DESIGN AND ANALYSIS OF ERGONOMIC AND GREEN FLOOR CHAIR

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DESIGN AND ANALYSIS OF ERGONOMIC AND GREEN FLOOR CHAIR

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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2024

DECLARATION

I hereby, declared this report entitled "Design and Analysis of Ergonomic and Green Floor Chair" is the result of my own research except as cited in references.

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Date : 28 June 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

…………………………………………………

(DR. RAHIMAH BINTI HJ ABDUL HAMID)

ABSTRAK

Projek ini sebahagian daripada Fundamental Research Grant (FRGS) FRGS/1/2023/TK02/UTEM/02/2 yang memerlukan kerusi lantai yang ergonomik, mampan, dan sesuai untuk ruang kerja bersama terbuka di Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan. Sumbangan kajian ini adalah untuk mencadangkan reka bentuk konsep kerusi lantai ergonomik yang diperbuat daripada bahan hijau. Reka bentuk kerusi lantai ini perlu memenuhi beberapa keperluan reka bentuk seperti ergonomik, boleh dilipat, bahan hijau, dan kecekapan ruang. Lima reka bentuk konsep dicadangkan dan dinilai menggunakan kaedah TOPSIS dengan pertimbangan reka bentuk ergonomik, boleh dilipat, bahan mampan, kecekapan ruang, dan proses pembuatan konvensional. Dua peringkat tinjauan pelanggan dijalankan untuk mendapatkan keperluan pelanggan dan menilai reka bentuk konsep, dengan jumlah 77 responden. Reka bentuk 3 dikenal pasti sebagai penyelesaian terbaik kerana mempunyai berat lebih tinggi dalam faktor kemampanan, boleh dilipat dan ergonomik berbanding reka bentuk lain. Kajian ini mengintegrasikan konsep hijau dengan memilih bahan menggunakan perisian Granta EduPack, dan menyimpulkan bahawa kayu lembut (khususnya pine mengikut urat kayu) dan buih polimer fleksibel adalah pilihan terbaik untuk struktur dan padding kerusi. Analisis ergonomik menggunakan perisian RULA dan CATIA mengesahkan bahawa reka bentuk akhir memenuhi piawaian ergonomik yang boleh diterima untuk peratusil ke-95 dan ke-50 data antropometrik lelaki dan peratusil ke-5 data perempuan, dengan skor akhir RULA 2. Walau bagaimanapun, proses fabrikasi kerusi lantai tidak merangkumi skop dan akan dijalankan oleh perunding projek berdasarkan maklumat mengenai reka bentuk dan jenis bahan yang dicadangkan kepada mereka. Cadangan untuk kajian lanjut termasuk analisis mengenai tingkah laku struktur kerusi lantai dan penilaian kesan bahan kerusi lantai terhadap alam sekitar. Projek ini sejajar dengan Sustainable Development Goal (SDG) 3 menonjolkan sumbangannya dalam memastikan kehidupan yang sihat dan mempromosikan kesejahteraan dengan menyediakan penyelesaian tempat duduk ergonomik.

ABSTRACT

This project is part of the Fundamental Research Grant (FRGS) FRGS/1/2023/TK02/UTEM/02/2, which requires floor chairs that are ergonomic, green, and suitable for the open co-working space at the Faculty of Industrial and Manufacturing Technology and Engineering. Existing products reveal a significant lack of ergonomic floor chair made from green materials, resulting in environmental concerns among eco-conscious consumers. Therefore, the contribution of the study is to propose a conceptual design of ergonomic floor chair that is made of green materials. The floor chair design requires fulfilling several design requirements needed such as ergonomics, foldability, green material and space efficiency. Five conceptual designs are proposed and evaluated using the TOPSIS method with the design features of ergonomics, foldability, sustainable material, space efficiency, and conventional manufacturing process. Two-tier of customer surveys were conducted to get the customer requirements and to evaluate the conceptual design, with 77 total number of respondents. Design 3 was identified as the optimal solution due to the higher weightage in sustainability, foldability and ergonomic factors, compared to the other designs. The study integrated green concepts by selecting materials using Granta EduPack software, concluding that softwood (specifically pine along the grain) and flexible polymer foam were the best choices for the chair structure and padding, respectively. Ergonomic analysis using RULA and CATIA software confirmed that the final design met acceptable ergonomic standards for the 95th and 50th percentiles of male anthropometric data and the 5th percentile of female data, with a final RULA score of 2. However, the fabrication process of the floor chair is not within the scope of study and will be conducted by a project consultant based on the information of the design and type of materials proposed to them. Recommendations for further studies include an analysis of the structural behaviours of the floor chair and an evaluation of the environmental impact of the floor chair's materials. The project aligns with Sustainable Development Goal (SDG) 3, which highlights its contribution to ensuring healthy lives and promoting well-being by providing ergonomic seating solutions.

DEDICATION

my beloved father,

AHMAD SIDI BIN ABDUL RAHMAN

my appreciated mother,

NORSHAMIDA BINTI RAMLI

my adored brothers,

ASYRAF SYAKIR BIN AHMAD SIDI

AKASYAH SYAHMI BIN AHMAD SIDI

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

In the name of ALLAH, the Most Gracious and the Most Merciful, I express my sincere gratitude. All praises are due to ALLAH for His blessings and guidance throughout the completion of this study. Alhamdulillah, I am thankful for the opportunities, trials, and strength that have been bestowed upon me, enabling me to successfully conclude this Project Sarjana Muda (PSM) report. My deepest appreciation goes to the holy Prophet Muhammad (Peace be upon him), whom way of life has served as a continuous source of guidance for me.

First and foremost, I would like to express my sincere gratitude to me beloved supervisor, Dr. Rahimah Binti Hj Abdul Hamid. She has consistently provided guidance, understanding, patience, and, most importantly, positive encouragement and a warm spirit throughout the completion of the PSM period. It has been a great pleasure and honour to have her as my supervisor.

My deepest gratitude goes to all of my family members. It would not have been possible to navigate through this journey without the moral support they provided. Last but not least, I would like to sincerely express my deepest thanks to anyone who may have been involved in this journey, either directly or indirectly, for being my anchors during both ups and downs. Without their guidance, teaching, and sharing, I would never be able to successfully complete this PSM report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	-	2 Dimensional
3D	-	3 Dimensional
CAD	-	Computer-Aided Design
FRGS	-	Fundamental Research Grant
FTKIP	-	Faculty of Industrial and Manufacturing Technology and Engineering
HDM	-	Human Digital Model
I.K	-	Inverse Kinematic
MCDM	-	Multi-Criteria Decision-Making
MDSs	-	Musculoskeletal Disorders
MYR	-	Malaysian Ringgit
NIS	-	Negative Ideal Solution
PIS	-	Positive Ideal Solution
RULA	-	Rapid Upper Limb Assessment
SDGs	-	Sustainable Development Goal
TOPSIS	-	The Technique for Order of Preference by Similarity to Ideal Solution
TV	-	Television
UTeM	-	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

σ	-	Stress
cm	-	Centimetre
E	-	Young's Modulus
kg	-	Kilogram
mm	-	Millimetre
GPa	-	Giga Pascal
MPa	-	Mega Pascal
Kg/m^3	-	Kilogram per cubic meter
Mj/kg	-	Megajoules per kilogram

CHAPTER 1

INTRODUCTION

This chapter presents the background, problem statement, objectives, and scope of the study. The project aims to propose a green and ergonomic design of a floor chair, which is to be placed at the co-working space which is currently being developed at the Faculty of Industrial and Manufacturing Technology and Engineering (FTKIP), Universiti Teknikal Malaysia Melaka as part of the analysis in the Fundamental Research Grant Scheme (FRGS) project entitled Correlation Model and Neuroscience Analysis of Sustainable Co-working Space towards Human Interaction, Mental Health, Well-Being and Productivity in Educational Institution

1.1 Background of Study

The term co-working space or collaborative space refers to designing office space intended to streamline teamwork by encouraging open communication, stimulating innovation, and enabling team members to engage in impromptu discussion with one another (Barker Scott & Manning, 2022). One of the Fundamental Research Grant (FRGS) projects in FTKIP required floor chairs that are ergonomic, sustainable, and suitable for the open co-working space. The contribution of the study is to propose a conceptual design of ergonomic floor chair that is made of sustainable materials. Ergonomic chairs are crucial to this workspace's comfort and functionality for collaborative workers. Well-designed ergonomic chairs support the creation of a collaborative work atmosphere that improves physical well-being, active engagement, and idea exchange (Bushiri & Uk, 2014). There are several types of chairs, which are the common chair with legs and floor chair or legless chair. In this study, the floor chair is explored to develop a design that incorporates ergonomic features and utilizes sustainable materials.

Figure 1.1: Floor chair

Figure 1.1 shows an example of a floor chair. The floor chair is basically the chair that is placed directly on the floor without having legs or raised platform for the seat. There are many floor chair designs available in the market but the design which is not only ergonomic but sustainable is limited. To overcome these issues, it is essential to explore ergonomic design principles for floor chairs and incorporate sustainable material to enhance user comfort while promoting manufacturing sustainability. Its innovative approach to responsible consumption and production, designed for comfort and support, supports worldwide environmental goals (Akenji & Bengtsson, 2014). In this context, the study is centered on the design of a floor chair that adheres to ergonomic features.

This project aims to develop a floor chair by using sustainable materials and recycled materials to reduce the environmental impact of using new materials. The study evaluates strategies for material selection strategies for green material and selecting the most suitable materials for product development. The incorporation of sustainable materials in this study aims to contribute to the creation of an efficient and cost-effective floor chair, thereby promoting sustainable, and environmentally friendly practices. Sustainable design practices are essential due to rising environmental awareness and demand for eco-friendly materials, efficient manufacturing, and product lifetime and recyclability (Javaid et al., 2022).

Non-ergonomic chair usage can result in numerous complications, including lower back pain, spinal, neck, shoulder, and arm discomfort, as well as muscle paralysis (Sepehri et al., 2013). The floor chair design undergoes a comprehensive analysis to assess compliance with ergonomic principles. In this study, emphasizing the ergonomic aspect in the final conceptual design is essential to ensure a comfortable seating experience for the user. The positive impact of comfortable seating on productivity within educational institutions is a key consideration.

Therefore, this study aims to design an ergonomic floor chair and utilize the green material in product development for the collaborative workspace. A comprehensive analysis of the material selection strategies and an evaluation of the ergonomic aspect of the design was also performed. However, the project consultant will conduct the floor chair's physical development based on the information about the design and selected material provided to them, and it will not be within the project’s scope.

1.2 Problem Statement

The selection of the best conceptual design is important in any product design stage (Rosen, 2012), it serves as a roadmap for the entire product development. Without a conceptual design of the product, communication breakdowns among the stakeholders hinder idea exchange and lead to misunderstandings. The floor chair design requires to fulfill several design requirements needed such as ergonomics, foldability, and space efficiency. The selection of a design is crucial to prevent excessive costs in product development of the floor chair. The limited timeframe for completing this project further influenced the choice of the floor chair design, considering that more intricate design tends to require additional time for completion. In the absence of structured design selection method, the selection process may lead to the choice of an inappropriate design that fails to meet the required criteria, ultimately providing a suboptimal experience for the user.

The use of recycled material to fabricate new products is one of the ways to support Sustainable Development Goals (SDGs) 12 which is responsible consumption and production to ensure the sustainable consumption and production pattern. However, based on the literature, a limited number of individuals incorporate recyclable materials in the production of furniture especially floor chairs, while the majority resort to new materials, contributing to environmental harm through depletion, pollution, and increases landfill waste.

The utilization of non-recyclable materials for product development generates significant waste, thereby exerting a detrimental impact on the environment (Zhu & Niu, 2022).

A non-ergonomic chair does not provide comfort during use. Prolonged use can lead to discomfort in body posture. When using a non-ergonomic chair, poor posture, back pain, and neck pain are common issues. Even worse, it may lead to musculoskeletal issues that can affect the user's health, affecting the mental health of the users. Individuals, such as students, often use chairs for extended periods. Sitting in a non-ergonomic position can cause aches and pains in various body parts, reducing productivity. Poor sitting posture can cause spinal disc compression, resulting in early degeneration and chronic pain. The floor chair design is analyzed with a focus on the ergonomic aspects to provide comfort for the user and good mental health, which is the ultimate aim of establishing the co-working space at the faculty.

1.3 Objectives

The objectives of this study are as follows:

(a) To select the best conceptual design of the floor chair using TOPSIS method.

(b) To select the most suitable green material of the floor chair using Granta Edupack software.

(c) To evaluate the ergonomic analysis on the final conceptual design of the office floor chair using RULA analysis.

1.4 Scopes of Study

The scopes of this study are as follows:

a) The development of the floor chair will be done by the consultant, as this project is supported under the Fundamental Research Grant (FRGS) – FRGS/1/2023/TK02/UTEM/02/2.

b) The study only focuses to propose the design of the floor chair and green material for the development process.

c) The Malaysian anthropometric data is used as the reference for the design parameter and RULA analysis.

d) The material selection strategy focused on green material and was conducted through Granta Edupack software.

e) Ergonomic analysis for the final conceptual design was evaluated based on the RULA analysis through CATIA software.

1.5 Rationale of Study

The rationale of the study as follows:

a) The proposed floor chair design will be used in the collaborative working space at Faculty of Industrial and Manufacturing Technology and Engineering (FTKIP) for all students and staff.

b) Using sustainable materials in the floor chair is a testament to FTKIP's commitment to environmental friendliness, a feature we can all be proud of.

c) The ergonomic features of the floor chair promote back support to avoid the health impacts for user due to prolonged sitting.

d) The floor chair provides comfort for users to sit directly on the floor.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter reviews the history and contemporary uses of the floor chair in depth. It attempts to identify the optimal design and structure of the floor chair that can obey the rules of ergonomics. In addition, it gives an overview of the types of existing floor chairs and their design in order to give a bigger picture of the product design. This chapter also explains crucial aspects of 3D design and material selection for floor chair production. RULA analysis is known as the method to evaluate the required body posture of the user of the floor chair. The design of the floor chair should be ergonomically to reduce the impact on the user's body posture. In addition, this section also describes the functional of method or software that usually used for designing an ergonomic floor chair such as CATIA software, TOPSIS method, and Granta Edupack software.

2.2 History of Floor Chair Design

The historical trajectory of floor chairs is a captivating exploration spanning several periods, showcasing a wide range of regional customs and advancements in ergonomic design. Floor seating, which may be traced back to ancient civilizations in East Asia such as Japan, China, and Korea, has evolved to become an essential component of daily living. In Japan, floor chairs, such as the famed zaisu, were supported by cushions and tatami mats, which functioned as the underlying structure. The early designs emphasized both comfort and functionality, thereby emphasizing the significance of community meetings and shared spaces within these communities.

A zaisu is a traditional Japanese chair with no legs shown in Figure 2.1. They are typically found in traditional rooms with tatami mats and are frequently used for relaxing beneath hot kotatsu tables. In Japan, the proper seating position is seiza, which entails kneeling with the weight on top of the lower legs that are folded beneath the body. Many people prefer the zaisu, which supports the back and allows the legs to be positioned more easily, because it can be uncomfortable after sitting for long periods or for people who are not used to it.

Figure 2.1: Zaisu Chair

Across Japan's history, traditional sitting customs have been integral in upholding the nation's cultural heritage. These practices, shaped by unique architectural and cultural norms, encompass diverse seated postures. Seiza, a common posture, involves sitting on heels with legs folded underneath—a formality for ceremonies. Another, agura, with one leg crossed over the other, was more casual. Influenced by architecture like tatami mats and low tables, these practices embraced floor seating and offered ease in transitioning between positions (Fukuichi & Sugamura, 2022). Beyond cultural value, these traditions were believed to enhance health by improving posture and circulation, adding practical significance to their cultural importance.

2.2.1 Existing Floor Chair Design

Discover a variety of innovative floor chair designs for different preferences and activities. These floor chairs are comfortable and useful. Each design has a function, from the Backjack chair for meditation and floor-based activities to the Japanese zaisu chair for informal gatherings. Ergonomic gaming rocker seats and adjustable floor chairs with reclining options improve gaming.

2.2.1.1 Zaisu chair

A zaisu chair is a type of traditional Japanese seating usually designed for informal settings. It is made from a flat cushion or seat pad that is placed directly on the floor and is often accompanied by a backrest for lumbar support. This chair design allows for comfortable sitting for activities such as dining, relaxation, or tea ceremony and commonly combined with low tables known as kotatsu or chabudai (Richard & Scholar, 2023). Zaisu chairs are usually could be found in tatami rooms, where sitting on the floor is customary, and they also come in a variety of materials and styles, such as bamboo, wood, or lacquered finished with fabric or woven straw cushions. These chairs provide an adjustable backrest support, practical and have versatile seating solutions for various gatherings, and activities for Japanese households.

2.2.1.2 Floor rocker chair

A floor rocket chair, also known as a gaming rocker chair, is a low-seated chair with no traditional leges that is designed to be placed directly on the floor. These seats are popular among gamers and anyone who looking for a comfortable and immersive experience which is also provides ergonomics support for extended durations of use. The common features of floor rocket chairs are padded cushions, built-in speakers, and some of them having vibration or motion capabilities to enhance the gaming experience. Beyond gaming, these kinds of chairs are versatile and suitable for activities such as watching TV, reading, or relaxing. They usually come with a variety of designs and materials that suit well in various spaces. They also provide unique and comfortable seating options for those who prefer a lower, and ground-level position.

2.2.1.3 Backjack chair

Backjack chairs, also known as floor chairs or meditation chairs, are low, and portable and are intended to be placed directly on the floor. It usually does not have legs and provides back support, allowing the user to sit comfortably on the ground. Backjack chairs are often used for activities such as meditation, reading, watching TV, and playing video games. They are intended to promote proper posture while providing a comfortable seating option that is close to the ground. Backjack chairs are available in a variety of designs and materials, including padded versions for extra comfort. They are so popular among people who prefer a floor-level seating arrangement and wat a lightweight and portable option.

2.2.2 Patents for Floor Chair

Google Patents is a database that contains a large amount of information about patented inventions and technology. It also provides valuable insight into patented designs, technologies, inventions, and advancements in the scope of ergonomic floor chairs. This platform also facilitates market research and development that could help businesses make decisions. Overall, Google Patents provides several benefits to individuals and businesses that are involved in the ergonomic chairs industry (Noruzi & Abdekhoda, 2014). Several ergonomic floor chairs designs were discovered in Google Patents, showcasing a diverse range of ideas, designs, and technologies for applications such as seat portion, back portion, and surface grooves. These patents provide essential insights and inspiration for the advancement of an ergonomic floor chair and its incorporation into suitable seating postures.

