

## Inclusive Mobility Design System for Persons with Locomotor Disabilities (PWLD) in Malaysia

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**ABSTRACT** - Persons with Disabilities (PWDs) in Malaysia face significant challenges in adapting existing products to their needs, particularly in the area of mobility. This study underscores the importance of Inclusive Design as a guiding philosophy to address these challenges and fulfill the unique requirements of PWDs. Specifically, the research aims to identify the needs of individuals with physical disabilities who lack arms and legs, and to integrate Inclusive Design principles into a comprehensive Mobility Design System (MDS) tailored for this group.

The study adopts a Design and Development Research (DDR) framework, incorporating the ADDIE model comprising Analysis, Design, Development, Implementation, and Evaluation as its methodological structure. Qualitative approach is employed, qualitative interviews and survey. Data are analyzed thematically using NVivo software. Inclusive Design concepts are embedded throughout the Mobility Design System to ensure usability, accessibility, and relevance to PWDs without limbs. Expert validation is conducted to strengthen the reliability and applicability of the final framework.

The expected outcome of this study is an affordable, user-friendly Mobility Design System that enhances the daily living and independence of Persons with Locomotor Disabilities (PWLD). Additionally, this research provides design guidelines for future researchers, informs designers and manufacturers, and contributes to the development of new market segments for assistive mobility devices. Ultimately, it aims to promote inclusive and equitable design practices that elevate the quality of life for PWDs and Persons with Locomotor Disabilities (PWLD), in Malaysia.

## INTRODUCTION

Persons with Disabilities (PWDs) represent a significant and diverse demographic in Malaysian society. While the Persons with Disabilities Act of 2008 represents a legislative milestone, systemic barriers—particularly in the areas of physical accessibility, employment, and education—continue to hinder the full participation of individuals with disabilities in daily life. For Persons with Locomotor Disabilities (PWLDs), who often rely on mobility aids, the challenge is compounded by the limited availability of affordable and tailored assistive devices (Nasir, 2020).

The current literature underscores the importance of inclusive design as a philosophy for creating products and environments that accommodate human diversity. While previous studies have explored various aspects of assistive technologies (Nayak et al., 2016) (p. 4), accessibility in public infrastructure (Long & Siu, 2023), and user-sensitive inclusive design (Newell et al., 2010) (p. 4), a significant gap remains. There is a lack of comprehensive, affordable mobility systems specifically developed through

an inclusive design process to meet the unique needs of PWLDs without limbs or legs in the Malaysian context.

In response to this gap, this study proposes a Mobility Design System (MDS) framework that integrates inclusive design principles to create a cost-effective, user-driven solution. This research aims to contribute to the field by not only developing a specific mobility aid design but also by establishing a validated design process that can be used to inform future solutions and policy. By focusing on the lived experiences of PWLDs in Malaysia, this study seeks to empower them with greater autonomy and social engagement.

## LITERATURE REVIEW

This study's literature review systematically organizes keywords related to three main areas which is the subject itself – PWDs without limbs and leg, mobility design system and the inclusive design theory that embedded within. Its aim is to investigate and arrange previous research on inclusive design for persons with disabilities (PWDs) without limbs who use wheelchairs. The review focuses on applying inclusive design theory within vehicle mobility systems to support their daily activities as per below:

### Inclusive Design

Inclusive design is a framework that intentionally addresses the full spectrum of human diversity—such as differences in ability, language, culture, gender, and age—by embedding flexibility and personalization into design processes (Inclusive Design Research Centre, 1993). In contrast, universal design seeks to develop products and environments that are inherently usable by all people, minimizing the need for modifications or specialized interventions (Onsman, 2025). Accessibility, meanwhile, concentrates on removing obstacles that prevent individuals with functional limitations from fully engaging with services and spaces, thereby promoting equitable participation (Maione, 2025). Human-centered design, as described by the Design Research Society (2018), is a participatory and iterative methodology that centers on users' lived experiences, needs, and contexts through cycles of inquiry, prototyping, and evaluation.

This research is anchored in the conceptual and methodological principles of inclusive design (Figure 1), which advocate for the creation of products, environments, and services that accommodate a wide range of human abilities, including those of individuals with disabilities (Clarkson, Coleman, Keates, & Lebbon, 2003; Inclusive Design Research Centre [IDRC], 1993). Central to inclusive design is the intentional integration of user diversity into the design process, ensuring that solutions are flexible and responsive to varied contextual needs (Waller, Bradley, Peppé, & Pearson, 2015). In contrast, universal design promotes uniform solutions intended to be usable by all individuals without modification (Onsman, 2025), while accessibility-focused approaches concentrate on removing specific barriers that hinder participation for people with disabilities (Maione, 2025). A comparative diagram can effectively illustrate the distinct priorities and design philosophies underpinning inclusive design, universal design, and accessibility.

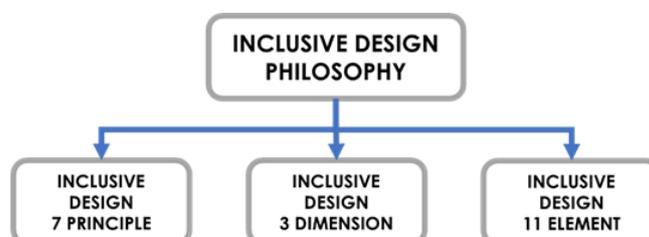
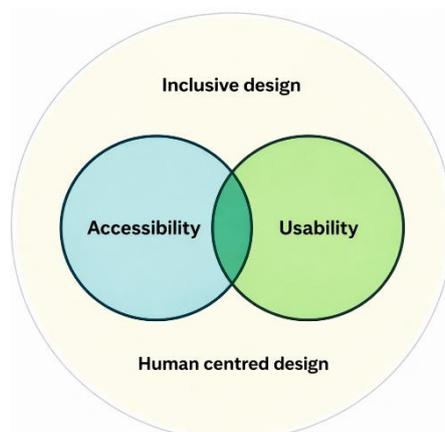


Figure 1. Inclusive Design Philosophy

Figure 2 below illustrates the conceptual distinctions between inclusive design and related frameworks—namely, universal design, accessibility, and human-centered design. While these approaches are interrelated, scholarly literature differentiates them based on scope, priorities, and application.



