAD Model Slicing

CAD model slicing is the process where the 3D CAD model is converted into STL file and upload into a slicer software. A slicer software will then help to generate a G-code based on the CAD model. This G-code is the coding that will be read by the 3D printing machine for printing process. For this process, since there are 2 machine that is used, there are 2 slicer that is used also.

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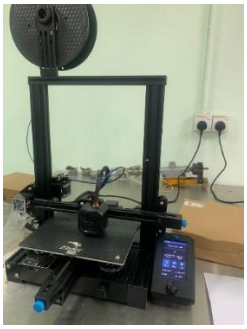
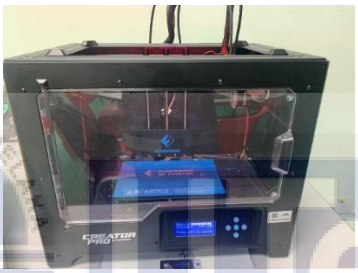
Table 4.13 FDM 3D printer and slicer

No.	Machine	Slicer
1.	Creality Ender 	Ultimaker Cura
2.	CreatorPro FlashForge 	Flashprint 5

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During this process, several setups for printing process have been set such as orientation, layer thickness, bed and nozzle temperature, and support setting. This set up is crucial because it can affect the printed part result.

2. Machine Bed Calibration

Bed is the machine part that will support or hold the printing part. Bed calibration is a must process to ensure the printing process runs smoothly. Bed calibration is done to ensure the bed of the machine is well leveled for printing process. An unleveled bed can cause the filament not to stick to the bed during the printing process. The method that is used to level the bed is by using a piece of paper and stuck it between the nozzle and the bed. Then the adjuster located under the bed is adjusted until a little friction is felt when the paper is moved.

The step is repeated to the whole bed to ensure the bed is well leveled. This method is used to close the gap between the nozzle and the bed.

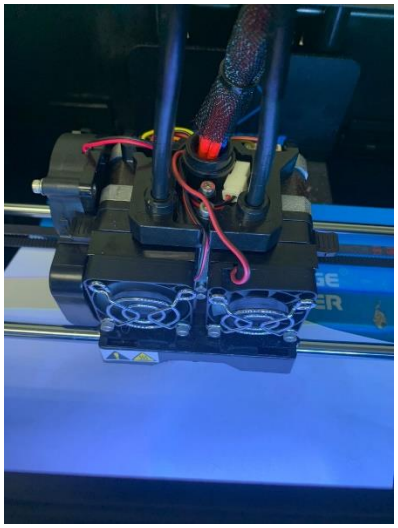

Figure 4.17 Bed leveling using paper

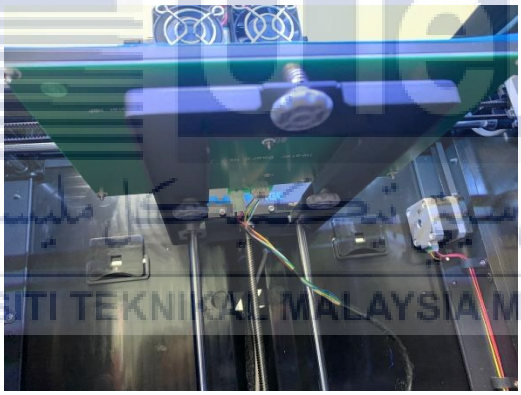

Figure 4.18 3 point bed adjuster

3. Filament Loading

Filament is the main material that is used for printing process. filament loading process is done to prepare the machine material so that it can feed for extrusion process during printing. Both machines have almost the same procedure for filament loading. There is a filament loading option in the machine interface. The option is pressed and then the machine will preheat the nozzle to 220 ℃. Then the nozzle is pushed into the

extruder manually until there is filament that is extruding through the nozzle. Then the process is completed. For the unloading process, the same procedure is done but instead of pushing the filament into the extruder the filament is pulled out from the extruder.

Figure 4.19 Filament laoding snd unloading menu in CreatorPro

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4.4.1.2 3D Print Machine Process

After finished preparation process is finished, the machine is ready to run for printing. The G-code that generated earlier is saved into an SD card. This is because the Creality Ender and Creator Pro FlashForge are using SD cards as file readers. The SD card is then inserted into the machine. Direct into print option and the G-code file saved is selected from the list. Then the machine takes several minutes to read and increase the temperature as the setup temperature. After all the parameters are the same as the setup parameters, then the machine started to print the part. During printing process, the machine is observed until it has completed several layers before it can be omitted. This is to ensure the printing process runs smoothly. Most of the print failures occur during the early printing stage which can be caused by incorrect parameters such as bed and nozzle temperature and the gap between the bed and nozzle. When a problem occurs, several ways and methods are done to overcome the

problem. After the printing process is finished, then the part is let to cool down for several minutes before scrapping process. scrapping process is process where the part is scrapped out from the bed and machine. The cool down time is to ensure that the part has the right temperature before scrapping. Part that is still hot is too soft and can bend easily if scrapped too early. After the part is scrapped out, the machine is cleaned, and the filament is unloaded for safe storage. The part is then cleaned from any support or brim that is still sticking to the part. Finishing process is done by sanding process to get better dimension tolerance.

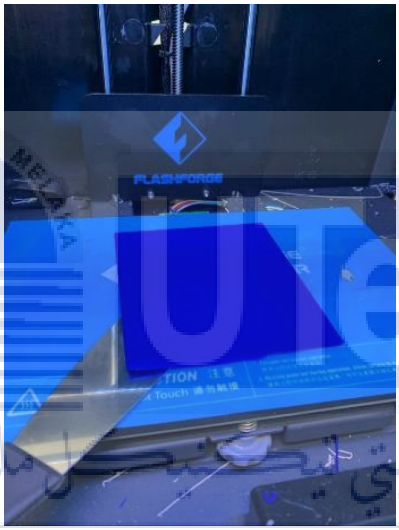

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Figure 4.20 Scrapping process

4.4.1.3 3D Print Post Process

1. Finishing process

For the finishing process, the sanding process is done to the part. This process is done to get better dimension tolerance for slot area. During printing process, the slot area is not having the exact dimension with the CAD model. This is because during the printing process, the slot area is occupied by the filament. The sanding process is done to the slot area to reopen the area and clearing the tolerance for the slot area.

2. Combining process

Since the part is printed part by part to ease the printing process, combining process is done to stick the part back together. During the CAD drawing, the part is separated into several parts. Each part contains simple slot that related to one another to ease the combining work. So it can self-locate the position of the part.

Figure 4.21 Finished compartment part

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4.4.1.4 Encountered Problems

During the 3D printing process, several problems have occurred and have been overcome in order to continue the progress. Some of the problems such as:

Table 4.14 Problem encountered

No.	Problems	Explanation	Effect
1.	Filament warpage	A filament warpage occurs when the filament that has been printed lifted from the bed and not sticking to the bed. When the machine continues to print, the	

		filament will follow the bending shape and cause the finished part to be in bending shape. In this project most of the warpage happens at the part edge.	
2.	Filament stringing	Filament stringing happens when the filament extruded is not directly stuck to the bottom. The extruded filament is tangled to the nozzle at first and then the filament is accumulated.	 Part chipped
3.	Bed malfunctions and leveling difficulty.	Bed malfunctions happened because the bed does not work ideally for the whole bed. This problem happened to the Creator Pro machine where the whole bed is not in good condition. Not good condition of the bed can cause the filament to not stick during first layer printing or warpage situation. This situation is also related to the difficulty to level the bed because of the location of the three-point adjuster under the bed.	 The surface is not clean

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6.	Changing dimension	Since the whole part is broken into several smaller parts, it causes the dimension to change and not in the tolerance. Plus, the finishing and combining process also can lead to reduction to the dimension. After finished combining process, it is realized that the dimension of the part is different from the original CAD model.	 Item not fit properly

4.4.2 Wood Working Process

Woodworking process is chosen as the fabrication process for the bag and filter stand part because of the simple design and low thickness of the design. Board has been seen as the closest and easiest way to replicate it design. Plus, sturdy and strong surface can help to show the external features of the product.

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4.4.2.1.1 Dimensioning process

Dimensioning and marking process is done to mark all the dimensions of the product before cutting. For this process, both part is separated into several parts to make it feasible to fabricate. Tools that is used for dimensioning and marking process:

Table 4.15 Meauring process tools

No.	Tools Name	Functions
1	Measuring tape	To measure larger dimension of larger part
2	Ruler	To measure a precise dimension of the part
3	T-square	To guide for making a straight line on the board
4.	Sharpie	To make the line and marking.

Figure 4.22 Measuring and marking process

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4.4.2.2 Cutting process

The cutting process is done to cut the board or wood into smaller pieces and marked shape. During the cutting process, several tools is used for different purpose.

Table 4.16 Cutting tools

No.	Tools Name	Functions
1	Hand grinder machine 	Used to cut the board or wood using two different disc blades: 1. Grinding disc Precise cutting line for MDF board since the board is not so hard. Using wood cutting disc for MDF could destroy the board more than cutting. 2. Wood cutting disc. Steady cutting for plywood since the plywood is harder than MDF and more force is needed.
2	Sanding machine 	Used for sanding the part. When cutting the wood, the dimensions are not the same as the marking. Sanding process is needed in order smaller the dimension.

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3	Drilling machine 	Used to make hole at the center of the board.
4	Hand drill machine 	Used to help sanding area which sanding machine cannot reach or cannot sanding such as filter area which is circle in shape.

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4.4.2.3 Combining process

After finishing cutting all the board and wood, combining process is done to start build up the product. The process is done from the biggest part and moved to smaller part. There is two types of glue that is used for this process which is:

Table 4.17 Combining process tools

No.	Tools Name	Functions
1	502 super glue	Used to stick between MDF board with other boards. This glue is used because of its instant and strong sticking power. It is strong enough to hold the MDF board since the MDF board surface does not absorb the liquid in a short time.
2	Carpenter glue	Used to stick between the plywood with the plywood. This is because the plywood surface absorbs liquid very fast that the 502 super glues are not able to dry first. This glue does not have instant dry and instant sticking even though it does have strong sticking power towards wood. This glue takes times about a day to fully dry and fully stick the wood.

