A USER-CENTERED APPROACH TO PACKAGING DESIGN FOR EXOSKELETON FOR SOLAT

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B052010056

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

A USER-CENTERED APPROACH TO PACKAGING DESIGN FOR EXOSKELETON FOR SOLAT

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

by

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010804-10-0146

FACULTY OF INDUSTRIAL AND MANUFACTURING

TECHNOLOGY AND ENGINEERING

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **A USER-CENTERED APPROACH TO PACKAGING DESIGN FOR EXOSKELETON FOR SOLAT**

Sesi Pengajian: **2023/2024 Semester 2**

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Date : 28 June 2024

APPROVAL

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

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ABSTRAK

Tesis ini membentangkan pembangunan penyelesaian pembungkusan yang disesuaikan untuk exoskeleton yang direka untuk Solat, bertujuan untuk mengoptimumkan kemudahalihan dan perlindungan semasa pengangkutan. Objektifnya adalah untuk mengenalpasti keperluan dan pilihan pengguna melalui tinjauan, mendedahkan cabaran fizikal semasa Solat seperti ketidakselesaan lutut dan sakit belakang. Responden menekankan ciri seperti menggunakan bahan yang ringan, kebolehcapaian yang mudah dan ketahanan yang tinggi. Reka bentuk 1 yang berbentuk segi empat muncul sebagai pilihan berbanding reka bentuk 2 (beg beroda), terkenal dengan kesederhanaan dan reka bentuk yang jimat ruang. Secara metodologi, analisis matriks pemilihan menggunakan House of Quality (HoQ), tapisan konsep dan pemarkahan untuk memuktamadkan pembungkusan reka bentuk yang mengutamakan perlindungan dan mudah alih. Reka bentuk 1 dikenal pasti sebagai optimum, cemerlang dalam ketahanan dan mudah alih walaupun mempunyai ruang yang terhad. Pemilihan bahan tertumpu pada Polylactic Acid (PLA) kerana sifatnya yang ringan, biodegradasi dan kelebihan kemampanannya. Bahan berasas PLA menangani keperluan pengguna khusus untuk keselesaan ergonomik semasa perjalanan jarak dekat ke masjid, memastikan perlindungan yang teguh dengan pelapik dalaman dan tali yang selamat. Analisis struktur menggunakan ANSYS mengesahkan kesesuaian PLA di bawah beban simulasi 4 kg, menunjukkan ubah bentuk minimum dan kepekatan tegasan dalam had operasi yang selamat untuk mencapai keberkesanan yang direka dalam melindungi rangka luar untuk Solat. Rapid Upper Limb Assessment (RULA) menganalisis keberkesanan reka bentuk yang memfokuskan pada analisis ergonomik, menunjukkan risiko ergonomik yang rendah untuk manikin lelaki dan perempuan. Kajian ini berjaya memenuhi keperluan pengguna sambil memberikan perlindungan yang berkesan. Penambahbaikan masa hadapan boleh menumpukan pada peningkatan ergonomik untuk mengurangkan ketegangan lengan dan pergelangan tangan.

ABSTRACT

This paper presents the development of a tailored packaging solution for exoskeletons designed for Solat, aimed at optimizing portability and safeguarding during transportation. The objective was to identify user needs and preferences through survey on optimal packaging design solutions for an exoskeleton for Solat. Respondents emphasize features like lightweight materials, easy accessibility, and durability. Design 1, a square hand-carry case, emerged as the preferred choice over Design 2 (roller bag), noted for its simplicity and space-efficient design. Methodologically, a selection matrix analysis utilizing House of Quality (HoQ), concept screening and scoring to finalize design packaging that prioritized protection and portability. The square hand-carry case was identified as optimal, excelling in durability and portability while acknowledging storage limitations. Material selection focused on Polylactic Acid (PLA) due to its lightweight, biodegradable properties and sustainability advantages. The PLA-based hand-carry case addressed specific user needs for ergonomic comfort during short-distance travel to mosques, ensuring robust protection with internal padding and secure straps. Structural analysis using ANSYS validated PLA's suitability under a simulated 4 kg load, demonstrating minimal deformation and stress concentrations within safe operational limits to achieve the designed effectiveness in safeguarding the exoskeleton for Solat. Rapid Upper Limb Assessment (RULA) analyzed designed effectiveness focusing on ergonomic analysis, indicated a low ergonomic risk for both male and female manikins carrying the hand-carry case. Moderate concerns in forearm and wrist-arm areas highlighted the need for ergonomic adjustments, particularly for female users, to enhance prolonged use comfort. The study successfully meeting user needs while providing effective protection. Future improvements could focus on ergonomic enhancements to reduce forearm and wrist strain.

DEDICATION

This thesis is dedicated to my family whose unwavering support and encouragement have been a foundational pillar throughout this academic pursuit. Their unwavering faith in my capabilities has been a driving force behind my determination to make a meaningful contribution to the academic community.

I would like to extend my sincere gratitude to my supportive supervisor, Dr. Zulkeflee, whose intellectual advice and insights have greatly enhanced the substance of this study. I express my deep gratitude to my friends for encouraging me and assist me in this journey. Lastly, I want to thank me for countless hours of dedication and hard work poured into this endeavour. This thesis is a testament to personal growth and resilience. I appreciate the invaluable inspiration from all those who have played a role in this academic pursuit.

ACKNOWLEDGEMENT

I extend my sincere gratitude to those who have contributed to the completion of this thesis.

First and foremost, I am deeply thankful for the unwavering support of my family. Their encouragement and understanding provided the solid foundation for this academic endeavour. I would like to express my appreciation to my supervisor Dr. Zulkeflee for his invaluable guidance, expertise and constructive feedback throughout the research process. His mentorship played a pivotal role in shaping the trajectory of this work. I am also grateful to my friends who provided insightful discussions and a supportive academic community.

Lastly, I acknowledge the countless hours dedicated to this endeavour, a commitment fuelled by personal passion and the pursuit of knowledge. Each of these people played a significant role in the realization of this project and for that I am truly thankful.

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LIST OF ABBREVIATIONS

ANSYS	-	Analysis System
ABS	-	Acrylonitrile Butadiene Styrene
CAD	-	Computer-Aided Design
CAM	-	Computer-Aided Manufacturing
CAE	-	Computer-Aided Engineering
CATIA	-	Computer-Aided Three-Dimensional Interactive Applications
FEA	-	Finite Element Analysis
RP	-	Rapid Prototyping
PLA	-	Polylactic Acid
SDG	-	Sustainable Development Goal

CHAPTER 1
INTRODUCTION

1.1 Research Background

The study concerning developing user-centered packaging for exoskeleton for Solat specifically customized for elderly individuals is prompted by a significant gap in the current literature. Research and studies that are thorough in their approach to the design and development of packaging or carriers intended explicitly for transporting exoskeletons are noticeably lacking.

Exoskeletons are a specific type of orthosis that work harmoniously with their users to enhance physical performance and enable the completion of tasks or movements. The possibility of reducing muscular activity in the supported body area by using an exoskeleton was shown in three evaluations on exoskeletons that support the upper limbs and back (Theurel & Desbrosses, 2019). Due to aging societal issues, increasing demand for such assistive technology to help senior citizens remain independent has arisen recently, bringing new situations for helping older adults with daily living tasks to light. A crucial component of being independent is personal mobility capacities. Exoskeleton for Solat tailored to augment mobility and facilitate prayer for elderly or physically limited individuals. In catering to the unique needs of the elderly, it is imperative to acknowledge that an ideal packaging design extends beyond the conventional parameters. The ability of optimal packaging design to preserve the package's stability and mechanical strength is crucial (Fadiji *et al.,* 2018). It is crucial for protecting the exoskeleton but also thoughtfully crafted to align with the physical capabilities and preferences of elderly users. This gap in the literature emphasizes the urgency with which tailored packaging solutions are needed, particularly considering the specific requirements of elderly individuals who require exoskeletons for assistive support tools during prayer.

The study will leverage advanced simulation tools such as ANSYS for structural behaviour and CATIA for ergonomic analysis to ensure the effectiveness and efficiency of the packaging design. ANSYS simulation employs a structural analysis that specifically utilizes its Finite Element Analysis (FEA) capabilities, providing insights into potential stress and strain areas. A product's reaction to stresses and other physical elements it may experience in the actual world can be forecast through a computer simulation technique named Finite Element Analysis (FEA). This tool can assess a product's potential for failure to function as intended (Fadiji *et al.,* 2018). ANSYS allows the evaluation of the stress distribution, total deformation, and safety factor by generating a virtual packaging model and applying the relevant material characteristics, geometrical dimensions, and boundary conditions (Dubey *et al.,* 2023). This step is crucial for ensuring the structural integrity and protection of the exoskeleton during transportation.

The software Human Builder in CATIA has tools to create digital human models or manikins, allowing manipulation and interaction analysis with products. The resulting manikin is essential for evaluating the design aspect of comfort. CATIA simulates the ergonomic aspects of carrying the packaging, focusing on user comfort and ease of handling. This simulation involves analyzing the human-product interaction, considering factors such as weight distribution, handle design and overall ergonomic consideration.

By integrating simulation tools into the research methodology, the study aims to not only design user-centered packaging for elderly individuals but also validate the design through analysis. This approach is expected to result in a packaging solution that ensures the physical protection of the exoskeleton and enhances the overall user experience, addressing the specific challenges elderly individuals face in managing and transporting exoskeletons. The research thus aligns to improve the quality of life for elderly individuals within the context of emerging technologies like exoskeletons.

1.2 Problem Statement

This research is prompted by a significant challenge faced by Muslim elderly individuals who want to utilize an exoskeleton designed for Solat, experiencing notable hurdles in transporting these assistive devices to the mosque for prayer. A critical aspect of this challenge is the need for existing packaging tailored to accommodate the exoskeleton's unique form and functionality. Unlike conventional products, the exoskeleton for Solat requires specialized packaging to ensure safe and secure transportation. A user-friendly packaging design needs to be improved to the complexity of managing and transporting the exoskeleton for older adults.

The consequences of this gap in packaging solutions are far-reaching, impacting not only the ease of mobility for older users but also their active participation in religious practices, particularly praying at the mosque. Without a specific packaging solution that meets the complexities of exoskeleton, older people may get burdened, reducing their ability to bring this supportive tool into their daily lives. This study seeks to bridge this gap by developing a user-centered packaging solution designed specifically for the exoskeleton for Solat.

The proposed packaging prioritizes portability and ergonomic design to enhance user experience, focusing on the specific needs of older people. It aims to safeguard the Solat exoskeleton during transportation and improve usability by addressing challenges such as reduced strength, limited mobility, and difficulty handling heavy objects. Features like lightweight materials, ergonomic handles, intuitive opening mechanisms, and balanced weight distribution minimize physical strain and make the exoskeleton more accessible to older users.

This innovative approach empowers Muslim elderly individuals by fostering independence and facilitating active engagement in religious practices. Furthermore, significantly enhance their well-being by promoting physical activity, reducing isolation and encouraging social involvement. By making the exoskeleton easy to transport and use, the packaging solution helps elderly individuals stay active and engaged in their communities.

1.3 Objectives

The objectives are as follows:

(a) To identify user needs on optimal packaging design solutions for an exoskeleton for solat.

(b) To design packaging solutions that prioritize protection and portability for exoskeleton for Solat throughout storage and transportation, incorporating ergonomic design elements to ensure convenient and secure handling.

(c) To analyze the designed packaging solutions effectiveness in safeguarding the exoskeleton for Solat while prioritizing user-friendly access, focusing on ergonomic analysis and easy portability.

1.4 Scopes of the Research

The scopes of research are as follows:

(a) Explore the needs and preferences of Muslim elderly and physical limitation regarding the exoskeleton and its packaging.

(b) Develop packaging prototypes that prioritize robustness and ease of use, considering accessibility features for individuals with various disabilities or physical limitations.

(c) Assess the effectiveness of designed packaging in protecting the exoskeleton and ease of use for diverse user groups to ensure the packaging is intuitive and functional.

(d) Refine packaging designs based on feedback for better protection and accessibility for user-friendly.

1.5 Rational of Research

There are some potential benefits with study this project that can be used in the industry. By reducing all the impact that affect to the project, good surface finish be produced and can be apply to all the company.

1.6 Thesis Organization

The thesis follows a structured format, starting with preliminary pages, an introduction highlighting the research question, and a thorough literature review. The methodology details the research design and emphasizes the use of CATIA and ANSYS for analysis. Findings are presented in the data analysis section, followed by a concise discussion of results and their implications. The conclusion summarizes key findings, recommendations, and avenues for future research. The thesis ends with a reference list and appendices containing supplementary material. This organized structure ensures a clear and efficient presentation of the research.

CHAPTER 2
LITERATURE REVIEW

This chapter mainly describes the theories and research that established and carried out over the years by different researchers. References and a discussion based on their study about material qualities, ergonomic principles, design packaging, and user preferences are from earlier studies.

2.1 Exoskeleton for Solat

2.1.1 Exoskeleton

Wearable robotic technology called an exoskeleton attaches to the body to help people with activities, including walking, climbing stairs, and carrying weights (Viteckova *et al.,* 2013). Therefore, unlike prostheses, which replace a limb in the body and function in series with the adjacent limb, an exoskeleton is a wearable robot that functions in parallel with the human body.

Exoskeletons are commonly classified into two types of wearable machines: (1) passive and (2) active. While active exoskeletons have actuators that transform energy—such as electrical, air, or hydraulic force—into mechanical force to support and strengthen human movement, passive exoskeletons use a combination of springs and dampers to store energy from human motion and reuse it when needed to improve a posture or motion (de Looze *et al.,* 2016). Several classification criteria can be used to group exoskeletons into distinct categories, including the number of degrees of freedom, actuation type, intended application, and others. The bodily component or parts that the exoskeletons support can be used to identify them as follows: the upper extremities (upper body exoskeletons) and the lower limbs (lower body exoskeletons) (de Looze *et al.,* 2016). Figure 2.1 shows the various types of exoskeletons for the upper limb used in industrial and medical areas with different functionalities. Figure 2.2 shows single-joint powered lower limb-assisted exoskeletons.

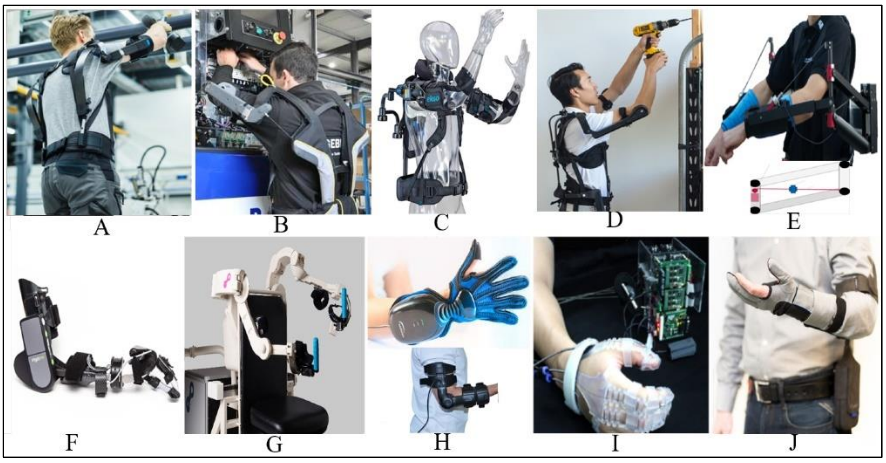


Figure 2.1: Type of exoskeleton for upper limb with different functionalities.

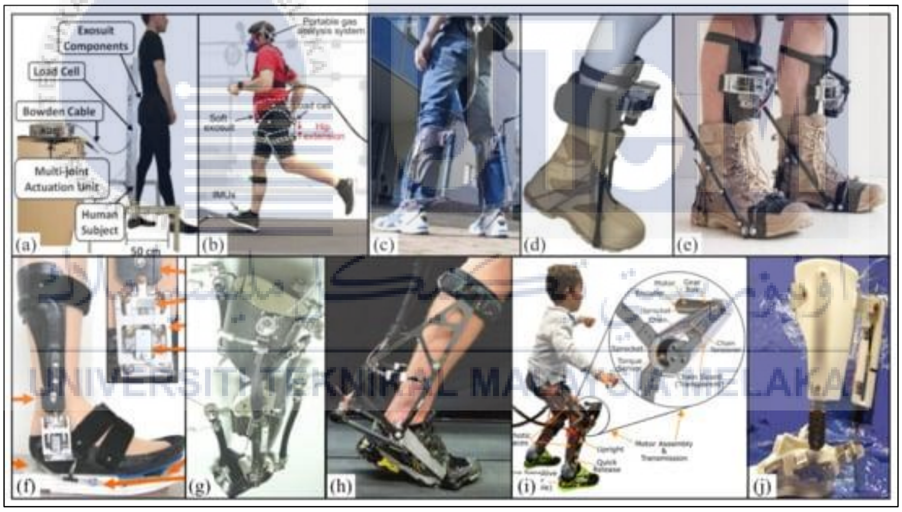


Figure 2.2: Single-joint powered lower limb assisted exoskeleton.

Exoskeletons have primarily been used in medical and rehabilitation settings, where the devices are meant to assist individuals who are physically weak, injured, or disabled in carrying out a variety of motions necessary for everyday tasks like walking, climbing stairs, sitting and standing, reaching, and grasping (Viteckova *et al.,* 2013).

The emergence of exoskeletons in various fields, particularly healthcare, presents a bionic future where these devices can significantly impact patient care and rehabilitation (O’Connor, 2021). From assisting individuals in assuming specific postures for religious rituals to aiding in the mobility of the older and patients with physical weaknesses, the design and application of exoskeletons are continuously evolving to enhance human capabilities and well-being. As the use of exoskeletons expands, particularly in medical rehabilitation, it is essential to prioritize user-centered approaches and rigorously test the efficacy of these devices to ensure their safety and effectiveness in diverse settings. The potential of exoskeletons to reduce injuries and fatigue, improve mobility and support patients in various clinical areas highlights their promising role in the future of healthcare and beyond (Kim *et al.,* 2019).

2.1.2 Overview of Exoskeleton for Solat

The exoskeleton for Solat (Islamic prayer) is an ingenious solution to the physical challenges preventing individuals, particularly older adults or those with physical limitations, from comfortably performing prayer postures. Its design primarily for the lower limbs' exoskeleton revolves around addressing common issues such as back pain, knee problems and overall physical weakness, which can obstruct the smooth execution of the various movements required during prayer.

The Solat done by Muslims follows a similar pattern throughout the world. Different postures are associated with solat, including standing (qiyam), bowing (rukoo'), prostrating (sujood), and sitting during salutation (tahayat) (Ur Rahman, 2018). Most of the body's muscles and joints are used during performing Solat (Ur Rahman, 2018). Solat could be seen as a specific kind of stretching exercise. Simple, light physical activities during Solat are appropriate for people of all ages and physical conditions. Muscle flexibility without overexertion is achieved during Solat by carefully contracting and relaxing the muscles in harmony.