**Figure 2.** Other theory related with inclusive design

Inclusive design, as conceptualized by the Inclusive Design Research Centre (IDRC, 1993) and further supported by human-centered design principles (Design Research Society, 2018), is a design methodology that embraces human diversity by accommodating differences in ability, language, culture, gender, and age. It promotes adaptable solutions that respond to varied user needs. In contrast, universal design seeks to develop products and environments that are inherently usable by all individuals, minimizing the need for customization or specialized interventions (Onsman, 2025). Accessibility, meanwhile, targets the removal of specific barriers that impede usability for individuals with functional impairments, thereby fostering equitable access to services and built environments (Maione, 2025). Human-centered design complements these approaches by emphasizing user-driven problem solving through iterative engagement with users' lived experiences, needs, and contexts, involving cycles of research, prototyping, and evaluation (Design Research Society, 2018)

### **Application of Inclusive design concept towards PWDs**

Inclusive design is pivotal in shaping environments and products that respond to the diverse functional needs and lived experiences of persons with disabilities (PWDs). Harahap et al. (2024), emphasize that individual experiences significantly influence how PWDs engage with their occupational contexts, underscoring the importance of personalized design approaches. Long and Siu (2023), investigated the accessibility of public information and communication technologies, revealing structural impediments and advocating for integrative solutions to reduce digital marginalization. Nayak et al. (2016) proposed a user-centered model for assistive technologies by creatively adapting everyday household items to meet specific user needs. Newell et al. (2010) introduced the concept of "User Sensitive Inclusive Design," which calls for immersive engagement with marginalized populations—such as older adults and individuals with disabilities—through ethnographic methods to enhance the relevance and effectiveness of design outcomes. Building on these foundational insights, the current study aims to develop a Mobility Design System (MDS) specifically for individuals without limbs or legs, promoting independent mobility and supporting the execution of daily tasks.

### **Definition of PWDs without limbs and leg**

This study focuses on individuals with limb absence—a subset of physical disabilities—within the broader category of persons with disabilities (PWDs). According to Disability in Organizations (2008), PWDs are defined as individuals with long-term physical, mental, intellectual, or sensory impairments that, when combined with environmental and societal barriers, hinder full participation in everyday life.

These impairments are commonly classified into seven domains: hearing, vision, speech, physical, learning, mental, and multiple disabilities.

In Malaysian academic and policy discourse, the term Persons with Locomotor Disabilities (PWLD) is occasionally used to describe individuals with mobility-related impairments, including those with significant limb loss or absence (Manderson et al., 2006). The classification of PWDs encompasses both congenital and acquired conditions, reflecting a broad spectrum of lived experiences (Forma-Slova, n.d.). The United Nations Convention on the Rights of Persons with Disabilities (2006) promotes a person-centered approach, emphasizing the importance of recognizing individual identity beyond diagnostic categories.

In Malaysia, individuals with limb absence face unique challenges in accessing public infrastructure and essential services. To address these barriers, the government enacted the Persons with Disabilities Act 2008 under the Ministry of Welfare, which mandates equitable access to public facilities, education, and employment. Registration as Orang Kurang Upaya (OKU) through the Ministry of Women, Family, and Community Development (KPWKM) enables individuals to access targeted support, including medical fee exemptions, priority healthcare, inclusive education, vocational training, accessible transportation, and financial aid. This research investigates the lived experiences and functional needs of individuals with limb absence (Figure 3) in the Klang Valley, chosen for its concentration of healthcare and administrative institutions that facilitate data collection.

### Challenges Face by PWDs without limbs and leg

To accurately profile Persons with Locomotor Disabilities (PWLD) in this study, it is essential to consider the incidence and nature of congenital limb deficiencies. Murphy (2020), mentioned that congenital limb reduction defects occur at a frequency ranging from approximately 0.26 to 1 per 1,000 live births. However, these figures may underestimate the true incidence due to the exclusion of miscarriages in birth registry data. Notably, upper limb deficiencies are reported to be two to three times less common than lower limb deficiencies. Furthermore, limb reduction anomalies are frequently associated with other congenital malformations, occurring in approximately 12% to 33% of cases, which underscores the importance of identifying syndromic patterns and related developmental conditions (Murphy, 2020).



Figure 3. Examples of limbs absence

Persons with Locomotor Disabilities (PWLD) encounter numerous daily obstacles, such as the high cost, limited availability, maintenance requirements, and access barriers to assistive devices (Weerasinghe et al., 2015). Yet, many PWLD achieve notable functioning and skill development with the support of prosthetic limbs (McDonald et al., 2020). Although mobility problems persist, assistive

devices can improve quality of life, independence, and social participation. Advances in modern technology have enabled even individuals with severe disabilities, including four-limb amputees, to gain greater independence through innovative assistive solutions (Borade et al., 2019; Cooke et al., 2016). Nevertheless, PWLD frequently face difficulties navigating complex healthcare systems and experience social stigma, which can hinder access to appropriate assistive devices (Borade et al., 2019).

Therefore, to enhance support for PWLD, improvements are needed in infrastructure, awareness, funding, and ongoing maintenance of assistive devices (Weerasinghe et al., 2015). In Malaysia, the PWLD population largely consists of individuals with middle to low incomes, restricting their ability to obtain essential ADs for daily activities (Weerasinghe et al., 2015).

### **Mobility Design System**

Recent advancements in assistive technologies have demonstrated design for PWDs significant potential in restoring mobility and independence among individuals with locomotor disabilities (PWLD). For example, researchers at the Massachusetts Institute of Technology (MIT) developed a prosthetic leg controlled by the user's nervous system, enabling natural gait patterns and effective obstacle navigation for amputees (Herr et al., 2024). Similarly, integrated technological solutions have been shown to benefit individuals with severe disabilities, such as quadruple amputees, by enhancing their ability to interact with their environment and perform daily activities (Cooke et al., 2016). User-centered design methodologies have also been incorporated into the development process to ensure that assistive devices align with the practical mobility needs of PWLDs (Morris et al., 2022). These inclusive mobility design systems have been found to significantly improve quality of life, social participation, and autonomy for this population (Yunos et al., 2022; World Health Organization, 2024).

Accordingly, the present study focuses on the development of a wheelchair that integrates inclusive mobility design principles, specifically tailored to address the functional and contextual needs of persons with locomotor disabilities.

### **Affordable Mobility Design System for PWL**

Recent research underscores the advancement of affordable and inclusive mobility solutions for individuals with disabilities. Ariff et al., (2024), employed a Design Development Research approach to construct an Assistive Mobility Design System, emphasizing inclusive design principles and integrating feedback from wheelchair users and industry professionals. Similarly, Gomez Torres et al. (2019) developed a cost-effective smart wheelchair equipped with autonomous indoor navigation and collision avoidance capabilities, guided by a participatory design process involving end users. Kim et al. (2024) introduced a lightweight powered wheelchair through participatory action design, addressing user preferences concerning weight, aesthetics, cost, and functionality. Roe (2020) emphasized the critical role of user-centered inclusive design in the evolution of mobility technologies. Collectively, these studies highlight the importance of user-centered methodologies that prioritize safety, accessibility, and durability (Gomez Torres et al., 2019; Kim et al., 2024). These initiatives aim to enhance the quality of life for individuals with disabilities by delivering innovative and economically viable mobility solutions.

In the Malaysian context, a significant proportion of Persons with Locomotor Disabilities (PWLD) reside in medium- to low-cost housing and apartments and typically have modest incomes, necessitating targeted governmental support. Consequently, this study focuses specifically on medium- and low-income PWLDs to address their mobility needs within socioeconomically constrained environments.