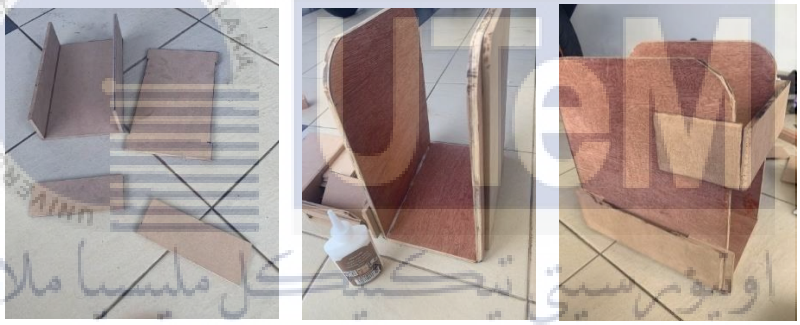

Figure 4.23 Combining process of the main body and filter stand

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4.4.2.4 Finishing process

The finishing process is done to make the final or finished product neater. In this project, there are 3 finishing processes that are done to the product.

Table 4.18 Finishing process

No.	Tools Name	Functions
1	Filler process	The filler process is a process where a wall filler is used to close any unneeded hole that appears to the wood. Plus, this process is also used to cover up any flaw that appears to the product. The flaw also includes dimension flaw where two parts have slightly different measurement due to the human error during cutting process. The wall filler is spread at the flaw area and then flattened following the surface. 
2	Sanding process	The sanding process is done to ensure the surface of the wood is smooth. This sanding process is using sandpaper with lower grade (100 Cw) only just to rub out the roughness off the wood edge.
3	Painting process	The painting process is done to further clean up the product after filling and sanding. Paint used for this process is spray paint type. Spraying process is done as many as 3 layers to ensure the paint is well sprayed through the whole product. Since the material that is used is wood, there is a certain area in which the wood directly absorbed the paint. So, after the first layer, the area in which the paint is absorbed by the wood is covered with wall filler.

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		Then the spray is continued until the third layer and the product is covered with color.   

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4.4.3 Post Fabrication process

After the body of the product is completed and finished, the strap is attached to the body. The attachment process used is sewing. The strap is sewed to the top holder and bottom

holder of the body part. Sewing method is used to have a more secure attachment method between the strap and the main body.

Figure 4.24 Attachment of the strap to the main body

4.5 Finished prototype.

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Figure 4.25 Front view

Figure 4.26 Left side view

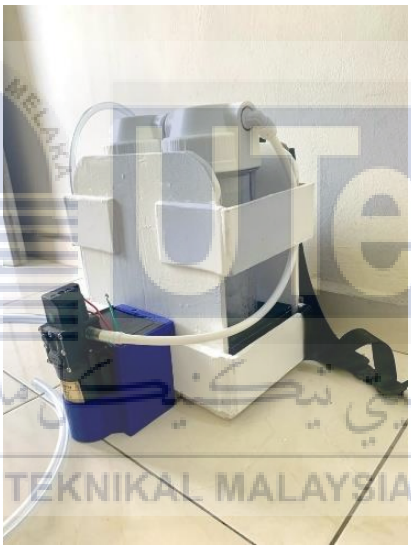

Figure 4.27 Right side view

4.6 Design improvements and relevant

4.6.1 Customer request

In the early process of this project, there are several survey that have been made towards customer to try the original design of the product. Ans some of the feedback are:

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Table 4.19 Design relevant

No.	Customer feedback	Response in new design	Comparison (Picture)	
			Original	Redesign
1.	Hard strap with small surface.	- School bag strap is used to increase the surface with sponge to make it softer.		
2.	Strap harness position	- Sewing method is used instead of harness. - Strap joint placement is away from contact surface		
3.	Compartment slot fitting	- Hook concept is used instead slotting.		
4.	Heavy product	- The infill of the main body is reduced		

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5.	Hard surface contact with body.	- Sponge is attached to the main body to make a softer surface that will interact with the human body.		

4.7 Comparison between original and redesigned analysis result

4.7.1 RULA Analysis

4.7.1.1 Original design

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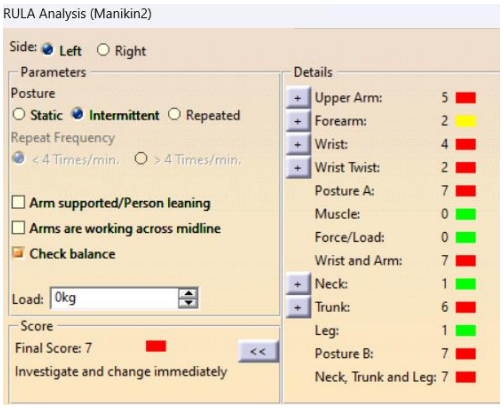
Figure 4.28 Original setup posture using manikin



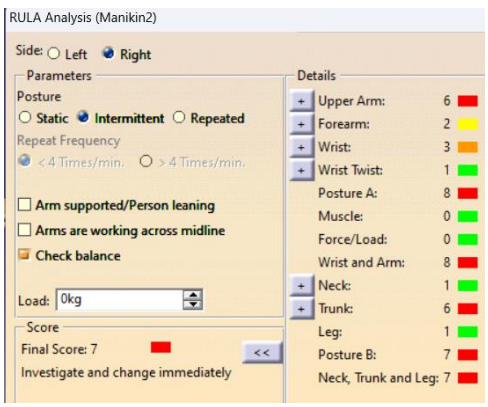


Figure 4.29 RULA assessment of the original product (left & right)

4.7.1.2 Redesign

Figure 4.30 Redesigned setup posture using manikin

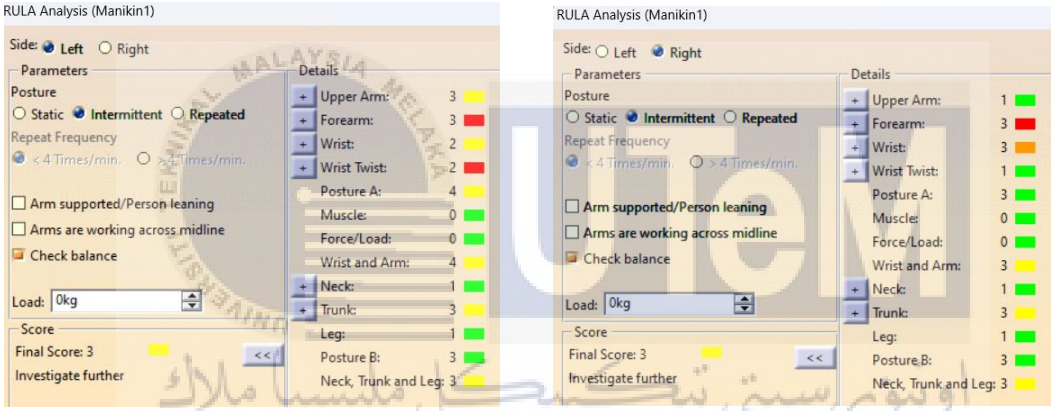


Figure 4.31 RULA assessment result of the redesigned product (left & right)

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From the result, it is clear that redesigned product gives better setup posture with score of 3 than the original design with score of 7. This is because the original design does not have any features to help fix the tube which is already attached to the pump and filter. So, users need to bend every time want to use it. Compared to redesigned products, the hose can be held even if they are already attached to the pump and filter. So the user does not need to attach and detach the hose every time of usage. If the score of 7 is continue to be applied to the product, it will increase the risk of injury or back pain to the user's back body.

4.7.2 Boothroyd evaluation

4.7.2.1 Original design

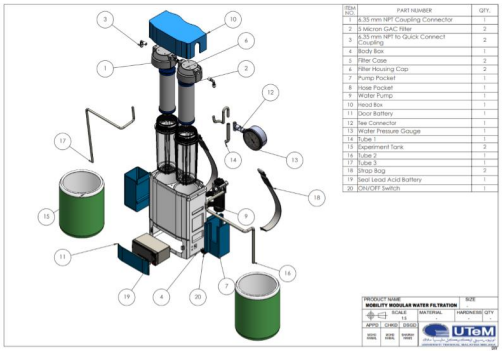

Figure 4.32 Original design

Table 4.20 BD evaluation table (original)

Original design											
α	β	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
360	360	4	1	30	1.95	00	1.5	3.45	-	1	Body box
360	180	5	1	20	1.8	30	2	3.8	-	1	Water filter
360	180	19	1	20	1.8	00	1.5	3.3	-	1	Seal lead acid battery
360	360	11	1	33	2.51	30	2	4.51	-	1	Door battery
360	360	9	1	30	1.95	40	4.5	6.45	-	1	Water pump
360	360	7	1	30	1.95	34	6	7.95	-	0	Pump pocket
360	360	8	1	30	1.95	34	6	7.95	-	0	Hose pocket
360	360	10	1	30	1.95	30	2	3.95	-	0	Head box
180	0	14	3	01	1.43	32	4	5.43	-	1	Tube/hose
360	360	18	2	33	2.51	30	2	4.51	-	1	Strap bag
TOTAL								51.3	-	7	**Design Efficiency** (E) = 3N/T = 3(7)/51.3 =0.409
								T_a	C_a	N	

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4.7.2.2 Redesign

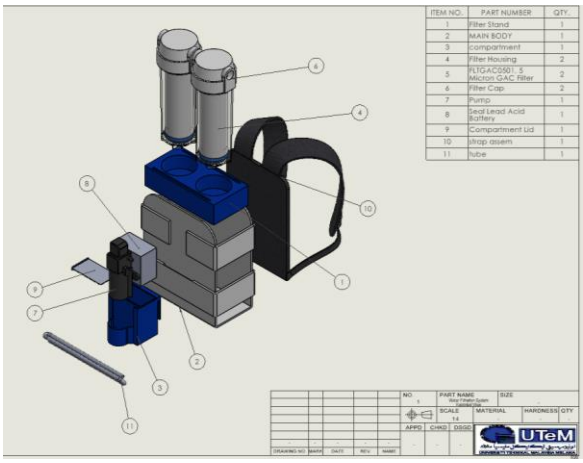

Figure 4.33 Redesigned product

Table 4.21 BD evaluation table (redesign)

Redesigned											
α	β	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
360	360	2	1	30	1.95	00	1.5	3.45	--	1	Main body
360	180	4,5,6	1	20	1.8	30	2	3.8	-	1	Water filter
360	180	8	1	20	1.8	00	1.5	3.3	-	1	Seal lead acid battery
360	360	7	1	30	1.95	40	4.5	6.45	-	1	Water pump
180	0	11	3	01	1.43	32	4	5.43	-	1	Tube/hose
360	360	10	1	33	2.51	06	5.5	8.01	-	1	Strap bag
360	360	3	1	30	1.95	30	2	3.95	-	1	Compartment
360	180	1	1	10	1.5	30	2	3.5	-	0	Filter stand
360	180	9	1	10	1.5	30	2	3.5	-	1	Compartment lid
TOTAL								41.39	-	8	**Design Efficiency**
								T_a	C_a	N	(E) = 3N/T = 3(8)/41.39 =0.58

From the Boothroyd Dewhurst evaluation result, it is clear that the redesigned product has higher design efficiency than the original product. This is by

implementing the principle of minimize part count of the product. The total number of part is reduced from 10 in the original product to 9 in the redesigned product. Plus, for the insertion manual value is for the pump is improved from 7.95 in the original product to 3.95 in the redesigned product. Plus, there are two pocket with same manual insertion value in the original product compared to redesigned product. Higher design efficiency gives lower effort for the assembly process of the product.