This exoskeleton's functionality is centeres on its components, each strategically crafted to aid in specific prayer postures. The inclusion of a seat provides crucial support during the seating and offers relief for those with difficulty bending their knees or sustaining that posture due to pain or weakness. The extender sticks are designed to adjust the seating position based on individuals' preferences. Meanwhile, the base for the support ensures stability throughout the prayer movements reducing the risk of imbalance or falls. Waist straps act as secure fastenings, reinforcing the exoskeleton around the waist to enhance stability and support. The waist strap can be adjusted to fit the wearer's body, ensuring a secure and comfortable fit (Yong *et al.,* 2019). The waist strap can often be a suspension system that helps anchor the exoskeleton to the wearer's body, providing a stable platform for the device to operate (Xu *et al.,* 2021). This ensures the exoskeleton remains in place and supports the wearer during Solat. Figure 2.3 shows the exoskeleton for Solat that helps in performing prayer.

Figure 2.3: Exoskeleton for Solat that helps in performing Solat.

This design directly addresses the problem statement by catering to the challenges faced by individuals experiencing physical limitations. It acknowledges the difficulties in assuming and sustaining prayer postures, aiming to mitigate these obstacles. By specifically focusing on assisting in during bending, standing and transitioning between postures, the exoskeleton strives to minimize the risk of injuries that could occur due to strained movements (Flor-Unda *et al.,* 2023). This is particularly crucial for the elderly or those with back pain or knee issues, allowing them to pray without enduring undue physical strain. This exoskeleton facilitates a smooth transition between sitting and standing positions during solat, catering to the diverse needs of users.

Beyond its immediate application for Solat, the exoskeleton's adaptability for tasks involving extended standing, heavy lifting or uncomfortable postures further extends its utility. Solving physical strain during these activities, aims to enhance overall well-being and reduce the likelihood of injuries caused by repetitive or awkward movements (Bär *et al.,* 2021). Ultimately, the exoskeleton for Solat is integrating of technology to address age-old challenges, ensuring inclusivity and accessibility in religious practices while significantly improving the quality of life for individuals with physical limitations.

2.2 User-Centered Approach Packaging

2.2.1 Packaging Exoskeleton

The absence of packaging for exoskeleton for solat presents a challenge, hindering users from easily transporting their exoskeletons to the mosque. This not only affects mobility but also limits active participation in communal prayers. The packaging options for exoskeletons are diverse and tailored to the specific requirements of different exoskeleton types, including industrial, medical, and rehabilitation-focused models. The packaging solutions are essential for ensuring the safe storage, transportation, and delivery of exoskeletons, safeguarding their integrity and functionality throughout the supply chain and in clinical or industrial settings (Sabee *et al.,* 2022).

For industrial exoskeletons, such as those used in manufacturing, the packaging needs to be robust and tailored to the device's dimensions and weight to prevent damage during transit and handling. Additionally, the packaging for industrial exoskeletons should ensure the safe handling of power sources and electronic components, as some exoskeletons are powered by batteries or gas (Süli, 2019).

In the medical field, particularly for medical exoskeletons used in rehabilitation and patient handling, specialized packaging is required to maintain the devices' integrity and functionality. This packaging is designed to provide protection against impact, environmental factors, and ensure the sterility of the devices in clinical settings (Supriya *et al.,* 2020).

Moreover, there is a growing interest in sustainable packaging solutions for consumer exoskeletons. Researchers and companies are exploring eco-friendly alternatives to traditional packaging materials, such as biodegradable polystyrene substitutes made from the exoskeletons of plastic-eating insects and foam crafted from shellfish exoskeletons. These innovative packaging options demonstrate the potential for sustainable and eco-friendly alternatives to traditional packaging materials (Donkor *et al.,* 2023).

Hardcase packing is a term used to describe materials used in packaging that are strong and stiff, giving the contents more protection. It is frequently used for precious or fragile goods while they are being shipped or stored. The materials, which are made to resist forces and impacts from outside forces. Hardcases provide excellent protection since they are made of sturdy materials like carbon fibre, aluminium, or Acrylonitrile Butadiene Styrene (ABS) plastic (Bhaskar *et al.,* 2022). There are various products of hard cases that comes in different shapes and size according to their functioning as shown in Table 2.1. Figure 2.4, Figure 2.5 and Figure 2.6 showcasing different types of functional hardcase.

Table 2.1: Hardcase packaging with various size and shape.

 Figure 2.4: Hardcase suit packaging	 Figure 2.5: Hardcase luggage packaging	 Figure 2.6: Hardcase backpack packaging
Hardcase suit	Hardcase luggage	Hardcase backpack

An exoskeleton can be safely stored in hardcase packaging to prevent damage from occurring during storage or transportation. The exoskeleton needs to be protected from impact and kept safe with a hardcase customized specifically for it. For the most effective protection, a hardcase must be designed or utilized with the exoskeleton's unique dimensions and specifications in consideration.

2.2.2 Design Requirements for Packaging for Exoskeleton

Packaging plays a crucial role in ensuring the safe storage, transportation and delivery of exoskeletons. When designing the packaging for exoskeleton for Solat, several factors should be considered to ensure the exoskeleton's safety, functionality and user satisfaction.

(a) Ergonomic Design

To minimize detrimental effects on health, all products including clothing, consumer goods, and living and working environments should be tailored to the anthropometry of the user, according to the user-centered design approach. Poorly built and ill-fitting devices that do not fit the users' anthropometry are regarded to be one of the variables that can enhance the chance of acquiring musculoskeletal pain and discomfort as shown in Figure 2.7. Ergonomic design, integral to enhancing user experience, particularly benefits individuals with physical limitations, emphasizing ease of handling, unboxing, and overall usability. This design philosophy starts with thoughtful considerations for packaging handling and carrying. Well-designed handles or grips play a crucial role, strategically placed to ensure even weight distribution, thereby reducing strain on the user's hands and arms during lifting and carrying. The ergonomic approach extends to user-friendly opening mechanisms, where easy-to-access closures guarantee that individuals, including the elderly or those with limited dexterity, can effortlessly access the exoskeleton without grappling with complex or challenging opening methods (Bošnjaković & Vladić, 2020). Organizing components logically within the packaging is another key element of ergonomic design (Bošnjaković & Vladić, 2020). The use of compartments to neatly arrange different parts simplifies the assembly process, and clear labeling aids users in identifying and accessing specific components without confusion or frustration. Furthermore, ergonomic packaging design optimizes space and weight distribution, featuring compact packaging that efficiently utilizes space while ensuring an even weight distribution. This approach not only safeguards the exoskeleton but also contributes to a seamless user experience, particularly beneficial for those facing physical challenges.

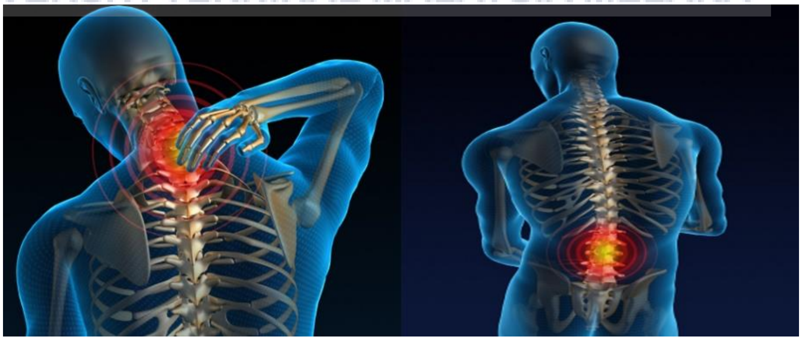


Figure 2.7: Common musculoskeletal disorders (MSD) for body region.

(b) Portability

Ensuring the portability of exoskeletons is crucial, particularly for users with limited mobility or those requiring assistance during activities like prayer. Packaging must be designed to be both compact and flexible, with protection being given first priority while maintaining mobility. Lightweight materials play a pivotal role in enhancing portability, ensuring that the packaging doesn't unnecessarily burden users, including the elderly or those with limited strength. Materials that are produced as light as feasible, subject to limitations, are referred to as lightweight materials. Lightweight materials are utilized not just to reduce weight, but also to improve structural efficiency. Incorporating ergonomic handles or mobility-enhancing features directly onto the packaging contributes significantly to improved portability, making it easier to lift and carry the package, particularly during storage or travel. Packaging innovations that offer user-friendly mobility solutions—like wheels or collapsible designs—are especially helpful for large exoskeletons. Ensuring safety during handling entails utilizing rounded edges, cushioning materials, and careful consideration of weight distribution to reduce the possibility of accidents occurring during the unpacking or transportation of the packed exoskeleton. Overall, a focus on portability in both design and packaging is essential to facilitate the seamless movement and use of exoskeletons, particularly for those with physical limitations.

2.2.3 Material Requirement for Packaging for Exoskeleton for Solat

The choice of materials for packaging exoskeleton tailored for Solat is crucial in ensuring the safety, protection and preservation of exoskeleton.

2.2.3.1 Impact-Resistant Materials

Impact resistance, often known as impact strength, is the capacity of a substance or an item to withstand shock or impact energy without breaking (Shah *et al.,* 2019). Durable and impact-resistant materials such as high-density foams, rigid plastics or composite materials are essential for cushioning the exoskeleton components. These materials absorb shocks and protect sensitive parts from damage during handling, transportation and storage.

(a) Custom-Molded Foam Inserts and Cushioning Materials

The importance of utilizing custom-moulded foam inserts or specifically designed cushioning materials within the packaging that these materials are tailored to the unique contours and shapes of fragile components such as electronic circuits, extendable sticks or sensitive mechanical parts. By conforming precisely to these components, they absorb shocks and vibrations during transit, preventing potential damage caused by impact.

(b) Shock Absorption and Vibration Damping

The need for utilizing materials characterized by outstanding shock-absorbing properties is paramount. Specifically, specialized foams or gel-like substances have proven to be effective solutions in dissipating impact energy. This capability safeguards mechanical structures from the jolts and vibrations encountered during handling, shipping, or accidental drops.

(c) Customized Packaging Structure

Implementing tailored packaging structures that integrate multiple layers of protection is essential. This may entail the utilization of a combination of shock-absorbent foam inserts, reinforced corners, and impact-resistant barriers within the packaging design. The objective is to establish a buffer zone that safeguards delicate components from external forces and reduces the transfer of impact energy to the exoskeleton.

(d) Form-fitting Enclosures

The requirement for foam-fitting enclosures within the packaging is crucial. These enclosures are meticulously designed to securely cradle and immobilize fragile components. By minimizing movement and maintaining a snug fit, they effectively prevent any shifting or dislodging of sensitive parts. This, in turn, significantly reduces the risk of damage stemming from internal friction or collision.

2.2.3.2 Waterproof Materials

One essential method for shielding structures from the effects of moisture and water is waterproofing (Gomes *et al*., 2023). The packaging should shield the exoskeleton from environmental factors like moisture, dust and temperature variations. Waterproof or moisture-resistant materials and sealing mechanisms can protect the exoskeleton from damage caused by adverse conditions.

(a) Moisture Protection

Moisture can be detrimental to the mechanical parts of exoskeleton. Packaging solutions often incorporate moisture-resistant materials or coatings to create a barrier against humidity, rain or accidental spills during transportation and storage. Sealing mechanisms further prevent moisture ingress, preserving the exoskeleton’s functionality.

(b) Long Term Storage Considerations

The packaging should be designed to withstand prolonged storage conditions without compromising the device’s functionality. Factors such as degradation of materials are considered in the packaging design to ensure device readiness upon unboxing.

2.3 Packaging Design

Packaging design involves the strategic and creative process of crafting the visual and structural elements that encase and protect a product. It encompasses considerations for functionality, aesthetics, branding, and user experience, aiming to create a protective yet appealing enclosure for the product. For the purpose of modeling, simulating, and visualizing package designs, a variety of tools including CAD software like CATIA or specialist applications can be employed. The design process involves conceptualizing, prototyping, and refining packaging solutions that cater to specific product requirements, ensuring precise fit, protection during transportation and ease of use. Ultimately, effective packaging design serves as a crucial bridge between product and consumer, enhancing the product's appeal, usability, and safety while aligning with brand identity and environmental considerations.

Software can be used to design the packaging for exoskeletons, offering various benefits and features to streamline the design process and improve the final packaging design. Computer-Aided Design (CAD) software is a powerful tool used extensively across industries for designing and modeling various products including packaging.

2.3.1 Software Tool (CATIA)

A sophisticated software suite offers a diverse range of functionalities tailored to intricate 3D modelling, simulation and product lifecycle management. CATIA can also facilitate design of packaging through various capabilities.

(a) Advanced 3D Modelling

CATIA's robust 3D modelling tools enable designers to create precise and detailed packaging designs. These tools allow for the creation of packaging components with exact dimensions ensuring a perfect fit for the exoskeleton components.

(b) Packaging Prototype and Visualization

The software's visualization features allow designers to create realistic 3D representations of packaging concepts. This capability aids in visualizing the final packaging design, offering a comprehensive view of how the packaging will look and function.

(c) Assembly Modeling and Simulation

CATIA's assembly modelling capabilities assist in creating and simulating how different packaging components fit together. This functionality ensures that the packaging design accounts for the assembly process, optimizing the packaging's structural integrity and functionality.

(d) Precision and Measurement

CATIA's precise measurement tools ensure accuracy in the packaging design process. Designers can specify exact dimensions and tolerances, critical for creating packaging that perfectly accommodates the exoskeleton components.

2.3.2 Design Packaging

In this instance, the packaging design process involves considering into account factors related to the product's value, appearance, manufacture, sustainability, standards, or competitiveness. The process of designing packaging for exoskeletons can be broken down into several steps, from ideation sketches to the final design. Figure 2.8 show instructional design for design packaging.

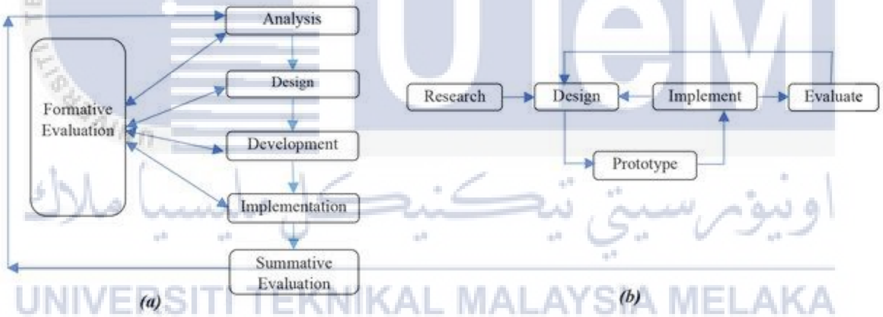


Figure 2.8: Instructional design of (a) ADDIE model adapted from Kulvietiene & Sileikiene (2006), and (b) Rapid Prototyping (RP).

(a) Design Ideation

In the early stages of exoskeleton packaging design, researchers emphasize the crucial role of creative ideation. CATIA's tools facilitate this process by providing a virtual canvas for designers to brainstorm and conceptualize ideas. Ideation is a key moment in the design process where an individual or group takes steps to generate ideas relevant to their design.

(b) Research

The next step is to conduct research on the market or users for whom the packaging is being designed. This includes analysing competitors, identifying trends and understanding user needs. Transforming research findings into useful design parameters is made easier with the help of CATIA.

(c) Concepts

The conceptualization stage is multifaceted, commencing with design sketches, CATIA's drawing capabilities help translate abstract thoughts into physical representations (Kumar et al., 2021). This transition from 2D to 3D is noted as a pivotal step allowing designers to visualize and refine their concepts.

i. Sketches design. The role of CATIA's sketching tools in facilitating the creation of detailed and expressive design sketches. This allows for an initial visualization of the packaging concepts, setting the stage for further development.

ii. Include measurement. The incorporated dimensions ensure that the initial concepts align with specific size and shape requirements.

iii. Visualization in 3D modelling. The seamless transition from sketches to 3D modelling using CATIA in this step bringing conceptual designs to life, providing a more realistic and tangible representation for further assessment.

(d) Concept Development

Parametric modelling within CATIA allows to refine and adjust the design based on evolving requirements. This flexibility is crucial for adapting to changing design consideration and ensuring optimal functionality. Refines and polishes the ideas generated in the previous step, selecting the most promising concepts and developing them further.

(e) Design Review

The ability of CATIA to render and visualize ideas clearly puts it in a position to deliver revised concepts to stakeholder and get feedback on design ideas.

(f) Iterate

Iteratively adjust and finetune the packaging design based on feedback, ensuring continuous improvement and alignment with evolving requirements.

(g) Prototypes

By creating and testing prototypes of the package design, prototypes enable through evaluation of the design’s viability and attractiveness and guarantee that it complies with all necessary regulations.

In conclusion, the design process for exoskeleton packaging as delineated through the structured steps outlined is a comprehensive and iterative journey. The transition from initial sketches to precise measurements and 3D modelling allows to visualize and refine packaging concepts effectively. The parametric modelling capabilities of CATIA are pivotal in concept development, enabling continuous refinement to align with evolving requirements. Prototyping ensures a thorough evaluation of design viability and compliance with regulations.

2.3.3 ANSYS Simulation

The analysis of packaging design involves a comprehensive assessment and evaluation of various aspects related to the packaging solution. This process aims to ensure that the packaging aligns with the product's needs, user expectations, industry standards, and environmental considerations.

ANSYS is engineering simulation software widely used in industries to perform Finite Element Analysis (FEA) and other simulation. ANSYS provides a comprehensive set of tools for engineers and designers involved in the packaging industry. It allows users to perform detailed simulations to understand how packaging materials and structures will behave under various loads and conditions. This enables the optimization of packaging designs for durability, safety and cost-effectiveness. This paper sets up the Finite Element Analysis (FEA) to calculate load distribution on the packaging. FEA is a mathematical method to simulate the real-world physics system by using several simple interaction elements (unites) to achieve a finite number of unknown elements to approximate a real system with infinite unknown elements (Lin, 2023).

There are 8 steps in FEA preprocessing. Step 1: Define the geometry for the problem; Step 2: Create the material model; Step 3: Choose the type of elements and mesh the model; Step 4: Define element conditions; Step 5: Assemble the equation into a system equation solution; Step 6: Define the boundary conditions; Step 7: Solve postprocessing and finally Step 8: Review the results and analyse what they mean to the real world problems (Lin, 2023). Figure 2.11, Figure 2.12 and Figure 2.13 show the example of simulation of packaging box that analyse for deformation and stress distribution.

Figure 2.9: Example of 3D packaging box.

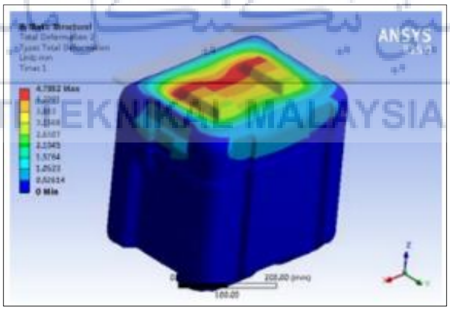


Figure 2.10: Example of 3D packaging box experiencing comprehensive deformation.

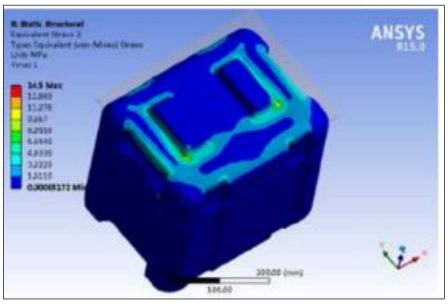


Figure 2.11: Example of 3D packaging box experiencing stress distribution.

2.3.3.1 FEA Principles for Packaging Optimization

Finite Element Analysis (FEA) principles play a crucial role in optimizing packaging designs by providing insights into how materials and structures respond to various loads and conditions.