## **METHODS**

This study uses a Design and Development Research (DDR) framework based on the ADDIE model, which includes Analysis, Design, Development, Implementation, and Evaluation. It applies qualitative methods such as interviews, surveys, and observations to explore the mobility challenges faced by Persons with Locomotor Disabilities (PWLDs) in Malaysia. The data gathered will then be analyzed thematically with the assistance of Nvivo to identify key themes and sub-themes that answer the research question and the hypothesis.

The Research Question aims to answer the following questions:

1. Research Question 01 - What are the daily activities and characteristics of PWLDs?
2. Research Question 02 - What are the mobility-related difficulties faced by wheelchair-using PWLDs?
3. Research Question 03 - How can a wheelchair design system effectively mitigate these mobility difficulties?

### Phase 1: Analysis

This initial phase focused on collecting qualitative data to understand user needs and design requirements, as structured by the ADDIE and DDR methods [Figure 4]. A detailed theoretical framework was subsequently developed following a literature review and the initial field study [Figure 05]. Data collection proceeded as follows:



RESEARCH PHASE	DATA COLLECTION OBJECTIVE	TYPE OF DATA	METHOD	EXPECTED
<b>Gathering information</b>	TO IDENTIFY • EXPERT INTERVIEW ON WHEELCHAIR	• QUALITATIVE EXPLORATORY	• INTERVIEW (DESIGN EXPERT)	• INFORMATION ON LOCAL WHEELCHAIR
	• CHARACTERISTIC & DIFFICULTY FACED BY PWDS ON WHEELCHAIR	• QUALITATIVE EXPLORATORY	• INTERVIEW (PWDS RESPONDENT)	• DATA FROM PWDS RESPONDENT
<b>PHASE 2A DESIGN &amp; DEVELOP</b>	• TO DESIGN & DEVELOP CONCEPT DESIGN USING	• QUALITATIVE EXPLORATORY	• DOCUMENTATION	• GENERATING CONCEPT DESIGN
<b>PHASE 2A DESIGN &amp; DEVELOP</b>	• TRANSFORM CONCEPT DESIGN TO 3D MODEL, INTEGRATE SCENE IN CAD AND	• QUALITATIVE EXPLORATORY	• CONSTRUCT 3D MODELS & INTEGRATE WITH SCENE IN CAID	• CAD DATA TO JUSTIFY PROPOSITION AND HUMAN FACTOR ON NEW MDS DESIGN
<b>PHASE 2B IMPLEMENT</b>	• TRANSFORM CONCEPT DESIGN TO 3D MODEL, INTEGRATE SCENE IN CAD AND	• QUALITATIVE EXPLORATORY	• CONSTRUCT 3D MODELS & INTEGRATE WITH SCENE IN CAID • MEASURE USING CAD DRAWING	• CAD DATA TO JUSTIFY PROPOSITION AND HUMAN MDS DESIGN
<b>PHASE 3 VALIDATE</b>	• EXPERT VALIDATION (5 EXPERT)	• INTERVIEW • QUANTITATIVE	• INTERVIEW (EXPERT) • SURVEY (LIKERT SCALE)	

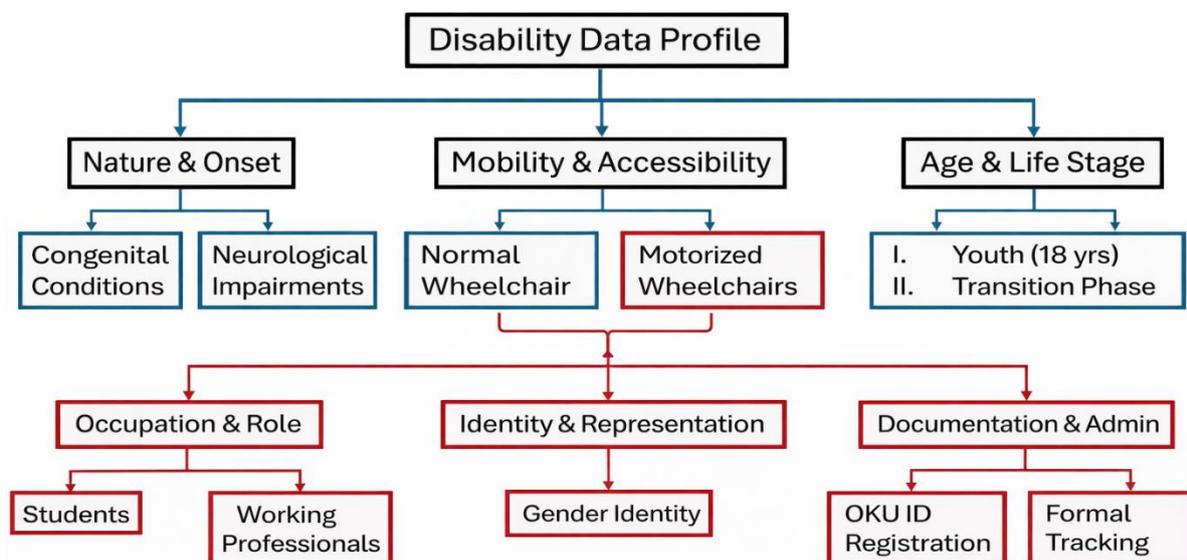
**Figure 4.** Application of Mix Method (Qualitative & Quantitative) in DDR method

As illustrated in the diagram above, a detailed theoretical framework was subsequently constructed (figure 5) after literature review and field study data collection. The data collection was structured as follows:

- **Expert Interviews:** A survey was conducted with five design experts to gather their insights on the limitations of current wheelchair designs and to solicit suggestions for improvement.
- **User Interviews:** A qualitative approach, including semi-structured interviews and a survey, was employed with ten PWLDs who use wheelchairs. These respondents were selected to provide a deep understanding of their daily activities, behaviors, and the specific difficulties they encounter with existing mobility devices.
- **Ethical Considerations:** Prior to data collection, ethical approval was secured from Universiti Putra Malaysia's Research Ethics Council, and a Non-Disclosure Agreement (NDA) was signed with each respondent to protect their personal information and ensure the study's ethical integrity.

Thematic analysis of the interview and survey data was performed using NVivo software to identify key themes and sub-themes. This analysis addressed the research questions by categorizing participant characteristics, daily activities, and mobility challenges. Additionally, expert recommendations were analyzed to inform the design process.

Based on the thematic analysis of interview data, the findings for RQ1, concerning PWLD characteristics, were tabulated [Figure 07a]. Subsequently, the three primary themes and associated sub-themes derived from the analysis were converted into design criteria using a Priority Ranking Chart [Figure 8]. This guided the conceptual design process for PWLDs, emphasizing three key domains: Physical and Functional aspects, System and Operational mechanisms, and Human Dimension and Ergonomic considerations. The synthesis of this data directly addresses RQ2 by documenting the difficulties experienced by PWLD respondents



**Figure 5.** Thematic analysis method breakdown to generate main theme and sub theme

As indicated within the red box Figure 5 above, this section delineates the focal area of the research, informed by the feedback from PWLD respondents regarding the characteristics of their symptom. Consequently, the findings of RQ1 have been addressed through the interviews, which are tabulated according to the aforementioned criteria.