Table 4.22 Reduced components

No.	Reduced part	Explanation
1.	Combining both pump and battery into a single compartment.	- Battery and pump is complimentary component which is both are needed to fully operate the system. - Ensure the components to placed close to each other to simplify the layout of the product especially for the electrical connection.
2.	Eliminate the hose pocket component.	- Instead of putting the hose into a particular component, the hose is placed or hold around the main body.
3.	Eliminate the main body cover	- Taking from the open design concept of the main body, the covers is eliminated since the function is counter by the open design itself.

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4.8 Summary

Overall, this chapter have showed the progress of the product development in details through the product planning process. The findings in this chapter may could help the design improvement of the product become more clearer.

CHAPTER 5 CONCLUSION

5.1 Conclusion

As for the conclusion of this project, it seems that the purpose of design improvement for the mobility modular water filtration system for flood victims has been achieved successfully. This project is targeted to improve and increase the ergonomics aspect of the product. The improvement are based on the RULA analysis of the product through the setup posture. From this project, the RULA score has been increased from the score of 7 for both sides of the body to score 3 for both side of the body. From this result, it can conclude that the ergonomics aspect has been improved for the product.

In addition, the response in the new product from the customer feedback also helped to improve the product in the ergonomic aspect. Some of customer feedback which are giving response towards the original product about the comfort and related to the ergonomic risk factor (ERF). So, in the new design, the customer response is emphasized to avoid and eliminate the risk factor from the product. This helped to increase the ergonomic aspect of the product.

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Other than that, the improvement of the product also involving the assembly process of the product which are basing on the Boothroyd Dewhurst evaluation method. This method are used to help to reduce the total number of the product part and increasing the design efficiency of the product. Based on the result, the original design of the product have an efficiency of 0.409 compared to the redesign product with design efficiency of 0.58. So, it can conclude that the design efficiency of the product has been improved.

5.2 Project Reccomendation

Throughout the time of completing this project, certain upgrade and improvement comes to mind that can help to get the product better in the future. Some of the improvement is:

1. Improvement of both RULA and Boothroyd Dewhurst result.

In this study, the objective of the study has been achieved by saying that both RULA assessment and Boothroyd Dewhurst evaluation is increased compared to the original product. Unfortunately, the improvement of the design did not reach the maximum result for both analyses, especially RULA analysis because it is related to human interaction and risk of injury. This is due to the limitation of machine and method to be use in order to fabricate a complex design. Since the method used is manual woodworking process, the design is chosen to be minimalist so that it is feasible to fabricate. In the original idea of view, it is better to have hand handle so that the product will be within reach of user hand even if locate at the floor and also built in tube or hose that directly connected to the pump and filter with using external hose so that no setup posture is needed to place the tube to the pump and filter.

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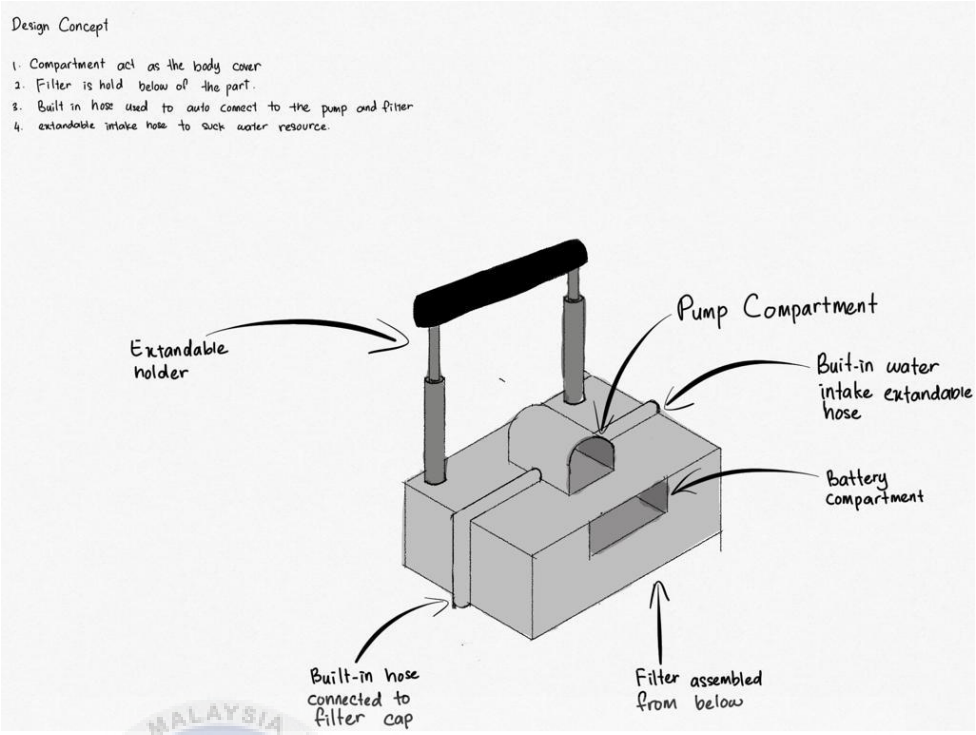

Figure 5.1 Rough concept design tom improve the RULA result

2. Self-fastener for strap

In this project, the strap is only fastened by using sewing method in order to avoid the usage of harness that can disturb the contact surface between the product and the human body. The sewing method seems to give benefit towards the customer but it gives bigger disadvantage towards the manufacturer due to the process that will take a longer time.

3. Versatile concept

Versatile concept is a concept which enable the product to adapt with other situation. In this case, the flood situation as we well inform are quite frequent happened in Malaysia. But the frequency of the disaster hit our country is only once or twice in a year. To ensure this product can be accept in the market, it should has other features

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that allow the product to have other functions to be use for other purpose which is by implimenting a versatile concept.

5.3 Project Potential

As the main purpose of the product, it is targeted for flood victims during the flood disaster that often hit Malaysia. This means that the product have a high potential to be equipped with the authorities so that authorities can control the product to be locate at a specific location like the community centre or rescue centre during the flood. It is because the product is much more suitable to be categorize as an emergency tools instead of just a redular tools for daily usage. Plus, the feature of the product which only targeted for a single scenario make it not worth of buying for a regular usage.

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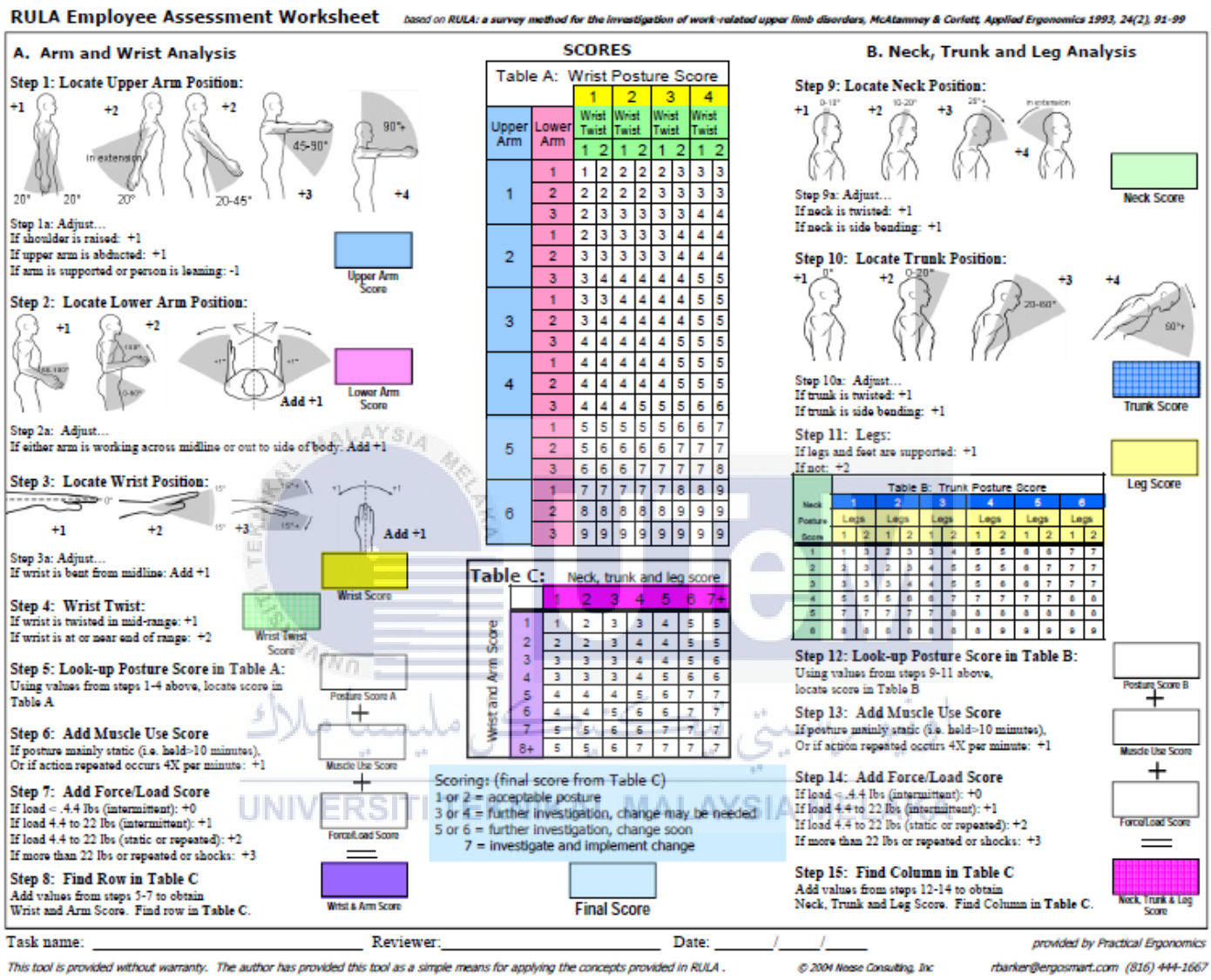
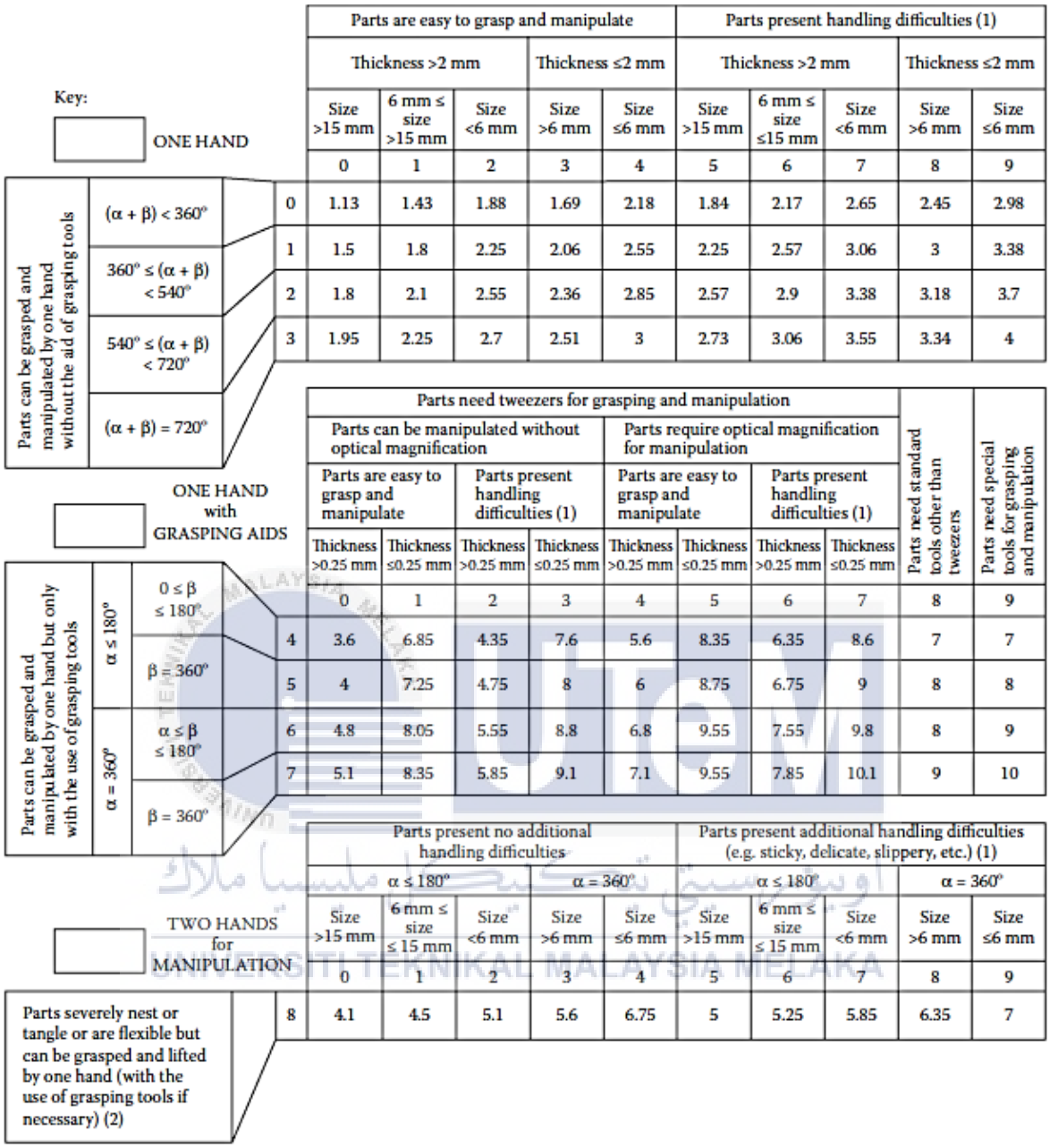
APPENDICES