2.2.2.1 Patent 1

Kanda Fumihiro (2019) invention is described a floor chair characteristic included a seat portion and a back portion. The chair has grooves formed on the surface of the seat portion which is extending in a front-to-back direction. The ischial tuberosity of the user's body is intended to correspond by these grooves that are designed. The grooves have sloped surfaces that slope gradually in a lateral direction (from left to right). The purpose of this design is to provide enough support and correction for the pelvis that also promotes a better alignment of the body while sitting on the chair.

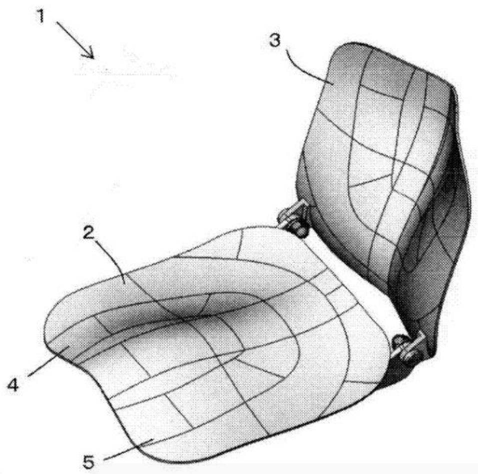


Figure 2.2: Patent 1

The aim of this patent is to disclose a floor chair design with grooves formed into the seat portion. These grooves are designed to accommodate the body's ischial tuberosity or sitting bones to offer the user comfort and support. The groove's inclined surfaces gradually inclined in a lateral direction to improve the ergonomic support that is provided by the chair.

2.2.2.2 Patent 2

Myung W Lee (2021), published his functional floor chair patents on Google Patents described that the patent of designed legless chair aims to provide comfort while stably supporting a user's right posture when seated. He addresses issues such as maintaining lumbar spine posture, providing solid lower back support, and actively responding to front-to-back movements during seating. The patent includes several features such as a lever principle for supporting the user's waist and back, a heating function for long-term seating comfort, and a design that minimizes the chair's left and right shaking. These characteristics distinguish the functional floor chair from the other chair designs in the market.

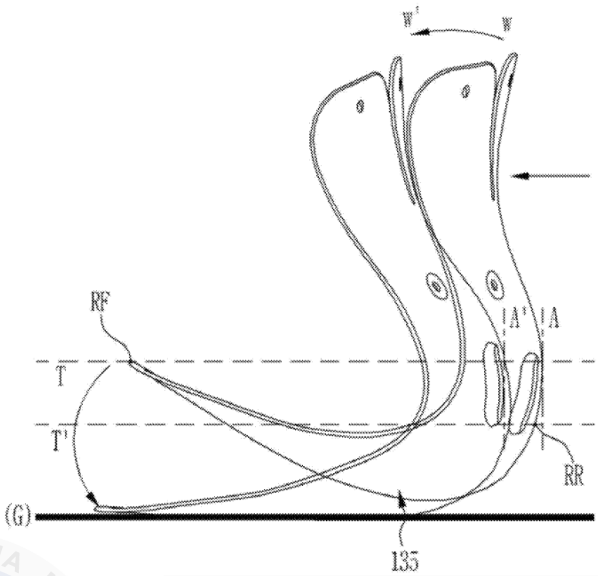


Figure 2.3: Patent 2

However, the patent design from the author for functional floor chair exhibits several limitations. One of the primary issues that arise is the lack of effective heating function, which could be a drawback in colder environments where the users seek warmth and comfort. Another issue is the design of the hip support part, which is not flat but rather to be gently curved, recessed shaped. The material of the floor surface may influence the stability of this design, potentially leading to shaking in the chair. Thes issues highlight ways to improve the functional floor chair's functionality, convenience, and stability.

2.2.2.3 Patent 3

As stated on the invention patent by Pokrishevsky Y et al. (2007), their floor chair designed to prevent backward falling when the seatback of the chair is forced to inclined backwardly. A seat, seatback, and a flexible member that extends backwardly from the rear side of the seat are included in the chair design. The flexible member bends and provides a damping effect to reduce the backward tilting angle of the chair whenever the users apply force to the seatback, which could cause the seat and seatback to tilt backward. This ensures the user safety from falling backward. In addition, the backrest of the chair can be folded forward, reducing the overall size of the chair which makes it easier for storage and transportation purposes.

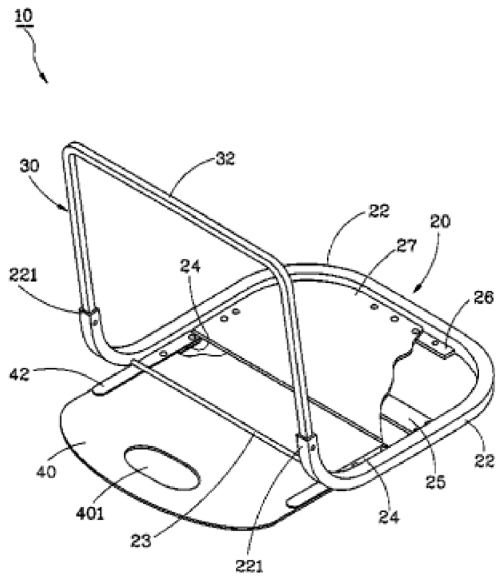


Figure 2.4: Patent 3

2.2.2.4 Patent 4

Albecker W. J. (1995) has patented his design on backrest floor chairs made with a foundation. The patent described that the chairs have a support foundation and lumbar support for maintaining the natural curve of the user's back. The design also came out with a seat cushion to prevent slipping and included a headrest pillow. The chairs have been designed specifically for people who prefer reclining positions for activity such as watching television. The patent also includes the alternative seat and leg rest systems, which is a folding seat cushion and a two piece of seat and leg rest cushion. This patent aims to provide an economical, attractive, compact, and comfortable seating options for users who prefer seating in reclining position.

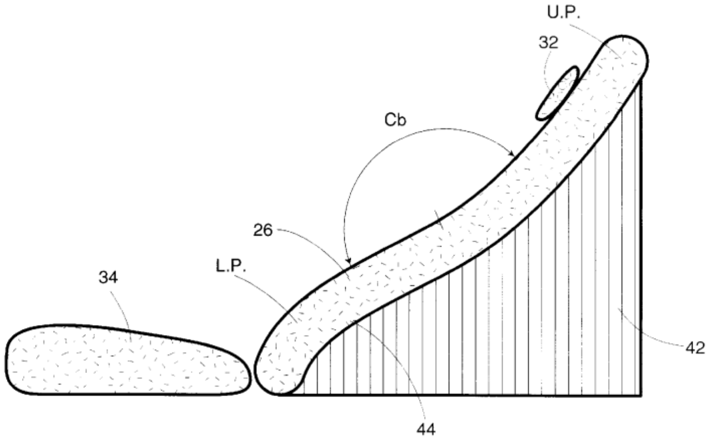


Figure 2.5: Patent 4

2.2.2.5 Patent 5

According to the patent that published by Albecker W. J. (2009), the invention focusing on a structure for floor leisure chairs with armrests. The patent mentions several specific features and innovations of the floor leisure chairs design that make it unique. The features include then factors such as stability, lumbar support, adjustment mechanism, and mirror arrangement. The patent is designed to be more stable and less likely to tip forward when user pushes on the front of the armrests to get out from the chair. The chairs also have a simple and sturdy adjustment mechanism that allows for easy reclining. The left and right side of the floor leisure chair are designed to be in a generally mirror arrangement for providing symmetry and balance.

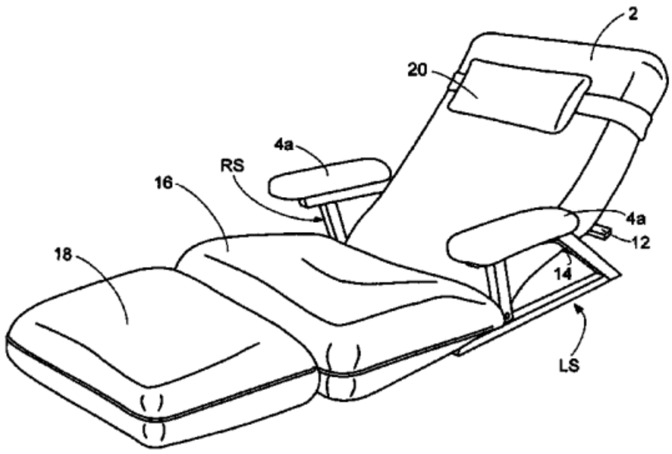


Figure 2.6: Patent 5

The aim of the floor leisure chairs with armrests described in the patent by Walter Albecker is to provide a comfortable seating option for activities such as sitting at home watching television, reading, and working on laptop. The design of the chair enables the users to sit very close to the ground and offers stability and support for the low back region. The reclining mechanism of the chair and adjustment mechanism being added for comfort.

2.3 Ergonomic Aspect in Chair Design

Ergonomics has garnered global recognition in the contemporary era due to its significant impact on the workplace and product. It is among the numerous fields that are prevalent in virtually all types of workplaces. The objectives of office ergonomics are to analyze the conditions of the workplace and make efforts to modify it in a way that accommodates the working preferences of employees or users in terms of ease of use while also considering the organization's needs.

Mueller & Hassenzahl (2010) investigated the relationship between people's comfort perception while sitting in office chairs and the chairs' objective ergonomic design, as well as the method used to evaluate them – whether it was intuitive (free) exploration or structured (guided) exploration. Fifty participants were assigned randomly to different conditions, carrying the ergonomic design of the chairs (inferior versus superior) and the exploration instructions (no instruction (free) exploration versus various levels of oral and written guidance). The findings revealed that when participants were provided with guided exploration, their comfort perceptions aligned with the objective chair designs. However, during free exploration, participants rated the inferior chair as more comfortable. Interestingly, the specific type of guided exploration did not influence evaluations.

According to research by Warren et al. (2010), men who spent more than 23 hours per week sitting and watching television had a 64% higher chance of dying from cardiovascular disease than those who watched television for only 11 hours. Furthermore, persons who sit more are 147% more likely to have a heart attack or stroke. An ergonomic chair will minimize muscle fatigue, boosts productivity, and decrease the quantity and severity of work related to musculoskeletal disorders (MDSs).

2.4 Anthropometry

The study of body measurements, particularly those related to size, shape, strength, and labor capability, is known as anthropometry. Wignjosoebroto (2008) defines anthropometry as the study of measuring the measurements of the human body. Anthropometry is the study of various human body dimensions, including weight, standing posture, arm length, body circumference, leg length, and so forth. Anthropometric information is utilized in many contexts, including product design, workstation design, and facility design. Anthropometric measurements refer to the collection of human external body dimensions such as body shape, size, work, capacity, and strength in static and dynamic conditions. These measurements are used in ergonomic design, physical anthropology, apparel sizing, the design of consumer products, and the design of tools and equipment. Anthropometric measurements are also known as anthropometric data (Mahantesh et al., 2023).

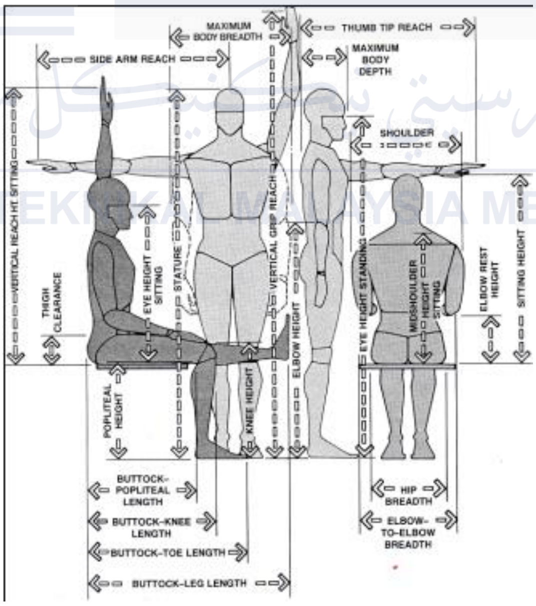


Figure 2.7: Anthropometric body measurement

A multitude of factors influence human body dimensions. Diversity in ethnicity is always a significant aspect that could impact anthropometric data and the applications that can be made of it (Brolin, 2016). This data is critical or multi-racial user of the product, equipment, or workstation. UTeM having multi-racial students and different body dimensions among them makes anthropometry data essential to identifying the best design that suits everybody. Differences in overall body size and bodily proportions between various groups may be seen in their body dimensions. The most common ways that ethnic groups differ are in terms of mean anthropometric measurements, such as stature and sitting height. Bodily proportions, or the ratios of physical dimensions, represent another essential ethnic difference (Heymsfield et al., 2016). One body dimension divided by a given reference dimension yields the bodily proportion, a scaling relation.

2.5 CATIA V5R21 Software

Historically, product designers have neglected to consider the ergonomic needs of a product at its conceptual phase. However, the comprehensive analysis of ergonomics is deferred until the development of a prototype. The lack of ergonomic analysis by designers can be attributed to the unavailability of suitable virtual tools (Kumar, 2006). Computational Ergonomic has had significant advancements, moving beyond the simple utilization of formulas, questionnaires, data tabulation, and empirical data collection. In contrast, the advent of Human Digital Models (HDM) marked the initiation of a novel era in computer-aided design technology. CATIA offers a diverse range of ergonomic tools that utilize human digital models. HDM has the potential to enhance computer analysis of interactions between humans and machines, hence enabling the development of more effective ergonomic solutions even in situations when real users are not available (Roetting, 2007).

With the use of computer-aided ergonomics systems, designers can now more easily obtain the ergonomics feedback needed when creating workplaces or products for human use early in the design process, when making changes to the design would be relatively inexpensive. Using ergonomics software in the early stages of design, the manufacturer can incorporate ergonomics knowledge and bring to market a product that requires fewer prototypes, is less expensive, and better suits the needs of the user (Högberg, 2005). A condensed version of the product design cycle and its ergonomics evaluation phases are shown in Figure 2.8.

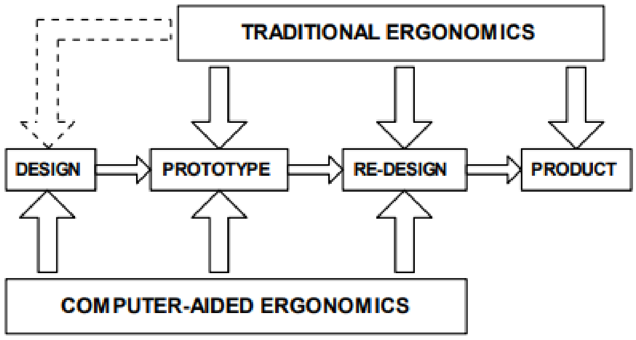


Figure 2.8: Ergonomic analysis in design

In the publication titled "Ergonomics Analysis Based on Digital Human Modelling," Sari & Şahin (2020) discuss their research findings in Journal of Polytechnic (2020). In the conducted experiment, an ergonomic analysis was employed utilizing a digital manikin, and a range of operations were performed on CATIA V5. The researchers conducted a DHM analysis on school furniture which is specifically focusing on school benches. Additionally, the manikin was created through the utilization of anthropometric data within the CATIA software. The manikin provides coordinates for both standing and seating positions. One of the most significant concepts in the field of human factors engineering is ergonomics, which is rooted in the principles of Digital Human Modelling (HDM). The analysis project incorporated DHM by utilizing the referenced data. The outcome of the study involved conducting a Rapid Upper Limb Assessment (RULA) analysis to evaluate the impact of the design on the user's anatomical factors. Based on this analysis, a determination was made by researchers regarding the necessity of implementing improvements to the design. The DHM approach and the RULA analysis could offer benefits in terms of efficiency and cost-effectiveness.

2.5.1 Rapid Upper Limb Assessment (RULA)

The goal of the scientific field of study known as ergonomics is to find ways to improve the interaction between humans and their environment to enhance comfort, safety, and efficiency. The Rapid Upper Limb Assessment, often known as RULA, is a tool that is used for ergonomic assessment which specifically focuses on evaluating the posture and movements of the upper body during a variety of activities. In the context of floor chair design, RULA has become an important tool for ensuring that the chairs promote proper body alignment and prevent musculoskeletal disorders which are associated with prolonged sitting.

Previous studies have shown that RULA analysis is an effective method in context of chair design, highlighting its ability to identify and mitigate ergonomic risks of the design. According to Sari & Şahin (2020), their studies was conducted by using RULA analysis for designing an ergonomics school furniture. The studies compared their design with the known school furniture design and has a better RULA score which indicates that it provided a better ergonomic study environment. By applying RULA to the project of designing and developing an ergonomic chair, the designer can systematically assess the impact of the various design elements on the human body posture.

Kumar Mandal & Math (2021), the findings of their study indicate that the chair's biomechanics and RULA analysis show an ergonomic posture, with compression and joint shear limits well below their maximum standard limits. This implies that the digital model's seated position aligns with ergonomic standard. Furthermore, the RULA analysis indicates predominantly a lower score between 0 and 2 for most body parts, signifying a posture with reduced risks. The study underscores the significance of incorporating ergonomics, specifically based on Indian anthropometric standards, into the design of chairs for computer users.

2.6 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is multi-criteria decision-making (MCDM) method introduced by Hwang and Yoon in 1981. The TOPSIS technique is based on the principle that the optimal option should possess the lowest distance from the positive ideal solution and the most significant distance from the negative perfect solution (Tzeng & Huang, 2011). The utilization of this approach is applicable in the resolution of intricate real-world issues, as it facilitates the provision of a ranking for each available alternative (Mitra & Kundu, 2017).

The TOPSIS techniques incorporate all scores obtained by each alternative from the evaluation criteria in the construction of a decision matrix. The determination of the positive ideal solution and the negative ideal solution involves considering all relevant factors. The TOPSIS method is a helpful approach for ranking alternatives by considering their optimal ideal solutions. The TOPSIS method considers the relative proximity to the ideal solution while calculating the distances to both the ideal and negative ideal solutions (Chakraborty, 2022).

The essential factor in the TOPSIS technique is the assignment of criteria weights. The criteria weight can be determined using subjective, objective, or mixed weighting approaches. The subjective consequences are established based on the decision-makers preferences, whereas the objective weights are determined using the data from the decision-making matrix (Yazid et al., 2023). The positive ideal solution (PIS) optimizes the favorable criteria. It minimizes the unfavorable criteria, whereas the negative ideal solution (NIS) maximizes the unfavorable criteria and minimizes the favorable criteria (Kelemenis & Askounis, 2010).