NVIVO – EXTRACT THEME & SUB-THEME BASED ON INTERVIEW TRANSCRIPT BASED ON RQ2			
THEME			
SUB-THEME	1 MULTI FUNCTION	2 INTER SECURITY	3 DISCOMFORT
	• LACK OF INFRASTRUCTURE	• STATIC MOVEMENT OF WHEELCHAIR	• DISCOMFORT OF WHEELCHAIR MOVEMENT
	• UNBALANCE OF WHEELCHAIR	• DIFFICULTY OPERATION OF WHEELCHAIR	• DISCOMFORT OF WHEELCHAIR SPACE
	• THE ABILITY TO RISE	• DIFFICULTY LIFTING OF WHEELCHAIR	• UNCOMFORTABLENESS THAT OCCURRED IN THE WHEELCHAIR SMOOTHNESS AND PERFORMANCE
	• DIFFICULTY ADJUSTING OF WHEELCHAIR		• DISCOMFORT OF WHEELCHAIR SEAT
• DIFFICULTY IN TURNING RATIO			
	• Lack of infrastructure	• Static movement of wheelchair	• Discomfort of wheelchair movement
	• Unbalance of wheelchair	• Difficulty operation of wheelchair	• Discomfort of wheelchair space
	• The ability to rise	• Difficulty lifting of wheelchair	• Discomfort of wheelchair seat
	• Difficulty adjusting of wheelchair		
	• Difficulty in turning ratio		

Figure 6. Thematic analysis method generated by NVivo to extract main theme and subtheme to answer RQ3

The three principal themes and their corresponding sub-themes (Figure 6) will be transmuted into design criteria utilizing a Priority Ranking Chart. This chart will steer the visual representation process and catalyze the development of conceptual designs for Persons with Limb Disabilities (PWLD). By employing this methodology, the researcher can methodically prioritize and concentrate on essential domains: Physical and Functional aspects, Systemic and Operational mechanisms, and Human Dimension and Ergonomic considerations as delineated in Figure 7 below:

TITLE	SUBTHEME ON DIFFICULTIES FACED BY PWDs RESPONDENT											RQ2	
NEED ANALYSIS OUTPUT GENERATE MAIN THEME	LACK OF INFRASTRUCTURE	UNBALANCE OF WHEELCHAIR	THE ABILITY TO RISE	DIFFICULTY ADJUSTING IN WHEELCHAIR	DIFFICULTY IN TURNING RATIO	STATIC MOVEMENT OF WHEELCHAIR	DIFFICULTY IN OPERATING WHEELCHAIR	DIFFICULTY IN LIFTING THE WHEELCHAIR	DISCOMFORT OF WHEELCHAIR MOVEMENT	DISCOMFORT OF WHEELCHAIR SPACE	UNCOMFORTABLENESS OCCURRED IN WHEELCHAIR SMOOTHNESS & PERFORMANCE	DISCOMFORT OF WHEELCHAIR SEAT	WHAT IARE THE DIFFIULTIES FACTORS FACED BY PWDs ON MOVING AROUND ON WHEELCHAIR IN THEIR DAILY ACTIVITIES
													AREA TO STUDY
MULTI-FUNCTION	✓	✓	✓	✓	✓								PHYSICAL & FUNCTIONAL
INTERSOCIETY						✓	✓	✓					SYSTEM & OPERATIONAL
DISCOMFORT									✓	✓	✓	✓	HUMAN DIMENTION & ERGONOMIC

Figure 7. Inclusive Design Criteria for PWLD on wheelchair

As elucidated previously, the compendium of data within the Priority Ranking Chart illuminates the findings of RQ2, which pertains to the challenges encountered by respondents with disabilities, subsequently distilled into three principal themes. This information will serve as a foundational basis for transmuted data into conceptual design.

Expanding upon the preceding analysis, the inquiry into Persons with Disabilities with Limb Loss (PWLD) encompasses six pivotal domains: physical and functional dimensions, systemic and

operational frameworks, human factors and ergonomics, cost and pricing considerations, aesthetic appeal, and spatial adequacy. Furthermore, recommendations derived from respondent feedback will undergo thematic analysis by the researcher to discern overarching themes and sub themes. These insights will profoundly enhance the value and pertinence of the Malaysian Disability Standards (MDS), as delineated in figure 8 and figure 9 below:

NVIVO – EXTRACT THEME & SUB-THEME BASED ON INTERVIEW TRANSCRIPT BASED ON RQ3					
THEME					
1	2	3	4	5	6
SAFETY	FUNCTIONALITY	COMFORT	AFFORDABLE	AESTHETIC	ERGONOMIC
WHEELCHAIR WITH MOTORIZED BATTERY	ADJUSTABLE	COMFORTABLE MOVEMENT	ECONOMICAL	FLEXIBLE OF WHEELCHAIR	PROPOSITION
SAFETY FEATURES OF WHEELCHAIR	FOLDABLE ARMREST	RELIABLE & STRONG	MOTORIZED WHEELCHAIR	CUSTOMIZED	ERGONOMIC SEAT CUSHION
THE ABILITY TO USE	TURNING RATIO	EASE OF USE	RECHARGABLE	UPGRADED DESIGN WHEELCHAIR	ABILITY TO EXTEND THE LEG
TOOLS TO ASSIST MOVEMENT IN CROWD	MOVEBLE		COST EFFECTIVE	ATTRACTIVE LOOK	
THE ABILITY TO RECLINE	ELEVATED			WHEELCHAIR LOOKS MORE ATTRACTIVE	

**Figure 8.** Thematic analysis method generated by NVivo to extract main theme and subtheme to answer RQ3

TITLE	SUBTHEME ON RECOMMANDATION BY PWDs RESPONDENT														RQ3											
NEED ANALYSIS OUTPUT GENERATE MAIN THEME	WHEELCHAIR WITH MOTORIZED BATTERY	SAFETY OF WHEELCHAIR	THE ABILITY TO RISE	TOOL THAT ASSIST MOVEMENT IN THE CROWD	DIFFICULTY IN TURNING RATIO	ADJUSTABLE	FOLD UP ARMREST	TURNING RATION 360/180	ELEVATED HIGH AND LOW	COMFORD MOVEMENT OF WHEELCHAIR	RELIABLE AND STRONG	RETRACTABLE	COST EFFECTIVE	MOTORIZED VEHICLE	RELIABLE & STRONG	EASE OF USE	DIFFICULTY IN TURNING RATIO	FLEXIBLE WHEELCHAIR	UPGRADABLE DESIGN WHEELCHAIR	LOOK AESTHETIC	WHEELCHAIR LOOKS MORE ATTRACTIVE	PROPOTION	ERGONOMIC CUSHION	ABILITY TO EXTEND THE LEG.	HOW TO SOLVE PROBLEMS FOR PWD TO OVERCOME THEIR DIFFICULTIES ON MOVING AROUNDON WHEELCHAIR IN THEIR DAILY LIFE ACTIVITIES?	
SAFETY	√	√	√	√	√																				AREA TO STUDY	• PHYSICAL & FUNCTIONAL
FUNCTIONAL						√	√	√	√																	• SYSTEM & OPERATIONAL
COMFORT										√	√	√														• HUMAN DIMENTION & ERGONOMIC
AFFORDABLE													√	√	√	√										• COST & PRICE
AESTHETIC																	√	√	√	√	√					• APPEARANCE
ERGONOMIC																						√	√	√		• SPECIOUS

**Figure 9.** Thematic analysis method generated by NVivo to extract main theme and sub-theme to answer RQ3

The researcher devised an innovative design concept to answer **RQ3** by synthesizing insights from individuals with disabilities, effectively addressing their articulated challenges and recommendations. While certain preliminary findings were anticipated, the proposed design necessitates the incorporation of cutting-edge technological and ergonomic advancements to attain optimal functionality.