APPENDIX A RULA employee assessment score



APPENDIX B Manual handling chart



Key:

ONE HAND

ONE HAND with GRASPING AIDS

TWO HANDS for MANIPULATION

			Parts are easy to grasp and manipulate					Parts present handling difficulties (1)				
			Thickness >2 mm			Thickness ≤2 mm		Thickness >2 mm			Thickness ≤2 mm	
			Size >15 mm	6 mm ≤ size >15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm	Size >15 mm	6 mm ≤ size ≤15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm
			0	1	2	3	4	5	6	7	8	9
Parts can be grasped and manipulated by one hand without the aid of grasping tools	(α + β) < 360°	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	360° ≤ (α + β) < 540°	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	540° ≤ (α + β) < 720°	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	(α + β) = 720°	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

			Parts need tweezers for grasping and manipulation								Parts need standard tools other than tweezers	Parts need special tools for grasping and manipulation
			Parts can be manipulated without optical magnification				Parts require optical magnification for manipulation					
			Parts are easy to grasp and manipulate		Parts present handling difficulties (1)		Parts are easy to grasp and manipulate		Parts present handling difficulties (1)			
			Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm		
			0	1	2	3	4	5	6	7	8	9
Parts can be grasped and manipulated by one hand but only with the use of grasping tools	α ≤ 180°	0 ≤ β ≤ 180°	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
		β = 360°	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
	α = 360°	α ≤ β ≤ 180°	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		β = 360°	7	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

		Parts present no additional handling difficulties					Parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
		α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
		Size >15 mm	6 mm ≤ size ≤ 15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm	Size >15 mm	6 mm ≤ size ≤ 15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm
		0	1	2	3	4	5	6	7	8	9
Parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

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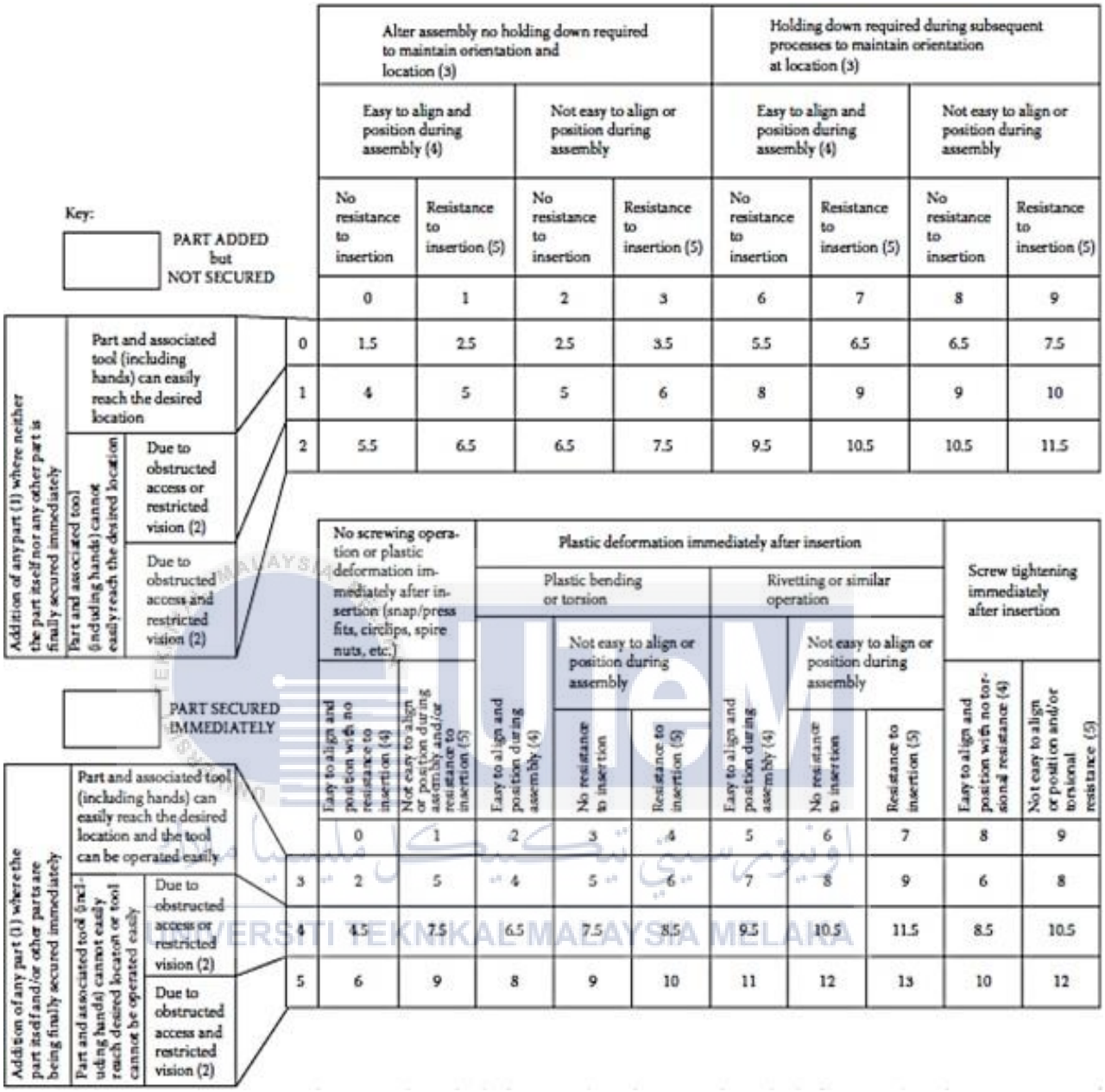
APPENDIX C Manual insertion chart



Key:

PART ADDED but NOT SECURED

PART SECURED IMMEDIATELY

Addition of any part (1) where neither the part itself nor any other part is finally secured immediately

	Alter assembly no holding down required to maintain orientation and location (3)				Holding down required during subsequent processes to maintain orientation at location (3)			
	Easy to align and position during assembly (4)		Not easy to align or position during assembly		Easy to align and position during assembly (4)		Not easy to align or position during assembly	
	No resistance to insertion	Resistance to insertion (5)	No resistance to insertion	Resistance to insertion (5)	No resistance to insertion	Resistance to insertion (5)	No resistance to insertion	Resistance to insertion (5)
	0	1	2	3	6	7	8	9
Part and associated tool (including hands) can easily reach the desired location	0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
Part and associated tool (including hands) cannot easily reach the desired location: Due to obstructed access or restricted vision (2)	1	4	5	5	6	8	9	9	10
Part and associated tool (including hands) cannot easily reach the desired location: Due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

Addition of any part (1) where the part itself and/or other parts are being finally secured immediately