Utilizing the TOPSIS approach can result in a variety of positive outcomes. According to Ighravwe & Babatunde (2018), the TOPSIS technique is acceptable for all challenges since its methodology acknowledges the greatest and least scenarios that occur between sets of choices in planning. In addition, this approach has been recognized as one of the most well-known mathematical models for controlling the optimal solution to an MCDM (Slebi-Acevedo et al., 2019). This distinction was awarded to the method in question. Aside from that, TOPSIS presents the decision-maker with the option that is the most similar to the target, which according to the score produced by the judgement (Marzouk & Sabbah, 2021), is judged to be the superior choice.

2.7 Material Selection of Floor Chair

The material selection for an ergonomic floor chair is a crucial aspect in ensuring both comfort and durability of the product. Ideally, the floor chair should be manufactured from high-quality, breathable materials that offer proper support to the user’s body. The seat and backrest of ergonomic floor chair might benefit from a combination of materials such as cushioned foam for comfort, layered with a breathable fabric or mesh to allow for airflow and moisture wicking. Additionally, the frame and structural components of the product should be sturdy and resilient, constructed from materials like reinforced steel or durable polymers, to provide stability and support over time. This thoughtful selection of the materials not only contributes to the ergonomic chair design, but also enhances its overall longevity and user satisfaction. To aid in the material selection process for ergonomic legless chairs, software tools like Granta Edupack are highly capable. These software programs offer a thorough database of materials as well as tools and resources for materials analysis and selection (Figuerola et al., 2016).

2.7.1 Granta Edupack Software

The Granta Edupack software, which was created by Granta Design, provides significant materials and education resources, and can aid in the material selection process for an ergonomic floor chair. Granta Edupack offers an extensive collection of materials suitable for seat and back rest structures of the legless chair, including foams, composites, natural material, and polymers, within its comprehensive material database. The material property data accessible through Granta Edupack facilitates the assessment of critical attributes, including weight, rigidity, mechanical strength, and thermal properties (Ashby et al., 2021). These characteristics are critical in determining the appropriateness of materials for the construction of ergonomic floor chairs.

In specific circumstances, Granta Edupack is deemed more advantageous because of its focus on material education and extensive collection of resources. Due to its emphasis on education, comprehensive material data properties, material selection tools, and sustainability considerations, Granta Edupack is extraordinarily useful. It facilitates material education through the provision of interactive resources that augment comprehension and learning. The extensive collection of resources in Granta Edupack facilities the examination and comparison of materials, whereas the instrument for selecting resources streamlines the process of making decisions (Parnell, 2018). Additionally, sustainability is a consideration with software, which promotes sustainable engineering and design practices.

The material selection tools of the software facilitate the comparison and analysis of various materials in accordance with application-specific or property-specific requirements. Through the use of graphical tools and data visualizations, it is possible to identify materials that satisfy weight restrictions, mechanical performance requirements, and other critical factors for the construction of ergonomic legless chairs. Figure 2.9 illustrates the Granta Edupack user interface.

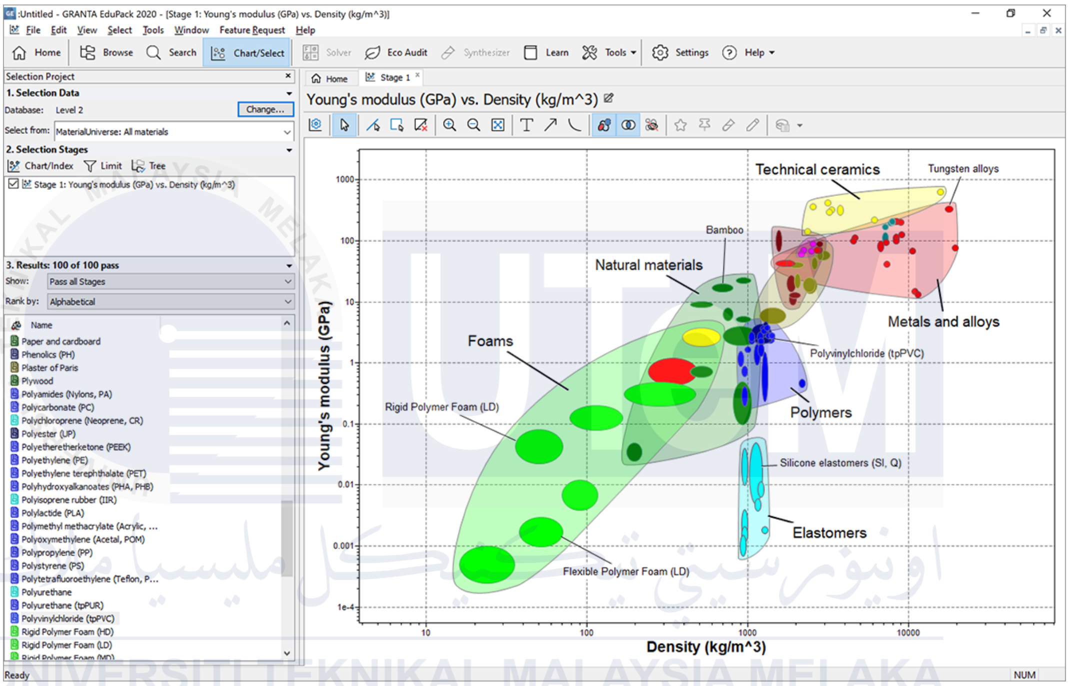


Figure 2.9: Granta Edupack software

Granta Edupack's material database helps designers to choose materials based on the mechanical, thermal, and environmental properties, revolutionizing floor chair design. This empowers them to make informed choices that prioritize support, comfort, and durability of the product. The software also assesses environmental effect and costs, encouraging sustainable and affordable material choices. With visualizations and integration with CAD software, Granta Edupack streamlines the design workflow and making it an invaluable tool for designer seeking to create innovative, high quality ergonomic floor chairs that meet both functional and environmental standards.

2.8 Floor Chair Materials

The materials of overall structure play a critical role in the design and performance of the ergonomic floor chair. Different materials have different characteristics and properties that influence various aspects such as cost, weight, strength, and durability. The most commonly used materials in floor chair manufacturing include wood, metal, foam padding, and fabric or upholstery.

2.8.1 Wood

Wood is one of the most widely used materials for making benches and chairs due to its easy construction, rich appearance, and durability (Namichev & Petrovski, 2019a). Wooden floor chairs can withstand regular use over extended periods due to their inherent durability, making them a reliable and long-lasting seating option (Abdulkadir, 2018). Additionally, wood's adaptability allows for intricate shaping, carving, and crafting that provide a wide range of design options. Beyond functionality, wood as raw material also could hold a natural and timeless aesthetic appeal of the product, adds warmth and character to furniture and contributes to the overall ambiance of a space. The most popular hardwoods for making chairs include walnut, teak, ash, beech, birch, cherry, oak, maple, pecan, and poplar. The most popular softwoods for making furniture are redwood, pine, and cedar. Furthermore, the emphasis on sustainability has resulted in the promotion of responsibility sourced wood, which aligns with eco-conscious manufacturing processes. Wood provides a versatile palette for producing precise colors, textures, and finishes to meet a wide range of design preferences due to its flexibility to be customized through staining, painting, and finishing.

2.8.2 Metal

Metal is commonly used as a raw material for floor chair production due to its several key advantages. Metal could provide exceptional strength and durability to ensure that floor chairs could withstand rigors of regular use over extended periods (Almandrawy et al., 2018). Because of its durability, metal is a great material for producing sturdy and solid floor chairs that also have a long-lasting seating solution. Furthermore, the malleability of metal facilitates precise shape and welding which allows manufacturers to create a wide variety of innovative and ergonomic designs. Moreover, the durability of floor chairs constructed from metal is enhanced by their resistance to environmental elements like moisture and pests. Metal can be recycled, which lessens the environmental impact of furniture manufacturing and promotes more sustainable production methods (Hartini et al., 2019). The combination of these characteristics makes metal an excellent choice for the construction of floor chairs since it combines longevity, adaptability, and a contemporary aesthetic.

2.8.3 Foam Padding

Foam primarily offers a surface that is comfortable and supportive, by conforming to the body’s contour, hence alleviating pressure spots and augmenting general comfort throughout extended periods of chair utilization. Foam primarily offers a surface that is comfortable and supportive, by conforming to the body’s contour, hence alleviating pressure spots and augmenting general comfort throughout extended periods of chair utilization (Ferguson-Pell & Martin Ferguson-Pell, 1990). The shock-absorbing characteristics of this material offer notable benefits by reducing the effect on human body throughout periods of sitting or transitioning between different positions. With varied densities and thickness, foam can be customized based on chair design and desired support levels. The malleability of foam allows designers to create chairs with ergonomic shapes that conform to the body’s natural curves. The cost-effectiveness of foam makes it a realistic choice for manufacturer producing floor chairs that balance comfort and support.

2.9 Effects of Non-Ergonomic Chair to Human Body

Using a non-ergonomic chair can be harmful to the human body which results in a variety of musculoskeletal disorders and discomfort (Sholihah et al., 2019). These chairs usually lack adequate support for the natural curvature of the spine that could result in poor body posture and pain on the back and neck. Prolonged use of non-ergonomic chairs may lead to tension, muscle stiffness and fatigue. Furthermore, insufficient lumbar support might cause strain on the lower back (Alnaser & Wughalter, 2009). Chairs that are poorly designed may also restrict blood circulation, leading to numbness and tingling in the extremities. The cumulative effects of these factors can lead to more severe conditions which are chronic pain and long-term spinal misalignment. Overall, non-ergonomic chairs can have a negative impact on an individual’s overall well-being by compromising posture, causing discomfort body posture, and could potentially contributing to more serious health issues.

2.9.1 Poor Posture and Spinal Strain

Poor posture caused by non-ergonomic floor chairs could lead to significant spinal stain and discomfort. These chairs often lack lumbar support requirement to preserve the natural curvature of the spine, particularly in the lower back (Huang et al., 2012). Users who adopt positions that do not appropriately correspond with the natural curvature of the spine might cause strain on the muscles and ligaments that support the back. This strain may cause muscle fatigue, tension, and even misalignment of the vertebrae over time. The cumulative effects of poor posture may cause chronic lower back pain and increase the risk of developing musculoskeletal issues, emphasizing the importance of ergonomic design in chair to support spinal health and overall well-being.

2.9.2 Low Back Pain

Non-ergonomic floor chairs may lead to lower back pain by promoting poor body posture, lacking lumbar support, and restricting natural body movement. These chairs often lack adjustability and proper padding that may result in increasing strain on the lower back and discomfort over time (Bontrup et al., 2019). The lack of proper ergonomic design may result in chronic issues, affecting spinal health and increasing the risk of musculoskeletal disorders. It is essential to choose seating options that provide support that could promote good posture and allow for comfortable movement. Investing in ergonomic seating that prioritizes proper lumbar support and adjustability is critical for preventing and alleviating back pain that is caused by prolonged sitting.

2.9.3 Musculoskeletal Disorders (MSDs)

Musculoskeletal disorders may result from non-ergonomic postures. Prolonged sitting fixed and awkward body postures are some of the risk factors that increase pressure on the human body which can cause MSDs (Soares et al., 2019). It may affect shoulders, arms, elbows, wrists, hands, back, and legs. Musculoskeletal disorders also often encompass pathologies affecting the musculature, tendons, nerves, and associated supportive anatomical systems (Sumardiyono et al., 2014). MSDs are a class of nontraumatic conditions affecting the soft tissue, which are mostly induced or worsened by the individual's interactions within their work environment. The posture of the person seating on a chair does not depend only on the chair design but also on the tasks that are being performed and including the sitting habits when they attempt to find a better seating position.

2.10 Summary of Literature

In summary, this chapter provides an overview of the floor chair's history, design specifications, existing product in the market, patents of ergonomic floor chair, and all about the design and development of ergonomic floor chair. The TOPSIS method will be used for the selection of design concept of ergonomic then the design will be analyzed by using RULA analysis in the CATIA software to evaluate the comfort level of the chair design. The TOPSIS method helps the decision making by providing consideration of multiple criteria and allows for sensitive analysis that helps the designer to understand the impact of the change's criteria weights on the final decision. RULA analysis provides postural analysis for the design which could help to identify risk factors that allows to address the potential of awkward postures that may lead to discomfort and musculoskeletal problems. In addition, Granta Edupack software provides a wide range of material selection with a vast database of materials properties, allowing designers to explore and compare the different materials for various components of the floor chair.

CHAPTER 3

METHODOLOGY

The chapter explores the methods employed to fulfill the study's objectives. It details the design process, design selection, material selection, and analysis, incorporating insights from previous studies. The primary aim of this chapter is to provide a comprehensive framework of procedures and resources optimally suited for conducting this study.

3.1 Relationship between Problem Statements, Objectives and Methodology

Table 3.1 describes the relationship between the problem statement and the objectives. This correlation enhances comprehension of how methodology syncs with the stated objectives.

Table 3.1: The ramifications of the chosen research methodology

Problem Statement	Objectives
The absence of a structured evaluation method for selecting the most suitable conceptual design of a floor chair poses a significant challenge, potentially leading to subjective decision-making, design inefficiencies, and user dissatisfaction (Rosen, 2012).	Objective 1: To select the best conceptual design of the floor chair using TOPSIS method.
Using new materials in making office floor chairs causes environmental harm through resource depletion, pollution, and overflowing landfills,	Objective 2: To select the suitable green material of floor chair using Granta Edupack software.

Problem Statement	Objectives
highlighting the need to switch to sustainable practices by using sustainable materials (Abubakar et al., 2022).	
Prolonged use of non-ergonomic chairs can lead to Musculoskeletal Disorders (MSDs), resulting in complaints of muscle pain in the shoulder area, neck stiffness, and back pain (Sholihah et al., 2019).	Objective 3: To evaluate the ergonomic analysis on the final conceptual design of the floor chair using RULA analysis.

Table 3.2 shows the relationship between the objectives and the methodology of this study. There are three objectives for this study, which a selection of conceptual design for the floor chair has been conducted using TOPSIS method that excellent in multi-criteria decision analysis, material selection process for floor chair structure and padding using Granta Edupack software, and ergonomic analysis through RULA analysis on CATIA software.

Table 3.2: Relationship between Objective and Methodology

Objective	Methodology
To select the best conceptual design of the floor chair using TOPSIS method.	• Collected data survey 1 • Conceptul Design • Collected data survey 2 • TOPSIS analysis
To select the suitable green material of floor chair using Granta Edupack software.	• Utilization of Granta Edupack software • Material selection process (translation, scoring, ranking, documentation)
To evaluate the ergonomic analysis on the final conceptual design of the floor chair using RULA analysis.	• RULA Analysis • 5th , 50th , and 95th percentile of Malaysia anthropometric data • Final selected design

3.2 Flow Chart of Study

Figure 3.1 visually outlines the sequential actions in the processes and workflow, ensuring timely completion of tasks.

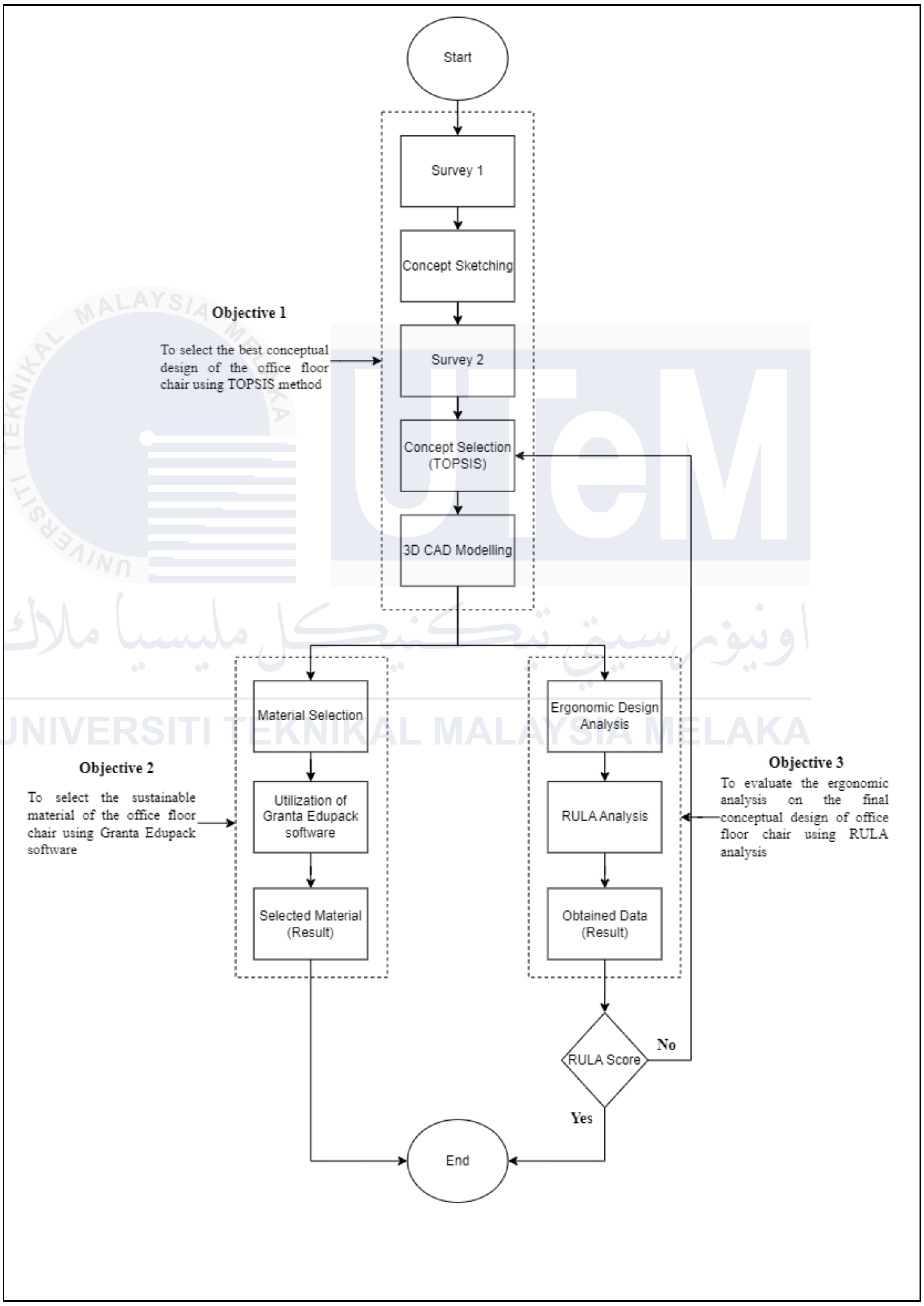


Figure 3.1: Flowchart of the study

3.3 Survey on Design Criteria

The survey was conducted to identify the design criteria for the ergonomic floor chair. Several questions provided in this survey for respondent to answer for design consideration. The estimated total number of respondents is approximately 30 to 40 students and lecturers. These are the questions that included in the survey:

1) Is the ergonomic design of a floor chair important to you for ensuring comfort during prolonged use?
2) Do you consider the environmental impact of materials when choosing furniture?
3) Would you prioritize a floor chair made from sustainable materials over one made from non-sustainable materials?
4) Is having a lightweight floor chair important to you for ease of portability and manoeuvrability?
5) Do you prefer a floor chair with added padding for increased comfort during use?
6) Is the adjustability of a floor chair important in terms of customization for personal comfort?
7) Is the versatility of a floor chair, allowing it to be used for various purposes important to you?
8) Is space efficiency a key consideration for choosing a floor chair?
9) Do you prioritize stability as a crucial factor when selecting a floor chair for your use?