(a) Material Selection and Properties

FEA allows to input material properties such as elasticity, strength, and density. Different materials respond differently to loads, and FEA helps assess their behaviour under various conditions. By analysing the stress and strain distribution in packaging materials, FEA assists in selecting optimal materials to enhance structural integrity and reduce material usage.

(b) Load Distribution Simulation

FEA enables the simulation of realistic loading conditions such as stacking, compression, and vibrations during transportation. Understanding how the packaging will respond to these loads is essential for optimization. FEA helps identify areas of high stress or deformation, allowing to strengthen these regions or modify the design to distribute loads more effectively.

(c) Geometry and Meshing

FEA involves dividing the packaging structure into smaller elements through meshing. Detailed meshing is critical for accurate simulations, capturing the geometry intricacies and ensuring precise results. FEA provides insights into how changes in packaging geometry impact performance. Design can iterate and adjusting geometry to enhance strength and stability.

(d) Boundary Conditions

Accurate representation of boundary conditions is essential in FEA. Constraint can be simulated such as fixed supports or constraints due to adjacent packaging in a stack, providing a realistic simulation environment. FEA allows for the application of various loads on the packaging structure and simulate different scenarios to assess the packaging's response under different conditions.

2.3.3.2 Static Structural Analysis: Load Distribution

Static structural analysis, particularly in the context of Finite Element Analysis (FEA), is a powerful method employed to evaluate the response of structures to various loads. Understanding load distribution is a fundamental aspect of this analysis, providing insights into how different components within a structure bear the applied loads and the resulting stress and deformation patterns. Static loads refer to forces and moments that do not change with time (Gefen *et al.,* 2022). These loads can include forces acting in different directions, moments causing rotational effects, and distributed loads such as pressure or thermal loads. In static structural analysis, the system is assumed to be in equilibrium, meaning that the sum of forces and moments is zero. Load distribution refers to the allocation of external forces and moments across different elements of a structure. Understanding how loads are distributed is critical for evaluating the stress and strain experienced by each component. This knowledge aids in identifying areas of potential failure or deformation within the structure. The analysis process involves defining the geometry of the structure, specifying material properties, applying boundary conditions to simulate the structure's constraints, and assigning loads to represent external forces and moments. FEA software then discretizes the structure into smaller elements, allowing for a detailed analysis of load distribution. Materials with linear elastic behaviour—that is, a linear connection between stress and strain within the elastic limit—are frequently assumed in static structural analysis. Figure 2.12 simplifies the analysis process and facilitates the prediction of structural responses.

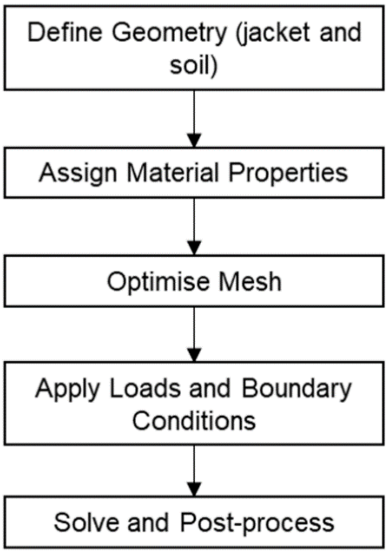


Figure 2.12: Basic flowchart of the FEA process.

The primary outcomes of static structural analysis are stress and deformation distributions within the structure. Stress is a measure of internal forces, while deformation indicates the extent of structural displacement. These results will analyse to ensure that stresses remain within the material's allowable limits and that deformations are acceptable for the given application. In the specific context of packaging, static structural analysis is instrumental in assessing how packaging materials and configurations respond to static loads during stacking, transportation, or storage. It enables the optimization of packaging designs to ensure they can withstand expected loads without compromising the integrity of the packaged contents.

2.3.4 CATIA Simulation

A software suite called CATIA (Computer-Aided Three-Dimensional Interactive Application) is used for computer-aided manufacturing (CAM), computer-aided engineering (CAE), and computer-aided design (CAD). CATIA provides a comprehensive set of tools for designing and modelling products in 3D, performing simulations and analyses and generating manufacturing documentation (Praneeth Kumar *et al*., 2021).

2.3.4.1 CATIA Human Builder Tool for Ergonomic Simulation

CATIA Human Builder is a specialized module within the CATIA suite designed for human-centric simulations. It enables designers to create virtual human models and simulate their interactions with products and environments. The human-centric approach of CATIA Human Builder allows for the accurate representation of how users interact with the exoskeleton packaging. Through simulations can analyse factors such as reach, grasp and overall comfort providing insights into potential stress points or discomfort during handling. The existing literature from (Bošnjaković & Vladić, 2020) underscores the importance of incorporating ergonomic considerations in packaging design. Beyond the traditional focus on protection during transit, this involves ensuring that the packaging aligns seamlessly with human anatomy and movement patterns. CATIA Human Builder facilitates the visualization and analysis of these ergonomic aspects, contributing to the creation of user-friendly packaging solutions.

2.3.4.2 Load Distribution Simulation

The initial step involves creating a virtual human model (mannikin) meticulously detailing anthropometric data to faithfully represent the complexities of the human body. Non-invasive quantitative measurements of the body are called anthropometric measurements. An important way to evaluate a child's or adult's nutritional condition is by anthropometry, according to the Centers for Disease Control and Prevention (CDC). The fundamental components of anthropometry are skinfold thickness, height, weight, head circumference, body mass index (BMI), and measurements of the limbs, waist, and hips to determine adiposity. This virtual human is seamlessly integrated into the CAD environment alongside an intricately designed 3D model of the packaging, considering dimensions, weight and material properties. The subsequent simulation scenarios span diverse load conditions, mirroring real-world activities of lifting, holding and transporting the packaging. CATIA Human Builder's tool are then leveraged to apply ergonomic principles, analysing joint angles, postures and biomechanical effects to ascertain potential stress points. Load distribution analysis, encompassing force distribution and pressure mapping, unveils how the packaging weight is distributed across critical body parts. Stress points are identified using sophisticated stress analysis tools, offering insights into potential discomfort areas.

2.3.4.3 Impact on Posture and Comfort

The impact of packaging on posture and comfort is a critical consideration in product design, particularly in the context of exoskeleton packaging. CATIA Human Builder facilitates detailed posture analysis during various simulated activities, such as lifting and carrying the exoskeleton packaging. The virtual human model enables to evaluate joint angles, spial alignment and overall body posture dynamically. By doing so, the simulation provides valuable insights into how the packaging influences the natural posture of the user during different stages of interaction. The virtual simulation allows for nuanced examination of how the packaging weight and design affect muscle engagement, skeletal alignment and overall biomechanics. This insight crucial in identifying potential stress points and discomfort associated with specific postures. The analysis tools evaluate how the packaging weight is distributed across the user's body. The literature reveals that a balanced and well-distributed load is directly correlated with enhanced comfort. Simulation results guide in optimizing packaging features to achieve an even distribution, minimizing impact on specific body regions and ensuring a more comfortable experience for the user.

CHAPTER 3
METHODOLOGY

This chapter outlines the suggested research methodology, which consists of the fundamental techniques that will be used to carry out the study. After carefully reviewing the specifications and details of earlier research, the material selection, designing, processing, and testing will also be given. The fundamental principle of methodology is to provide appropriate procedures, tools, and strategies for accomplishing this study.

3.1 Overview

The methodology involves CATIA for design, ANSYS for load distribution simulation, and CATIA's Human Builder for ergonomic analysis. Starting with conceptualization and 3D modelling, ANSYS simulates load scenarios, optimizing the design. Human Builder assesses ergonomic factors through virtual simulations, ensuring user-friendly packaging. This integrated approach combines design modifications from both CATIA and ANSYS simulations to achieve a packaging solution that excels in both structural robustness and user-centered ergonomics.

3.2 Flowchart

The flowchart as in Figure 3.1 illustrated the step-by-step methodology for designing and analysing packaging for exoskeleton for Solat.

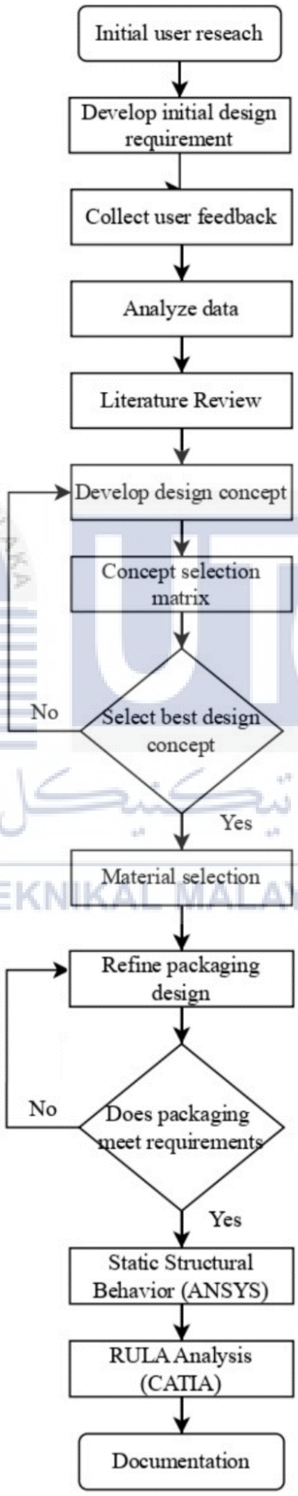


Figure 3.1: Flowchart for the project.

3.3 Initial User Research

In the initial phase of research methodology, initial user research was conducted to identify critical pain points and gaps in the current handling and transportation of exoskeleton for Solat to achieve the first objective of identifying user needs on optimal packaging design. The absence of a dedicated packaging solution emerged as a significant issue, leading to challenges in safely transporting the exoskeleton, even when disassembled.

A user-centric approach to address these handling issues was adopted through a survey of 44 respondents from the Muslim community to gather insights on their experiences and needs. This data collection provided a comprehensive understanding of requirements during the transportation of exoskeleton. Subsequently, the findings were analyzed to identify key themes that informed the development of potential packaging solutions.

The survey was conducted to address these questions divided into three sections. The first section was a demographic question related to respondents and the questions were as follows:

1. Personal information about respondents such as gender and age.
2. Do you have any physical limitations when performing Solat? If yes, state the type of physical limitation you had.
3. Have you ever experienced performing Solat using a chair?

The following section exposed the exoskeleton for Solat explaining its functioning and what makes it different from other typical chairs used in performing Solat:

1. The invention of the exoskeleton for Solat is to help the user align the saf with other Jemaah and not cause any disruption to the saf at the back due to limited space. Did you know about the exoskeleton for Solat?
2. The exoskeleton for Solat comes with a structure that can be easily disassembled. In your opinion, what type of carrier/bag is the most suitable for them to carry an exoskeleton?
3. Based on your choice above, indicate the level of importance for each feature that should be present in a carrier/bag. (Portability, lightweight, easy-to-reach compartment, storage capacity, flexibility for different uses, ease of use and

handling, comfort carrying in prolonged time, versatility in carrying option, durability).

The last section gathered preferred features of carrier/bag to ensure the chosen carrier accommodates their needs:

1. How much does the aesthetic appeal of a carrier/bag influence your choice?
2. Do you prefer a carrier/bag with wheels for more effortless mobility?
3. Would you be interested in carrier/bag with integrated technology features (e.g., charging port, tracking device)?
4. Suggestion for improvement.

3.4 Concept Selection Matrix

Applying a selection matrix multifaceted approach such as House of Quality (HoQ), concept screening and scoring mechanisms to design packaging that prioritizes protection and portability for exoskeleton throughout storage and transportation. This approach underscored the importance of thorough evaluation and refinement, ultimately leading to a design that meets the project's objectives.

3.4.1 House of Quality (HoQ)

This phase began with the creation of a House of Quality (HoQ) matrix as in Figure 3.2, which translated the gathered user needs and requirements into specific design criteria. These four existing design concepts were compared under design requirements.

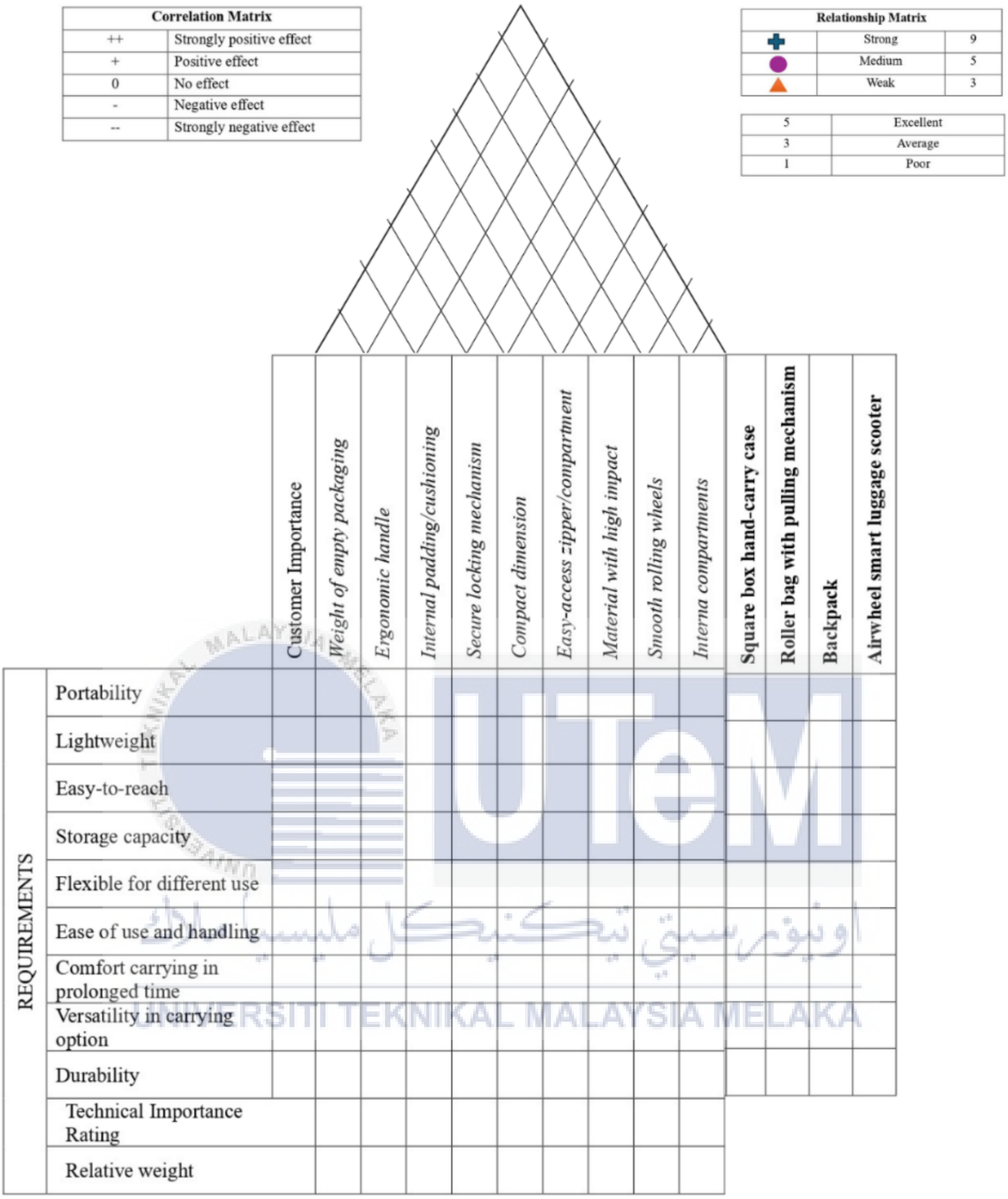


Figure 3.2: House of Quality template.

3.4.2 Concept Screening

The process generated potential packaging concepts to address the identified handling and transportation issues. These initial concepts were then evaluated using a design screening matrix narrowing down options, eliminating concepts that failed to meet basic requirements and focusing on concepts that show promise for further evaluation as shown in Table 3.1.

Table 3.1: Design Screening for four proposed designs.

	Concept Design			
Selection Criteria	**Design 1**	**Design 2**	**Design 3**	**Design 4**
Portability				
Lightweight				
Easy-to-reach compartment				
Storage Capacity				
Flexible for different use				
Ease of use and handling				
Comfort carrying/riding in prolonged time				
Versatility in carrying option				
Durability				
Sum +'s				
Sum -'s				
Net Score				
Rank				
Continue				

3.4.3 Concept Scoring

The remaining potential concepts underwent a detailed scoring process, assessing numerical values or ratings to each alternative against predefined criteria as in Table 3.2. This approach ensured the final design incorporated best practices that met the user's needs.

Table 3.2: Design scoring for final design.

		Concept Design					
		Design 1		Design 2		Design 3	
Selection Criteria	**Weight (%)**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Portability	14						
Lightweight	14						
Easy-to-reach to compartment	11						
Storage Capacity	9						
Flexible for different use	9						
Ease of use and handling	11						
Comfort wearing/carrying in prolonged time	11						
Versatility in carrying option	7						
Durability	14						
Total Score							
Rank							
Continue							

3.5 Material Selection

The material selection process aligned with Sustainable Development Goal 12 (SDG 12), which focused on responsible consumption and production. This phase involved evaluating potential materials based on their environmental impact, durability and recyclability to ensure that the final packaging solution would be effective and eco-friendly. A list of potential materials as in Table 3.3 was compiled and assessed for its environmental impact. Materials that offered high durability and protection for exoskeleton while being lightweight and easy to handle were prioritized.

Table 3.3: List of potential material.

Material 1	
Advantages	Disadvantages
Material 2	
Advantages	Disadvantages
Material 3	
Advantages	Disadvantages

3.6 Static Structural Behaviour

The analysis began with applying ANSYS, a finite element analysis (FEA) tool, to evaluate the design's structural integrity and analyze the designed packaging's effectiveness in safeguarding the exoskeleton. This allowed for a comprehensive assessment of the packaging's ability to protect the exoskeleton, ensuring it remains undamaged throughout storage and transit.

The primary objective of this ANSYS simulation was to gain a comprehensive understanding of the structural behavior of packaging when subjected to a 4-kg load. Specifically, the focus lies on analyzing the stress distribution in total deformation and safety factors across critical areas, namely for the packaging handle. The ultimate goal is to ensure the packaging can withstand the intended load without encountering structural failure, providing valuable insights into the design's robustness and durability.

3.6.1 Procedure

A detailed analysis was performed using ANSYS software to analyze static structural behavior for the packaging of an exoskeleton for Solat. Firstly, a static structural system was set up within ANSYS Workbench to stimulate the physical condition of the packaging. Material for the analysis was assigned as polylactic acid (PLA) inputting its mechanical properties such as Young's modulus, Poisson's ratio and density as in Table 3.4.

Table 3.4: Material properties for polylactic acid (PLA).

Material 1: Polylactic Acid (PLA)	**Value**
Yield Strength (Pa)	34.487 MPa
Young's Modulus (E)	2.473 GPa
Poisson's Ratio (v)	0.33

The CAD model of the packaging was imported into ANSYS to accurately represent its shape and dimensions as in Figure 3.3.