	No screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		Plastic deformation immediately after insertion						Screw tightening immediately after insertion	
			Plastic bending or torsion			Rivetting or similar operation				
			Easy to align and position during assembly (4)	Not easy to align or position during assembly		Easy to align and position during assembly (4)	Not easy to align or position during assembly			
	Easy to align and position with no resistance to insertion (4)	Not easy to align or position during assembly and/or resistance to insertion (5)		No resistance to insertion	Resistance to insertion (5)		No resistance to insertion	Resistance to insertion (5)	Easy to align and position with no torsional resistance (4)	Not easy to align or position and/or torsional resistance (5)
	0	1	2	3	4	5	6	7	8	9
Part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily	2	5	4	5	6	7	8	9	6	8
Part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: Due to obstructed access or restricted vision (2)	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
Part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: Due to obstructed access and restricted vision (2)	6	9	8	9	10	11	12	13	10	12

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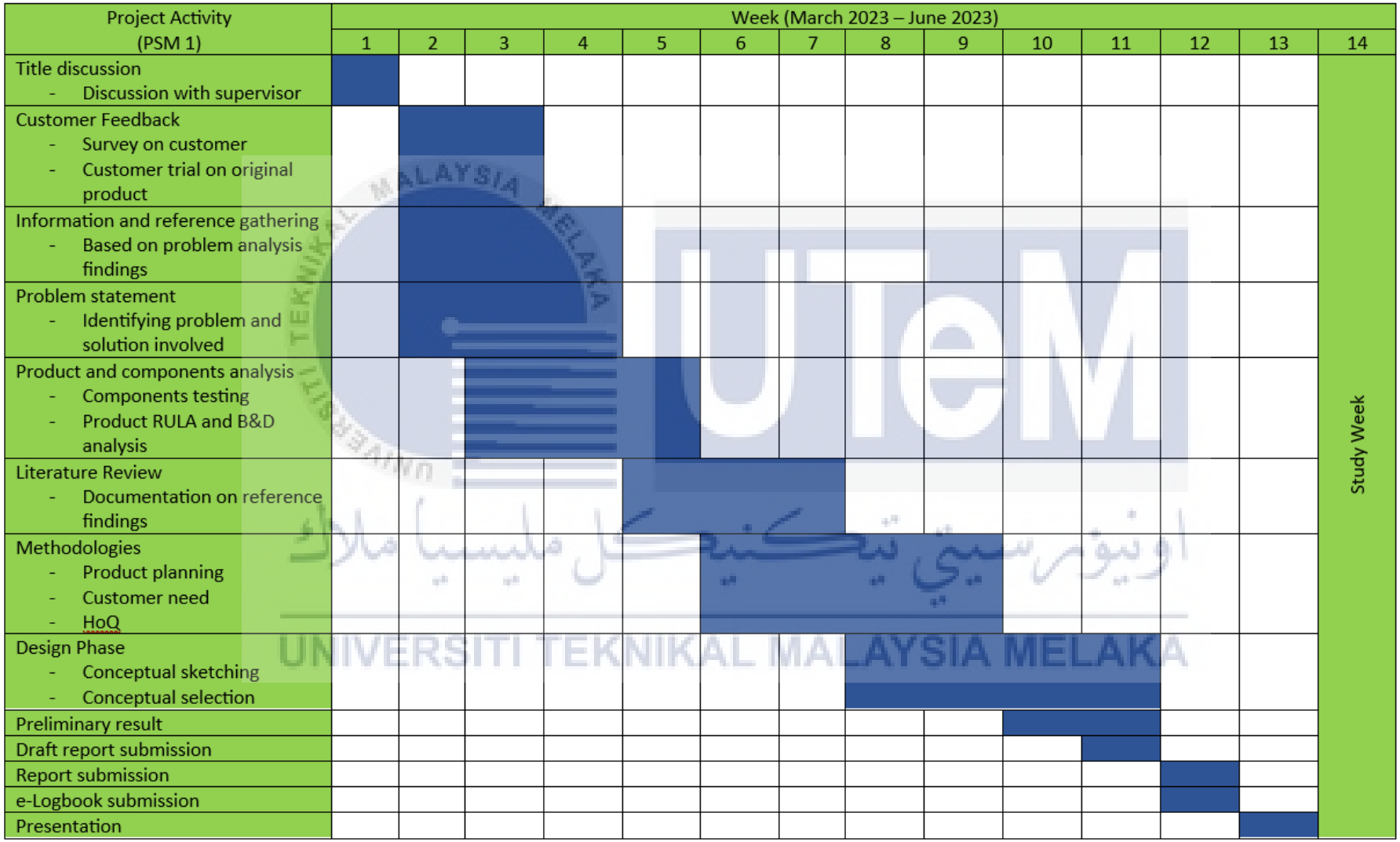
APPENDIX D Gantt chart for PSM 1



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APPENDIX E Gantt chart for PSM 2

Project Activity (PSM 2)	Week (October 2023 – February 2024)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project discussion - Discussion with supervisor about previous report and progress														Study Week
Project Improvement - Correction on previous report and progress														
Final sketch - Confirming the design of the product with supervisor														
Product development - 3D modelling in SolidWorks														
Costing budget - Material selection - Bill of material														
Prototype fabricating - FDM 3D printing - Wood working process														
Final product - Finished prototype														
Poster for presentation														
Draft report submission														
Report submission														
e-Logbook submission														
Presentation														

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APPENDIX F Respondents feedback survey

Respondent 1

1. Name : Muhammad Nur Akmal Ridzuan Bin Abu Bakar
2. Age : 22
3. Gender : Male
4. Flood experience : -
5. Response :

a) Ergonomics

- Strap harness pressing body.
- Bottom edge of the body box pressing the waist.
- Hard to wear.

b) Assembly

- The pocket is to fit and difficult to insert.
- Door battery too loose.

c) Others

- Strainer on the hose

Respondent 2

1. Name : Raja Jamalullail Bin Raja Muhaiyatdin
2. Age : 24
3. Gender : Male
4. Flood experience : Flash flood, short term flood
5. Response :

a) Ergonomics

- Bottom edge of the body box pressing the waist.
- Strap pulling the body.
- Body box unbalanced.

b) Assembly

- Low clearance slot for the pocket. Difficult to slot in.

c) Others

- No

Respondent 3

1. Name : Kassa Ezzudin bin Khairul Anuar
2. Age : 22
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Heavy product
- Strap harness pressing body.
- Bottom edge of the body box pressing waist

b) Assembly

- Low clearance slot for the pocket. Difficult to slot in.

c) Others

- No

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Respondent 4

1. Name : Ahmad Dynee Asyraff bin Ahmad Azyzee
2. Age : 22
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Harness pressing body.
- Small strap pressure the shoulder

b) Assembly

- Low clearance slot for the pocket. Difficult to slot in.

c) Others

- No

Respondent 5

1. Name : Muhd Fauzan bin Sani
2. Age : 25
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Strap harness pressing the body.
- Hard to wear.

b) Assembly

- Low clearance slot for the pocket. Difficult to slot in.

c) Others

- No

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Respondent 6

1. Name : Nuqman Daniel bin Nordin
2. Age : 23
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Strap harness pressing body.
- Strap pressuring the shoulder.

b) Assembly

- Low clearance slot for the pocket. Difficult to slot in.

c) Others

- No

Respondent 7

1. Name : Ahmad Nassem Bin Mohd Asri
2. Age : 21
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Body box pulling the body.
- Strap harness pressing body.

b) Assembly

- Easy if get proper instruction.

c) Others

- No

Respondent 8

1. Name : Nur Adlina Afrina Binti Mohd Kamil
2. Age : 24
3. Gender : Female
4. Flood experience : No.
5. Response :

a) Ergonomics

- The body box is pulling body to the back.
- Harness pressing the body.
- Hard material contact with body.

b) Assembly

- Easy if get proper instruction.
- Okay

c) Others

- No

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Respondent 9

1. Name : Nuralifah Ilyana Binti Mohd Bakri
2. Age : 23
3. Gender : Female
4. Flood experience : No.
5. Response :

a) Ergonomics

- Harness is pressing the body.
- Body box loose and pulling the body.
- Heavy for female

b) Assembly

- Easy if get proper instruction.

c) Others

- No

Respondent 10

1. Name : Nor Hani Binti Md Besa
2. Age : 22
3. Gender : Female
4. Flood experience : No.
5. Response :

a) Ergonomics

- Body box a little higher.
- Heavy for female.
- Uncomfortable strap concept

b) Assembly

- Easy if get proper instruction.

c) Others

- No

Respondent 11

1. Name : Siti Noor Hidayah Binti Abd Rahman
2. Age : 22
3. Gender : Female
4. Flood experience : No.
5. Response :

a) Ergonomics

- Body box a little higher.
- Heavy for female.
- Uncomfortable strap concept

b) Assembly

- Easy if get proper instruction.

c) Others

- No

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Respondent 12

1. Name : Muhammad Aiman Nurhakim bin Shaifol
2. Age : 23
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Heavy
- Big size body box. Restrict body movement.
- Strap pressuring the shoulder.

b) Assembly

- Easy if get proper instruction.
- A little fit slot

c) Others

- No

Respondent 13

1. Name : Muhammad Nasrul Aiman Bin Muhd Zulqarnain
2. Age : 24
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- The strap is giving too much pressure to the shoulder.
- Heavy
- Bottom edge pressing the waist.

b) Assembly

- Easy if get proper instruction.
- Too fit pocket slot, worried will break the part.

c) Others

- No

Respondent 14

1. Name : Muhammad Noor Haikal Bin Abd Aziz
2. Age : 23
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Harness pressing body.
- The strap is giving too much pressure to the shoulder.
- Loose body box, uncomforted during walking.

b) Assembly

- Too fit pocket slot, hard to slot in.

c) Others

- No

Respondent 15

1. Name : Aliff Najmuddin Bin Sabri
2. Age : 23
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Heavy body box
- Strap give too much pressure to shoulder.
- Harness pressing body.

b) Assembly

- Easy if get proper instruction.

c) Others

- No

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Respondent 16

1. Name : Muhammad Khairul Hafies Bin Baharuddin
2. Age : 25
3. Gender : Male
4. Flood experience : No.
5. Response :

a) Ergonomics

- Heavy
- Product is pulling body backwards.
- Difficult to wear.