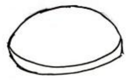
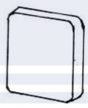
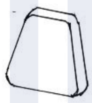
3.4 Conceptual Design

The conceptual design is very important for producing a floor chair. The conceptual design visualizes how the floor chair is designed before fabrication process. The design was generated to visualize the idea of the floor chair structure from the survey data from the respondents.

3.4.1 Morphological Chart

Table 3.3 shows the morphological chart for floor chairs. The design consists of 5 different designs for each chair component which are seat, back, and armrest.

Table 3.3: Morphological Chart for Floor Chair

Chair Components	Physical Solution				
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Seat	 Square	 Half round	 Rectangle	 Round	 Ellipsoidal
Back	 Square	 Trapezoidal a	 Trapezoidal b	 Round	 Ellipsoidal
Armrest	 L-Shape	 T-Shape	 J-Shape	 Ellipsoidal	 U-Shape

3.4.2 Design Concept

The total conceptual design of the floor chair that was generated for the study is 5 designs by referring to the survey data from respondents. Each of the designs are different between each other. The design has its own designs characteristics based on the design criteria. But the conceptual designs have the same components and structure such as seat and back rest but with different shapes or designs.

3.5 Survey on Conceptual Design

A survey second was conducted to assess the effectiveness of designs based on feedback from potential users. This survey aims to identify scores for each design on every criterion, with participant's feedback providing valuable input for the TOPSIS decision matrix. The scale reflected the characteristics of each design, determining whether it aligns with user preferences based on specified criteria. These are the questions that included in the survey:

1) Ergonomic Structure:
   - How well does the chair's design prioritize comfort and support for extended use?
   - 1 (Not Prioritized) to 5 (Highly Prioritized)
2) Foldability:
   - Can the design be made fully foldable to ensure easy storage?
   - 1 (Least) to 5 (High)
3) Sustainable Material:
   - Can the design be fabricated using green materials, specifically natural materials?
   - 1 (Least) to 5 (High)
4) Space Efficiency:
   - How efficiently does the chair's design utilize space in different environments?
   - 1 (Inefficient) to 5 (Highly Efficient)
5) Conventional Process:
   - Can the design be fabricated using traditional conventional processes?
   - 1 (Least) to 5 (High)

The participants for this survey are students and lecturers within the Faculty of Industrial and Manufacturing Technology and Engineering (FTKIP). Two-tier of customer surveys were conducted to get the customer requirements and to evaluate the conceptual design, with 77 total number of respondent.

3.6 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Method

TOPSIS is founded on the fundamental notion that the optimum solution is the one that is closest to the positive-ideal solution and farthest away from the negative-ideal solution. Alternatives are ranked by using an overall index based on their distances from the optimal solutions. The TOPSIS methodology evaluated 5 criteria of the product design which are ergonomic structures, foldability, sustainable material, space efficiency, and conventional manufacturing process to 5 design alternatives.

The methodology of TOPSIS approach can be explained as a set of steps shown below:

Step 1: Construct a decision matrix, X.

The decision matrix $X = (x_{ij})_{I \times J}$ consists of I alternatives and J criteria. The decision matrix is based on the data gained from a survey on the conceptual design.

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1J} \\ x_{21} & x_{22} & \dots & x_{2J} \\ \dots & \dots & \dots & \dots \\ x_{I1} & x_{I2} & \dots & x_{IJ} \end{bmatrix}$$

The normalized ratings can be calculated by using the equation (1):

$$Y = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{I} x_{ij}^2}} \tag{1}$$

The process of conversion simplifies comparing attributes using dimensionless units, yet it presents challenges when attempting direct comparisons due to differing scale lengths. The matrix Y represents the normalized performance ratings y_{ij}.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1J} \\ y_{21} & y_{22} & \dots & y_{2J} \\ \dots & \dots & \dots & \dots \\ y_{I1} & y_{I2} & \dots & y_{IJ} \end{bmatrix}$$

Step 2: Integrate weight with ratings.

Construct a weighted ratings combination to form the weighted-normalized decision matrix R by using the formula (2):

$$r_{ij} = W_j \times y_{ij} \, ; (i = 1, 2, \dots, I \, ; j = 1, 2, \dots, J) \tag{2}$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1J} \\ r_{21} & r_{22} & \dots & r_{2J} \\ \dots & \dots & \dots & \dots \\ r_{I1} & r_{I2} & \dots & r_{IJ} \end{bmatrix}$$

Step 3: Find positive and negative ideal solutions.

The positive ideal solution set, denoted as $R^+$and the negative ideal solution set, denoted as R^- which can be detected from matrix R.

$$R^+ = [r_1^+, r_2^+, \dots, r_J^+] \tag{3}$$

$$R^- = [r_1^-, r_2^-, \dots, r_J^-] \tag{4}$$

Where,

$$r_j^+ = \begin{cases} \max r_{ij}, if\ j\ is\ a\ benefit\ attribute \\ \min r_{ij}, if\ j\ is\ a\ cost\ attribute \end{cases}$$

$$r_j^- = \begin{cases} \min r_{ij}, if\ j\ is\ a\ benefit\ attribute \\ \max r_{ij}, if\ j\ is\ a\ cost\ attribute \end{cases}$$

Step 4: Obtain the separation values.

The separation measure calculates the distance between each alternative rating and both the positive and negative ideal solutions using the principles of Euclidean distance theory. The equations (5) and (6) depict the steps for calculating positive and negative separations, respectively.

$$S_i^+ = \sqrt{\sum_{j=1}^{J} (r_{ij} - r_j^+)^2} \tag{5}$$

$$S_i^- = \sqrt{\sum_{j=1}^{J} (r_{ij} - r_j^-)^2} \tag{6}$$

Step 5: Calculate the overall preference score.

The resultant overall preference score Vi for each alternative Ai is derived as equation (7) below:

$$P_i = \frac{S_i^-}{S_i^- - S_i^+} \quad (7)$$

The ranking of alternative based on the higher value of P_i.

The highest rank among the design candidates is chosen as the conceptual design for the ergonomic floor chair. Then the design was evaluated based on ergonomic analysis by using RULA analysis.

3.7 3D CAD Modelling

The selected conceptual design from TOPSIS method will then be designed in 3D modelling through CATIA software. The design parameter considered based on the Malaysian anthropometric data. There is only one selected design which is the design that ranked as the highest among the design candidates designed in 3D model by using the software. The 3D model started with the 2D sketching in the software and then extruded to be the 3D model. The drafting of the 3D model also be conducted to illustrate the dimensions of the design.

3.8 Material Selection for Floor Chair Structure

Material selection for floor chair structure is very important to ensure the product is strong, lightweight, and durable. It is to ensure that the chair can withstand the user body weight and to avoid fracture. The suitable material for the floor chair could be identified by achieving the second objective of the study which is to perform materials selection procedure by using Granta Edupack Software. The criteria of the materials should be sturdy, lightweight, sustainable, and durable to support varying weights, provide adequate comfort for extended sitting also maintain durability on different floor surfaces.

3.8.1 Granta Edupack

Granta Edupack is a software for educational conduct that provides features of materials database and educational resource about materials properties. The use of Granta Edupack software helps to identify the materials' impact on the environment which is crucial to provide sustainable for floor chair production. The steps on how to use the Granta Edupack software for material selection are listed below:

Step 1: Database Access

- The Granta Edupack software will be launched by opening the software and accessing the material database.
- Searching for suitable materials for chair applications such as polymers, elastomers, metal, or natural materials could be done by selecting 'MaterialUniverse' table and 'All materials' on the Browse panel.

Step 2: Define Material Properties

- The relevant properties like selecting materials based on criteria could be identified such as lightweight, strength, and durability.
- Then the software also could help to filter the materials for desired properties by finding the specific material or material properties on 'Search' tool and it will appear all the information about the material.

Step 3: Property Chart Creation

- Bar charts and bubble charts are usually used for a great visualization and communication of material properties, as well as being a key tool to support systematic materials selection.
- The bar chart and bubble chart could be created by clicking on the 'Chart/Index' tool, then set the selection data as 'MaterialUniverse: All materials', then 'Chart' on the selection stages.
- The chart has been set for y-axis and x-axis which depends on the attributes. For example, to identify the correlation between density and strength of the materials, Young's modulus for y-axis attribute and density for the attribute of x-axis could be selected.

- ‘Show Family Envelopes’ button shows the data for a given family of materials clustered together.

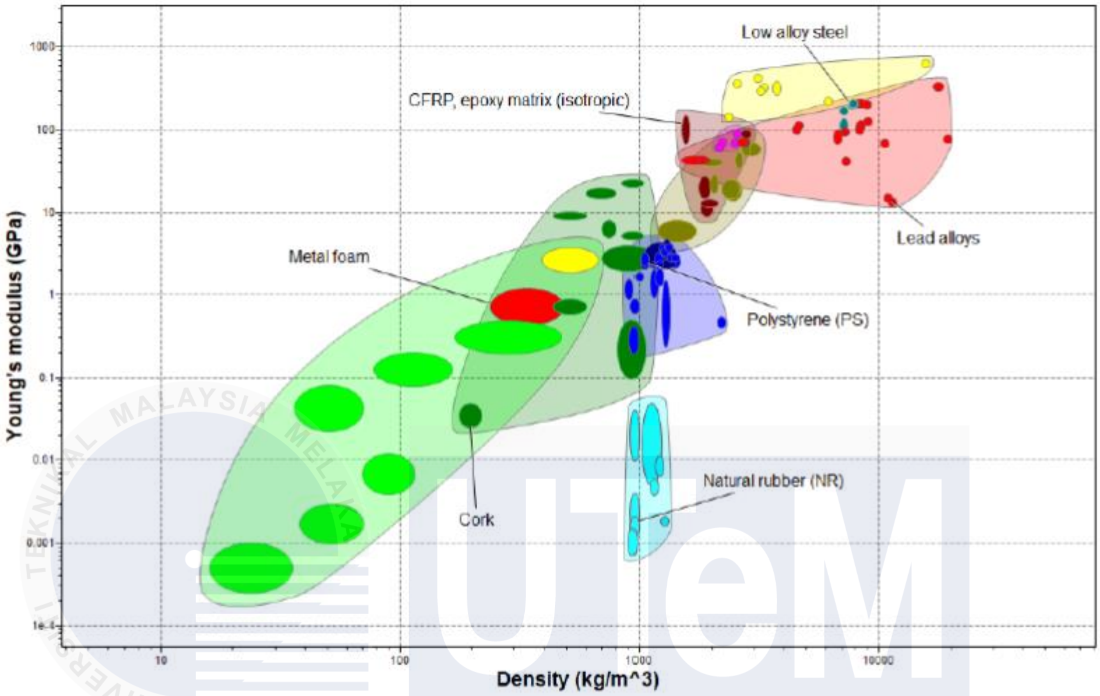


Figure 3.2: Granta Edupack software materials family

Figure 3.2 shows the correlation between materials stiffness and density properties. The chart visualizes the cluster of the materials family and the indicator on the y-axis and x-axis identify the different material properties of each material. The comparison of each material could be made and be able to identify the materials that most suitable or closest to the desired specification of the floor chair.

The material selection process involves comprehensive evaluation across several strategic steps. It commences with an examination of design requirements, followed by translation, screening, ranking, and documentation processes. The materials are chosen based on their properties, ensuring they align seamlessly with the specific design requirements. This selection process takes into account various critical properties, such as material cost, density, durability, sustainability, and strength, all of which are facilitated through the analytical capabilities of the Granta Edupack software.

3.9 Rapid Upper Limb Assessment (RULA) Analysis In CATIA

Rapid Upper Limb Assessment (RULA) evaluates ergonomic risk factors associated with the upper extremities. Its aim is to assess the biomechanical and postural demands on the neck, trunk, and upper limbs. The digital RULA score aligns with the Manikin. When the Human Digital Model (HDM) is positioned within the digitally simulated floor chair, the entire analysis previously conducted through observation becomes accessible with just a click of the mouse. As per the analysis, the Manikin's postures vary. The optimization criteria within the Inverse Kinematic (I.K) Behavior panel help enhance posture for RULA analysis or postural scoring. The RULA Analysis tool is launched to choose the Manikin. Figure 3.3 shows criteria for conducting RULA analysis in CATIA.

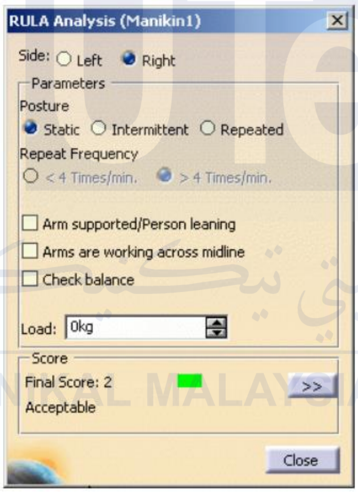


Figure 3.3: RULA Score Sheet

Tasks are considered intermittent when repeated four times or fewer within a minute. The posture options of Static and Repeated involve tasks repeated more than four times per minute. Within these posture options, choices like Arms Supported/Person leaning and Arms Working Across Midline are available to assess balance. Each choice should be made based on the analysis's context. The 'Load' parameter specifies the object's weight manipulated by the individual. The final score is displayed in the score box, with each body part's score range detailed in Figure 3.4. RULA analysis evaluates risk factors such as the frequency of movements, sustained muscle effort, working posture, and uninterrupted work duration. Scores colored green (ranging from 1 to 2 indicate an acceptable posture). The study only analyzes the ergonomic risks related to the upper body posture, specifically on the upper limbs, neck, and trunk of user while sitting on the floor chair.

Segment	Score Range	Color associated to the score					
		1	2	3	4	5	6
Upper arm	1 to 6						
Forearm	1 to 3						
Wrist	1 to 4						
Wrist twist	1 to 2						
Neck	1 to 6						
Trunk	1 to 6						

Figure 3.4: RULA Score Range

A score of 3 to 4 (Yellow) suggests a need for deeper investigation or minor design adjustments. Scores of 5 to 6 (Red) indicate an urgent need for design changes. The responsibility of a design engineer involves making modifications to ensure the score falls within the acceptable range of 1 to 2 (Green). The study will select the whole body of the manikin, focusing on postures labeled as 'intermittent' and 'arms supported' for analysis. The final prediction of the RULA score is between 1 and 2 that ensures the floor chair design is acceptable in ergonomic aspect. If the RULA score more than 2 means that the design of the floor chair needs to be investigated for design improvement.

3.9.1 Human Digital Model Preparation for Analysis

To perform RULA analysis by using Human Digital Model (HDM), it's necessary to input human size dimensions, which can differ based on ethnicity, gender, and age group. Anthropometric data for the HDM is accessible in CATIA for American, Canadian, French, Japanese, and Korean populations. In cases where the data isn't available within the software, a Manikin can be constructed by inputting available measurements. The Manikin's posture is configured as seated when analyzing sitting postures by selecting the corresponding option within the product. For the study, HDM applied with Malaysian Anthropometric dimensions of 5th, 50th, and 95th percentile for having the size of Malaysian Manikin. Table 3.6 shows the 5th, 50th, and 95th percentile of Malaysian Citizen Anthropometric Dimensions for three types of Human Digital Models.

3.9.2 Anthropometric Data Collection of Malaysia Citizen

Creating an ergonomic floor chair involves considering vital anthropometric data. Through a literature review, it was discovered that there are 13 key anthropometric measurements in mm (millimeter) unit crucial in chair design. Figure 3.5 shows the anthropometric measurement position for the human body. This chair is intended for use by both men and women, so a blend of male and female anthropometric data was incorporated to ensure its usability for a broader population. Table 3.4 shows the anthropometric data of Malaysian citizen in 2010.

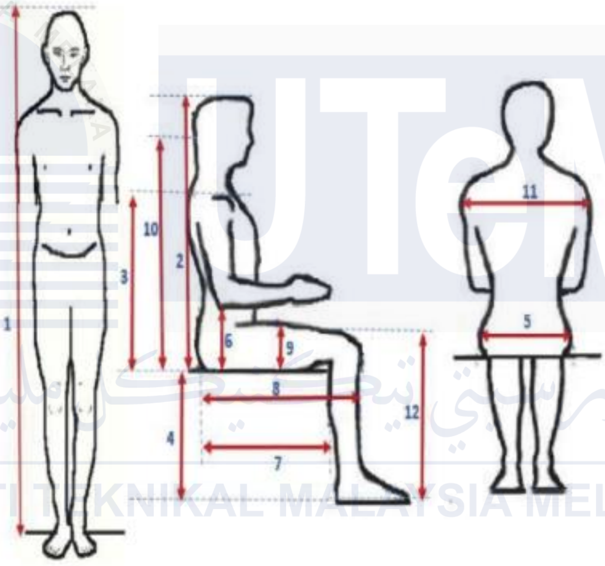


Figure 3.5: Anthropometric Measurement Position

Table 3.4: Anthropometric data for Malaysian Citizen, 2010

No	Anthropometric Dimensions	5th Percentile	50th Percentile	95th Percentile
1	Stature (body height)	1466.69	1565.00	1663.31
2	Sitting height (erect)	667.12	792.86	918.59
3	Shoulder height, sitting	412.45	515.84	619.23
4	Lower leg length	354.38	424.80	495.21
5	Hip Breadth	261.22	378.34	495.45
6	Elbow height, sitting	130.91	224.66	318.41
7	Buttock-popliteal length	367.87	448.60	529.33
8	Buttock-knee length	373.25	464.67	532.13
9	Thigh clearance	114.41	196.62	278.83
10	Eye height, sitting	559.14	697.08	799.01
11	Shoulder (bideltoid) breadth	346.77	438.97	531.17
12	Knee height	338.87	436.81	534.76
13	Body mass (weight) (kg)	48.28	60.40	146.88

CHAPTER 4

RESULTS & DISCUSSION

This chapter explores the results and discussion of the study. The conceptual design of the floor chair is based on specific design criteria. The final design was selected using survey data and the TOPSIS method analysis. Additionally, a RULA analysis was performed on the selected design to evaluate its ergonomics. Material selection analysis was conducted using Granta Edupack software.