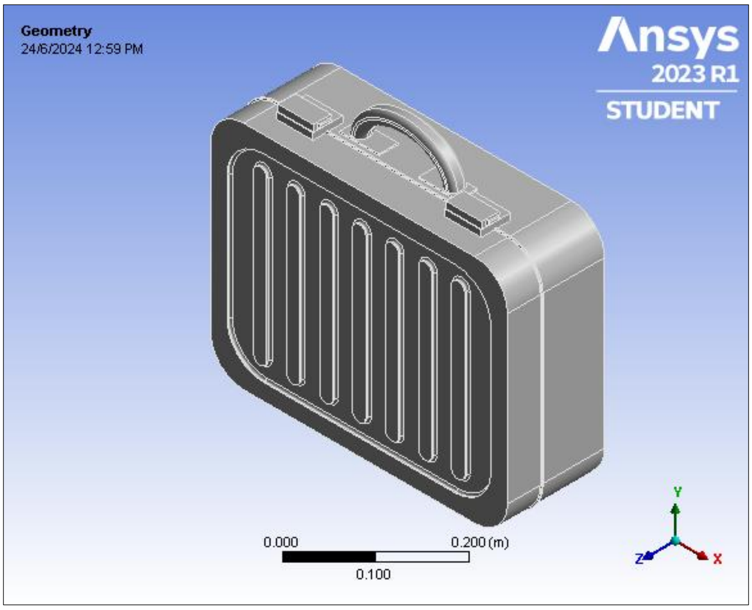


Figure 3.3: CAD model of packaging.

Mesh for CAD geometry was created to discretize the model into smaller elements as in Figure 3.4. Mesh type was defined as in Table 3.5, and the sizing and coarseness were both adjusted to balance accuracy and computational efficiency.

Table 3.5: Mesh properties.

Mesh Type	Mixed mesh (tetrahedral and hexahedral)
Mesh Method	Automatic mesh
Element Size	5 mm
Mesh Quality Metrics	Average skewness: 0.30
	Maximum aspect ratio: 4.0
	Minimum Jacobian ration: 0.80
Nodes	25398
Element	14529

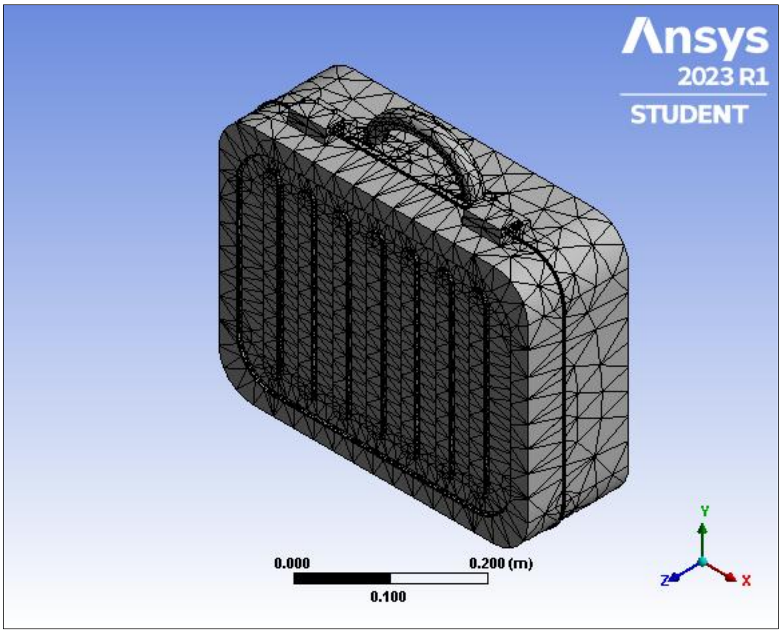


Figure 3.4: Mesh for CAD geometry.

Standard earth gravity was applied to simulate the weight of the packaging going downward. Fixed support was defined at the base of the handle packaging, representing a structure bolted to a rigid foundation. Point-fixed supports facilitated the transfer of loads throughout the structure to ensure that applied loads were correctly distributed across the model. The load of 39.24N was applied to the packaging handle to simulate the forces experienced during handling and transportation. Table 3.6 and Figure 3.5 show details for the static structural model.

Table 3.6: Force properties.

Coordinate System	Global Coordinate System
X Component	0 N
Y Component	39.24 N
Z Component	0 N

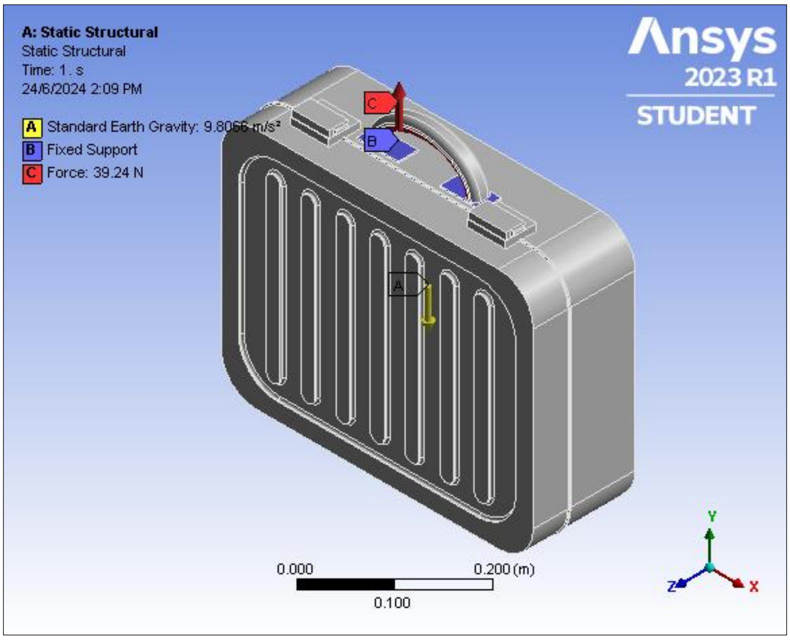


Figure 3.5: Static Structural model.

Key parameters for the analysis were specified, such as total deformation, equivalent elastic strain, equivalent stress and safety factor. Total deformation was assessed to measure the overall displacement of the packaging under applied loads. Strain distribution was assessed within the material and equivalent stress was used to evaluate stress distribution and identify potential failure points. Safety factor was calculated to ensure the packaging could withstand the applied loads without failure.

Static structural analysis was executed to simulate the behavior of the PLA packaging under the defined conditions. The result was analyzed to determine if the packaging met the required performance standards. Table 3.7 summarized the result of the analysis.

Table 3.7: Results of static structural analysis.

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress	Safety Factor
Minimum				
Maximum				
Average				

3.6.2 Assumption Made

In conducting the ANSYS simulation for the packaging analysis, several assumptions were made to streamline the modeling process and focus on key aspects of structural behavior. Firstly, a fundamental assumption involves material homogeneity, considering the packaging as composed of uniform and isotropic materials. This simplification allows for a more straightforward representation of material properties, with the understanding that actual packaging materials may have slight variations in composition. Additionally, the simulation assumes linear elasticity, implying that the packaging materials behave elastically within the specified loading conditions. Another assumption pertains to the static nature of the simulation, assuming that the loads applied to the packaging are constant and that dynamic effects, such as sudden impacts or vibrations, are negligible.

3.7 RULA Analysis

CATIA simulation is instrumental in optimizing packaging design through an in-depth analysis of force and pressure distribution coupled with motion analysis using manikins. By employing force and pressure parameters, the simulation allows for a meticulous examination of how the packaging interacts with the human body during handling. This comprehensive analysis aligns with the final objective of analyzing the designed packaging's ergonomic effectiveness to ensure that the weight distribution is optimized, minimizing the potential for discomfort or strain on specific body parts. Simultaneously, motion analysis enables the evaluation of ergonomic factors related to posture and movement during tasks such as carrying, loading and unloading. By considering these parameters, packaging design can be refined to enhance user comfort, prevent musculoskeletal issues and reduce the risk of injuries. The simulation process provides valuable insights into the impact of various design iterations on force exertion, pressure points and overall ergonomic performance, facilitating the creation of packaging that meets functional requirements and prioritizes user well-being.

3.7.1 Procedure

The Human Builder workbench in Ergonomic Design and Analysis was activated for this study. The manikin was integrated into the simulation, and critical anthropometric parameters were adjusted to replicate real-world human dimensions, precisely resembling an older man. The 3D model of the packaging was imported into the workbench. The position of the packaging was adjusted to ensure proper alignment with the manikin. Control settings for the manikin's shoulder, back, and forearm were adjusted to match the posture of carrying the hand-carry case as illustrated in Figure 3.6.

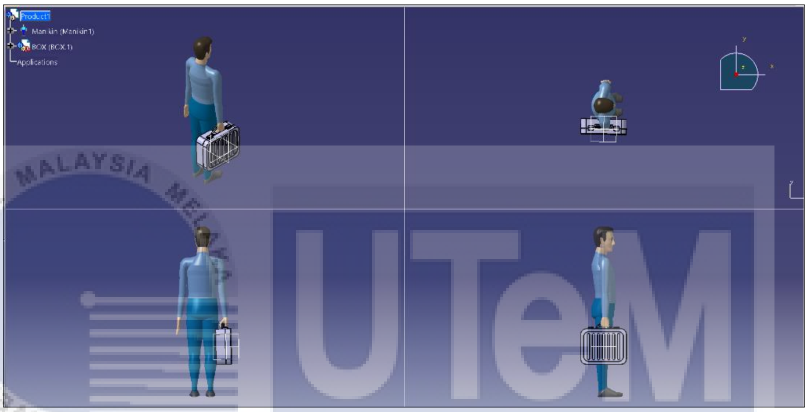


Figure 3.6: Manikin’s posture of carrying the hand-carry case.

The RULA Analysis tool in Figure 3.7 was utilized to assess how the packaging design influenced the user's comfort. Load of 4 kilograms applied to the packaging inserted reflecting the total weight of the right hand need to carry in the posture of intermittent.

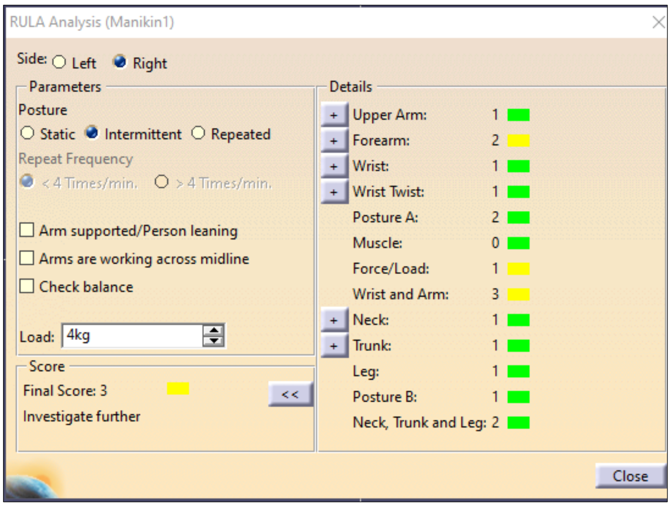


Figure 3.7: RULA Analysis.

The step was repeated to assess RULA analysis on female manikin as in Figure 3.8. A 3D packaging model was attached to the right hand of the manikin with a load of 4kg in the standing posture. RULA analysis was utilized to evaluate the ergonomic risk.

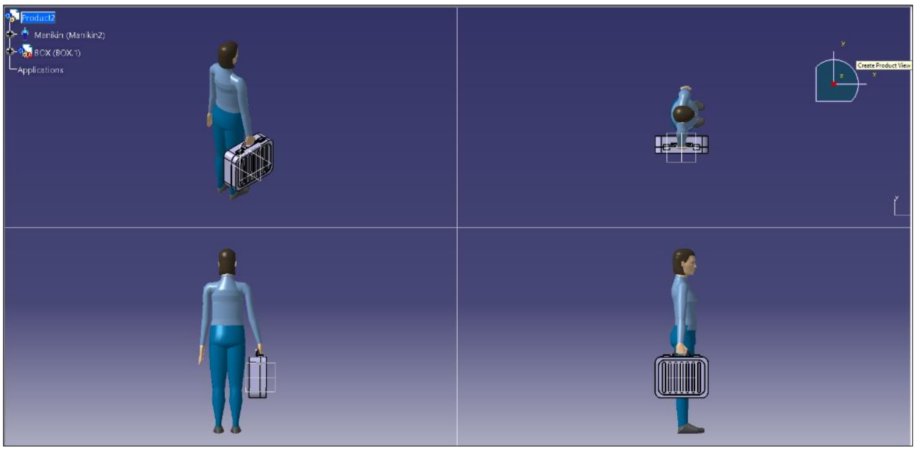


Figure 3.8: Female manikin's posture carrying the hand-carry case.

In conclusion, utilizing CATIA to simulate a manikin carrying packaging is a valuable and efficient process for optimizing ergonomic design. The impact of packaging features on the human body can be accessed by systematically incorporating force and pressure distribution parameters and motion analysis. This simulation-driven approach allows for iterative testing and adjustments, ensuring the final design aligns with ergonomic principles. The utilization of CATIA's features helps in developing packaging that is more user-centric and efficient by prioritizing comfort over functionality.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presented the survey results conducted to determine the preferred packaging type and vote for the proposed exoskeleton packaging design. It also included the results of the selection matrix, which involved the House of Quality, concept screening and scoring. Additionally, this chapter presented the results of the static structural behaviour analysis using ANSYS and the ergonomic design analysis using RULA analysis.

4.1 Survey Results

The target respondents for the survey were individuals aged 40 years and above, with a small population size of 50 individuals. Using a sample size calculator for the parameters applied: Population size (N): 50, Desired margin of error: ± 10%, Confidence level: 90% and population proportion (p): 0.5, the calculation indicated that a sample size of approximately 29 respondents required to achieve desired margin of error and confidence level. However, to enhance the reliability of the survey results, data was collected from 44 respondents.

The objective of the survey was to identify user needs and preferences to develop optimal packaging design solutions for an exoskeleton used for performing Solat. This exoskeleton weighs approximately 3 kilograms and designed to be portable to aid in the prayer process. However, the absence of suitable packaging complicates its transportation. The survey aimed to gather insights into these preferences to support the design process.

(a) Gender participation

The survey attracted a total of 44 respondents, with a slightly higher representation of females (52.3%) compared to males (47.7%) as shown in Figure 4.1.

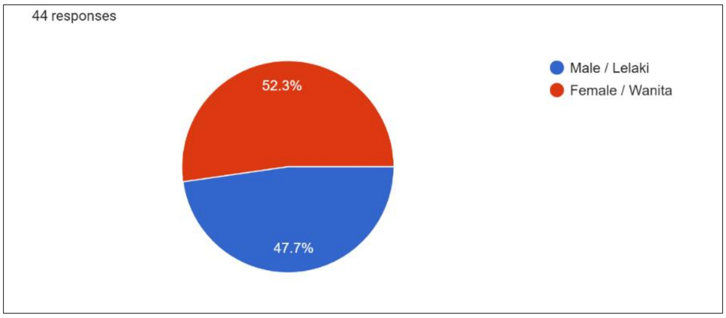


Figure 4.1: Gender participation in the survey.

The survey was conducted to assess interest and participation across genders in evaluating the Packaging Design for Exoskeletons. Both male and female respondents were invited to provide feedback on aspects like functionality, portability, ease of use, and overall appeal of the design. This survey aimed to determine the level of engagement and interest from different genders in contributing to the assessment.

(b) Age range of respondents

The survey was run to gather insights across various age groups regarding the Packaging Design for Exoskeletons. The aim was to understand perceptions related to visual appeal, functionality, and product suitability. The survey participants as appear in Figure 4.2 were segmented into four age groups: 40-50 years (13 respondents), 51-60 years (17 respondents), 61-70 years (8 respondents), and 71 years and above (6 respondents).

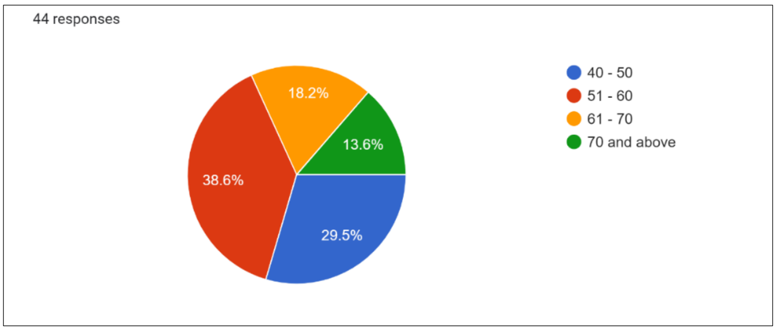


Figure 4.2: Age range for respondents participating in the survey.

Specifically, individuals aged 40-50 years, often seeking modern, functional designs, may emphasize the importance of clear and relevant information. Older adults aged 61 years and above might prioritize readability and simplicity, emphasizing legibility and accessibility in their feedback (Hou G, Anicetus U and He J, 2022). By analysing the data, actionable recommendations were derived to optimize the exoskeleton packaging design, tailoring it to better resonate with diverse age groups and enhance consumer acceptance.

(c) Physical limitations in performing Solat

The question asked for "Do you have any physical limitations in performing Solat? If yes, state the type of physical limitation you had" to investigate the physical limitations encountered during the performance of Solat.

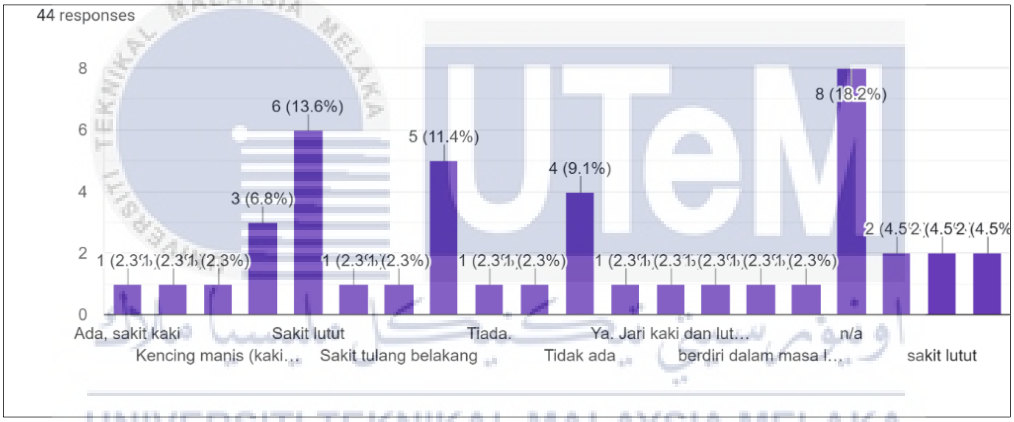


Figure 4.3: Types of physical limitations in performing Solat stated from respondents.

Among the respondents, 7 individuals reported experiencing knee pain while performing Solat as shown in Figure 4.3. One respondent mentioned having lost a leg due to diabetes and now relies on a wheelchair for prayer. Additionally, another respondent reported experiencing back pain and related limitations during prayer. The majority of respondents cited leg pain and difficulty standing for extended periods as common challenges. These challenges not only affect their physical comfort but also impact their ability to fully participate in Solat. These findings underscore the relevance and potential impact of an exoskeleton designed to assist with mobility and physical strain.

(d) Respondent’s experience on performing prayer using chair

The fourth question asked, “Do you ever experience performing Solat using chair?” to gather insights on respondent’s experiences of performing prayer using a chair, which is crucial in functionality of exoskeleton for solat. Figure 4.4 revealed the majority of respondents (33 out of 44 or 75%) reported being experienced in performing prayer while seated on a chair.