b) Assembly

- No

c) Others

- No

Respondent 17

1. Name : Muhammad Nasrul Hakim Bin Ruslan
2. Age : 24
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Heavy
- Short strap

b) Assembly

- No

c) Others

- No

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Respondent 18

1. Name : Muhammad Aiman Fahmi bin Zamrisham
2. Age : 25
3. Gender : Male
4. Flood experience : Yes
5. Response :

a) Ergonomics

- Uncomfortable strap
- Strap pressuring shoulder

b) Assembly

- Strap assembly is unsecure

c) Others

- No

Respondent 19

1. Name : Anas Bin Malik
2. Age : 26
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Short strap
- Difficult to wear
- Hurting human back

b) Assembly

- Slotting difficult

c) Others

- No

Respondent 20

1. Name : Mohammad Hakim bin Mohd Ramaly
2. Age : 20
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics

- Strap not suitable
- Heavy
- Hard surface contact with human body

b) Assembly

- Pocket slotting difficulty

c) Others

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Respondent 21

1. Name : Safuraa Aghnia Bt. Shamsul
2. Age : 23
3. Gender : Female
4. Flood experience : No
5. Response :

a) Ergonomics

- Poking waist
- Heavy
- No sponge at the back
- Strap not comfortable

b) Assembly

- Pocket slotting difficult

c) Others

- No

Respondent 22

1. Name : Ahmad Haikal bin Mohd Nasir
2. Age : 22
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics
- Heavy
- Loose strap
- Need to use three way strap

b) Assembly
- No

c) Others
- No

Respondent 23

1. Name : Izzat Affendi
2. Age : 32
3. Gender : Male
4. Flood experience : Yes
5. Response :

a) Ergonomics
- Not ergonomics and not comfortable for wearing
- Heavy

b) Assembly
- No

c) Others
- No

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Respondent 24

1. Name : Muhammad Amin bin Alias
2. Age : 25
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics
- Heavy
- Hard surface contact
- Short and hard strap
- Strap too pressuring on shoulder
- Harness poking body

b) Assembly
- Fit slotting for pocket

c) Others
- No

Respondent 25

1. Name : Muhammad Arif Nur Asyraff bin Nordin
2. Age : 25
3. Gender : Male
4. Flood experience : Yes
5. Response :

a) Ergonomics
- Heavy
- Not suitable for woman

b) Assembly
- Slotting little bit difficult

c) Others
- No

Respondent 26

1. Name : Nur Azalina Binti Anua
2. Age : 23
3. Gender : Female
4. Flood experience : No
5. Response :

a) Ergonomics
- Heavy
- Harness poking body
- Add sponge padding on the surface

b) Assembly
- No

c) Others
- No

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Respondent 27

1. Name : Raja Laily Arfah Binti Raja Mahaiatdin
2. Age : 27
3. Gender : Female
4. Flood experience : No
5. Response :

a) Ergonomics
- Heavy
- Strap too thin

b) Assembly
- Difficult slotting

c) Others
- No

Respondent 28

1. Name : Farid Ikram bin Azman
2. Age : 24
3. Gender : Male
4. Flood experience : No
5. Response :

a) Ergonomics
- Eliminate the harness
- Add padding or sponge

b) Assembly
- No

c) Others
- No

Respondent 29

1. Name : Nur Syazwana binti Haspul Anuar
2. Age : 23
3. Gender : Female
4. Flood experience : No
5. Response :

a) Ergonomics
- Unsuitable strap
- Main body loose

b) Assembly
- Difficult slotting

c) Others
- No

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Respondent 30

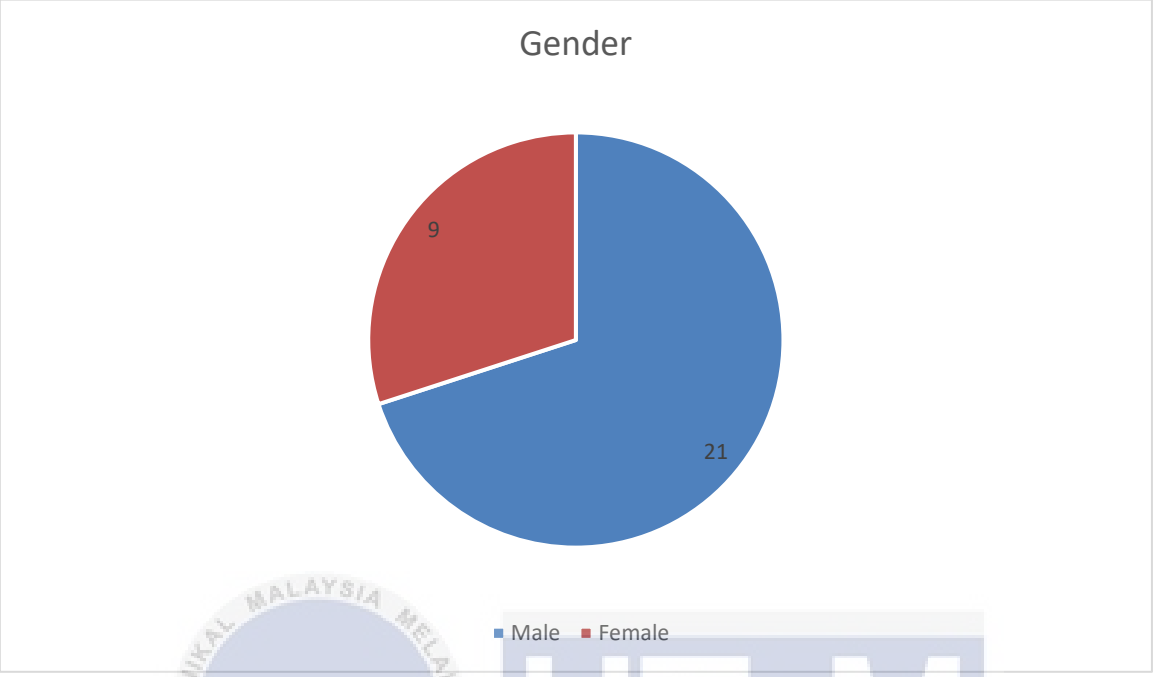
1. Name : Miera Sofea Binti Kamaruzaman
2. Age : 26
3. Gender : Female
4. Flood experience : No
5. Response :

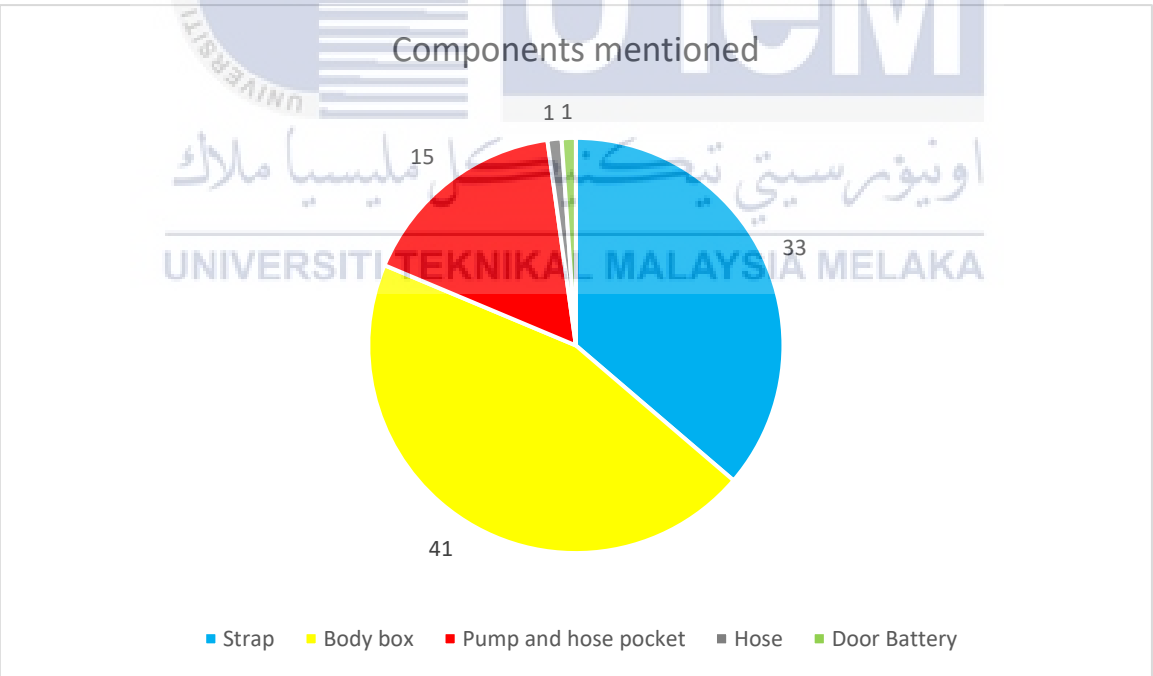
a) Ergonomics
- Heavy
- Main body loose

b) Assembly
- No

c) Others
- No

APPENDIX G Respondents analysis





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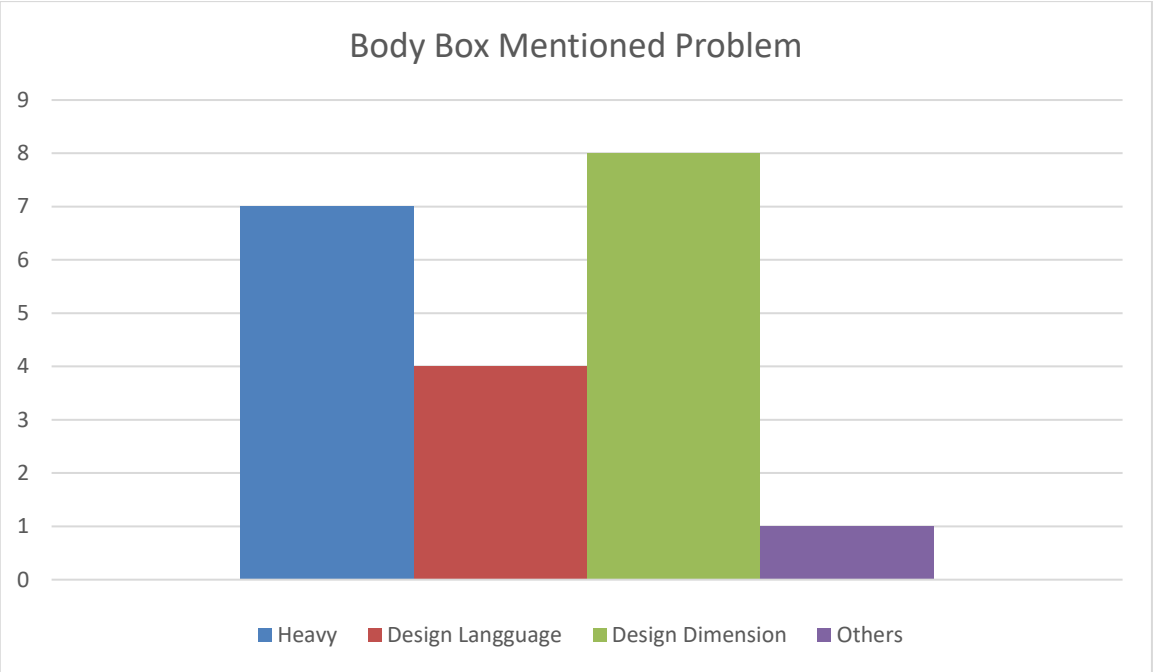