### Phase 2: Design, Develop, and Implement

Alshangiti (2020) underscores the paramount importance of incorporating human factors into research, particularly by taking into account users’ physical capabilities, traits, and constraints in the design of tools, environments, and tasks. Concurrently, he notes that wheelchairs are predominantly utilized by individuals facing mobility-related challenges, such as spinal cord injuries, arthritis, and balance disorders. Recent investigations have concentrated on advancing wheelchair design by augmenting

structural resilience and integrating user-centric safety features to foster greater autonomy and diminish reliance on caregivers.

In the conceptual design process during the second phase, an inclusive design methodology stands in stark contrast to traditional industrial design practices. Consequently, it specifically employs the V-model approach to cultivate concepts rooted in user requirements. Instead of dictating rigid engineering outcomes, this

model facilitates iterative development and customization, permitting solutions to evolve organically. Over the past quarter-century, this framework has been meticulously refined and validated across numerous multinational organizations (Treviranus, 2018). The design processes implemented in this study are depicted in figure 10 below:

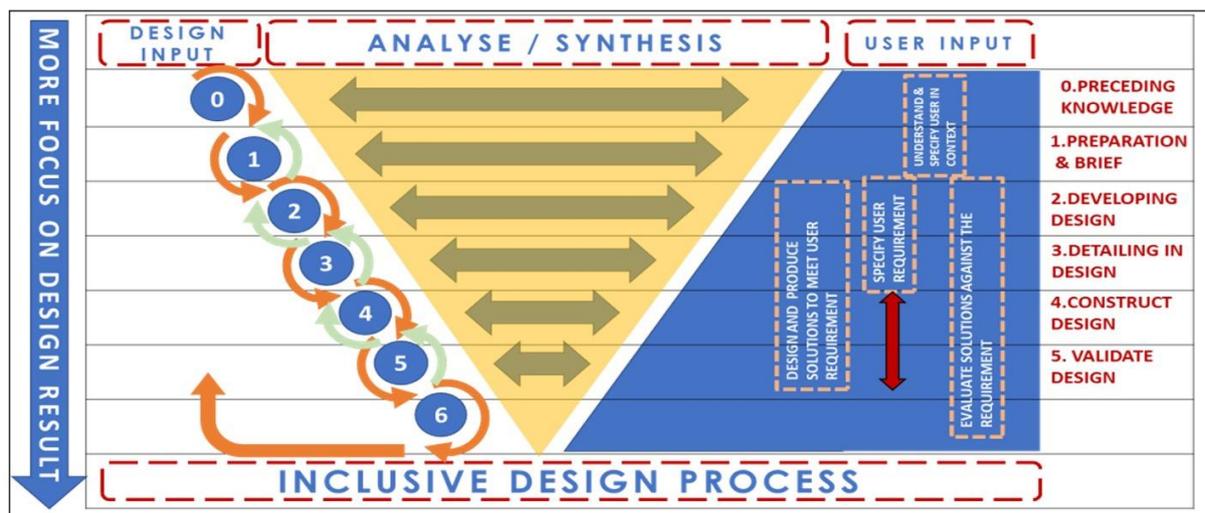


Figure 10. Inclusive Design Process for PWDs without limbs and legs

The inclusive design process, as delineated, encompasses a systematic five-stage framework. It commences with user research and needs identification, wherein data is meticulously gathered to ascertain design prerequisites. This is succeeded by the formulation of a design brief, which formalizes user expectations and delineates constraints. The third stage, conceptual design, entails the generation of preliminary solutions to the identified requirements. These concepts are subsequently elaborated into comprehensive designs, encompassing specific components and technical specifications. Ultimately, an expert review is undertaken to validate and refine the design based on specialized insights.

The inclusive design process comprises five principal stages:

Stage One - User Research: The initial phase involves the systematic collection of information to comprehend user needs and establish design parameters.

Stage Two - Design Brief: A formal document is crafted to delineate user requirements and project constraints.

Stage Three - Conceptual Design: Preliminary design concepts are developed to address the identified needs.

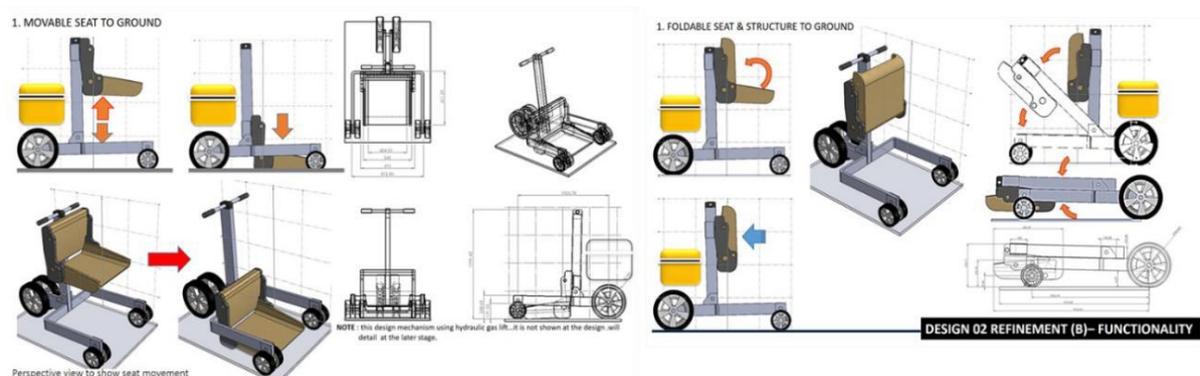
Stage Four - Detailed Design: The selected concepts are meticulously refined into specific technical plans and specifications.

Stage Five - Expert Review:

Post-Design Integration:

Subsequent to these phases, ergonomic and human-factor principles are meticulously employed to enhance user comfort and functionality. Computer-Aided

Industrial Design (CAID) tools facilitate this endeavor by incorporating quantifiable functional elements into the ultimate design (see figure 11).