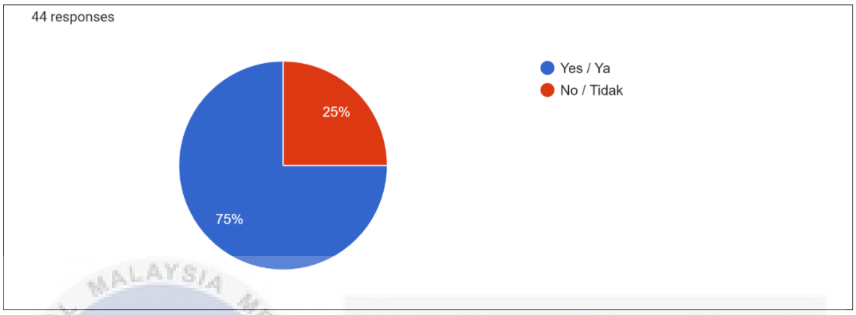


Figure 4.4: Data on respondent’s experience on performing prayer using chair.

These preference for chair-based prayer may be attributed to various factors including knee pain, difficulty standing for long periods or previous accidents resulting in physical limitations that make standing while praying is challenging and potentially harmful (Daghistani, 2016). In Islamic prayer, standing, bowing and prostrating are fundamental components. According to Islamic guidelines, it is permissible for a Muslim with health challenges to sit during prayer if standing is physically taxing or could worsen their condition or recovery (Muhammad Fahmi Rusli, 2020). Understanding these experiences and needs were essential for developing exoskeleton’s packaging that supports individuals who perform prayer while seated, improving accessibility and comfort.

(e) Familiarity with exoskeleton for Solat

The question of “The invention of exoskeleton for Solat is to help user align saf with other Jemaah and not cause any disruption to the saf at the back due to limited space. Did you know about exoskeleton for Solat?” was aimed to gather insights into respondents’ familiarity with exoskeleton designed for solat. In Figure 4.5, out of 44 respondents, 28 indicated they were unaware of exoskeletons for Solat, likely due to its absence from the current market.

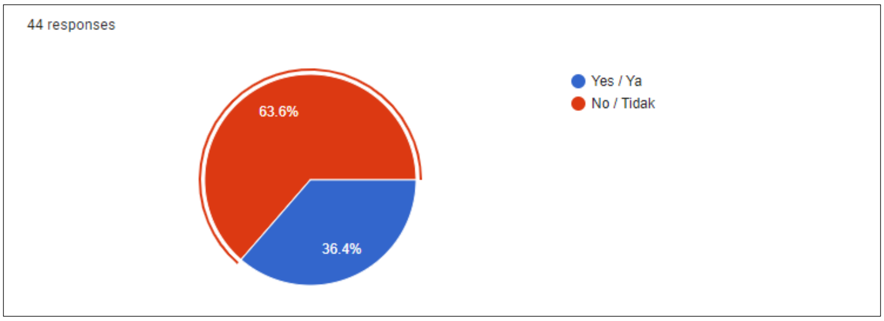


Figure 4.5: Data insight on familiarity with exoskeleton for solat.

Some respondents familiar with exoskeletons for Solat may have mistaken them for other technologies, like electronic sensor-equipped prayer chairs highlighted by Mohd Fauzi *et al*. (2020), aimed at assisting disabled Muslims during prayers. Notably, exoskeletons for Solat in this study boast unique features such as minimal space usage, allowing users to pray align with other Jemaah without disrupting those behind the prayer line. Additionally, they are portable and lightweight, enhancing their practicality to bring and use it anywhere.

(f) Type of carrier/bag suitable to carry the exoskeleton for Solat

The question as in Figure 4.6 was conducted with "Exoskeleton for Solat comes with a structure that can be easily disassembled. In your opinion, what type of carrier/bag is the most suitable for them to carry an exoskeleton?" to gather insights and data on people's preferences for suitable packaging types for carrying exoskeleton, which crucial for designing the shape of packaging that suitable with their functionality. Among the respondents, backpack type emerged as the most preferred carrier or bag for exoskeleton, receiving 31.8% of the votes. Shoulder bag followed closely as the second-highest choice, with 11 out of 44 respondents selecting them. Smart riding luggage received 8 votes, rolling bags received 6 votes and toolboxes received 5 votes.

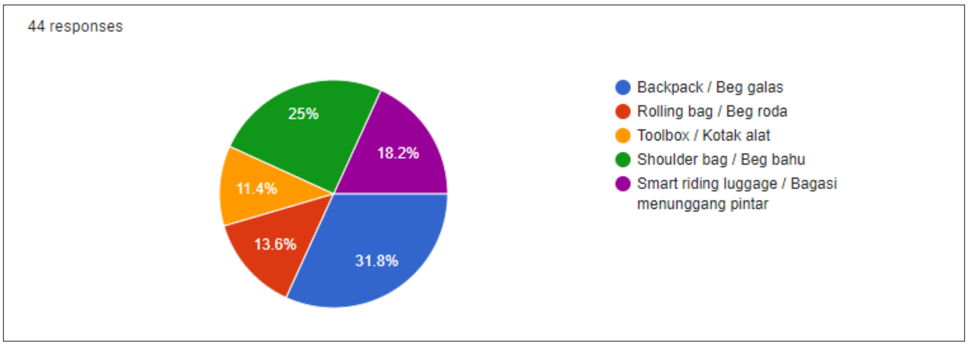


Figure 4.6: Data on type of carrier/bag suitable to carry the exoskeleton for Solat.

This outcome indicates that respondents favour straightforward packaging options for carrying their items. Backpacks were widely used globally as a load carriage system with millions of people relying on them daily from early childhood (Chen & Mu, 2018). They allowed users to carry items on their back using shoulder straps, effectively solving the portability issue. However, to access items from a backpack can still be challenging, requiring the user to remove backpack entirely. Despite the access challenges, backpack offered benefits such as appropriate weight distribution highlighted by Sturdy *et al.* (2021) make it suitable for elderly to carry their item and reduce effect of musculoskeletal impairments.

(g) Level of importance feature should present in a packaging

The survey in Figure 4.7 aimed to gather insights into the level of importance attributed to various features that should be present in packaging for exoskeleton under question of "Based on your choice above, indicate the level of importance for each feature that should be present in a carrier/bag. (5 – Very important, 1 – Not important at all)".

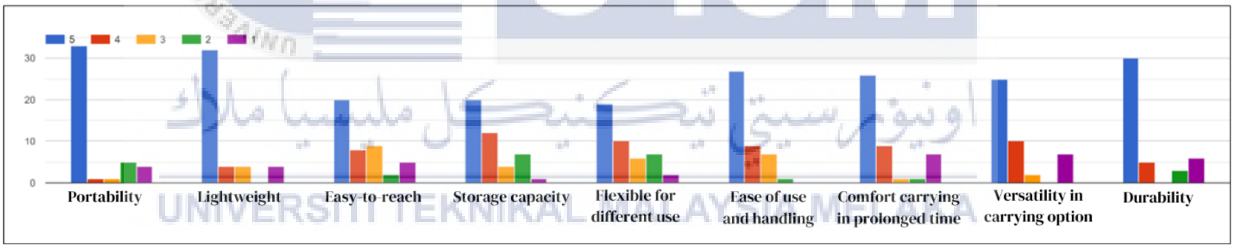
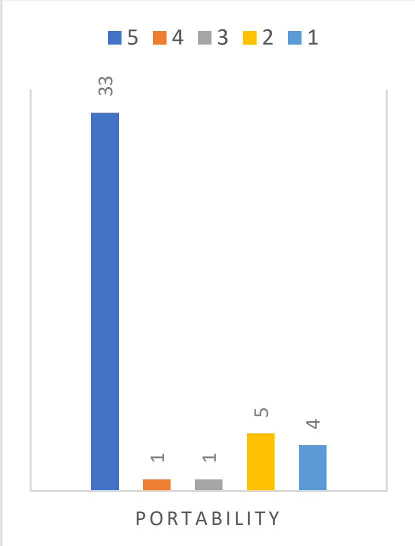
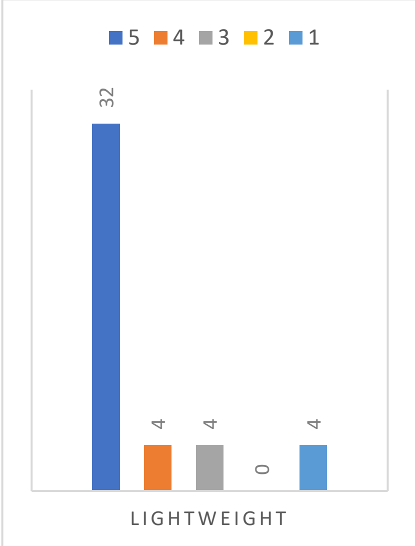
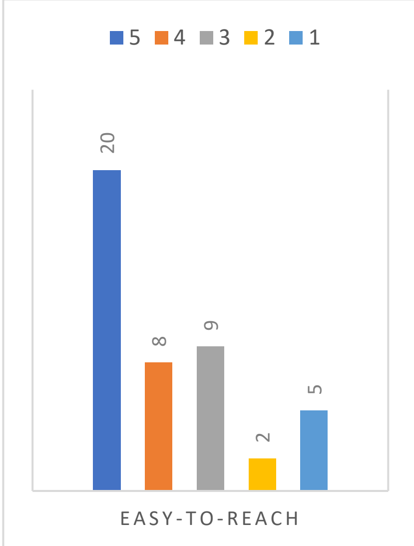
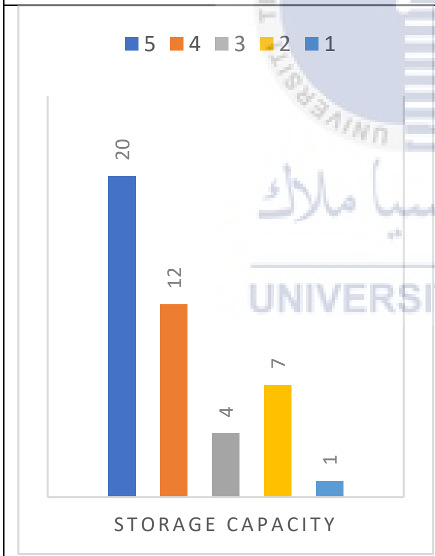
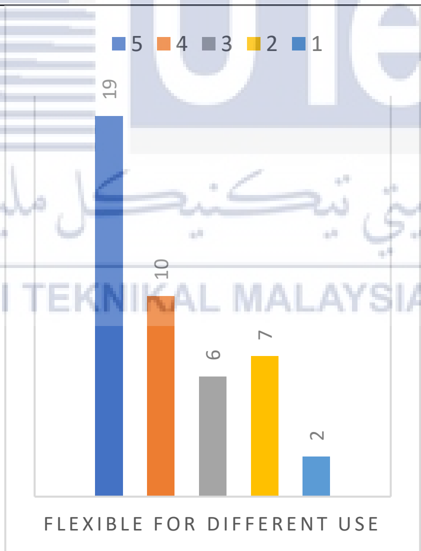
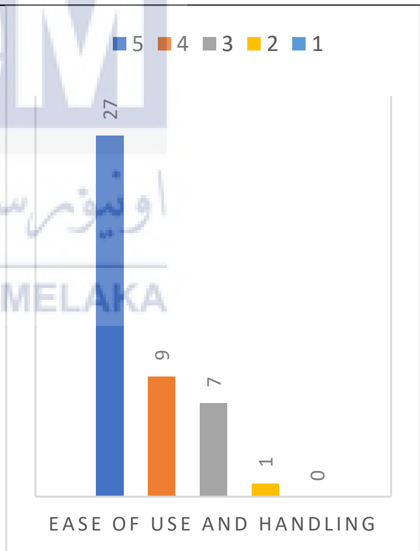


Figure 4.7: The level of importance for each feature that should present in a packaging.

Table 4.1: Chart of level of importance for each feature.

 The portability feature claimed to receive the highest vote of ‘the very important’ features.	 The lightweight feature with ‘very important’ vote received 32 votes.	 Easy-to-reach feature had the average vote for these 5 level of importace.
 Storage capacity received average vote for ‘very important’ features.	 Flexible for different use feature is not very important feature.	 Ease of use feature received no vote to be claimed as ‘not very important feature’.

<table>
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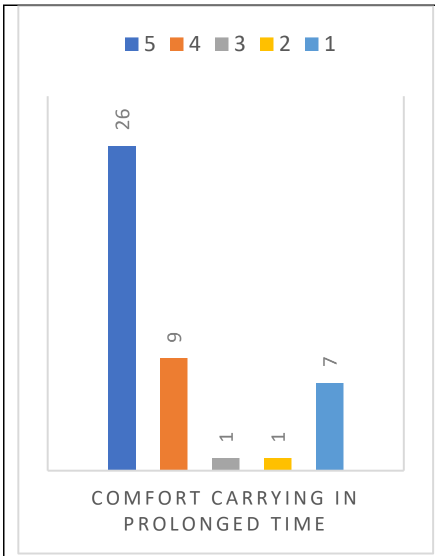
<td>
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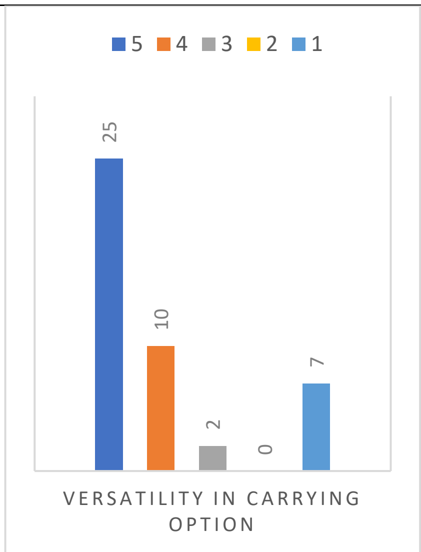
<td>
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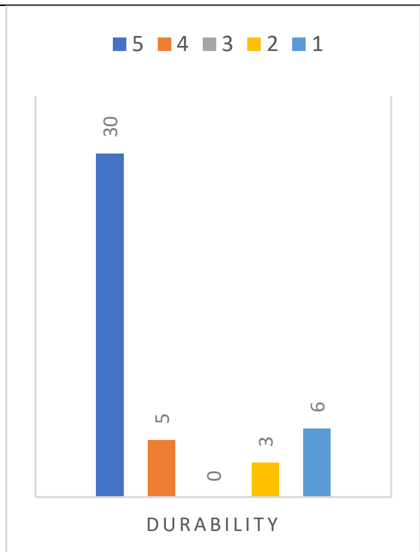
<td>
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<tr>
<td>Comfort carrying in prolonged time feature is included as important feature for the packaging.</td>
<td>The versatility in carrying option received high vote for ‘very important’ feature.</td>
<td>Durability feature is very important feature that should include in designing packaging.</td>
</tr>
</table>

Table 4.1 highlighted the chart for level of importance for understanding the significance placed on these features by respondents was essential for designing packaging that aligns with user needs and enhances the overall experience of using and transporting the exoskeleton.

(h) Influence of aesthetic appeal when choosing the packaging

A majority of respondents (45.5%) agreed on the question of “How much does aesthetical appeal of a carrier/bag influence your choice?” that aesthetic appeal significantly influences their choice of packaging as reflected in Figure 4.8. Additionally, 11 out of 44 respondents believed that aesthetic appeal somewhat influences their decision, while only 1 respondent indicated that it does not influence their choice at all.

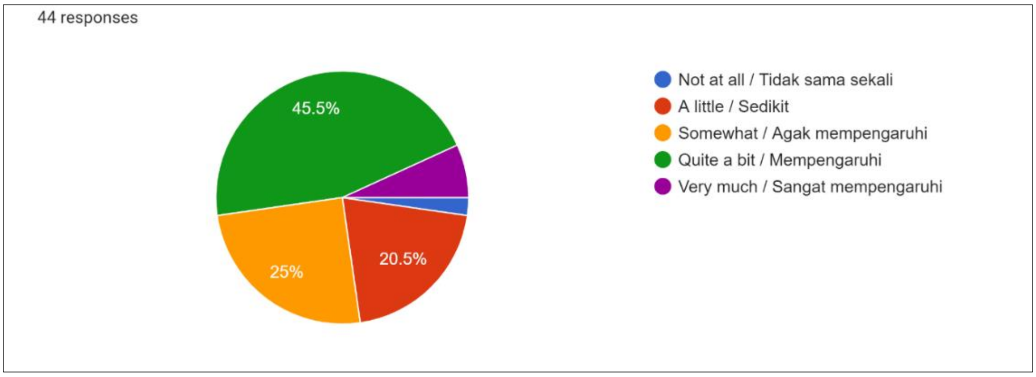

Figure 4.8: Influence of aesthetic appeal when choosing the packaging.

Design aesthetic played a significant role in product design as highlighted (Shi *et al.,* 2021). Consumers often used aesthetics to evaluate and differentiate products, influenced their purchasing decisions (R. Wang, 2024). The attractiveness of a product's appearance was determined by the argument of visual design element, making it essential to study and enhance these aspects in product appearance design (Liu, 2021). Understanding the importance of aesthetic appeal in packaging selection was essential for designing visually appealing and engaging packaging for exoskeleton, ultimately enhancing consumer satisfaction and product desirability.

(i) Preferability of wheels in carrier/bag

The result for question "Do you prefer carrier/bag with wheels for easier mobility?" was to gather insights into the preference for carrier or bag features among respondents, particularly focusing on the desirability of having wheels for easier mobility when designing packaging for exoskeleton for solat.

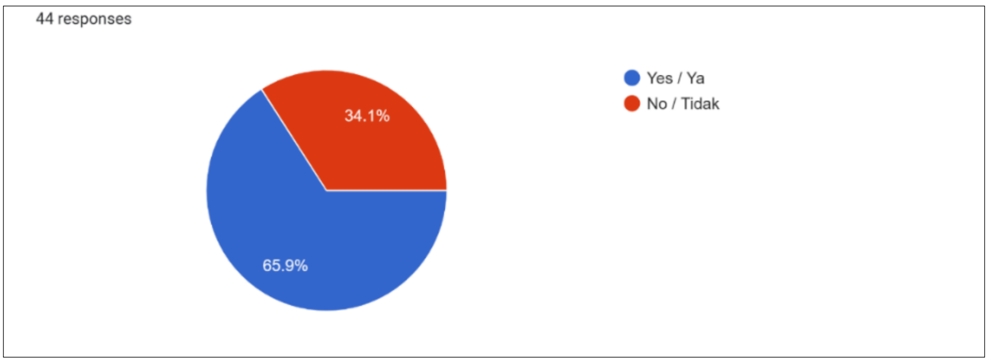

Figure 4.9: Preferability carrier or bag with wheels among respondents.

Figure 4.9 illustrated a majority of respondents (29 out of 44) indicated a preference for carriers or bags equipped with wheels for enhanced mobility and convenience. This preference aligned with the practical need to transport exoskeleton for Solat more effortlessly, reduced physical strain and enhanced efficiency (Chitena *et al*., 2022).

(j) Preferability carrier/bag with integrated technology features

The question for "Would you be interested in carrier/bag with integrated technology features?" was to oversee respondents' preferences for carrier or bag features, particularly focusing on the desirability of integrated technology features when designing packaging for exoskeleton for Solat. A significant majority of respondents (31 out of 44, or 70.5%) expressed a preference for carriers or bags equipped with integrated technology features as reflected in Figure 4.10.