4.1 TOPSIS Method Analysis for Design Selection

The first approach of this study was to select the most suitable conceptual design for an ergonomic floor chair using the TOPSIS method analysis. The design criteria for the floor chair were evaluated based on data collected from the first survey. This was followed by a second survey on the conceptual design of the floor chair. The data collected from the second survey were used as the decision matrix for the TOPSIS analysis.

4.1.1 Design Criteria of the Floor Chair Survey Data

A survey was conducted to determine the design criteria for the floor chair. Data was collected from 37 respondents within the FTKIP community. The survey included questions on design specifications such as ergonomics, sustainable materials, lightweight construction, comfort, and foldability. The results of the design criteria are as follows:

Table 4.1: Collected data design criteria survey

Design Criteria	Mark				
	1	2	3	4	5
Ergonomic	0%	2.7%	5.4%	40.5%	51.4%
Sustainable Material	0%	2.7%	16.2%	51.4%	29.7%
Lightweight	0%	0%	29.7%	21.6%	48.6%
Comfortability	2.7%	0%	5.4%	29.7%	62.2%
Foldability	0%	10.8%	32.4%	18.9%	37.8%

Table 4.1 presents the results of the collected data from the design criteria survey. The table consists of two primary columns: "Mark" and "Design Criteria." The cells within the table contain percentage values of the chosen marks from respondents, associated with each criterion across different marks. Under the "Mark" column, there are sub-columns labelled 1 through 5, ranging from "Least Important" to "Most Important."

The highest percentage for the ergonomic criteria is 51.4% at Mark 5, indicating that ergonomics is very important for the floor chair design. Respondents also indicated that sustainable materials are important, with the highest percentage at Mark 4. The survey shows that the lightweight aspect is crucial, with the highest percentage at Mark 3. Comfortability is also very important, with 62.2% of respondents rating it at Mark 5. Foldability has a significant percentage at Mark 5 (37.8%), emphasizing its relevance for space efficiency and convenience. Overall, the survey data suggests that all design criteria are important for inclusion in the floor chair design.

4.1.2 Conceptual Design

Based on the design criteria survey, the conceptual design of the floor chair has been developed to meet the necessary criteria. Five conceptual designs have been selected for evaluation through a second survey. This survey focused on conceptual designs and their evaluation with respect to several design criteria, including ergonomics, foldability, sustainable materials, space efficiency, and conventional manufacturing processes. Figures 4.1 through 4.5 show the final five conceptual designs that have been created and will be evaluated in the second survey.

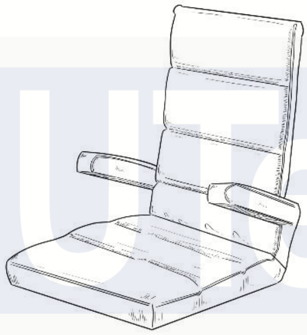


Figure 4.1: Design 1

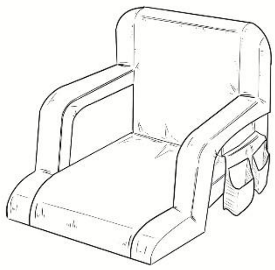


Figure 4.2: Design 2

Figure 4.3: Design 3

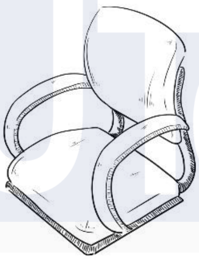


Figure 4.4: Design 4

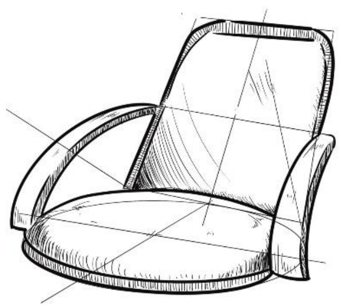


Figure 4.5: Design 5

4.1.3 Conceptual Design Selection

The conceptual designs have undergone a second data survey for each of the floor chair design criteria. Each design criterion for every design was rated by respondents. A total of 40 respondents participated in the survey, providing scores ranging from 1 to 5 for each design criterion on each conceptual design. The results of the survey are as follows:

Table 4.2: Conceptual Design Survey Data

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
Design 1	5	4	3	3	3
Design 2	4	4	3	3	3
Design 3	4	4	5	4	5
Design 4	4	1	4	2	4
Design 5	3	1	5	2	4

The result from the conceptual design survey used as decision matrix for TOPSIS method to select the best conceptual design for the floor chair. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is multi-criteria decision-making (MCDM) method. It is used to identify the best option among a set of alternatives based on various criteria. The decision matrix is the organized data that ensures all relevant information about the floor chair criteria on the conceptual design. These are the criteria for the evaluation: -

1. The ergonomic value of the design aims to provide comfort for prolonged sitting.
2. The foldable feature of the design is intended to facilitate easy storage.
3. The design allows for manufacturing using sustainable materials to promote sustainability.
4. The design is highly space-efficient, making it ideal for maximizing space savings.

5. The design accommodates the use of a conventional manufacturing process for producing the floor chair.

Table 4.3 shows the decision matrix for the conceptual design, serving as the foundation for the analysis. It contains data from the second survey used to evaluate the alternatives. Five different criteria were assessed for each of the five conceptual designs: ergonomics, foldability, sustainable material, space efficiency, and conventional process. The evaluation scores range from a maximum of 5 to a minimum of 1.

Table 4.3: Decision Matrix

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
Design 1	5	4	3	3	3
Design 2	4	4	3	3	3
Design 3	4	4	5	4	5
Design 4	4	1	4	2	4
Design 5	3	1	5	2	4

Table 4.4 shows the normalized decision matrix, which ensures that all criteria are on the same scale. The normalized values represent the relative performance of each alternative for each criterion.

Table 4.4: Normalized Decision Matrix

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
Design 1	0.5522	0.5657	0.3273	0.4629	0.3464
Design 2	0.4417	0.5657	0.3273	0.4629	0.3464
Design 3	0.4417	0.5657	0.5455	0.6172	0.5774
Design 4	0.4417	0.1414	0.4364	0.3086	0.4619
Design 5	0.3313	0.1414	0.5455	0.3086	0.4619

The study focused on several important criteria for the floor chair, specifically ergonomics and material sustainability. These two criteria were given significant preference in the floor chair design, each assigned a weightage value of 0.25, as shown in Table 4.5. Following these, the foldability criterion was given a weightage value of 0.20. The weight calculations for each criterion in each design were determined using Eq (2).

Table 4.5: Weighted Normalized Matric

Weightage	0.25	0.20	0.25	0.15	0.15
Conceptual Design	**Ergonomic**	**Foldability**	**Sustainable Material**	**Space Efficiency**	**Conventional Process**
Design 1	0.1380	0.1131	0.0818	0.0694	0.0520
Design 2	0.1104	0.1131	0.0818	0.0694	0.0520

Design 3	0.1104	0.1131	0.1364	0.0926	0.0866
Design 4	0.1104	0.0283	0.1091	0.0463	0.0693
Design 5	0.0828	0.0283	0.1364	0.0463	0.0693

Table 4.6 presents the positive ideal solution values for each design with respect to each criterion. For the positive ideal solution, higher values are preferable as they indicate better performance in meeting the desired criteria. The best ideal value for ergonomics is 0.1380, observed in Design 1. Similarly, the best ideal value for space efficiency is 0.0926, found in Design 3. These values identify the designs that excel in specific aspects. The positive ideal solution was calculated using Eq (3), providing a standard for determining the optimal values for each criterion.

Table 4.6: Positive Ideal Solution

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
Design 1	0.1380	0.1131	0.0818	0.0694	0.0520
Design 2	0.1104	0.1131	0.0818	0.0694	0.0520
Design 3	0.1104	0.1131	0.1364	0.0926	0.0866
Design 4	0.1104	0.0283	0.1091	0.0463	0.0693
Design 5	0.0828	0.0283	0.1364	0.0463	0.0693

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
V+	**0.1380**	**0.1131**	**0.1364**	**0.0926**	**0.0866**

Table 4.7 shows the negative ideal solution values for each design with respect to each criterion. For the negative ideal solution, lower values are preferable as they indicate a lesser negative impact on the design. The worst ideal value for ergonomics is 0.0828, observed in Design 5. Similarly, the worst ideal value for the foldability aspect is 0.0283, observed in both Design 4 and Design 5. These values highlight areas where the designs are farthest from the optimal criteria. The positive ideal solution was calculated using Eq (4), providing a benchmark for evaluating how well each design meets the desired standards.

Table 4.7: Negative Ideal Solution

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process
Design 1	0.1380	0.1131	0.0818	0.0694	0.0520
Design 2	0.1104	0.1131	0.0818	0.0694	0.0520
Design 3	0.1104	0.1131	0.1364	0.0926	0.0866
Design 4	0.1104	0.0283	0.1091	0.0463	0.0693
Design 5	0.0828	0.0283	0.1364	0.0463	0.0693
V-	**0.0828**	**0.0283**	**0.0818**	**0.0463**	**0.0520**

The Euclidean calculation determined the alternative closest to the ideal solution for both positive and negative criteria by measuring the distance between two points in a multi-dimensional space. Eq (4) was used to calculate the Euclidean distance from the positive ideal solution for each criterion of the designs. This distance reflects how far each alternative is from the ideal solution. The values of the Euclidean distance from the positive ideal solution are shown in Table 4.8. According to the data, the highest numerical Euclidean value for the positive ideal solution is 0.0276, which corresponds to Design 3, while the lowest numerical value is 0.1127, associated with Design 5. These calculations are crucial for assessing the performance of each design, helping to identify which designs are most aligned with the ideal solution.

Table 4.8: Calculation of Euclidean distance from the positive ideal solution

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process	Si+
Design 1	0.1380	0.1131	0.0818	0.0694	0.0520	**0.0686**
Design 2	0.1104	0.1131	0.0818	0.0694	0.0520	**0.0740**
Design 3	0.1104	0.1131	0.1364	0.0926	0.0866	**0.0276**
Design 4	0.1104	0.0283	0.1091	0.0463	0.0693	**0.1056**
Design 5	0.0828	0.0283	0.1364	0.0463	0.0693	**0.1127**
V+	0.1380	0.1131	0.1364	0.0926	0.0866	

The values of the Euclidean distance from the negative ideal solution are presented in Table 4.9. According to the data, Design 2 has the highest numerical Euclidean value from the negative ideal solution, recorded at 0.0922. Conversely, Design 3 has the lowest numerical value, recorded at 0.1195. These Euclidean distances were calculated using Eq

(5), which measures how far each design deviates from the negative ideal solution. The higher the Euclidean distance, the closer the design is to the ideal solution.

Table 4.9: Calculation of Euclidean distance from the negative ideal solution

Conceptual Design	Ergonomic	Foldability	Sustainable Material	Space Efficiency	Conventional Process	Si-
Design 1	0.1380	0.1131	0.0818	0.0694	0.0520	**0.1038**
Design 2	0.1104	0.1131	0.0818	0.0694	0.0520	**0.0922**
Design 3	0.1104	0.1131	0.1364	0.0926	0.0866	**0.1195**
Design 4	0.1104	0.0283	0.1091	0.0463	0.0693	**0.0425**
Design 5	0.0828	0.0283	0.1364	0.0463	0.0693	**0.0572**
V-	0.0828	0.0283	0.0818	0.0463	0.0520	

Table 4.10 presents the relative closeness to the ideal solution, also known as the overall preference score, for each design. The overall preference score, denoted as Pi, was calculated using Eq (7). The results indicate that Design 3 received the highest overall preference score, with a value of 0.8123, ranking it as the top design. This superior ranking is attributed to Design 3 meeting all the necessary criteria for the floor chair design, particularly excelling in ergonomic and sustainable aspects. Consequently, Design 3 has been chosen as the best conceptual design for the floor chair. This selection underscores the importance of integrating ergonomic and sustainability considerations in product design, ensuring both user comfort and environmental responsibility.

Table 4.10: Relative Closeness to Ideal Solution

Conceptual Design	Si+	Si-	Pi	Rank
Design 1	0.0686	0.1038	0.6020	2
Design 2	0.0740	0.0922	0.5548	3
Design 3	0.0276	0.1195	0.8123	1
Design 4	0.1056	0.0425	0.2870	5
Design 5	0.1127	0.0572	0.3369	4

The TOPSIS method provides a structured approach to decision-making for the selection process of floor chair conceptual design. It allows for the evaluation of multiple criteria simultaneously, ensuring a holistic assessment of each design alternative considering several factors such as ergonomics, foldability, sustainable material, space efficiency, and conventional process. This method facilities a robust and informed selection of the most suitable conceptual design for the floor chair, which is Design3, ensuring that the final product meets all the critical requirements effectively.

4.2 Material Selection of Floor Chair by using Granta Edupack Software

The material selection analysis for the floor chair structure and the padding cushion was conducted by using Granta Edupack software. The material properties that being considered for the analysis included the density, Yield Strength (strength), Young's Modulus (stiffness), and price of the materials. The analysis compared the material properties of each material candidate. The candidate's material with the highest material index value is chosen as the most suitable material.

4.2.1 Material Selection on Floor Chair Structure

The material selection for the floor chair structure focused on properties such as yield strength and density. The analysis primarily used a yield strength vs. density chart and was supported by additional material properties, including tensile strength, Young's modulus, heat of combustion, combustion CO2, and material price.

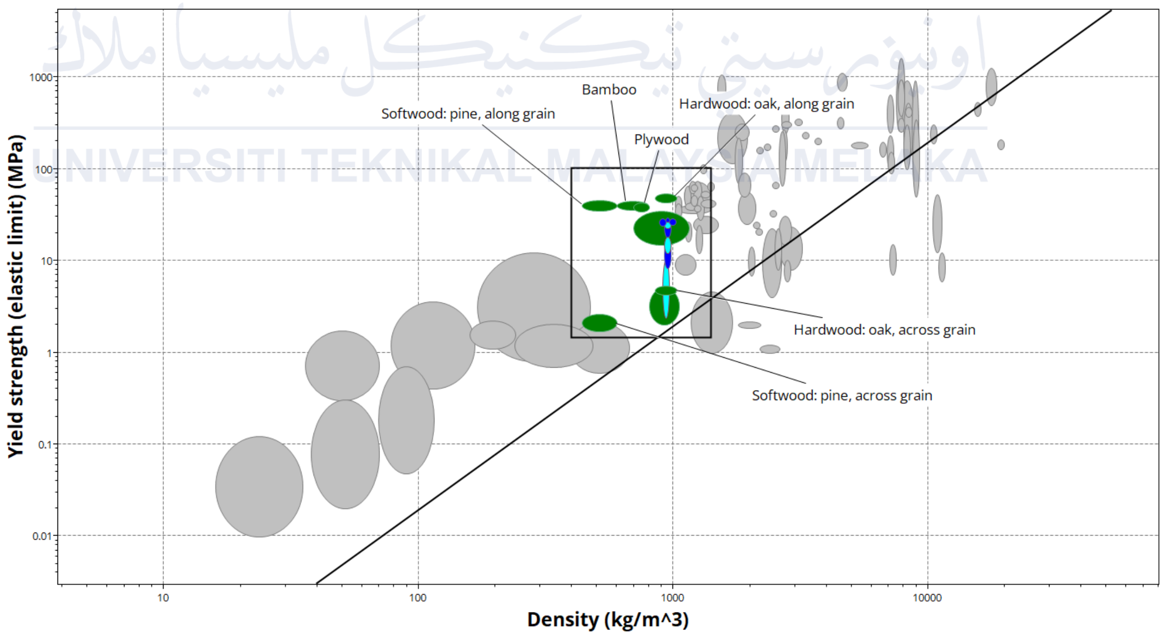


Figure 4.6: Yield Strength vs Density (Structure)

Figure 4.6 shows the correlation between Yield strength and density of the materials. The slope 3 used as line to reduce the number of candidates which respects to material index of (σ^1/2 / ρ). Upon evaluating materials aligned with design criteria, 6 material candidates have been identified potential used as material for floor chair structure. These are 6 materials candidates considered for floor chair structure: -

1. Bamboo
2. Plywood
3. Softwood: pine, across grain
4. Softwood: pine, along grain
5. Hardwood: oak, across grain
6. Hardwood: oak, along grain

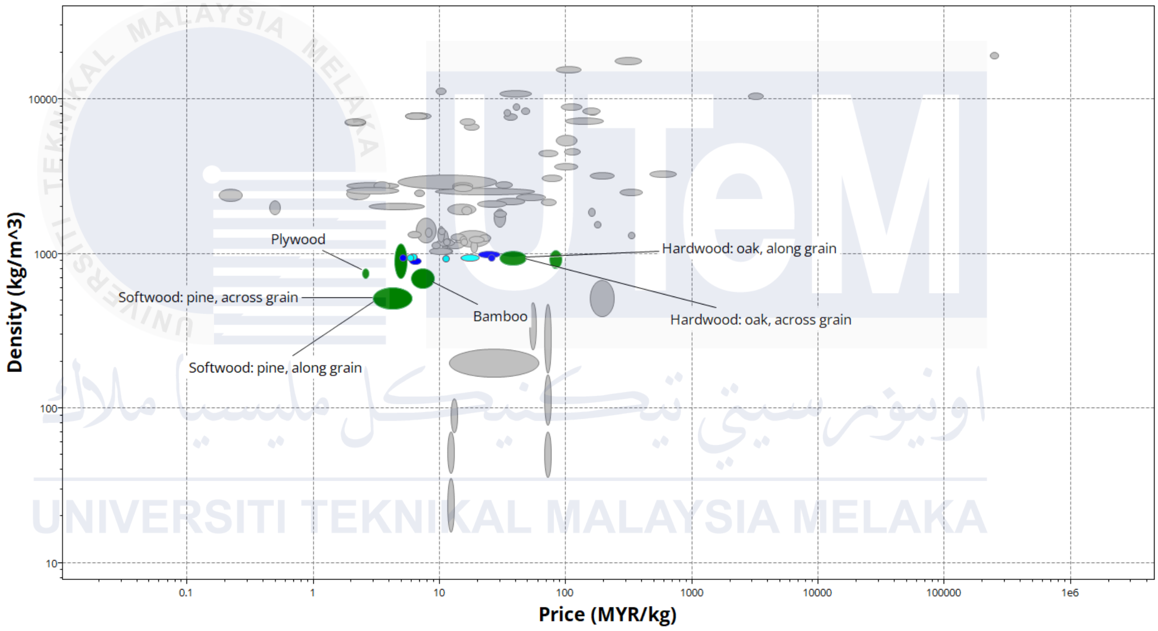


Figure 4.7: Density vs Price (Structure)

Figure 4.7 shows the correlation between the density and price of various materials. The study focuses on the low cost of floor chair production, highlighting the importance of considering price as a key factor in selecting materials for the floor chair structure. The graph indicates that plywood is the least expensive material among all the candidates. Meanwhile, softwood is the lightest material among the candidates, and hardwood has the highest density and is also the costliest among all the materials considered. The material properties of these materials are detailed in Table 4.11 below.