**Figure 11.** Inclusive Design Concept for PWDs without Limbs and Legs

As delineated above, the researcher has established the foundational design framework through the following meticulous process:

- **Design Basis:** The initial stage encompassed the collection of quantitative data and user insights, which significantly informed the development of the inclusive Mobility Design System (MDS).
- **Concept Development:** By employing innovative product development methodologies and CAID-supported 3D modeling techniques, the researcher meticulously crafted a comprehensive digital prototype of the MDS, delineating all components and assemblies.
- **Concept Validation:** Upon affirmation of the design concept, animated simulations were executed utilizing the 3D data to assess the system's functionality.
- **Human Factors Integration:** Ergonomic principles were seamlessly integrated to enhance user comfort and facilitate a smooth interaction between the user and the device.
- **Final Output:** The resultant design embodies both the objectives of inclusive design and ergonomic enhancements, as illustrated in the final concept visuals (See figure 12).

As outlined above, the researcher has achieved the following outcomes during the design stages:

- **Implementation Progress:** The design has advanced through the integration of human-centered and ergonomic principles within the Mobility Design System (MDS).
- **Upcoming Evaluation Criteria:** Key aspects to be assessed include material selection, weight optimization, jointing techniques, folding mechanisms, user comfort, and cost efficiency.
- **CAID Specifications:** The details related to Computer-Aided Industrial Design (CAID) are presented in the following figure 13.

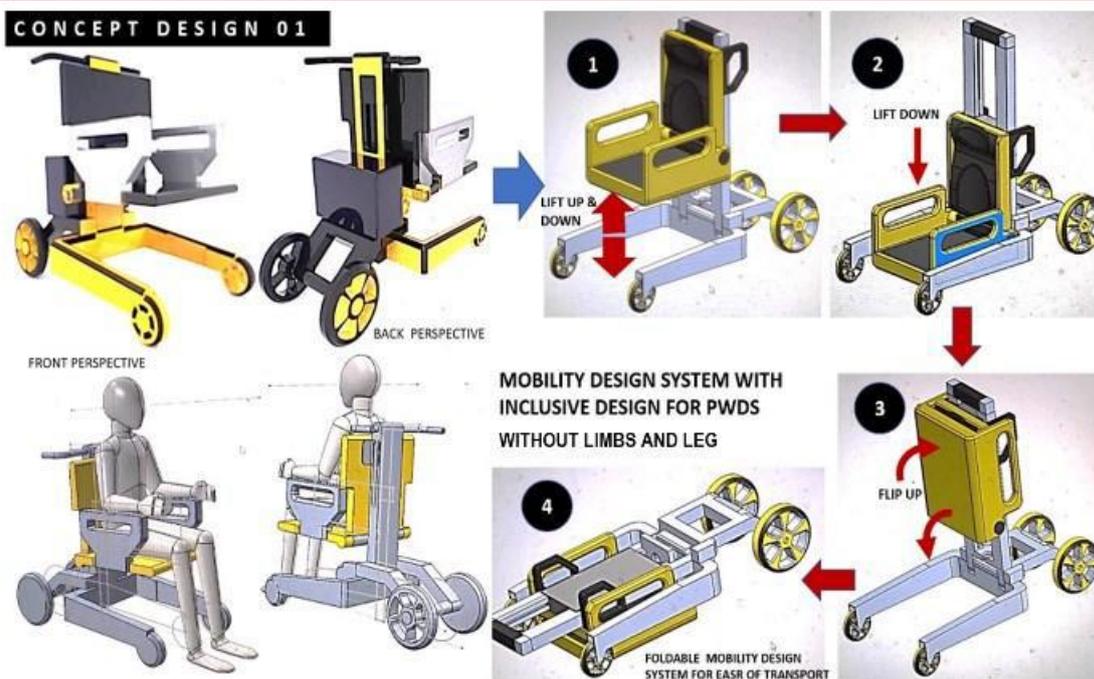


Figure 12. Final Inclusive Design Concept for PWDs without Limbs and Legs

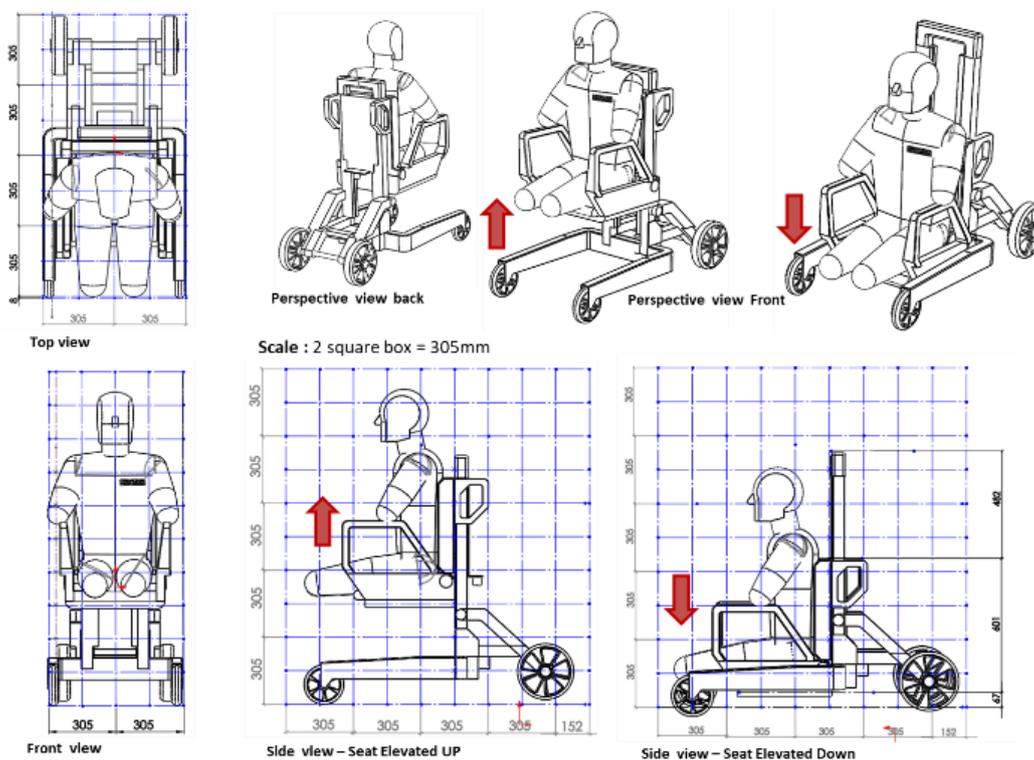
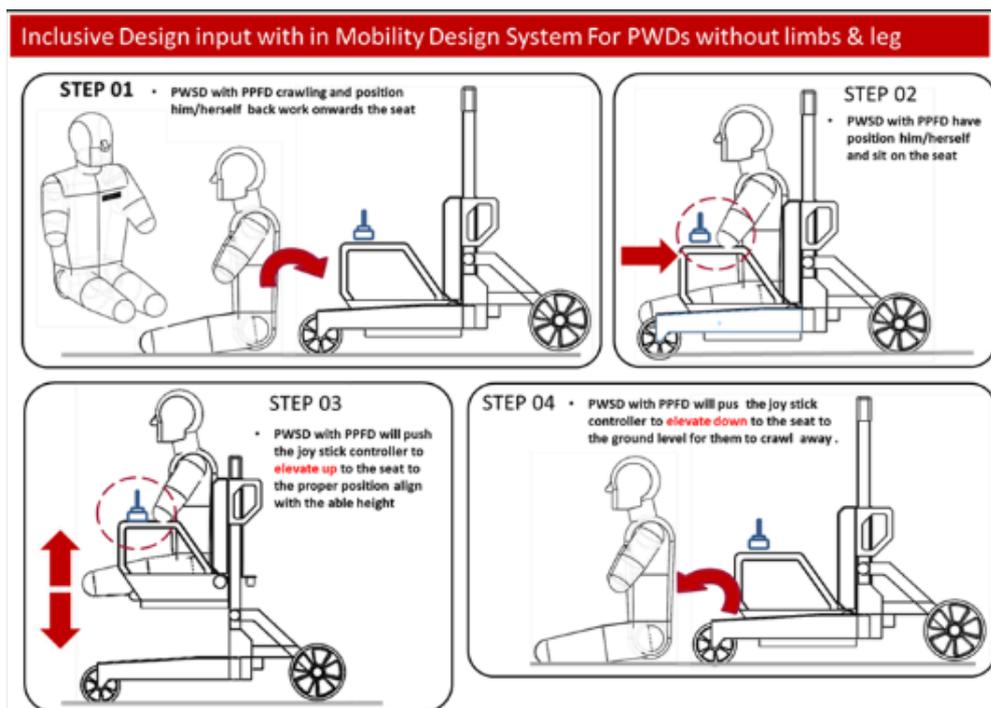