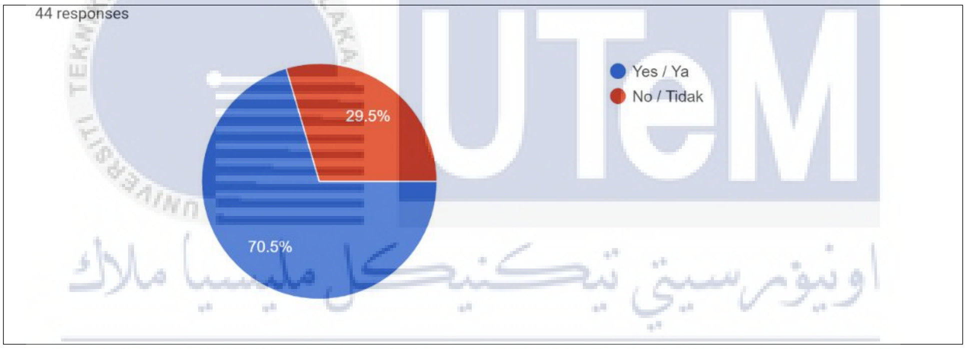

Figure 4.10: Preferability carrier or bag with integrated technology features among respondents.

Respondents were likely interested in the packaging with integrated technology features due to the enhanced usability, convenience and safety benefits these features offer. Features like built-in charging port enabled convenient recharging of devices on the go without having to open the packaging or carry an external power bank in hand. Older individuals may be more prone to misplacing or forgetting items like bags due to memory-related issues. Integrated an AirTag or tracking device into the packaging allowed for easy location tracking through smartphone apps, reduced the stress and inconvenience of losing important belonging (Sunitha *et. al.*, 2023).

(k) Suggestion for improvement

The last question was, “Do you have any other suggestions/comments about this study?” These insights as listed, underscored the importance of continually refining and iterating the design to meet user’s diverse needs and preferences.

- The target market is the older individuals, so emphasis should be placed on ease of setup and disassembly.
- The packaging type should be something that facilitates movement.
- The design should not look bulky.
- Facilitate the zipper opening mechanism.
- Add on for water bottle placement.

Several respondents offered insightful opinions and suggestions for improving the illustrated designs. One common suggestion was to ensure that the design remains compact and not overly bulky, which would optimize storage efficiency and save space. Several respondents emphasized the importance of optimizing the design for ease of setup and disassembly, particularly considering the challenges faced by older users. Older individuals may find it difficult and time-consuming to install the exoskeleton due to physical limitations and require sufficient space for assembly and disassembly. Additionally, bending over repeatedly to set up the exoskeleton can cause back pain for elderly users.

In conclusion, the survey with 44 respondents with slightly more females than males was segmented into age groups with the majority of 51 – 60 years old. Notably, many respondents reported physical limitations, such as knee and back pain, and had experience performing Solat using a chair, underscoring the need for an exoskeleton for Solat to assist in performing prayer. Backpack was the preferred carrier (31.8%) and features like portability, lightweight design, durability and versatility were prioritized. Respondents emphasized ease of setup, compact design and easy opening mechanism. These insights highlight the importance of designing user-friendly and practical packaging solutions for older individuals and those with physical limitations to enhance accessibility and comfort.

4.2 Selection Matrix Analysis

The selection matrix analysis employed an approach to identify the optimal packaging design to achieve the objective of designing packaging solution that prioritize protection and portability for exoskeleton for Solat. Utilized tools of House of Quality (HoQ), concept screening and scoring, the process began by mapping out the requirements of packaging and generated multiple design concepts. (HoQ) method was introduced to quantify the relationship between specific requirement and engineering specification in order to produce the final design (Ismail *et al.,* 2016). These concepts were then screened and evaluated against the criteria outlined in House of Quality which of portability, durability, ease of use and handling and other criterias. Through iterative refinement and quantitive analysis, the most suitable design concept was selected, ensured alignment with project objectives and satisfaction of end-user needs. This systematic method not only facilitated a thorough evaluation but also led to the identification of a packaging design that effectively balanced functionality with aesthetic appeal.

4.2.1 House of Quality (HoQ)

The House of Quality (HoQ) matrix served as a comprehensive tool to align customer requirements with engineering characteristics for the packaging design. Through the HoQ matrix, the correlation between customer needs and engineering features was established, ensuring that the final packaging design effectively balanced functionality, durability and user-satisfaction.

Figure 4.11 demonstrated the results obtained, in terms of customer importance ratings, it's evident that portability, lightweight, and durability rank highest, each scoring a 5. This indicated a strong customer preference for products that were easy to carry, lightweight, and built to last. Followed closely behind were ease of use, handling, and comfort during prolonged use, scoring a 4, highlighted their significant importance for customer satisfaction. While storage capacity ranks slightly lower with a score of 3, it remains a consideration for customers, albeit not as critical as other factors. Moving on to the design assessment, square box hand-carry case excels in durability, scoring a 5, aligning well with the high customer priority for durability. However, it falls short in storage capacity, which could potentially be a drawback. Conversely, roller bag offers higher storage capacity but lacks durability, scoring only 1, posing a concern given its low rating in a critical customer priority area. Airwheel smart luggage only scored for portability, storage capacity and durability even it was best to use as user did not have to carry instead ride on it.

Transitioned to the technical importance ratings, the engineering characteristic for an ergonomic handle emerged as paramount, with the highest importance rating (138) and a relative weight of 14.82%. This underscored the significance of investing in a comfortable handle design to enhance customer satisfaction. Additionally, the weight of empty packaging and material with high impact also held considerable importance, with a difference of 1, suggested their substantial influence on product performance. Furthermore, while the internal compartment remains important, its lower importance rating (5.8%) indicates that it may not be as critical to customer satisfaction as other factors.

Considered the correlation matrix findings, positive correlations between the weight of empty packaging and material with high impact suggested mutual influence, indicated that by reducing packaging weight could positively impacted material choice and vice versa. Additionally, positive effects between the weight of empty packaging and internal padding implied a need for balance when adjusted these factors to maintain product integrity. Conversely, the negative effect between the weight of empty packaging and compact dimensions highlighted a trade-off between size and weight. Finally, the positive effect between secure locking mechanisms and easy-access zipper/compartments suggested that these features complement each other, enhanced product functionality and security.

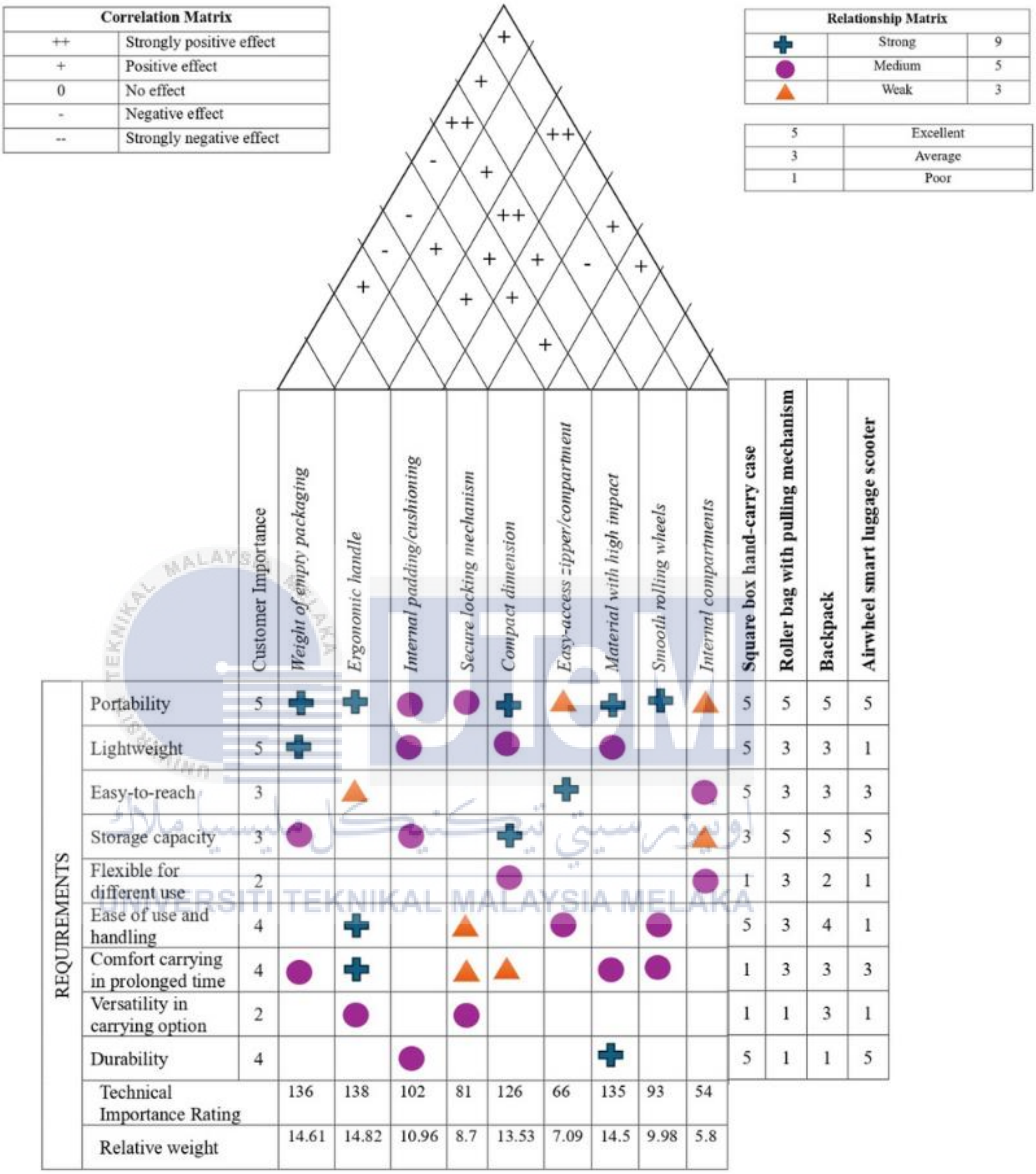

Figure 4.11: House of Quality to identify the optimal packaging concept.

4.2.2 Concept Screening

The concept scoring analysis evaluated the packaging design concept for the exoskeleton based on the criteria identified in the HoQ. This method enabled the comparison of different concepts, highlighted their strengths and weaknesses to determine the most suitable options for further development. There were four packaging design concepts assessed in Table 4.2 which were the square hand-carry case, roller bag with pulling mechanism, backpack and airwheel smart luggage scooter.

Table 4.1: Design screening for design concepts.

Selection Criteria	Square-box hand carry	Roller bag pulling mechanism	Backpack	Airwheel smart luggage scooter
Portability	+	+	+	+
Lightweight	+	-	-	-
Easy-to-reach compartment	+	-	-	-
Storage Capacity	-	+	+	+
Flexible for different use	-	+	-	-
Ease of use and handling	+	-	+	-
Comfort carrying in prolonged time	-	+	+	-
Versatility in carrying option	-	-	+	-
Durability	+	-	-	+
Sum +'s	5	4	5	3
Sum -'s	4	5	4	6
Rank	1	2	1	3
Continue	**Yes**	**Yes**	**Yes**	**No**

The concept scoring matrix evaluated each design based on a set of criteria, assigning positive (+) or negative (-) scores. Criteria included portability, lightweight, easy-to-reach compartments, storage capacity, flexibility for different use, ease of use and handling, comfort for prolonged carrying, versatility in carrying options, and durability. The Square-Box Hand Carry, with 5 positives and 4 negatives, ranked first and was recommended to continue. The Roller Bag Pulling Mechanism, with 4 positives and 5 negatives, ranked second and also continued. The Backpack, with 5 positives and 4 negatives, tied for first and continued. The Airwheel Smart Luggage Scooter, with 3 positives and 6 negatives, ranked third and was not recommended to continue.

The concept scoring analysis compared four packaging design concepts using various criteria, revealed key insights: The Square-Box Hand Carry and Backpack both scored highest with five positive and four negative attributes. The Square-Box Hand Carry was noted for its portability, lightweight, and compartment accessibility, despite its limited storage, flexibility, and prolonged carrying comfort, making it a viable option for further development. The Roller Bag Pulling Mechanism exceled in storage capacity and prolonged use comfort but struggled with weight, ease of use, and durability, presented usability and reliability challenges but still warranted consideration. The Backpack, praised for prolonged use comfort, handling ease, and storage capacity, was hindered by its weight and limited use flexibility, yet its strengths made it a strong candidate for users prioritized comfort and storage.

4.2.3 Concept Scoring

The concept scoring analysis provided a detailed evaluation of three packaging design concept for the exoskeleton: Design 1 (Square-box hand carry case), Design 2 (Roller bag with pulling mechanism) and Design 3 (Backpack). The concept scoring matrix as illustrated in Table 4.3 evaluated each design against the same nine selection criteria. Each criterion was assigned a weight percentage, reflected its importance and each design was rated on a scale of 1 to 5. The weighted scores were calculated by multiplying the rating by the weight percentage. The total score for each design was the sum of its weighted scores.

Table 4.2: Design scoring for two final proposed design.

		Concept Design					
		Design 1 (Square-box hand carry)		**Design 2** (Roller bag pulling mechanism)		**Design 3** (Backpack)	
Selection Criteria	**Weight (%)**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Portability	14	5	0.70	5	0.70	5	0.7
Lightweight	14	5	0.70	3	0.42	3	0.42
Easy-to-reach to compartment	11	5	0.55	3	0.33	3	0.33
Storage Capacity	9	3	0.27	5	0.45	5	0.45
Flexible for different use	9	1	0.09	3	0.27	2	0.18
Ease of use and handling	11	5	0.55	3	0.33	4	0.44
Comfort carrying in prolonged time	11	1	0.11	3	0.33	3	0.33
Versatility in carrying option	7	1	0.07	1	0.07	3	0.21
Durability	14	5	0.70	1	0.14	1	0.14
Total Score		3.74		3.04		3.20	
Rank		1		3		2	
Continue		**Develop**		**No**		**No**	

The concept scoring analysis evaluates three packaging design concepts based on weighted selection criteria: portability (14%), lightweight (14%), easy-to-reach compartment (11%), storage capacity (9%), flexibility for different use (9%), ease of use and handling (11%), comfort for prolonged carrying (11%), versatility in carrying options (7%), and durability (14%). The Square-Box Hand Carry design scored highest with a total score of 3.74, excelled in portability, ease of use, and durability, but lacked in storage capacity and comfort for prolonged carrying earned it the top rank and recommended for development. The Roller Bag Pulling Mechanism, with a score of 3.04, performed well in portability and storage capacity but fell short in ease of use and durability, ranked third and not recommended for further development. The Backpack design scored 3.20, performed well in portability, storage capacity, and ease of handling, but was hindered by weight, flexibility, and durability issues, ranked second and also not recommended for continuation.

4.3 Design Development

Figure 4.12 illustrates packaging design for exoskeleton aimed to facilitate ease of transportation for older individuals bringing their own exoskeleton to the mosque. The packaging crafted as a square box, equipped with a convenient handle to ensure effortless carrying. Additionally, it features a quick-go-clip, enhanced mobility with minimal exertion.

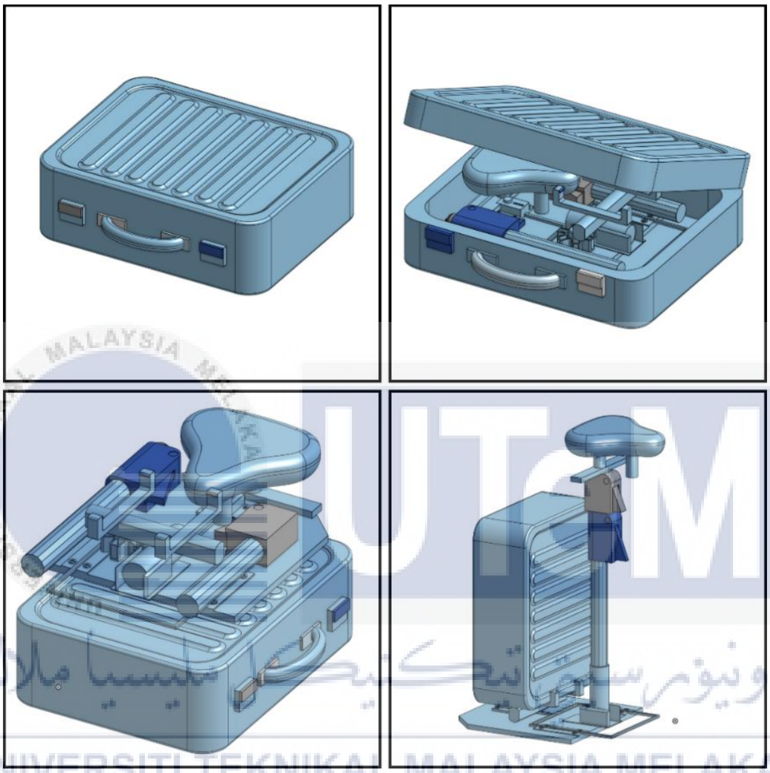

Figure 4.12: Final design solution for exoskeleton for Solat.

The primary focus of design was to provide optimal protection for the exoskeleton. This was achieved through the incorporation of a sturdy hard case, meticulously engineered to safeguard against potential cracks or damage during transit. Additionally, the inner packaging featured soft padding to further safeguard the exoskeleton from impacts inside the case. Notably, the bag included a stick attachment mechanism designed to be affixed to the exoskeleton's base. The feature served to optimize space utilization during prayer sessions, ensured the bag can be positioned beneath the exoskeleton without encroaching on surrounding space.

4.4 Justification for Selection of Design Concept

The selected toolbox design concept was chosen based on its strong alignment with the specified packaging requirements including protection, portability and ergonomic considerations tailored for the exoskeleton. The design concept underwent evaluation against predefined criteria to ensure confidence in the chosen solution's ability to deliver optimal outcomes for the packaging design.

Both concept selection matrices and survey results play complementary roles in the project development process, each offering unique benefits that contribute to overall project success. Survey results offer valuable insights into user preferences and perception, guiding design directions and validating user-centered features like usability and aesthetics. Concept selection matrices provide a structured framework for comparing and prioritizing design concepts based on objective criteria aligned with project goals and constraints. Integrating both methodologies enriches decision-making by combining technical requirements with user-centric feedback, ensuring that design meets functional requirements.

(a) Scope and Practicality

The scope of this packaging design was specifically for short-duration travel, where the target users need to carry the packaging from their vehicles into the mosque. Despite survey results indicating a preference for backpacks due to their familiarity and ease of use, the hand-carry case with its dimension of 450 x 350 x 150 mm, provided a compact yet sufficient spacious solution for transporting the exoskeleton. While it may be challenging for elderly individuals to carry this size while riding a motorcycle, it remained a practical and convenient option for short distance carrying due to its manageable size and ease of handling.

(b) Ease of Access

One of the primary advantages of the hand-carry case was its ease of access. The design incorporated an easy-open clip mechanism, allowed users to quickly and effortlessly reach the contents of the case. This was particularly beneficial for elderly and disabled users who may have limited dexterity or strength, making it challenging to manage complex access methods. In contrast, a backpack although advantageous for weight distribution, requires multiple steps to access items, including removing the bag, opening it, retrieving the item and resealing and wearing it again. This sequence of actions can be strenuous and time-consuming for the target users.