Table 4.11: Candidate Materials for Floor Chair Structure

Material	Bamboo	Plywood	Softwood: pine, across grain	Softwood: pine, along grain	Hardwood: oak, across grain	Hardwood: oak, along grain
Price, MYR/kg	6.01 – 9.02 @7.515	2.47 – 2.74 @2.605	3.01 – 6.01 @4.51	3.01 – 6.01 @4.51	30.1 – 48.5 @39.3	30.1 – 48.5 @39.3
Density, kg/m^3	602 – 797 @699.5	700 – 800 @750	440 – 600 @520	440 – 600 @520	850 – 1.03e3 @940	850 – 1.03e3 @940
Yield Strength, MPa	35.8 – 44.1 @39.95	34.4 – 42.1 @38.25	1.7 – 2.6 @2.15	35 – 45 @40	4.26 – 5.22 @4.74	43.2 – 52.8 @48
Young's Modulus, GPa	15.1 – 19.9 @17.5	5 – 8 @6.5	0.6 – 0.9 @0.75	8.4 – 10.3 @9.35	5 – 5.58 @5.29	20.6 – 25.2 @22.9
Tensile Strength, MPa	160 – 319 @239.5	45 – 70 @57.5	3.2 – 3.9 @3.55	60 – 100 @80	7.1 – 8.7 @7.9	133 – 162 @147.5
Heat of Combustion (Net), Mj/kg	19.7 – 21.3 @20.5	19.8 – 21.3 @20.55	20.7 – 22.1 @21.4	20.7 – 22.1 @21.4	19.8 – 21.3 @20.55	19.8 – 21.3 @20.55

Material	**Bamboo**	**Plywood**	**Softwood: pine, across grain**	**Softwood: pine, along grain**	**Hardwood: oak, across grain**	**Hardwood: oak, along grain**
Combustion CO2, kg/kg	1.69 – 1.79 @1.74	1.69 – 1.78 @1.735	1.76 – 1.85 @1.805	1.76 – 1.85 @1.805	1.69 – 1.78 @1.735	1.69 – 1.78 @1.735

Table 4.11 provides a comprehensive list of the properties for each candidate material. The properties detailed include price, density, yield strength, Young's modulus, heat of combustion, and combustion CO2. The values for these material properties were sourced from the Granta Edupack software, ensuring accurate and reliable data for the analysis. By presenting these values, Table 4.11 highlights the differences in each property among the candidate materials, allowing for a thorough comparison. This detailed comparison is crucial for selecting the most suitable material for the floor chair structure, as it underscores the variations in cost, mechanical strength, thermal properties, and environmental impact of each material. The scores for the candidate materials have been evaluated and are shown in Table 4.12 to determine the most suitable material for the floor chair structure based on their properties.

Table 4.12: Material Score for Floor Chair Structure

Material	**Bamboo**	**Plywood**	**Softwood: pine, across grain**	**Softwood: pine, along grain**	**Hardwood: oak, across grain**	**Hardwood: oak, along grain**
Price, MYR/kg	3	10	8	8	2	2

Material	Bamboo	Plywood	Softwood: pine, across grain	Softwood: pine, along grain	Hardwood: oak, across grain	Hardwood: oak, along grain
Density, kg/m^3	7	5	10	10	2	2
Yield Strength, MPa	8	7	2	9	3	10
Young's Modulus, GPa	8	3	1	6	4	9
Tensile Strength, MPa	10	6	2	7	4	8
Heat of Combustion (Net), Mj/kg	8	9	10	10	9	9
Combustion CO2, kg/kg	9	10	8	8	10	10

Material	Bamboo	Plywood	Softwood: pine, across grain	Softwood: pine, along grain	Hardwood: oak, across grain	Hardwood: oak, along grain
TOTAL SCORE	53	50	41	58	34	50

Table 4.12 shows the scores for the candidate materials based on their properties. The price and density properties are evaluated such that materials with lower prices and densities receive higher scores, aligning with the study's focus on optimizing the production cost and achieving a lightweight floor chair product. In contrast, for other material properties such as yield strength, tensile strength, heat of combustion and Young's modulus, higher values result in greater scores, reflecting their importance in the material selection process. The combustion CO2 property is evaluated such that materials with lower CO2 emissions receive higher scores, promoting a better and healthier environment by reducing CO2 emissions. The total scores of each candidate material indicate that Softwood (pine, along grain) received the highest mark with a total score of 58, while Hardwood (oak, across grain) received the lowest mark.

Table 4.13: Material Selection for Floor Chair Structure

Material	**Index, M = (MPa)^1/2 / (kg/m^3)**	**Comment**
Bamboo	9.04e-3	High tensile strength, good density and heat of combustion but high cost.

Material	Index, M = (MPa)^1/2 / (kg/m^3)	Comment
Plywood	8.25e-3	Inexpensive, high density, but low toughness.
Softwood: pine, across grain	2.82e-3	Inexpensive, excellent combustion CO2 but low strength and low toughness.
Softwood: pine, along grain	12.16e-3	Low density, inexpensive, high strength, and excellent heat of combustion.
Hardwood: oak, across grain	2.32e-3	Excellent combustion CO2 but high cost, low strength, low toughness and high density.
Hardwood: oak, along grain	7.37e-3	High strength, high toughness but high cost and high density.

Table 4.13 shows the material index value for each candidate material. Softwood (pine, along grain) has the highest material index value among the candidates with 12.16e-3 MPa/kgm^3. This material demonstrates high strength, low cost, low density, and excellent heat of combustion. Additionally, it has a low value of combustion CO2, providing a better environmental impact and greater sustainability. The Softwood: pine, along grain have been

chosen as the best material for the floor chair structure based on the material properties that fulfil the requirements needed.

Namichev and Petrovski (2019) stated that wood is a preferred choice for furniture production due to its natural qualities. Wooden furniture is valued for its durability, hardness, and ability to withstand various climatic conditions. Its natural properties also bring a fresh aesthetic to interior designs. However, it is important to protect wooden furniture from moisture, water, and dust, as these can cause significant damage. Engler, (2017) found that wood possesses greater strength along the grain compared to across it. This statement is also confirmed by the study on the material properties of softwood, specifically pine, which shows that tensile strength and yield strength across the grain are lower compared to along the grain. The tensile strength for softwood along the grain is 80 MPa, whereas across the grain it is 3.55 MPa. This difference is attributed to the fact that wood experiences greater movement across the grain than along it. Wood cells are composed of long, tough cellulose fibers bound together by a glue-like substance called lignin (Kramer, 2006). Cellulose is much tougher than lignin, making it difficult to break the wood across the grain, as this would involve snapping the cellulose fibers. Based on the study, the toughness of the material differs significantly in terms of Young's Modulus values especially for wood along grain and across grain. Softwood: pine demonstrate higher Young's Modulus values along the grain compared to hardwood oak across the grain, reaching up to 9.35 GPa.

4.2.2 Material Selection on Padding Cushion

The material selection for the padding cushion focused on key properties such as Young's modulus and density. The analysis primarily relied on Young's modulus vs. density chart to evaluate the suitability of various materials. This approach was further supported by considering additional material properties, including Poisson's Ratio, heat of combustion, and material price. By incorporating these factors, the selection process aimed to identify materials that not only meet the mechanical requirements but also offer optimal performance in terms of thermal properties and cost-efficiency. This comprehensive evaluation ensured that the chosen material would provide the best balance of strength, comfort, and sustainability for the padding cushion.

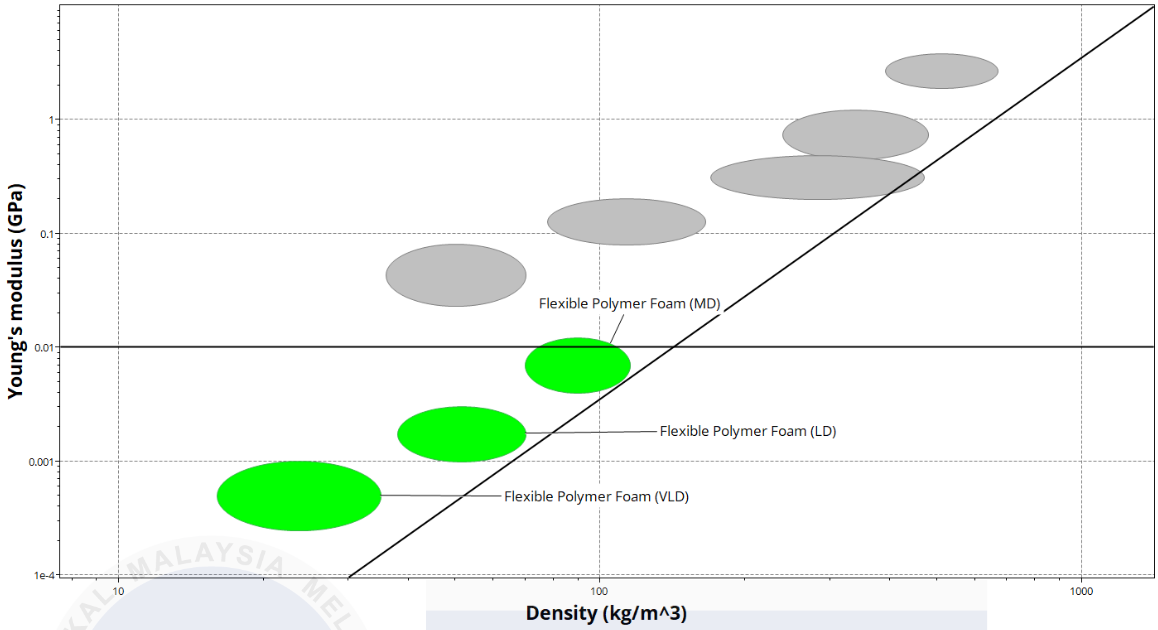


Figure 4.8: Young's Modulus vs Density (Padding)

Figure 4.8 illustrates the correlation between Young's modulus and density of the materials. The slope of 3 is used as a line to narrow down the number of candidates, in accordance with the material index of (E^1/3 / ρ). By evaluating materials that align with the design criteria, three potential candidates have been identified as suitable for use in the padding cushion. These three material candidates considered for the floor chair structure are: -

1. Flexible Polymer Foam Medium Density (MD)
2. Flexible Polymer Foam Low Density (LD)
3. Flexible Polymer Foam Very Low Density (VLD)

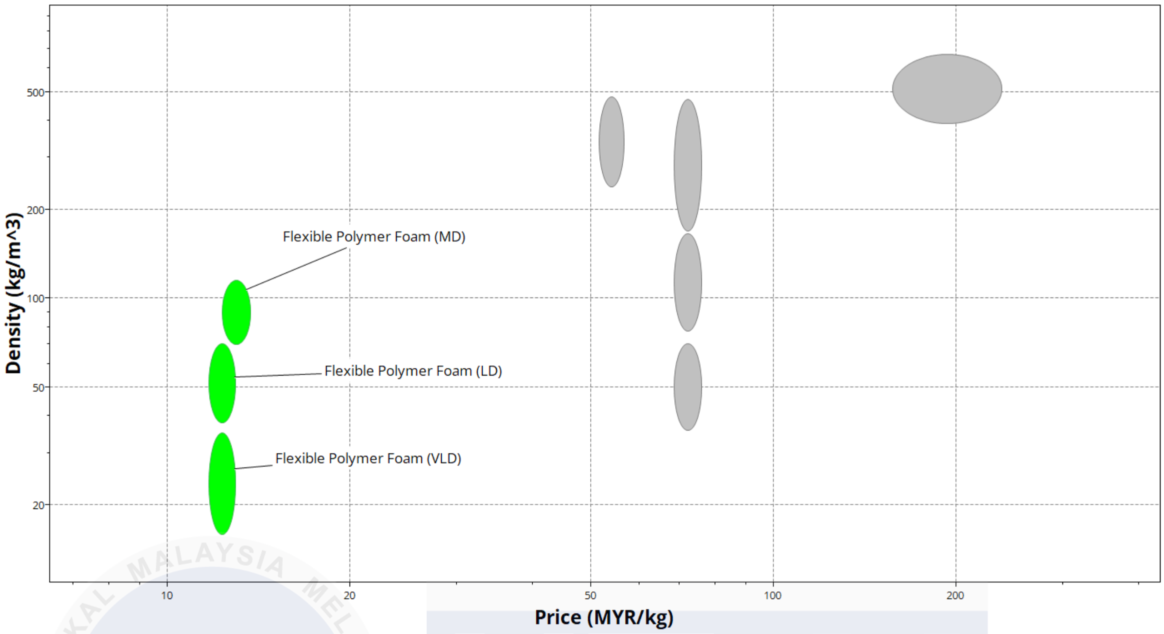


Figure 4.9: Density vs Price (Padding)

Figure 4.9 shows the correlation between the density and price of various materials. The study focuses on the low cost of floor chair production especially for padding foam, highlighting the importance of considering price as a key factor in selecting materials for the padding cushion. The graph indicates that Flexible Polymer Foam (LD) and Flexible Polymer Foam (LD) are the least expensive materials among all the candidates. Meanwhile, Flexible Polymer Foam (VLD) is the lightest material among the candidates, and Flexible Polymer Foam (MD) has the highest density and is also the costliest among all the materials considered. The material properties of these materials are detailed in Table 4.14 below.

Table 4.14: Candidate Materials Padding Cushion

Material	**Flexible Polymer Foam (MD)**	**Flexible Polymer Foam (LD)**	**Flexible Polymer Foam (VLD)**
Price (MYR/kg)	12.3 – 13.7 @13	11.7 – 12.9 @12.3	11.7 – 12.9 @12.3
Density (kg/m^3)	70 – 115 @92.5	38 – 70 @54	16 – 35 @25.5
Young's Modulus (GPa)	0.004 – 0.012 @0.008	0.001 – 0.003 @0.002	2.5e-4 – 0.001 @0.000625

Material	Flexible Polymer Foam (MD)	Flexible Polymer Foam (LD)	Flexible Polymer Foam (VLD)
Heat of Combustion (net)	43.9 – 46.2 @45.05	44 – 46.2 @45.1	44 – 46.2 @45.1
Poisson's Ratio	0.26 – 0.33 @0.295	0.23 – 0.33 @0.28	0.23 – 0.30 @0.265

Table 4.14 lists the properties of each candidate material, including price, density, Young's modulus, heat of combustion, and Poisson's Ratio. These values, sourced from Granta Edupack software, ensure accurate and reliable data for analysis. By presenting these values, Table 4.14 highlights the differences among the candidate materials, facilitating a thorough comparison. This detailed comparison is crucial for selecting the most suitable material for the padding cushion, as it underscores variations in cost, stiffness, thermal properties, and environmental impact. The scores for the candidate materials, shown in Table 4.15, have been evaluated to determine the most suitable material based on these properties.

Table 4.15: Material Score for Padding Cushion

Material	Flexible Polymer Foam (MD)	Flexible Polymer Foam (LD)	Flexible Polymer Foam (VLD)
Price (MYR/kg)	6	10	10
Density (kg/m^3)	2	4	10
Young's Modulus (GPa)	4	6	10
Heat of Combustion (net)	10	8	8

Material	Flexible Polymer Foam (MD)	Flexible Polymer Foam (LD)	Flexible Polymer Foam (VLD)
Poisson's Ratio	8	7	6
TOTAL SCORE	30	35	44

Table 4.15 shows the scores for the candidate materials based on their properties. For price and density, materials with lower values receive higher scores, aligning with the study's focus on optimizing production costs and achieving a lightweight floor chair product. In contrast, for other properties such as Poisson's Ratio, heat of combustion, and Young's modulus, higher values result in greater scores, reflecting their importance in the material selection process. The total scores indicate that Flexible Polymer Foam (VLD) received the highest mark with a total score of 44, while Flexible Polymer Foam (MD) received the lowest mark.

Table 4.16: Material Selection for Padding Cushion

Material	Index, M = (GPa)^1/3 / (kg/m^3)	Comment
Flexible Polymer Foam (MD)	2.16e-3	High density, high toughness, excellent heat of combustion but high cost.
Flexible Polymer Foam (LD)	2.33e-3	Low cost, good density, excellent heat of combustion.
Flexible Polymer Foam (VLD)	3.35e-3	Low cost, low density, low toughness and good heat of combustion.

Table 4.16 shows the material index value for each candidate material. Flexible Polymer Foam (VLD) has the highest material index value among the candidates, at 3.35e-3 GPa/kgm³. This material demonstrates low stiffness, which enhances comfortability, making it ideal for seating applications. Additionally, it boasts low cost, low density, and excellent heat of combustion properties. These attributes make Flexible Polymer Foam (VLD) a highly suitable choice for the floor chair structure, balancing cost-efficiency, comfort, and performance.

Flexible polymer foams are extensively utilized because of their advantageous properties. Their low density contributes to significant weight reduction compared to alternative materials (Kiss et al., 2021). Moreover, their flexibility and softness ensure enhanced comfort in furniture applications. These properties allow the foam to conform to the body's contours, providing a cushioning effect that improves seating comfort over extended periods. Polymer foams exhibit very low thermal conductivity due to the small amount of solid material within the foam, typically ranging from 3% to 10% of the total volume (Sivertsen, 2007). The flexible polymer also can be combusted for energy recovery. This means that when the polymer foam is burned, it releases heat energy, which can be harnessed for various purposes such as generating electricity or heating. It’s not only generating usable heat but also promotes sustainability by efficiently utilizing the material's energy content and reducing waste. The heat of combustion for flexible polymer foam (very low density) ranges from 44 to 46.2 MJ/kg stated in Granta software, showcasing its high energy potential for applications like power generation and heating systems at the end of the life cycle. Flexible polymer foams (VLD) are highly versatile materials, offering a combination of comfort, thermal efficiency, and energy recovery potential, making them valuable for sustainable practices and applications floor chair design.