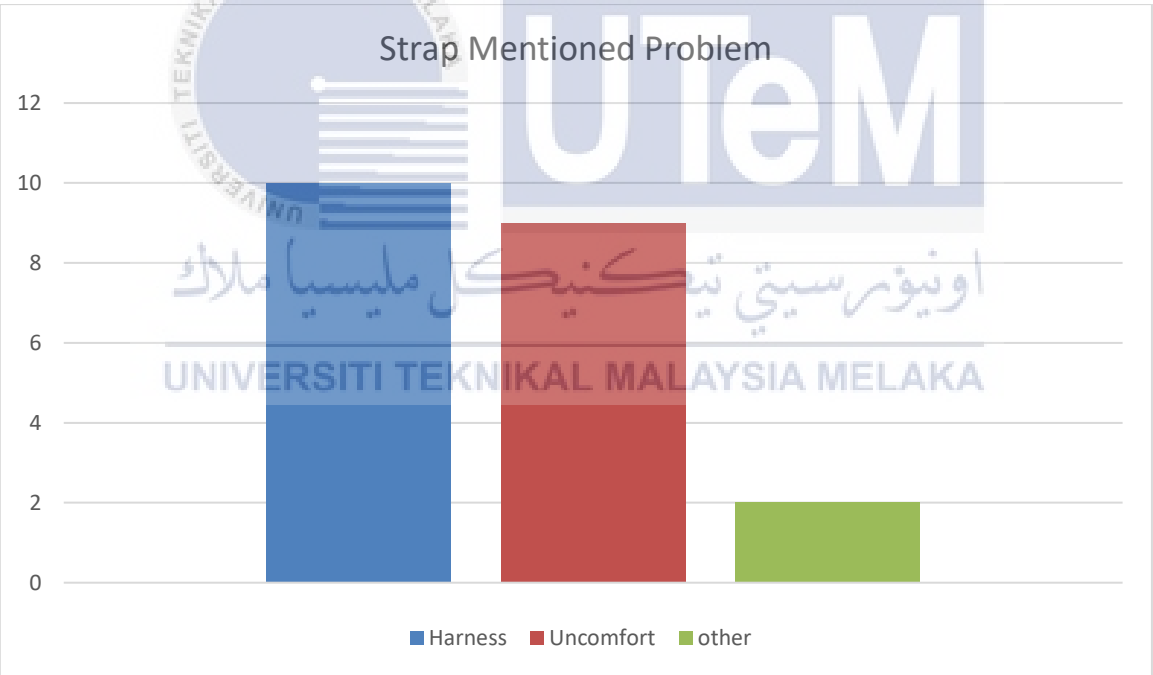

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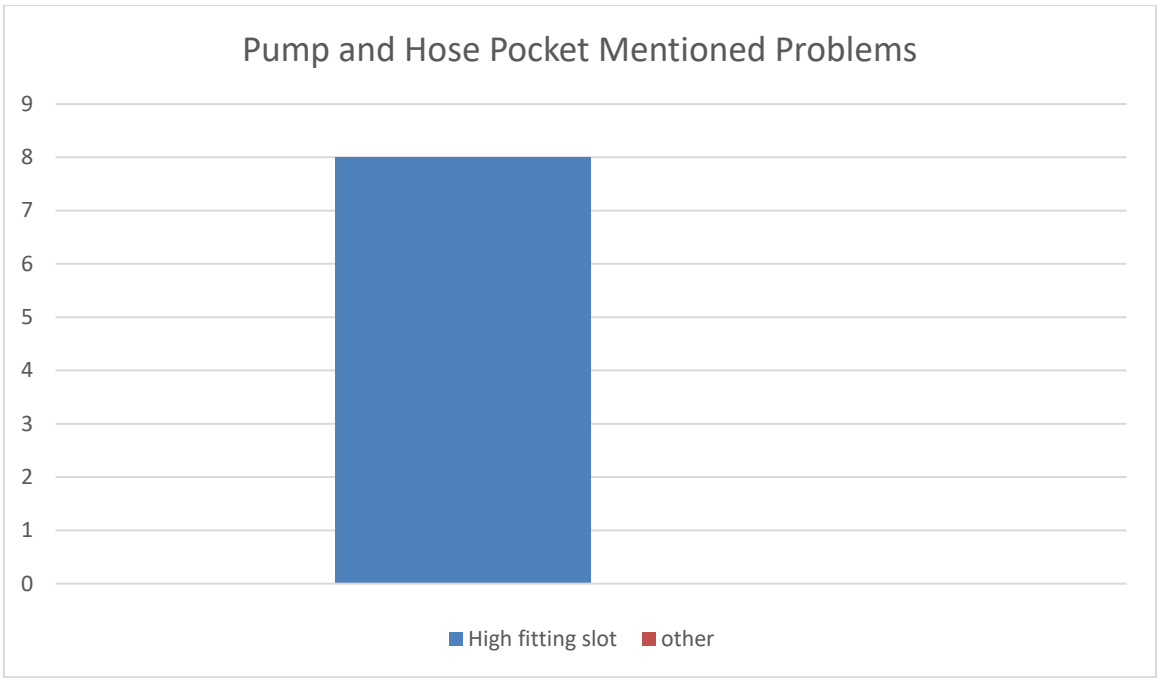

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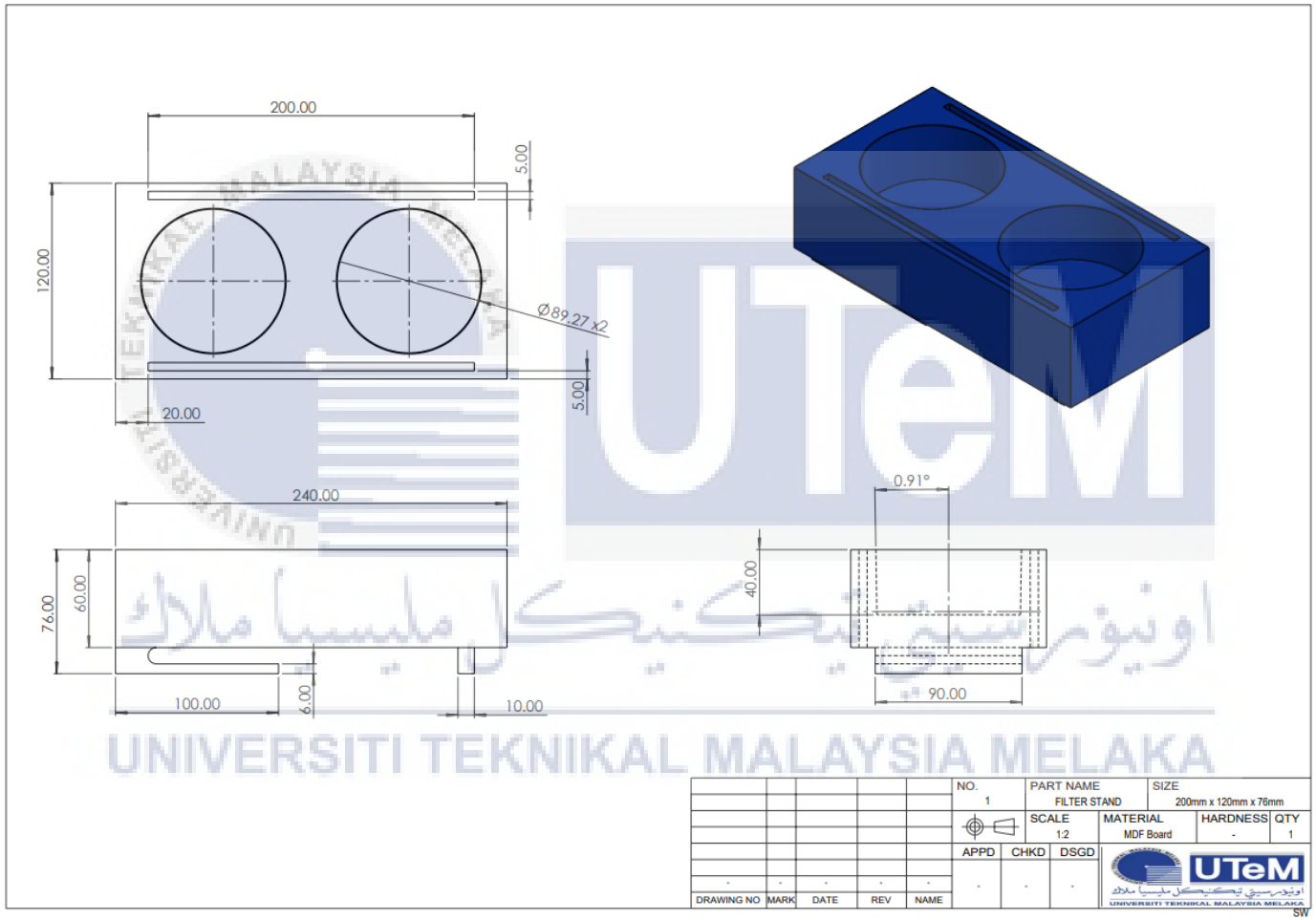
APPENDIX H Components Drawing