(c) Ergonomic Considerations

To address concerned about the weight of the hand-carry case, several ergonomic features to enhance comfort and usability was incorporated as in Figure 4.13. The handle was designed with ergonomic to provide a comfortable grip and ensuring optimal pressure distribution across the user's hand. This help in reduced strain and minimized discomfort during transport even with the 4-kg weight (Afrida Kabir *et al*., 2024). Furthermore, the choice of Polylactic Acid (PLA) material for the case not only emphasized sustainability and eco-friendliness but also contributed to a lighter overall weight compared to conventional materials.

(d) Internal Protection and Security

The hand carry case was designed with internal padding to protect the exoskeleton for Solat. This padding ensured that exoskeleton was cushioned against impact, reducing the risk of damage during transit (Patil & Patil, 2020). Additionally, straps inside the case help secured the exoskeleton prevented it from shifting and potentially sustaining damage.

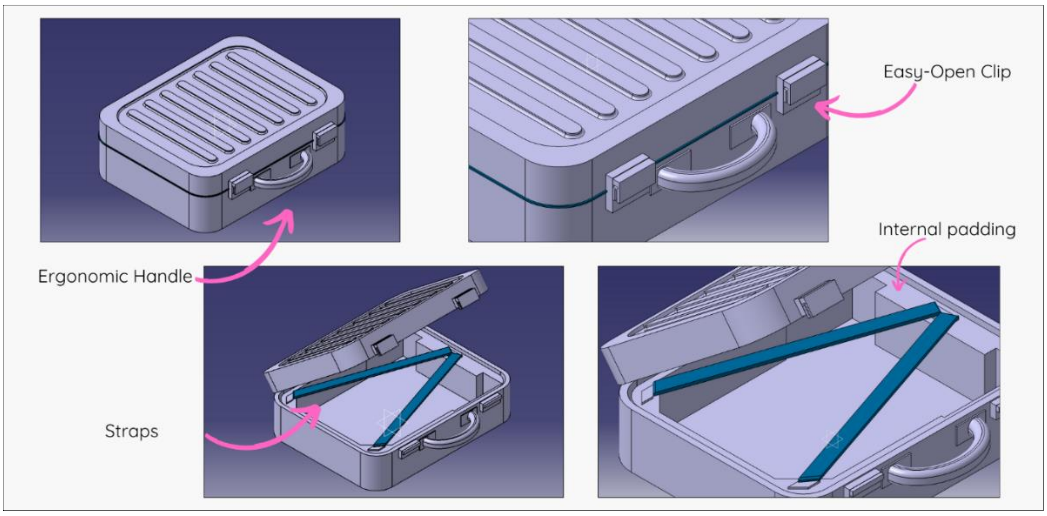

Figure 4.13: Revised design of square hand carry case.

(e) Comparative Analysis with Other Design Concepts

Compared with roller bag, the hand carry case eliminated the issue of dirt and space requirements associated with wheeled design. Roller bag can accumulate dirt on their wheels, posing hygiene concern and require additional space to locate, which can be problematic in crowded situation. The airwheel smart luggage while innovative, introduces complexity in handling and may not be practical for all users, especially those with limited mobility or balance. Additionally, the hand-carry case was more space efficient during travel compared to other design concepts making it a convenient option for short trips.

(f) Integration of survey results and concept selection matrix

Despite initial survey preferences for backpacks which highlighted user familiarity and perceived ease of use, the concept selection matrix utilizing tools such as House of Quality, design screening and scoring won the hand-carry case. This decision was driven by the hand-carry design's superior performance in meeting the predefined criteria such as durability, protection and optimal use of space. The matrix's systematic evaluation process identified the hand-carry design as best aligning with technical specifications and functional requirements for ensuring the exoskeleton's safe transport and usability. This approach minimizes the likelihood of selecting a design concept that may be popular but fails to meet critical technical or functional requirements. By integrating survey feedback with rigorous technical evaluation, the chosen design concept ensures optimal performance, aligning closely with project goals and user needs.

4.5 Material Selection

Several factors were considered when selecting a material for a hand-carry case designed to carry the exoskeleton for Solat including weight, durability and cost. Table 4.4 showed list of potential material with pros and cons in developing the packaging.

Table 4.4: List of potential material for the packaging.

Acrylonitrile Butadiene Styrene (ABS)	
Advantages: - Strong and impact resistant - Lightweight, easy to carry - Affordable - Easy to mold and fabricate	Disadvantages: - Can get scratched more easily - Derived from petroleum, not so biodegradable.
Polylactic Acid (PLA)	
Advantages: - Lightweight - Affordable - Made from renewable resources	Disadvantages: - Less impact resistance, may require thicker walls for sufficient strength
Polycarbonate (PC)	
Advantages: - Extremely strong and impact-resistance - Excellent durability and long lasting	Disadvantages: - Expensive than ABS and PLA - Heavier than ABS and PLA - Derived from petroleum, non-biodegradable

Considering the criteria for developing the packaging, Polylactic Acid (PLA) emerged as the most suitable material. Its key advantage included being lightweight biodegradable, which are crucial for ease of use and align with sustainable objectives. Polylactic Acid (PLA) is a biodegradable and bioactive thermoplastic derived from renewable resources such as corn starch or sugarcane (Singhvi *et al.*, 2019). Known for its environmental benefits, PLA is compostable under industrial conditions, breaking down into water, carbon dioxide and organic materials. It is non-toxic, and its production utilizes renewable agricultural products, reducing dependence on fossil fuels (Fogašová *et al.*, 2022). While it may require thicker walls for sufficient strength, the benefits of sustainability, safety and ease of handling make PLA the ideal choice for the packaging material.
Developed packaging design concept of square hand carry case using Polylactic Acid (PLA) material aligned with environmental sustainability goals and underscored a commitment to Sustainable Development Goal 12: Responsible Consumption and Production, by significantly reducing waste as its composability helps lessen the accumulation of plastic landfills and oceans (Schröder *et al.,* 2019). Additionally, PLA production supports resource

efficiency by using renewable source, promoting sustainable management of natural resource.

4.6 Static Structural Behaviour

The following section presented the results obtained from the ANSYS analysis of the static structural behavior of the packaging when subjected to a load of 4 kilograms on the handle of the case. This load accounts for the exoskeleton's weight which is 3 kilograms as stated by Halim *et al.,* (2024), plus an additional 1 kilogram for the packaging and potential accessories carried by users. This was done to analyze the designed packaging solutions effectiveness in safeguarding the exoskeleton. The packaging analyzed under material of PLA (Polylactic Acid) that known for its good strength and stiffness, contributes significantly to the structural performance of the hand-carry case. PLA typically has an elastic modulus of about 3.2 GPa and a tensile strength of approximately 49 MPa, as noted by Ranakoti *et al.* (2022), which supports the minimal deformation observed under the applied load. The analysis focused on four key parameters: deformation, equivalent elastic strain, equivalent stress and the safety factor. Each parameter was discussed in detail to evaluate the structural integrity and reliability of the packaging under typical load conditions.

4.6.1 Deformation Analysis

The deformation analysis was conducted to assess the displacement experienced by a square hand-carry case made entirely of PLA (Polylactic Acid) material under a specified load of 39.24 N (equivalent to 4kg). The primary focus was to evaluate the structural integrity of the packaging by observing the extent and distribution of deformation.

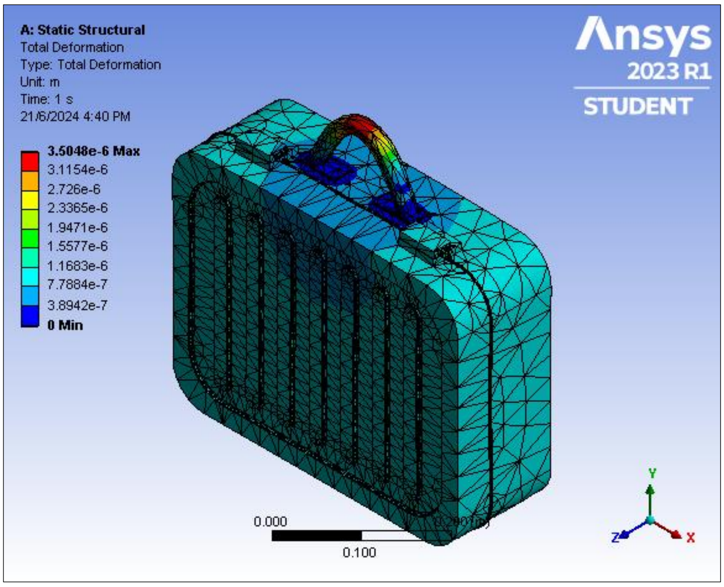

Figure 4.14: Total deformation of the hand-carry case applied to the handle.

Figure 4.14 demonstrated the maximum deformation recorded at the handle where the load was applied, measuring 3.5048 µm, indicated a critical area of stress concentration. However, the fact that this deformation was relatively minimal suggested that PLA, despite being a biodegradable polymer, offered sufficient strength and stiffness for this application (Naser *et al*., 2021). The uniform distribution of deformation across the surface, with the highest displacement at the center gradually decreased towards the edges, demonstrated effective load dispersal. The uniformity was vital as it prevent localized stress concentrations, which can lead to material fatigue or failure over time (Singh, 2016).

The minimal deformation at the base of the packaging underscored the stability of the structure. Maintaining stability at the base was crucial, as it supported the entire load and ensured that the packaging did not tip or collapsed under pressure (Q. Wang *et al.,* 2022). The low deformation levels across the case, included the handle and base, indicated that the PLA material can withstand repeated loading and unloading without significant wear or deformation. The performance was crucial for practical applications where the case might be subjected to frequent use.

4.6.2 Equivalent Elastic Strain

The equivalent elastic strain analysis assessed the performance and reliability of packaging materials to understand how a material responded to applied loads in terms of its deformation per unit length. The analysis in Figure 4.15 provided valuable insights into its elasticity and potential for permanent deformation under different loading conditions.

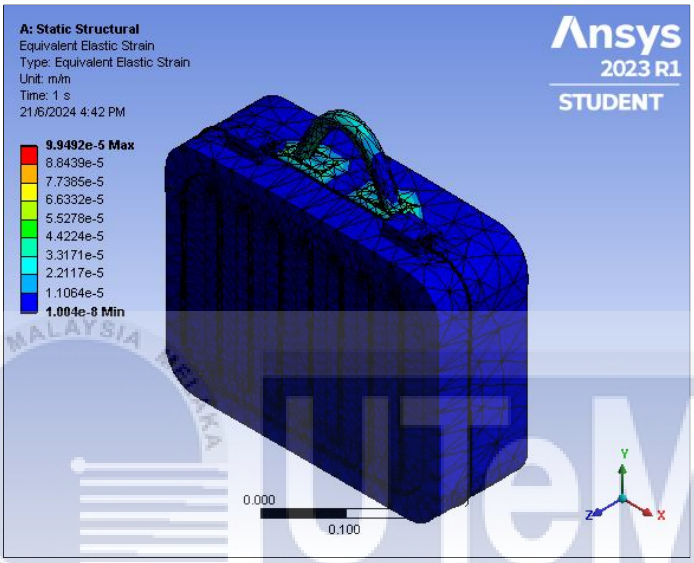

Figure 4.15: Equivalent elastic strain distribution of the hand-carry case.

The maximum equivalent elastic strain observed in the analysis was 99.5 µm/m. This value signified the material's extent of deformation under the applied load of 39.24 N (4 kg). The location of this maximum strain at the center of the top face, directly opposite the load application point, highlights the areas of potential vulnerability. The strain distribution pattern across the case revealed higher strain concentrations near the handle, where the load applied, with a gradual decreased towards the edges. This pattern indicated that the material effectively absorbs and distributes the load, minimized localized stress concentrations. Effective load distribution was essential for reducing the risk of material fatigue and failure, ensured the longevity and durability of the case.

4.6.3 Equivalent Stress

The equivalent stress or Von Mises stress analysis was conducted to evaluate the likelihood of failure due to yielding and to assess the structural integrity of a square hand-carry case made of PLA (Polylactic Acid) material (Park *et al.,* 2023). This stress measured combine the three principal stresses into a single value to predict yielding of materials under any loading condition.

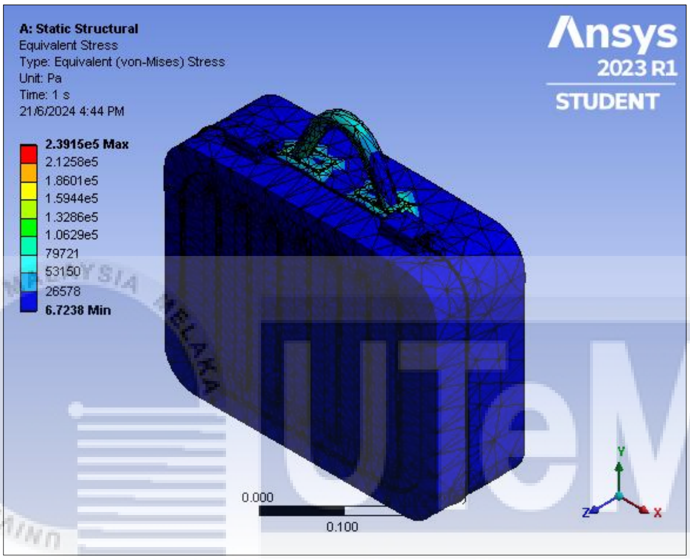

Figure 4.16: Equivalent stress distribution of the hand-carry case.

The maximum equivalent stress in Figure 4.16 recorded in the analysis was 239 kPa, located at the center of the top face of the case, directly opposite the load application point. This value indicated the highest stress experienced by the material, but it is within the safe operating range for PLA. Given PLA's typical yield strength, this stress level was moderate and suggested that the case can withstand the load without yielding or undergoing plastic deformation. This implied that the material retains its structural integrity under the specified loading conditions.

The stress distribution pattern revealed higher stress concentrations around the handle attachment points, with significantly lower stress values across the rest of the case. This pattern indicated effective load management and stress dispersion, which are crucial for maintaining the overall stability and durability of the packaging.

4.6.4 Safety Factor

The safety factor was defined as the ratio of the material's yield strength to the maximum equivalent stress experienced under load (Harries *et al.,* 2019). For PLA, with a yield strength of 49 MPa, this analysis help ensured that the design could withstand not only the specified loads but also unforeseen overloads without failure. A high safety factor indicated a significant margin between the operating stress and the material's failure point, enhancing reliability.

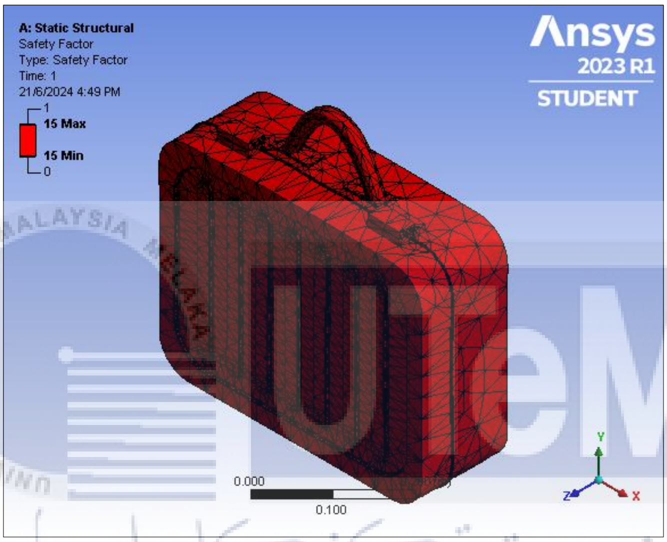

Figure 4.17: Safety factor on the PLA hand-carry case.

Figure 4.17 showed the minimum and maximum observed safety factor in the analysis both was 15. Given the yield strength of PLA (49 MPa), this translated to the maximum stress levels experienced being 3 times lower than the yield strength. This high safety margin indicated that the material operates well within its capacity, ensured that even under the highest stress points, such as around the handle, the material will not yield or fail. This was critical for maintaining the structural integrity of the case under both normal and excessive loads.

The combined results from the deformation, strain, stress, and safety factor analyses demonstrated that the PLA hand-carry case was structurally sound, durable, and reliable under the specified load. The case showed minimal deformation, maintains its shape and functionality, effectively managed and distributed load stresses, and operated well within safe limits with a high safety factor. These findings validated the use of PLA as a suitable material for sustainable packaging solution, ensured both performance and environmental benefits. Future design optimizations could further enhance material efficiency while maintaining safety and durability.

4.7 Rapid Upper Limb Assessment (RULA)

The Rapid Upper Limb Assessment (RULA) analysis was conducted to achieve the objective of analyzing the designed packaging effectiveness prioritizing ergonomic analysis by evaluate the ergonomic risks associated with a manikin performing tasks in posture of carrying a hand-carry case. The RULA scores provide insight into the potential for musculoskeletal disorders (MSDs) due to the observed postures (Tahir *et al.,* 2023).

4.7.1 RULA Analysis on Male Manikin

The analysis in Figure 4.18 was performed under conditions of static posture: A standing manikin held a 4kg hand-carry case in the right hand. The final RULA score of 3, along with the detailed breakdown in Table 4.5, indicated the posture and load-related stresses experienced by different parts of the body. The overall RULA score of 3 suggested that the manikin's posture while carrying the case was relatively low risk. According to RULA guidelines, a score of 3 indicated that the posture was medium risk level, but further investigation may be needed if the task repeated frequently or sustained for long periods (Cremasco *et al*., 2019).

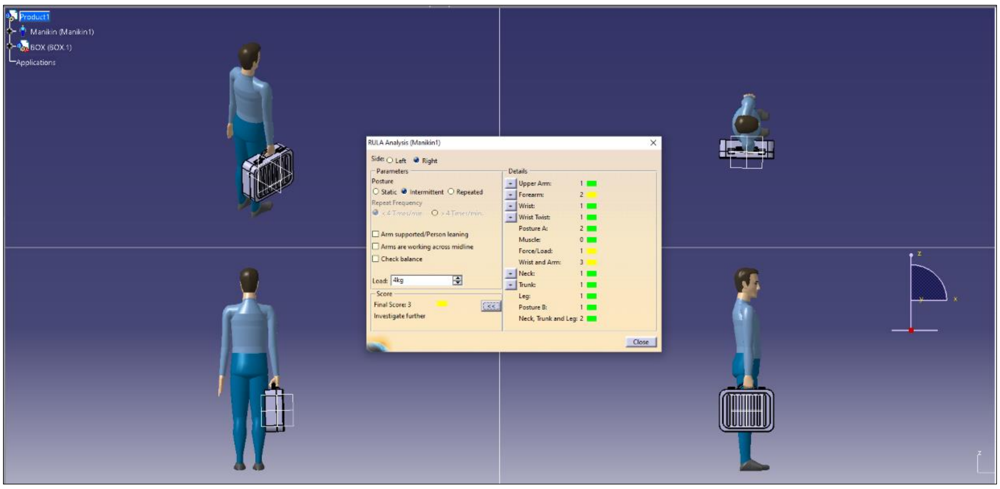

Figure 4.18: RULA analysis on standing manikin with right hand carrying packaging.

The detailed breakdown of score showed in Table 4.5 that the upper arm scored 1 (Green), indicated a neutral position with minimal musculoskeletal risk. The forearm, with a score of 2 (Yellow), suggested a slightly elevated risk due to the need to hold the case. The wrist and wrist twist both scored 1 (Green), indicated neutral positions and minimal risk of strain or discomfort. Posture A scored 2 (Green), reflected a generally acceptable posture with a slight concern, possibly due to the arm position while carrying the case. The muscle score of 0 (Green) indicated no significant muscle activity, suggested that the posture does not cause undue muscle strain. The force/load scored of 1 (Yellow) reflected the impact of carrying the 4 kg case, suggested a low to moderate load. The wrist and arm scored of 3 (Yellow) indicated a combination of arm and wrist posture that were slightly concern and might require adjustment or breaks if the task was repeated frequently.