Figure 13. Detail Design Concept for PWDs without Limbs and Legs

### Validation Process (Expert Validation)

In this phase also, the research needs to define the detailing, which includes the human factor, human percentiles, ergonomics, and any other concerns that emerge from the required analysis.



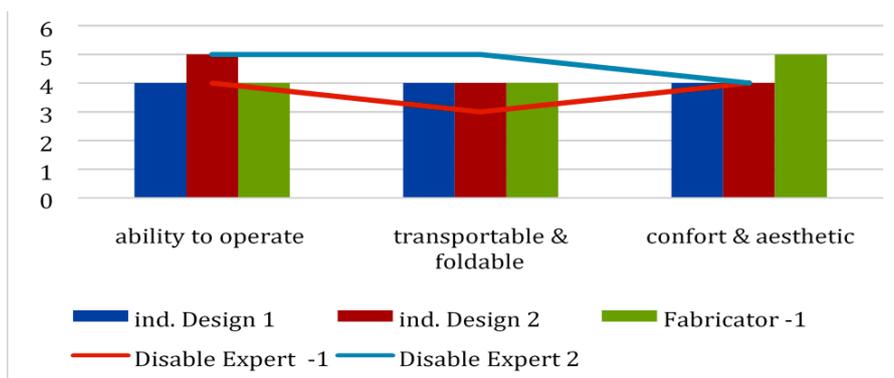
**Figure 14.** Detail Design Concept for PWDs without Limbs and Legs

Figure 14 illustrates the functional scope of the Mobility Design System (MDS), which is designed to facilitate the safe and independent descent of users from elevated surfaces to ground level.

**Pre-validation Preparation:** Prior to initiating expert validation, the researcher must ensure that all procedural steps are thoroughly refined to enhance the conceptual design’s effectiveness and reliability

**Design Focus:** The diagram highlights key stages in the development of the MDS, specifically tailored for persons with disabilities (PWDs) who are without limbs or legs. The design process prioritizes safety, usability, and reliability, with particular emphasis on optimizing.

In this expert validation, the ability to function only by people with disabilities without limbs and legs is considered transportable (see figure 15). Comfort and aesthetics are the primary factors established. The professionals examined and scored the criteria.



**Figure 15.** Mobility Design System with Inclusive Design Concept, score data from expert validation in graph form

As indicated above, expert validation revealed unanimous agreement regarding the features of the proposed wheelchair prototype, with all evaluative scores meeting or exceeding 4.0. This consensus highlights the critical role of inclusive design in mobility systems.

**Usability:** Two experts characterized the prototype as user-friendly, while three others described it as modular and easy to operate, reflecting an ergonomic and human-centered design approach.

**Transportability and Foldability:** Three experts rated the design as modularly easy to handle; one expert rated it as easy, and the owner assigned the highest possible score of 5.0.

**Comfort and Aesthetics:** Two experts awarded a score of 5.0, and three additional experts noted that the design was modularly easy to use.

**Overall Evaluation:** The collective feedback underscores the prototype's design strengths and demonstrates alignment with the preferences of both domain experts and potential end users.

## FINDINGS

Based on the above, the researcher has concluded the research findings as below:

i) It is difficult to classify the symptoms in terms of PWDs who use wheelchairs. People who utilize wheeled mobility devices frequently have worse health outcomes than the general population, according to NIH Institutes (2002). The physical impacts of prolonged wheelchair use are associated with a number of specific health issues, including extensive injuries to the shoulders, skin deterioration, and urinary tract issues. Accessing preventive healthcare and obtaining enough exercise may be difficult for wheelchair users.

ii) The category of the symptoms toward PWDs on wheelchair without limbs and legs outcomes is not only based on their physical outcome, but rather on other forms of body impacts, such as body imbalance, diabetes, neuropathy, paralysis, and so forth.

iii) It is also because majority of respondents were not in good health, it is very difficult for them to use the manual type of wheelchair especially for the elderly group and those using wheelchair with lower protection. Based on the online interview outcome, majority of PWDs preferred utilizing motorized wheelchairs over manual wheelchairs for ease of manoeuvring.

iv) NIH, (2002) claims that the population of PWDs using wheelchair for movement is large, diverse, and ill-defined. Many of them offer information on the severity of disability, few national surveys and databases have data on the kind, frequency, or duration of wheeled mobility device use. Therefore, wheelchair use is frequently overlooked in studies examining the effects of physical exercise in populations that are likely to include wheelchair users. Rather than investigating how using a wheelchair affect a person's overall health, the majority of wheelchair research focuses on resolving the underlying problem.

## CONCLUSIONS

This study successfully developed and validated a conceptual framework for an Inclusive Mobility Design System (MDS) tailored to the specific needs of PWLDs in Malaysia. Through a rigorous Design and Development Research (DDR) framework, qualitative interviews with users and experts, and thematic analysis using NVivo, the research identified key difficulties and requirements that existing solutions fail to address,

The findings underscore the critical importance of a user-centric approach that prioritizes comfort, transportation, and usability, ultimately resulting in a design concept that received unanimous validation from expert reviewers. The assessment of the prototype's features including its modularity, ease of operation, and aesthetic appeal demonstrates its potential to significantly enhance the daily living and independence of its intended users. The contributions of this research are three-fold:

**1. A Tailored Mobility Solution:** The study offers a validated conceptual design for an affordable, user-friendly MDS specifically for PWLDs without limbs or legs, a demographic often overlooked by mass-produced assistive devices.

**2. Robust Design Guidelines:** The research provides a detailed, step-by-step inclusive design framework derived from the ADDIE model and a V-model approach. This framework serves as a

practical guide for designers and manufacturers, facilitating the development of future assistive devices that are both effective and relevant.