4.3 Floor Chair 3D CAD Drawing using CATIA

The final selected conceptual design, determined using the TOPSIS method, was converted into a CAD drawing through CATIA software. This process ensured that the design's specifications and details were accurately represented in a digital format. This CAD model serves as a foundation for prototyping and manufacturing, ensuring that the conceptual design is faithfully realized in the physical product. Figure 4.10 shows the isometric view of the floor chair designed by using CATIA software.

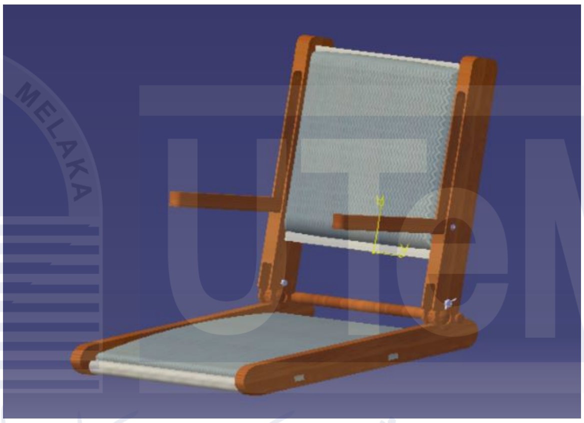


Figure 4.10: Isometric view

The multiple view of the floor chair is depicted in Figure 4.11. These views provide a comprehensive understanding of the chair's design from various angles.

Figure 4.11: Multiple view

The overall floor chair design was inspired by research findings published by (Abdullah et al., 2020). These studies suggested that a foldable could save space, enhancing space efficiency and contributing to a more sustainable design. The foldable feature not only allows for easy storage but also reduces the material footprint, aligning with modern sustainability goals. Figure 4.12 shows the drafting of assembly view of the floor chair.

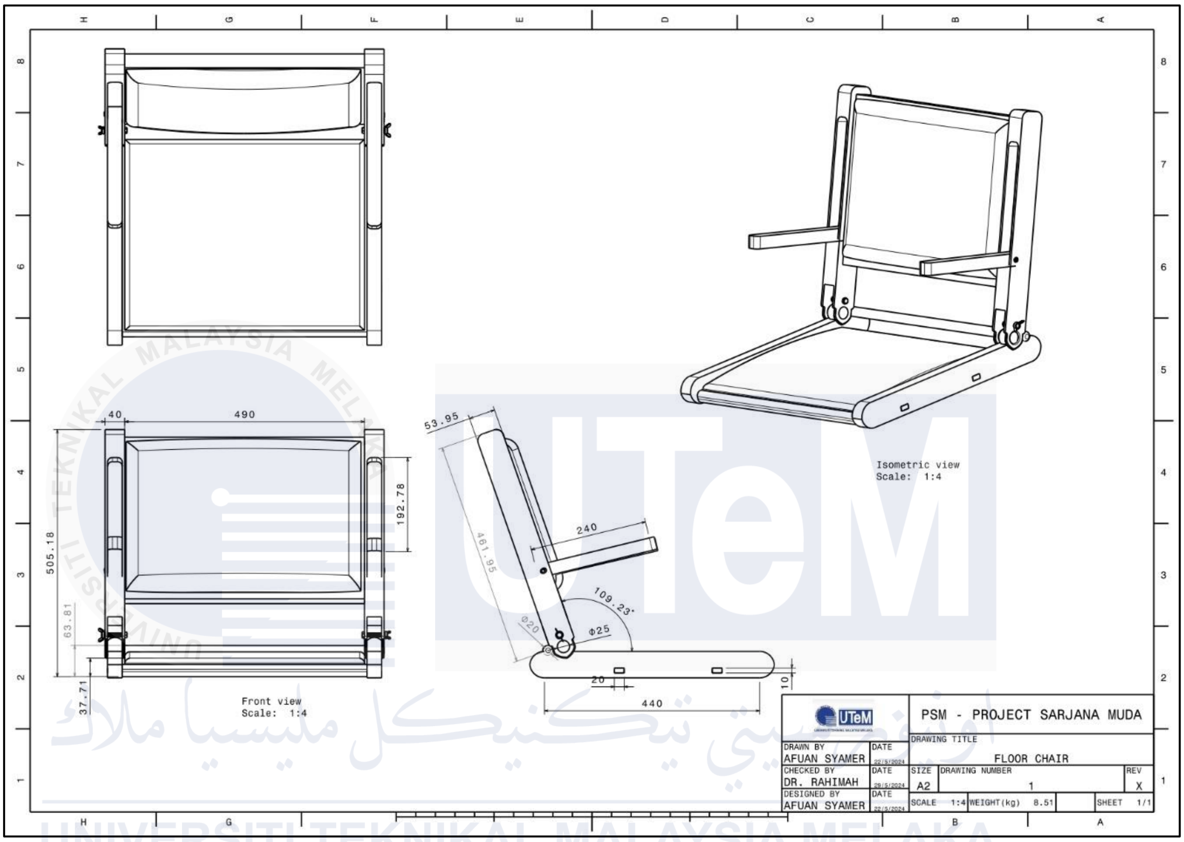


Figure 4.12: Technical Drawing of Assembly View

The technical drawing of the floor chair in CATIA drafting involves creating a detailed and precise representation of the chair’s design, dimensions, and specifications. Figure 4.12 shows the technical drawing of the assembly view for the floor chair, while Figure 4.13 presents the technical drawing of the exploded view along with the bill of materials (BOM) for the floor chair design, providing detailed information about the product's components. The dimensions of the floor chair design are 56 cm x 50 cm x 50.7 cm.

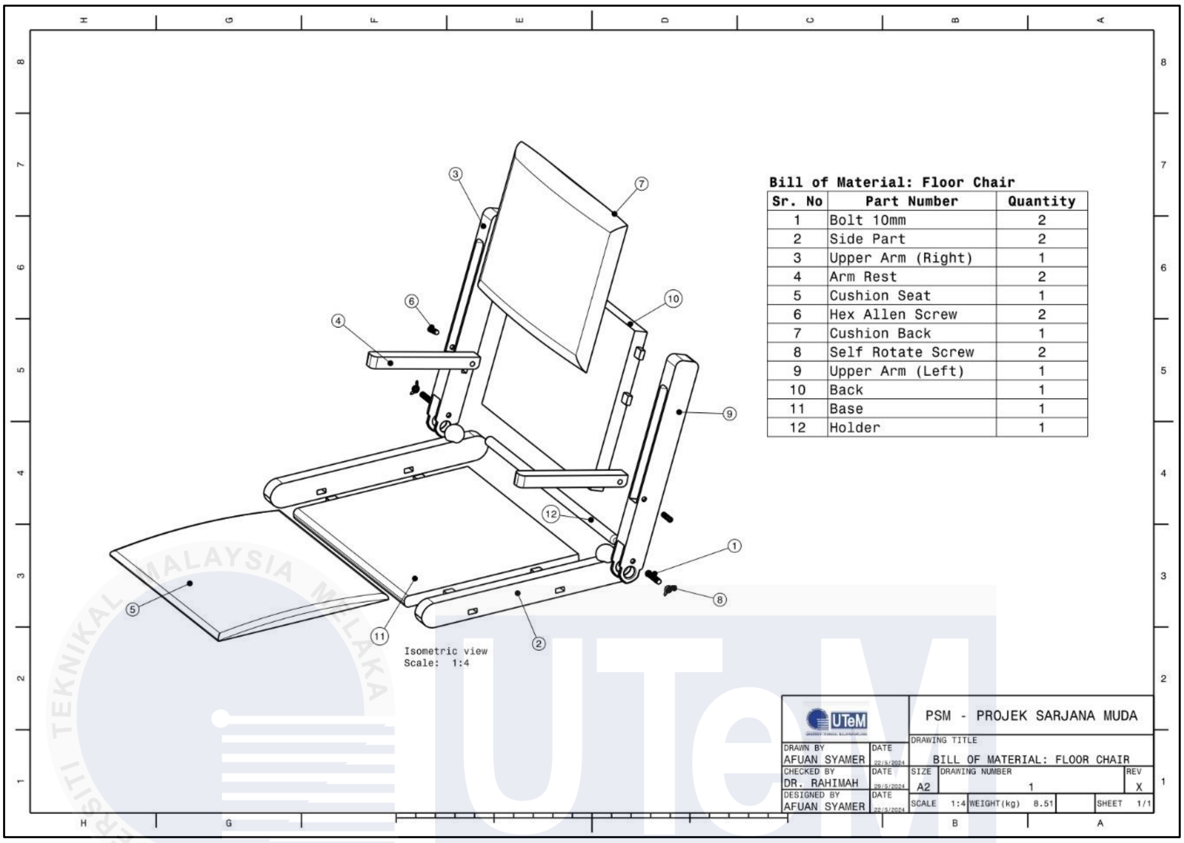


Figure 4.13: Bill of Materials

The floor chair design consists of a total of 17 parts, including paired components such as 10 mm bolts, side parts, armrests, hex Allen screws, and self-rotating screws. These drawings are crucial for ensuring accuracy in manufacturing and assembly, as they offer a comprehensive visual guide to the chair's construction and individual parts. The inclusion of the BOM in Figure 4.13 further aids in identifying and sourcing the necessary components, streamlining the production process.

4.4 RULA Analysis Results

This section presents the findings from the Rapid Upper Limb Assessment (RULA) analysis conducted to evaluate the ergonomic risks associated with the sitting posture of the Manikins by using CATIA software. The analysis focused on various body dimensions of the Manikins, using Malaysian anthropometric data from the 95th percentile, 50th percentile of males, and 5th percentile of females to determine the level of risk and ergonomic aspects of the floor chair. An acceptable final RULA score is 1 or 2, indicating that the floor chair design is ergonomic.

4.4.1 RULA analysis result for 5^{th} female percentile

The RULA analysis conducted for 5th percentile of female Manikin based on Malaysian anthropometric data. The anthropometric dimensions of the 5th percentile female Manikin stated in Table 4.17.

Table 4.17: Anthropometric dimension of 5^{th} female percentile

Anthropometric Dimensions	**5^{th} Percentile**
Stature	1466.69 mm
Sitting Height	667.12 mm
Chest Breadth	234.00 mm
Hip Breadth	261.22 mm
Weight (kg)	48.28 kg

The analysis was conducted using CATIA software with the Human Builder features to evaluate the ergonomic elements of human performance for sitting posture on the floor chair. The body posture was set to be intermittent, with a repeated frequency of less than four times per minute. Additionally, the arms were supported by armrests, and the body posture was leaning.

Figure 4.14: 5th percentile female Manikin

Figure 4.14 shows the 5th percentile female manikin attached to the floor chair model for RULA analysis. The body posture of the manikin has been adjusted to align with the floor chair model, ensuring an accurate assessment of the ergonomic fit and support provided by the chair for individuals within this percentile range.

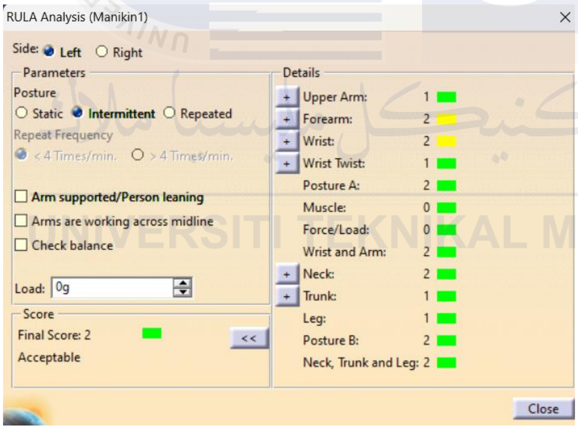


Figure 4.15: 5th percentile left side RULA score

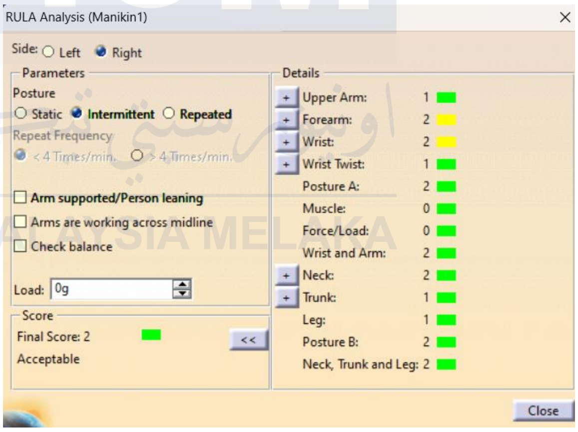


Figure 4.16: 5th percentile right side RULA score

The RULA score for the 5th percentile female manikin is shown in Figure 4.15 for the left side and Figure 4.16 for the right side. The results indicate that Posture A has a score of 2, which is acceptable for a RULA score. Posture B also has a RULA score of 2, with the forearm and wrist highlighted as scoring 2. Additionally, the neck, trunk, and leg scores are also 2. Thus, the final RULA score for the 5th percentile female manikin is 2, indicating an acceptable posture. Therefore, the floor chair design can be considered ergonomic for the 5th percentile of Malaysian females.

4.4.2 RULA analysis result for 50th male percentile

The RULA analysis conducted for 50th percentile of male Manikin based on Malaysian anthropometric data. The anthropometric dimensions of the 50th percentile male Manikin stated in Table 4.18.

Table 4.18: Anthropometric dimension of 50th male percentile

Anthropometric Dimensions	50th Percentile
Stature	1686.18 mm
Sitting Height	913.90 mm
Chest Breadth	354.64 mm
Hip Breadth	375.39 mm
Weight (kg)	66.64 kg

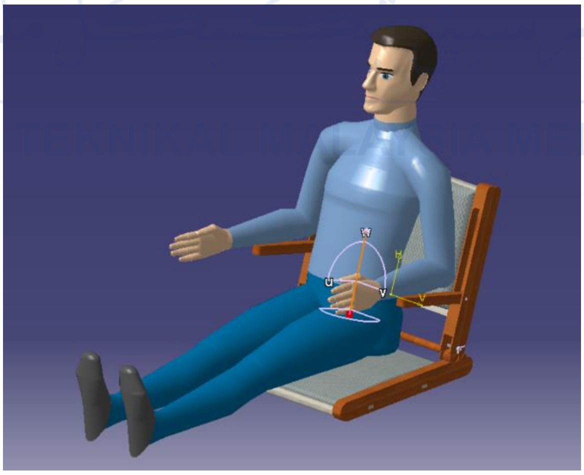


Figure 4.17: 50th percentile male Manikin

Figure 4.17 shows the 50th percentile male manikin attached to the floor chair model for the RULA analysis. The body posture of the manikin has been carefully adjusted to fit the contours and dimensions of the floor chair model, ensuring an accurate representation of how the chair supports the user. This setup allows for a detailed evaluation of the ergonomic suitability of the chair design for individuals within this percentile range.

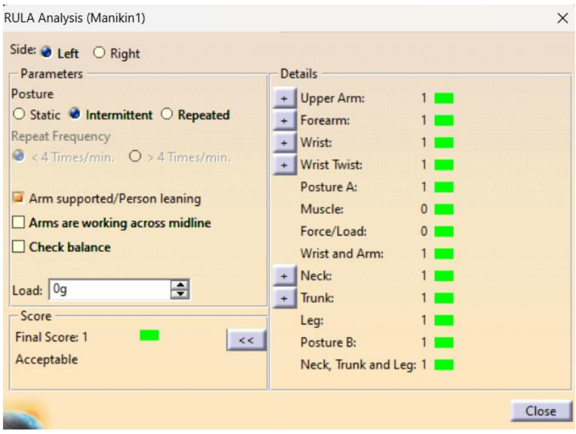


Figure 4.18: 50th percentile left side RULA score

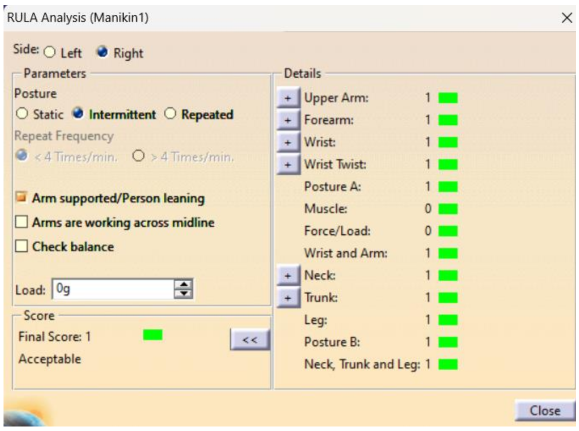


Figure 4.19: 50th percentile right side RULA score

The RULA score for the 50th percentile male manikin is shown in Figure 4.18 for the left side and Figure 4.19 for the right side. The results indicate that Posture A has a score of 1, which is an acceptable RULA score. Posture B also has a RULA score of 1, as do the wrist and arm scores. Additionally, the neck, trunk, and leg scores are also 1. Thus, the final RULA score for the 50th percentile male manikin is 1, indicating an acceptable posture. Therefore, the floor chair design can be considered ergonomic for the 50th percentile of Malaysian males.

4.4.3 RULA analysis result for 95th male percentile

The RULA analysis conducted for 95th percentile of male Manikin based on Malaysian anthropometric data. The anthropometric dimensions of the 95th percentile male Manikin stated in Table 4.19.

Table 4.19: Anthropometric dimension of 95th male percentile

Anthropometric Dimensions	95th Percentile
Stature	1797.93 mm
Sitting Height	956.02 mm
Chest Breadth	438.52 mm

Anthropometric Dimensions	95th Percentile
Hip Breadth	488.69 mm
Weight (kg)	126.46 kg

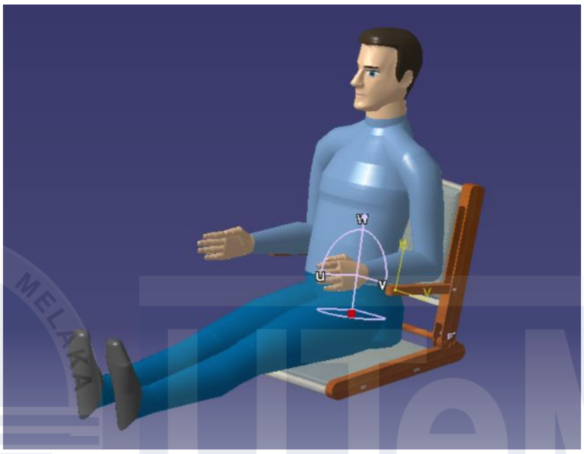


Figure 4.20: 95th percentile male Manikin

Figure 4.20 shows the 95th male Manikin attached to floor chair model for RULA analysis. The body posture of the Manikin has been adjusted according to the floor chair model.