The neck, trunk, and leg scores were all 1 (Green), indicated neutral postures with minimal risk of strain or discomfort. Posture B scored 1 (Green), reflected an overall good posture with low risk. The combined neck, trunk, and leg score of 2 (Green) indicated overall good posture while carrying the case. The key areas of concern highlighted by the analysis were the slightly elevated scores in the forearm (2) and wrist/arm combination (3). These scored suggest that while the overall posture was acceptable, there may be minor adjustments needed to reduce strain on the arms. This could involve adjusted the way the case was carried or provided short breaks during prolonged carrying tasks. The force/load scored of 1 reflects the load being carried. Ergonomic interventions, such as using a case with a more ergonomic handle or alternating carrying hands, might help reduce potential strain.

Table 4.3: Detail breakdown of the analysis results for male manikin.

Details	Scores	Color Indicator	
Upper arm	1	Green	
Forearm	2	Yellow	
Wrist	1	Green	
Wrist twist	1	Green	
Posture A	2	Green	
Muscle	0	Green	
Force/load	1	Yellow	
Wrist and arm	3	Yellow	
Neck	1	Green	
Trunk	1	Green	
Leg	1	Green	
Posture B	1	Green	
Neck, trunk and leg	2	Green	

In conclusion, the RULA analysis of carrying a 4 kilograms hand-carry case indicated a relatively low ergonomic risk with a final score of 3. The detailed breakdown showed that most body parts are in low-risk posture, with slight concerned in the forearm and wrist/arm areas due to the load.

4.7.2 RULA Analysis on Female Manikin

The analysis depicted in Figure 4.19 was conducted on a female manikin under static posture conditions. In this scenario, a standing manikin held a 4 kg hand-carry case in her right hand. The final RULA score of 3, as detailed in Table 4.6, highlighted the posture and load-related stresses experienced by different parts of the body. An overall RULA score of 3 suggested that the manikin's posture was relatively low risk.

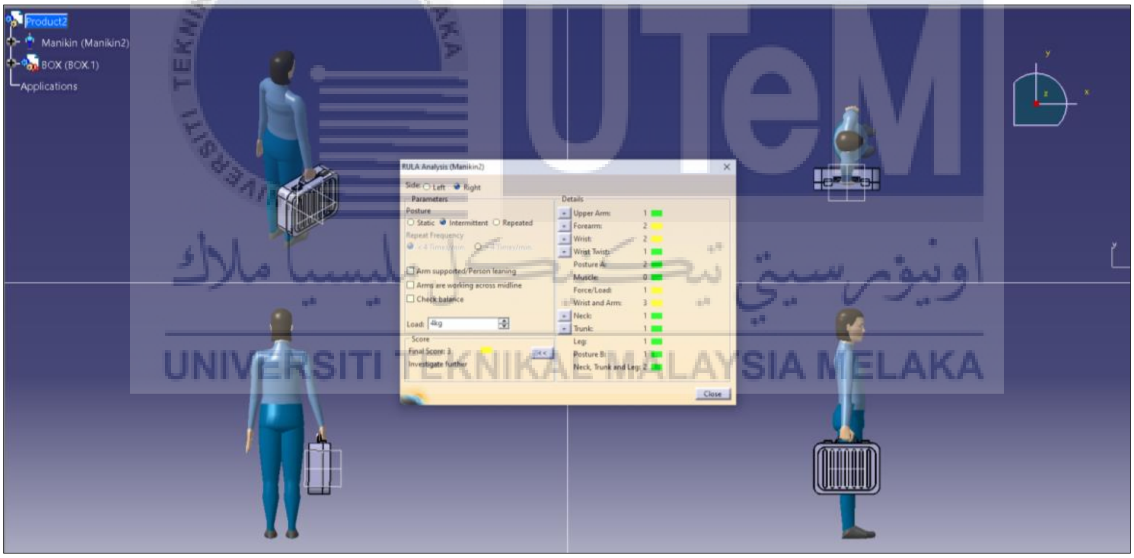

Figure 4.19: RULA analysis on woman manikin carrying hand-carry case.

The analysis indicated that the female manikin experienced slightly higher stress on the wrist compared to the male manikin, resulting in a wrist score of 2 (yellow) rather than 1 (green). This suggested a moderate level of risk in the wrist area, highlighting the need for potential ergonomic adjustments or further investigation, especially if the task performed frequently or sustained for long periods. The overall RULA score and other body parts remained consistent with the male manikin's results, indicated a generally low-risk posture except for the noted difference in wrist stress.

Table 4.4: Detail breakdown of the analysis results for female manikin.

Details	Scores	Color Indicator	
Upper arm	1	Green	
Forearm	2	Yellow	
Wrist	2	Yellow	
Wrist twist	1	Green	
Posture A	2	Green	
Muscle	0	Green	
Force/load	1	Yellow	
Wrist and arm	3	Yellow	
Neck	1	Green	
Trunk	1	Green	
Leg	1	Green	
Posture B	1	Green	
Neck, trunk and leg	2	Green	

The RULA analysis for both male and female manikins carrying a 4 kg hand-carry case in a standing posture revealed generally low-risk postures with specific areas requiring attention. The male manikin exhibited low-risk scored across most body parts with a slightly higher risk in the forearm and wrist-arm combination. The female manikin showed a slightly higher stress level in the wrist, resulting in a yellow indicator which suggested a moderate risk that may need further investigation, particularly if the task was repetitive or sustained over long periods.

Overall, both manikins demonstrated that the posture of carrying the case was relatively safe, but the slight differences in wrist stress for female manikin highlighted the importance of considering gender-specific ergonomic factors in the design and assessment of packaging solution. These insights emphasized the need for ergonomic adjustments to ensure user-friendly and easy portability while minimizing potential risks for all users.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter presented the conclusion of this study to design an effective packaging design solution for an exoskeleton for Solat focusing on enhancing user comfort, portability and ease of use.

5.1 Conclusion

The survey completed assisted the study carry out its first objective, which was to determine user needs for the best packaging design solution for the exoskeleton for Solat. The findings indicated that while respondents were generally unfamiliar with the concept of an exoskeleton for Solat, there was a recognized need for such a device, particularly among those who had experience performing Solat using a chair. Furthermore, the preference for type of packaging solution, along with desired features should present in packaging clearly identified. These insights guiding the design of a user-friendly and practical packaging solution that meets the needs of potential users.

The objective of designing a packaging solution that prioritizes portability and durability for exoskeleton throughout storage and transportation while incorporating ergonomic design elements to ensure convenient and secure handling has been successfully achieved through the evaluation of four design concepts: hand-carry case, roller bag, backpack and airwheel smart luggage. The final selection of the hand carry case was determined based on criteria of portability, ease of use, lightweight and durability as well as its ability to eliminate issues associated with hygienic wheeled design and complexity of handling, offered a more practical and space-efficient, particularly for short duration trips. To maintain sustainability, material selection for the hand-carry case was based on SD12 standards, resulting in the use of polylactic acid (PLA), a biodegradable and environmentally friendly material. The iterative design process demonstrated that the hand-carry case met the functional and required criteria to provide a practical, user-friendly solution thereby fulfilling the study's objective.

The final objective of analysing the designed packaging solution's effectiveness in safeguarding the exoskeleton, while prioritising user-friendly access has been successfully achieved through structural and ergonomic analyses. The static structural behaviour analysis assessed the packaging's performance under material of polylactic acid (PLA) across four parameters: total deformation, equivalent strain, von misses stress and safety factor. Results indicated that deformation occurred primarily at the handle area, with a safety factor of 15, suggesting that the packaging can withstand loads 15 times greater than the applied weight, thereby confirming its robustness and protective capability. Additionally, the RULA (Rapid Upper Limb Assessment) analysis was conducted to evaluate the ergonomic posture of users carrying the hand-carry case. This analysis, which involved a manikin in a standing posture carrying a 4kg load in the right hand, resulted in a final score of 3, indicating a medium risk level for ergonomic issues. This score reflects that while the design is generally user-friendly and portable, some improvements could be made to further enhance ergonomic safety.

5.2 Recommendation for Future Research

Several recommendations for further research are made to further improve the packaging's design and efficacy, based on the data and conclusions obtained from fulfilling the study's objectives for exoskeleton for Solat:

1. To conduct in-depth biomechanical studies to assess how different packaging designs impact user posture, movement efficiency and overall ergonomic comfort during transportation and use of exoskeleton.
2. To explore unconventional design concepts such as modular or customizable packaging systems that offer versatility and adaptability to evolve user requirements and technological advancements.
3. To develop smart packaging solution equipped with IoT (Internet of Things) capabilities, such as real time tracking, condition monitoring and adaptive functionalities to enhance safety, security and user convenience.

5.3 Sustainable Design and Development

This project demonstrates key entrepreneurial skills by prioritizing user needs and preferences while reflecting an entrepreneurial mindset through the selection of Polylactic Acid (PLA) as a sustainable material. PLA's lightweight and biodegradable properties align with the growing demand for environmentally friendly solutions, ensuring minimal environmental impact. This sustainable material choice not only meets the durability and portability requirements but also showcases the feasibility of integrating eco-friendly materials into practical applications. These entrepreneurial insights are crucial for developing products that are both functional, sustainable and commercially viable.

5.4 Complexity

The design process involved a multi-faceted methodological approach, including House of Quality (HoQ), concept screening and scoring. This comprehensive approach allowed for a thorough evaluation and selection of the optimal packaging solution. The square hand-carry case emerged as the preferred design, excelling in simplicity, space efficiency and user friendly. Structural analysis, using ANSYS validated the material's performance under simulated conditions, ensuring the case's robustness and reliability.

5.5 Life Long Learning (LLL)

The iterative design process highlighted the importance of continuous learning and adaption. Feedback from ergonomic analysis, the Rapid Upper Limb Assessment (RULA), provided valuable insights into user comfort and usability. Addressing moderate ergonomic concerns, especially for female users, underscores the ongoing need for refinement and improvement. This approach fosters a culture of lifelong learning, where continuous feedback and analysis drive design enhancements.

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APPENDICES

A. Gantt Chart of FYP I

DURATION	OCT'23				NOV'23				DEC'23				JAN'23	
ACTIVITIES	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
CHAPTER 1: INTRODUCTION								M I D S E M B R E A K						
1) Define objective and problem statement.														
2) Define specific scope of project concerning exoskeleton packaging.														
3) Completing introduction for the title.														
CHAPTER 2: LITERATURE REVIEW														
1) Review existing literature on exoskeleton and their pacakaging.														
2) Compile key findings and insights regarding packaging of exoskeleton.														
3) Summarize journal article.														
CHAPTER 3: METHODOLOGY														
1) Research method selection.														
2) Define the sources of data necessary for data collection.														
3) Finalise the specification of the packaging.														
4) Document the entire methodology adopted.														
DESIGN DEVELOPMENT														
1) Ideation and sketching for concept selection.														
2) Preliminary design development.														
3) Propose packaging design.														
4) Finalise packaging design.														
Presentation FYP 1														
Preparation Final Report FYP 1														

	Complete
	Delay
	In Progress

B. Gantt Chart of FYP II

DURATION	MAC'24				APR'24				JUNE'24				JUL'24	
ACTIVITIES	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
ASSEMBLY PROTOTYPE								M I D S E M B R E A K						
1) 3D printing of miniature prototype.														
2) Analysis and troubleshooting miniature prototype packaging.														
ANALYSIS DATA														
1) Simulation and data collection in ANSYS.														
2) Simulation with manikin in CATIA														
3) Research and data collection for environmental analysis.														
5) Integrate all reports and findings.														
Presentation FYP 2														
Submission Draft Report														
Preparation Final Report FYP 2														

	Complete
	Delay
	In Progress

C. Survey Questionnaire

Packaging Design for Exoskeleton For Solat

The study concerning developing user-centered packaging for exoskeleton for Solat specifically customized for elderly individuals.
Kajian berkaitan penciptaan pembungkusan/alat pembawa berpusatkan pengguna untuk exoskeleton untuk Solat yang disesuaikan khusus untuk individu warga emas.

sihasyaqirah@gmail.com Switch account

Not shared

* Indicates required question

Gender *
Jantina

- Male / Lelaki
- Female / Wanita

Age *
Umur

- 40 - 50
- 51 - 60
- 61 - 70
- 70 and above

Do you have any physical limitations in performing Solat? If yes, state the type of physical limitation you had. *

Adakah anda mempunyai sebarang batasan fizikal dalam melaksanakan Solat? Jika ada, nyatakan jenis had fizikal yang anda alami.

Your answer

Do you ever experience performing Solat using chair ? *

Adakah anda berpengalaman melakukan Solat menggunakan kerusi?

- Yes / Ya
- No / Tidak

Exoskeleton for Solat

The exoskeleton for Solat is designed to make solat easier for people, especially older individuals or those with physical challenges. It helps with common problems like back pain and weak knees, making the movements during prayer more comfortable. The exoskeleton makes switching between sitting and standing positions smoother and not causing any disruption to other Jemaah, catering to the needs of different users for a better prayer experience. The exoskeleton is structured from steel, weighing a total of 3 kg and measuring 30cm x 30cm in dimensions. The exoskeleton differs from typical mosque chairs because it occupies less space, ensuring users can pray without intruding on others' prayer areas.

Exoskeleton untuk Solat direka untuk memudahkan solat terutamanya individu yang tua atau mereka yang mempunyai kekurangan fizikal. Ia membantu masalah seperti sakit belakang dan lutut lemah, menjadikan pergerakan semasa solat lebih selesa. Exoskeleton menjadikan pertukaran antara posisi duduk dan berdiri lebih lancar dan tidak menimbulkan gangguan kepada jemaah lain, memenuhi keperluan pengguna untuk pengalaman solat yang lebih baik. Exoskeleton berstruktur daripada keluli besi, dengan berat keseluruhan 3 kg dan berukuran 30cm x 30cm dalam dimensi. Exoskeleton berbeza daripada kerusi masjid biasa kerana ia menggunakan ruang yang lebih kecil, memastikan pengguna boleh solat tanpa mengganggu ruang solat orang lain.

1) *
The invention of exoskeleton for Solat is to help user align saf with other Jemaah and not cause any disruption to the saf at the back due to limited space.

Did you know about exoskeleton for solat?

Penciptaan exoskeleton untuk Solat adalah untuk membantu pengguna menyelaraskan saf dengan jemaah lain dan tidak menyebabkan sebarang gangguan pada saf di belakang kerana ruang yang terhad.

Adakah anda tahu tentang exoskeleton untuk solat?

Problem: **Solution:**

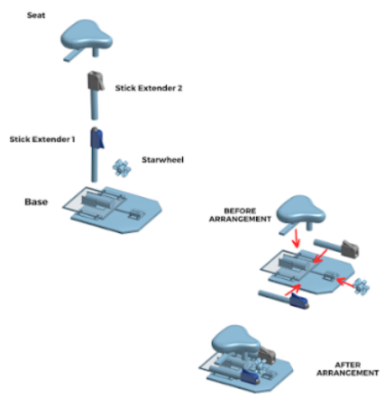
Comparison:

- Yes / Ya
- No / Tidak

2) *

Exoskeleton for Solat comes with a structure that can be easily disassembled. In your opinion, what type of carrier/bag is the most suitable for them to carry an exoskeleton?

Exoskeleton untuk solat direka dengan struktur yang boleh dipasang semula dengan mudah. Pada pendapat anda, apakah jenis alat pembawa/beg yang paling sesuai untuk membawa exoskeleton?



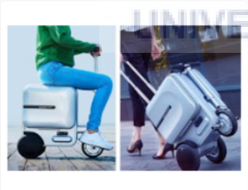
○ Backpack / Beg galas

○ Rolling bag / Beg roda

○ Toolbox / Kotak alat

○ Shoulder bag / Beg bahu

○ Other:



○ Smart riding luggage / Bagasi menunggang pintar

3) *

Based on your choice above, indicate the level of importance for each feature that should be present in a carrier/bag. **(5 - Very important, 1 - NOT important at all)**

Berdasarkan pilihan anda di atas, nyatakan tahap kepentingan bagi setiap ciri yang perlu ada dalam alat pembawa/beg. ***(5 - Sangat penting, 1 - Sangat TIDAK penting)***

	5	4	3	2	1
Portability / Mudah alih	○	○	○	○	○
Lightweight / Ringan	○	○	○	○	○
Easy-to-reach compartment / Bahagian (poket) yang mudah dicapai	○	○	○	○	○
Storage capacity / Kapasiti simpanan	○	○	○	○	○
Flexible for different use / Boleh digunakan untuk kegunaan yang berbeza	○	○	○	○	○
Ease of use and handling / Kemudahan penggunaan dan pengendalian	○	○	○	○	○
Comfort carrying in prolonged time / Keselesaan membawa/menunggang dalam masa yang lama	○	○	○	○	○
Versatility in carrying option / Fleksibiliti dalam kaedah pembawaan	○	○	○	○	○
Durability / Ketahanan	○	○	○	○	○

Preferred Carrier/Bag

Selecting a suitable carrier or bag for the elderly is crucial due to mobility challenges, such as arthritis or reduced strength. Many seniors need assistance in carrying essentials like medication or groceries. The current issue centers on addressing these challenges and ensuring the chosen carrier accommodates their needs for easy access, comfortable straps, and lightweight design. By choosing a thoughtful solution, caregivers can help seniors maintain independence, navigate daily tasks comfortably, and enhance overall well-being.

Memilih pembawa atau beg yang sesuai untuk warga tua adalah penting kerana cabaran untuk mereka bergerak disebabkan arthritis atau kekuatan yang berkurangan. Ramai warga emas memerlukan bantuan dalam membawa barang keperluan seperti ubat atau barangan runcit. Isu semasa tertumpu pada menangani cabaran ini dan memastikan pembawa atau beg yang dipilih memenuhi keperluan mereka untuk mudah akses, tali yang selesa dan reka bentuk yang ringan. Dengan memilih penyelesaian yang terbaik, penjaga boleh membantu warga emas mengekalkan kebebasan, menjalankan tugas harian dengan selesa dan meningkatkan kesejahteraan keseluruhan.

4) *

How much does aesthetic appeal of a carrier/bag influence your choice?

Sejauh manakah daya tarikan estetika (reka bentuk) alat pembawa/beg mempengaruhi pilihan anda?

○ Not at all / Tidak sama sekali

○ A little / Sedikit

○ Somewhat / Agak mempengaruhi

○ Quite a bit / Mempengaruhi

○ Very much / Sangat mempengaruhi

5) *

Do you prefer carrier/bag with wheels for easier mobility?

Adakah anda lebih memilih alat pembawa/beg yang mempunyai roda untuk memudahkan pergerakan?

- ◯ Yes / Ya
- ◯ No / Tidak

6)

Would you be interested in carrier/bag with integrated technology features (e.g. charging port, tracking device)

Adakah anda berminat dengan alat pembawa/beg dengan ciri teknologi kini (cth. port pengecasan, peranti penjejakan)

- ◯ Yes / Ya
- ◯ No / Tidak

7) Do you have any other suggestion/ comment related to this study? *

Adakah anda mempunyai cadangan/komen lain?

Your answer