**3. Promotion of Inclusive Practices:** By highlighting the challenges faced by PWLDs and demonstrating a successful methodology for creating equitable solutions, this study promotes a broader adoption of inclusive design standards. The findings are intended to inform policy and facilitate the creation of new market segments for assistive mobility devices, ultimately elevating the quality of life for PWDs in Malaysia.

Future research should focus on the implementation and evaluation phases of this framework, including material selection, cost-efficiency analysis, and real-world testing with users. Continued refinement and iteration of the design, based on direct user feedback from a wider cohort, will be essential to ensure its long-term success and scalability.

## REFERENCES

- Alshangiti, A. A. (2020). Human factors in assistive technology design. *International Journal of Industrial Ergonomics*, 78, 102964. <https://doi.org/10.1016/j.ergon.2020.102964>
- Borade, A. B., Kadam, S. S., & Patil, S. B. (2019). Assistive technology for amputees: A review. *Biomedical Engineering Letters*, 9(3), 323–335. <https://doi.org/10.1007/s13534-019-00123-4>
- Clarkson, J., Coleman, R., Keates, S., & Lebbon, C. (2003). *Inclusive design: Design for the whole population*. Springer. <https://link.springer.com/book/10.1007/978-1-4471-0001-0>
- Cooke, N. J., Pringle, H. L., & Pedersen, H. K. (2016). Technological aids for individuals with severe physical disabilities. *Assistive Technology*, 28(3), 129–137. <https://doi.org/10.1080/10400435.2016.1148576>
- Design Research Society. (2018). *Human-centered design: Foundations and methodologies*. London: Design Research Society
- Forma-Slova, A. (n.d.). Classification of physical disabilities and functional impairments. Retrieved from <https://www.disabilityworld.org>
- Gómez-Torres, M., Martínez-Santos, J. C., & Rivera, D. (2019). Smart wheelchair with autonomous navigation. *Sensors*, 19(11), 2485. <https://doi.org/10.3390/s19112485>
- Harahap, A. F., Ariff, A. F., Rahman, R., Zainol Fithri, Z. S., & Qiu, L. (2024). \*Adapting inclusive design concepts in developing assistive mobility design system for PWDs specific community in Malaysia using Design Develop Research (DDR)\*. *International Journal of Academic Research in Business and Social Sciences*, [https://doi.org/10.6007/IJARBSS/v14i5/21577] (<https://doi.org/10.6007/IJARBSS/v14-i5/21577>)
- Herr, H., Grabowski, A. M., & Goldfarb, M. (2024). Bionic prosthetics and neural control for amputee mobility. *Science Robotics*, 9(87), eadg5678. <https://doi.org/10.1126/scirobotics.adg5678>
- Inclusive Design Research Centre. (1993). *Inclusive design principles and guidelines*. Toronto: OCAD University.
- Inclusive Design Research Centre. (1993). What is inclusive design? Retrieved from <https://idrc.ocadu.ca/about-the-idrc/49-resources/online-resources/articles-and-papers/443-whatisinclusivedesign>
- Inclusive Design Research Centre. (1993). What is inclusive design? <https://idrc.ocadu.ca/about-the-idrc/49-resources/online-resources/articles-and-papers/443-whatisinclusivedesign>
- Kim, H., Park, J., & Lee, S. (2024). Participatory design of lightweight powered wheelchairs. *Applied Ergonomics*, 115, 104144. <https://doi.org/10.1016/j.apergo.2023.104144>
- Long, T., & Siu, K. W. M. (2023). Accessibility challenges in public information and communication technologies: Structural barriers and integrative solutions. *International Journal of Human-Computer Interaction*, 39(10), 911–927. <https://doi.org/10.1080/10447318.2023.1234567>
- Maione, L. (2025). Accessibility and equity: Designing for functional diversity.
- Maione, L. (2025). Accessibility-focused design strategies to remove barriers for people with disabilities. *Disability Studies Quarterly*, 35(2), 112–130.
- Manderson, L., Bennett, E., & Andajani-Sutjahjo, S. (2006). The social dynamics of disability and rehabilitation in Southeast Asia. *Disability & Society*, 21(3), 213–227. <https://doi.org/10.1080/09687590600617343>
- McDonald, C. L., Westcott-McCoy, S., Weaver, M. R., Haagsma, J. A., & Kartin, D. (2020). Function and participation after limb loss. *Archives of Physical Medicine and Rehabilitation*, 101(3), 511–518. <https://doi.org/10.1016/j.apmr.2019.10.183>

- Morris, J. T., Mueller, J. L., & Jones, M. L. (2022). User-centered wheelchair design for improved mobility. *Journal of Rehabilitation Research and Development*, 59(4), 567–580.
- Murphy, J. D. (2020). Congenital limb reduction defects: Epidemiology and clinical implications. *Journal of Pediatric Orthopedics*, 40(5), e381–e387. <https://doi.org/10.1097/BPO.0000000000001497>
- Nasir, M. N. A. (2020). The socio-economic situation of disabled persons in Malaysia. *International Journal of Business, Economics and Law*, 23(1), 74–82
- National Institutes of Health. (2002). *Rehabilitation engineering and assistive technology*. NIH Publication No. 02-5001.
- Nayak, R., Kumar, S., & Mishra, D. (2016). User-centered assistive technology design using low-cost household materials. *Assistive Technology*, 28(1), 1–9. <https://doi.org/10.1080/10400435.2015.1092189>
- Newell, A. F., Carmichael, A., Morgan, M., & Dickinson, A. (2010). Designing for older and disabled people: User-sensitive inclusive design. *Universal Access in the Information Society*, 9(1), 11–22. <https://doi.org/10.1007/s10209-009-0145-8>
- Onsman, A. (2025). Universal design: Principles and applications. *Journal of Accessibility and Design*, 12(1), 45–59
- Roe, P. R. (2020). User-centered inclusive mobility technologies. *Technology and Disability*, 32(4), 189–201.
- Treviranus, J. (2018). Inclusive design research and practice. *ACM Interactions*, 25(6), 18–23. <https://doi.org/10.1145/3274564>
- United Nations. (2006). *Convention on the Rights of Persons with Disabilities (CRPD)*. United Nations. <https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf>
- Waller, A., Bradley, M., Peppé, S., & Pearson, C. (2015). Evaluating the impact of inclusive design approaches. *Journal of Design Research*, 13(2), 145–162
- Weerasinghe, T. W., Senanayake, S., & Bandara, K. (2015). Accessibility and affordability of assistive devices for persons with disabilities in developing countries. *Disability, CBR & Inclusive Development*, 26(2), 5–22.
- World Health Organization. (2024). *Global report on assistive technology*. WHO. <https://www.who.int/publications/i/item/9789240094097>
- Yunos, A. R., Rahman, R., & Ariff, F. A. (2022). Inclusive mobility solutions for persons with disabilities in Malaysia. *Journal of Asian Design Studies*, 5(2), 45–58.