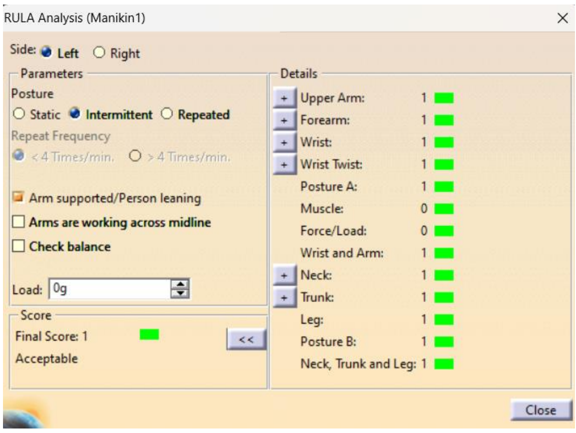


Figure 4.21: 95th percentile left side RULA score

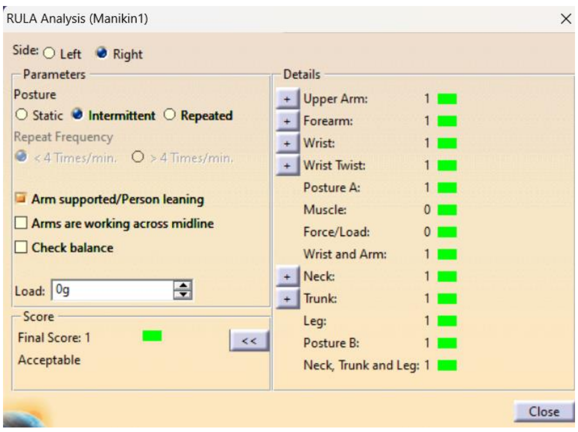


Figure 4.22: 95th percentile right side RULA score

The RULA score for the 95th percentile male manikin is shown in Figure 4.21 for the left side and Figure 4.22 for the right side. The results indicate that Posture A has a score of 1, which is an acceptable RULA score. Posture B also has a RULA score of 1, as do the wrist and arm scores. Additionally, the neck, trunk, and leg scores are also 1. Thus, the final RULA score for the 95th percentile male manikin is 1, indicating an acceptable posture. Therefore, the floor chair design can be considered ergonomic for the 95th percentile of Malaysian males.

Overall, the ergonomic analysis of the floor chair design has been completed. The results from the RULA analysis indicate that the design and dimensions of the floor chair model are suitable for the 5th percentile female, as well as the 50th and 95th percentile male manikins within the Malaysian population. The total final RULA scores range between 1 and 2, which are considered acceptable scores for the product to be deemed ergonomic. This indicates that the floor chair design provides adequate support and promotes proper posture for a broad range of body sizes, confirming its ergonomic suitability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The findings of the study on design and development of ergonomic and green floor chairs are summarized in this chapter. In addition, some recommendations for the future study for this project are also discussed.

5.1 Concluding Remarks

Throughout the comprehensive study on "Design and Analysis of Ergonomic and Green Floor Chair," the objectives were systematically and rigorously addressed and fulfilled. This process included identifying problem statements, developing design models, conducting ergonomic analyses, and interpreting data. The successful achievement of these objectives validates the chosen research methodology, strengthens the study's findings, and contributes significantly to the advancement of floor chair development in line with green concepts. This thorough approach ensures that the final design not only meets ergonomic standards but also adheres to sustainability principles, promoting both user well-being and environmental responsibility.

The initial problem highlighted that the design of the floor chair needed to fulfill several requirements such as ergonomics, use of green materials, comfort, and foldability. Several conceptual designs were developed based on these criteria. However, selecting the best conceptual design that meets all the criteria presented a challenge. To address this, a multi-criteria decision analysis was conducted to select the optimal design in accordance with the specified criteria. The TOPSIS method was employed for this analysis, as it systematically evaluates multiple criteria to determine the best option. This method involves several steps, including calculations that lead to the final preference scores for all alternatives, which are then ranked accordingly. The results of the TOPSIS analysis indicated that Design 3 is the best conceptual design based on all the evaluated criteria. This conclusion underscores the effectiveness of the TOPSIS method in making informed and balanced design decisions.

A green product is designed to minimize environmental impact. This includes products made from recycled materials, those designed for reuse or recycling, and those made from renewable resources. To implement the green concept in floor chair design, a material selection process was conducted using Granta EduPack software. This software was used to assess suitable materials for the floor chair structure and padding cushion, focusing on criteria such as low density, cost-effectiveness, and high strength properties. The results of this analysis indicate that softwood, specifically pine along the grain, is the best material for the floor chair structure. This material has great strength, low density, and low cost. For the padding cushion, flexible polymer foam with very low density was chosen as the best material. It is low in density, inexpensive, and has low toughness, providing comfort during sitting. Thus, it can be concluded that the objectives of this section have been successfully achieved.

A non-ergonomic floor chair design can cause discomfort, back pain, and poor posture, potentially leading to musculoskeletal issues with prolonged use (Sholihah et al., 2019). The third objective of this study was to analyze the ergonomic value of the floor chair design, determining user comfort for the 95th and 50th percentiles of male anthropometric data and the 5th percentile of female data. To accomplish this, a RULA analysis was performed on the 3D CAD model of the floor chair using CATIA software. The results showed that the final RULA score for both the 95th and 50th percentiles of male manikins were 2, which is an acceptable score and considered ergonomic for these body dimensions. Similarly, the final RULA score for the 5th percentile of female manikins was also 2, indicating that the floor chair design has an acceptable ergonomic score for all percentiles. Thus, the objective of achieving an ergonomic design was successfully met, as indicated by the final RULA score of 2. Consequently, it can be concluded that all the objectives of this study have been successfully achieved.

5.2 Recommendations

An extension of work for further study investigates the structural behaviours and sustainability of the materials can be sought, with suggestions as follow:

i. To study the structural behaviors of the floor chair design by using ANSYS simulation software.

ii. To evaluate the effect of material of the floor chair to the environment by using OpenLCA software.

5.3 Sustainability Element

In this study, sustainability is a key focus, driving the design and material selection for the green floor chair concept. Emphasizing eco-friendly and green materials, the research explores several natural options to minimize the environmental impact of floor chair production. The analysis leverages the Granta software to compare the material properties, ensuring that chosen materials align with sustainability principles. This includes considering the recyclability, biodegradability, and overall carbon footprint of each material. The green floor chair concept not only focuses on ecological concerns but also promotes sustainability in furniture production. It incorporates energy-efficient manufacturing processes and designs for disassembly and recycling at the end of the chair's lifecycle. This holistic ensures that the environmental benefits do not compromise the ergonomic quality of the floor chair, shows how responsible design choices can lead to products that support both a healthier lifestyle and planet. Through the focus on sustainability and green concept, the study contributes to a broader movement towards eco-friendly innovation in the furniture industry.

5.4 Complexity Element

The complexity element reveals several challenges encountered in this study. First, there was the challenge of obtaining information for the ergonomic design of a floor chair from previous research papers and identifying the design requirements, which included several criteria due to a lack of information and data. Additionally, the Granta software had limited materials to choose from for eco-friendly and green materials for the floor chair. Due to these limitations, the analysis focused only on several natural materials to compare their properties. Another complexity arose from the RULA analysis using CATIA software, which required using a Manikin that had only been preset in the software. The Malaysian anthropometric data was referred to as the scope of this study. The measurements of the Manikin were adjusted to respect Malaysian anthropometric data, but several parts of the body dimensions might not be accurate, affecting the RULA score results.

5.5 Lifelong Learning

This study embraces lifelong learning as a continuous, self-initiated process emphasizing personal growth and ongoing knowledge acquisition. The exploration of the material selection process for the floor chair, through comparison of several materials and their properties in respect to design requirements, has provided valuable insights into the realm of floor chair furniture production. In this context, lifelong learning is manifested through the continuous pursuit of knowledge and understanding to enhance the quality of material selection for green concept furniture, particularly floor chairs. The study also emphasizes the importance of multi-decision criteria analysis for floor chair design, achieved through the TOPSIS analysis method to determine the best design that fulfills the necessary criteria. Lifelong learning in this study is exemplified by recognizing the need to consider several requirements for an optimal design selection process. The design of the floor chair was found to affect the ergonomic results through RULA analysis. The ergonomic design enhanced the RULA score to be acceptable for the design. This keeps the field moving forward by demonstrating how the ergonomic and green aspects of furniture can improve human health, particularly seating posture, and positively impact the environment.

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APPENDICES

A Gantt Chart for PSM I

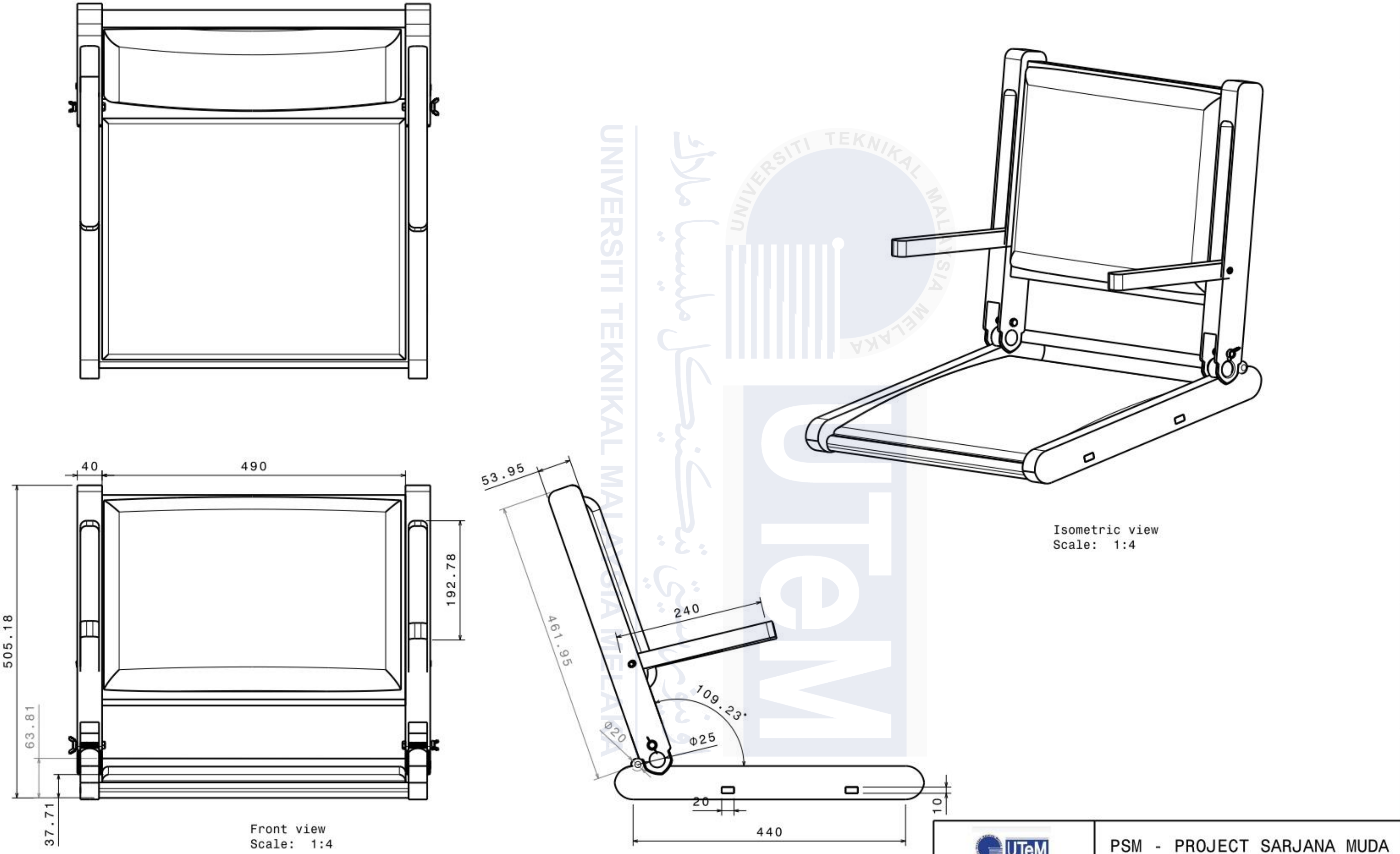
Table: Gantt Chart of PSM I

Activities	PSM I													
	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PSM Title Registration														
PSM 1 Briefing from Supervisor														
Discussion of the project progress														
Chapter 1: Introduction														
Chapter 2: Literature Review														
Chapter 3: Methodology														
Logbook PSM I Submission														
PSM I Presentation														
PSM I Report Submission														

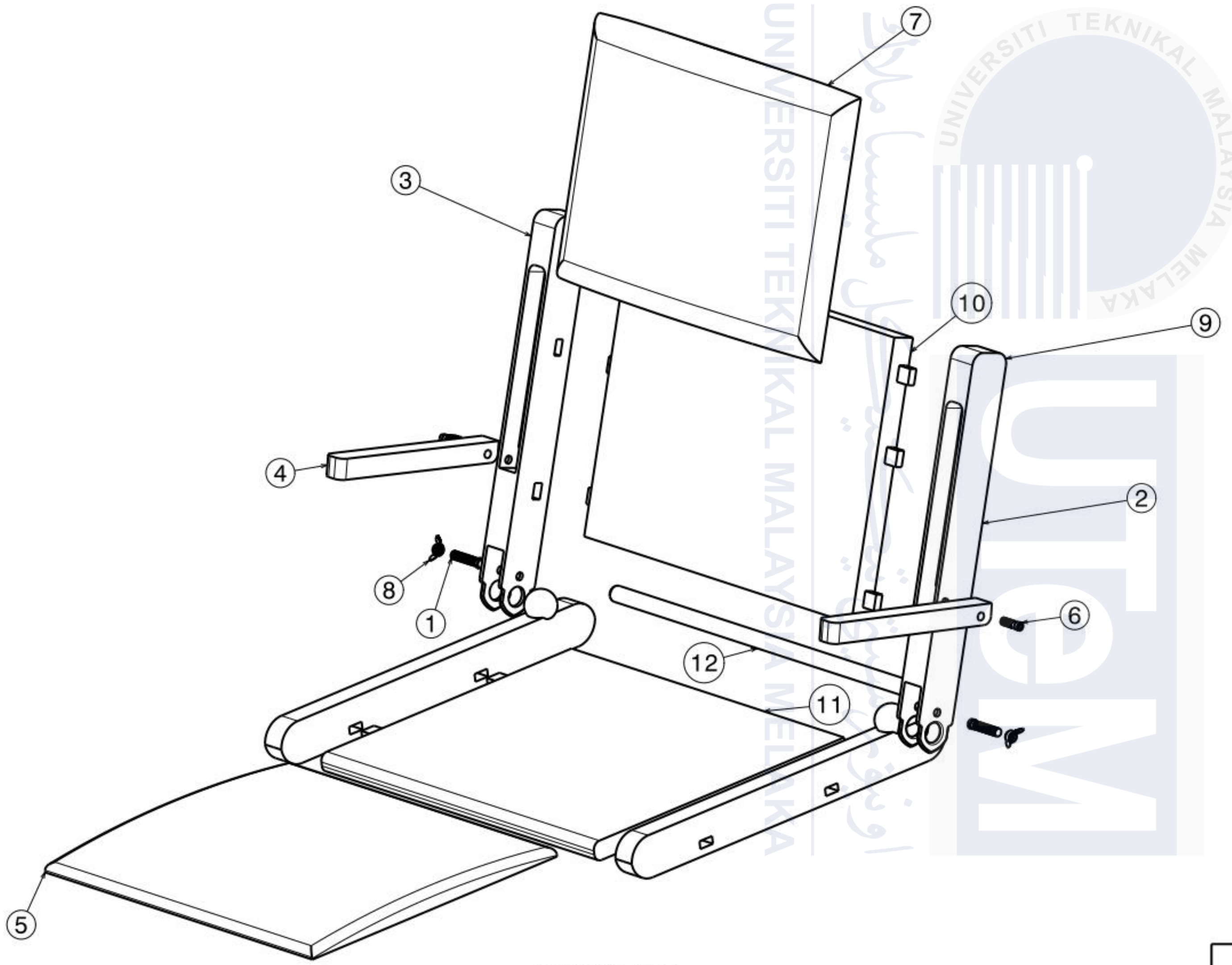
B Gantt Chart for PSM II

Table: Gantt Chart of PSM II

Activities	PSM II													
	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PSM II Briefing from Supervisor														
Survey 1: Design Criteria														
Conceptual Design														
Survey 2: Conceptual Design														
TOPSIS Analysis														
Material Selection (Granta software)														
3D CAD Model of Floor Chair														
RULA Analysis														
Report Writing														
PSM II Presentation														
PSM II Report Submission														



UTeM		PSM - PROJECT SARJANA MUDA				
DRAWN BY AFUAN SYAMER	DATE 22/5/2024	DRAWING TITLE FLOOR CHAIR				
CHECKED BY DR. RAHIMAH	DATE 29/5/2024	SIZE A2	DRAWING NUMBER 1			REV X
DESIGNED BY AFUAN SYAMER	DATE 22/5/2024	SCALE 1:4	WEIGHT(kg) 8.51		SHEET 1/1	



Isometric view
Scale: 1:4

Bill of Material: Floor Chair

Sr. No	Part Name	Quantity
1	Bolt 10mm	2
2	Side Part (Left)	2
3	Upper Arm (Right)	1
4	Arm Rest	2
5	Cushion Seat	1
6	Hex Allen Screw	2
7	Cushion Back	1
8	Self Rotate Screw	2
9	Upper Arm (Left)	1
10	Back	1
11	Base	1
12	Holder	1

UTeM		PSM - PROJECT SARJANA MUDA	
DRAWN BY: AFUAN SYAMER	DATE: 22/5/2024	DRAWING TITLE: BILL OF MATERIAL - FLOOR CHAIR	
CHECKED BY: DR. RAHIMAH	DATE: 29/5/2024	SIZE: A2	DRAWING NUMBER: 1 — REV: X
DESIGNED BY: AFUAN SYAMER	DATE: 22/5/2024	SCALE: 1:4	WEIGHT(kg): 8.51 — SHEET: 1/1