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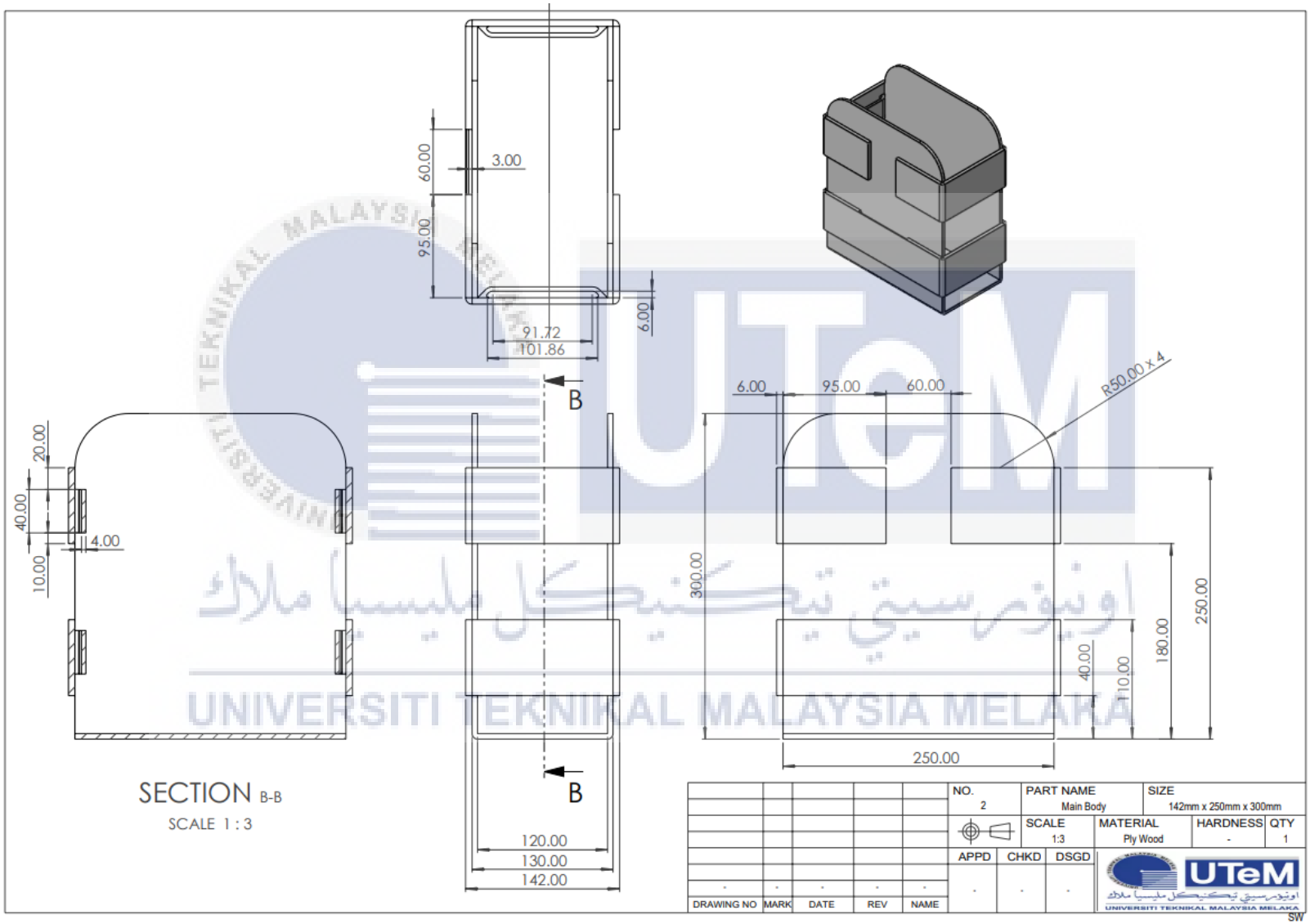

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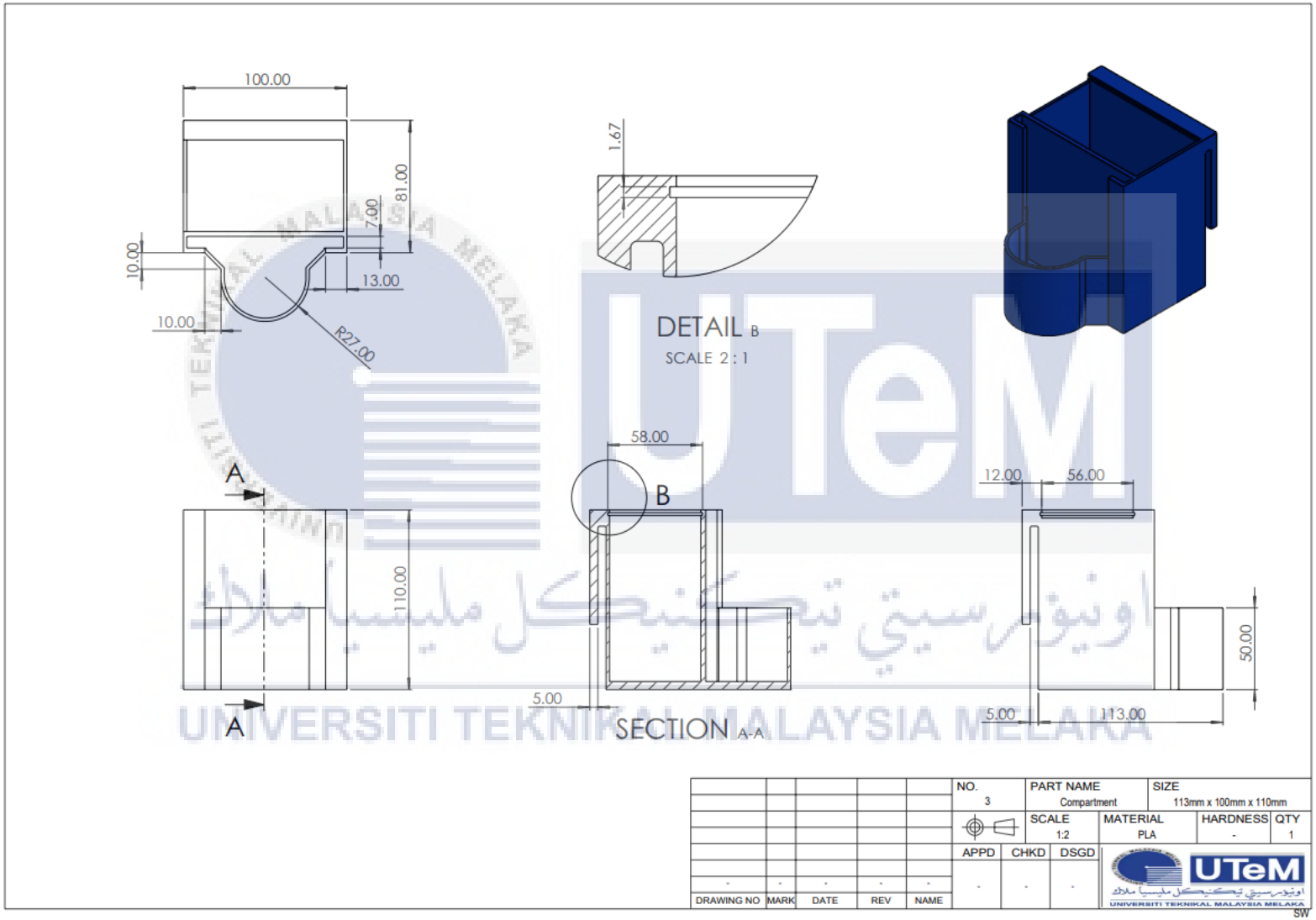

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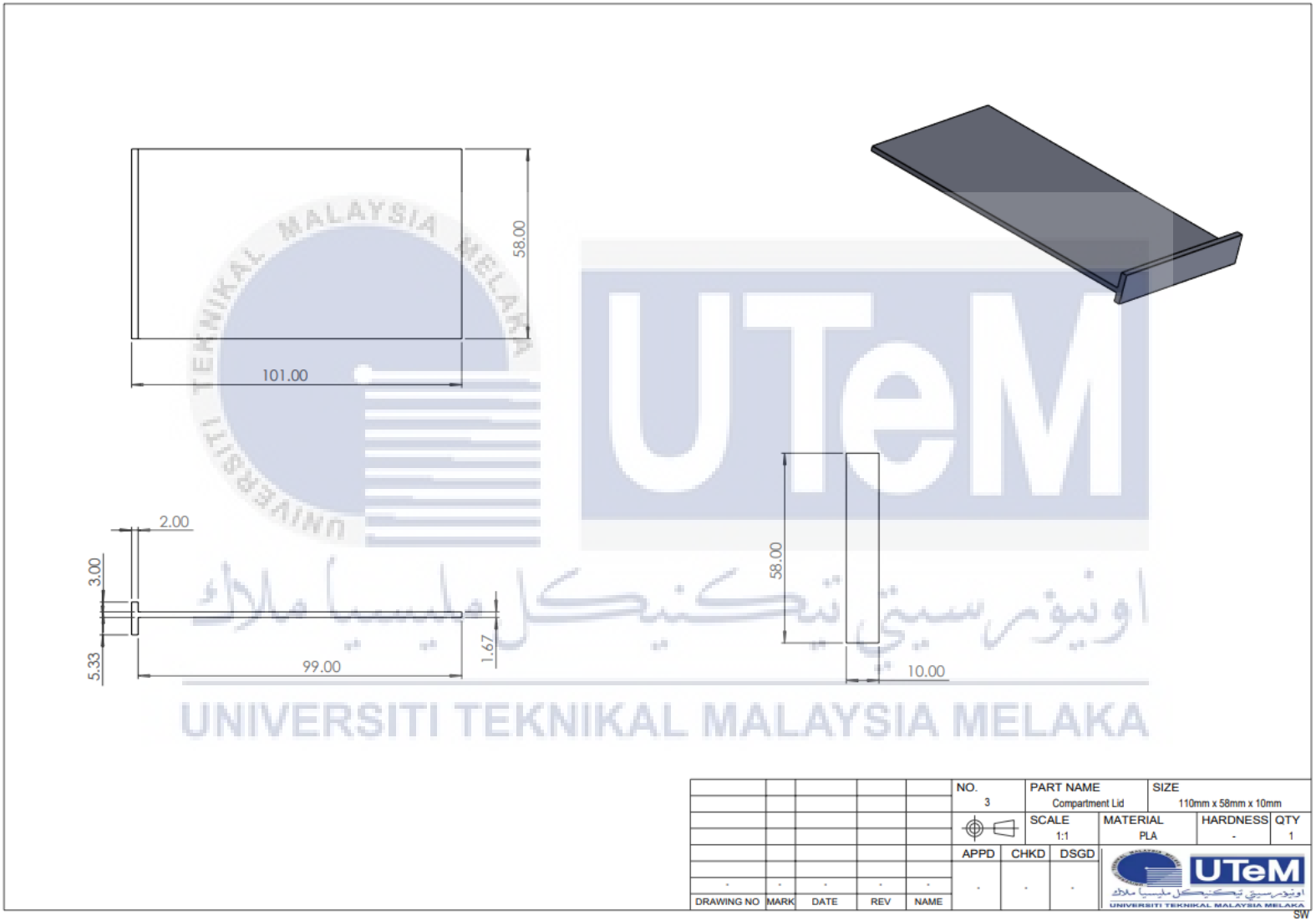

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					NO.	PART NAME	SIZE		
					3	Compartment Lid	110mm x 58mm x 10mm		
						SCALE	MATERIAL	HARDNESS	QTY
						1:1	PLA	-	1
						APPD	CHKD	DSGD	
-	-	-	-	-		-	-	-	
DRAWING NO	MARK	DATE	REV	NAME					

SW