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Ergonomic Mobility Aid Redesign for Older Adults Using QFD and Concurrent Engineering

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ABSTRACT IN ENGLISH

Global increases in life expectancy have led to a growing proportion of older adults experiencing functional decline and mobility limitations. In Indonesia, older adults account for 11.75% of the population, with musculoskeletal disorders being a major cause of disability and fall-related injuries. Mobility aids are essential to support independence and reduce fall risk. However, many existing designs lack adequate ergonomic considerations, limiting comfort and usability. This study aimed to optimize mobility aid design by applying ergonomic principles and a user-centered development approach to improve safety, functionality, and quality of life among older adults. Quality Function Deployment (QFD) was used to translate user needs into technical specifications, while Concurrent Engineering was applied to integrate ergonomic and technical considerations throughout the design and prototyping stages. The resulting design incorporates adjustable height, a foldable seat, lightweight durable materials, and a reliable braking system. Verification confirmed compliance with key technical requirements, including a handbrake force of 120 N and a height adjustment range of 75–88 cm. Validation with 30 older adult users demonstrated high satisfaction, particularly with stability and braking performance. Overall, the proposed mobility aid shows potential to enhance safety, usability, and functional independence among older adults.

Keywords:
Older adult; Ergonomic Design; Mobility aid; QFD; Concurrent engineering

1. INTRODUCTION

Global increases in life expectancy have resulted in significant demographic shifts. According to the World Health Organization, more than one billion people worldwide are currently over the age of 60, with projections indicating an increase to 2.1 billion by 2050 [1]. These trends reflect advancements in healthcare, medical technology, and overall quality of life that have enabled longer and healthier lifespans. Consequently, societies face the imperative of adapting to the evolving demographic structure by addressing the specific needs and challenges of older populations. The maintenance of functional ability among older adults represents a crucial factor in ensuring independence and reducing healthcare burdens [2], [3].

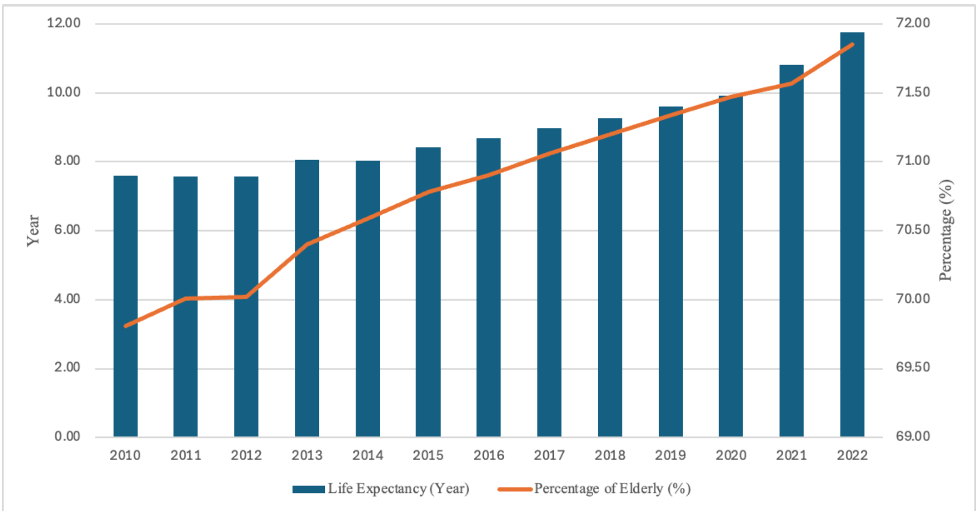

Figure 1 - Percentage of Older adult Population and Life Expectancy in Indonesia 2010-2022 [4]**.**

In Indonesia, the growing number of older adults has emerged as a critical policy concern. Data from the March 2022 National Socioeconomic Survey (Susenas) indicate that individuals aged 60 and over constitute 11.75% of the total population approximately 30 million people [4]. Efforts to ensure their quality of life increasingly emphasize health and mobility considerations. Aging is associated with heightened vulnerability to chronic conditions and functional decline, including reduced motor capacity that limits daily activities. These challenges place additional strain on healthcare and social systems, thereby underscoring the need for targeted interventions, improved healthcare policies, and the development of assistive technologies for mobility support [5], [6].

Health survey data further highlight these issues. In 2023, 41.49% of Indonesian older adults reported health complaints that directly affected their mobility [7]. The disability rate among this population reached 57.72%, with musculoskeletal disorders identified as the leading cause of disability [8], [9]. Such conditions undermine motor ability, elevate the risk of falls and injuries, and contribute to diminished quality of life and increased dependency. Mitigation of mobility limitations is therefore essential for the preservation of well-being and the promotion of independence among older adults [3].

The WHO (2020) defines "healthy ageing" as the process of developing and maintaining functional abilities that support well-being in older age. These functional abilities encompass mental and physical capacities such as walking, thinking, seeing, hearing, and interacting with the environment. Declining mobility not only increases the risk of falls but also contributes to social isolation, loss of independence, and greater burden on caregivers. Globally, more than 1.71 billion people experience musculoskeletal disorders, including lower back pain, arthritis, and osteoporosis, which remain the leading causes of disability. WHO reports that over two-thirds of older adults with musculoskeletal conditions faced difficulties performing basic activities such as walking, standing, or climbing stairs [10]. These limitations highlight the urgent need for effective mobility support solutions.

Assistive devices such as walkers represent essential tools for supporting mobility among older adults. These devices help reduce fall risk and encourage independent movement, thereby contributing to improved quality of life and greater social participation. However, many existing mobility aids designs exhibit limited ergonomic considerations, resulting in discomfort and restricted usability. Features such as inadequate adjustability, insufficient stability, and reduced ease of use limit their effectiveness in meeting the diverse needs of older users. Incorporation of ergonomic principles in mobility aid design remains essential for enhancing functionality, safety, and user experience. Contemporary mobility aids design increasingly include features such as hand brakes for improved stability, adjustable height systems for posture alignment, and foldable seats for resting [11], [12]. Lightweight yet durable materials also support usability across varied environments. Despite these improvements, significant gaps persist in the application of comprehensive ergonomic principles aimed at optimizing safety and user-friendliness.

Previous studies on mobility aids have largely emphasized mechanical performance and isolated design features, with limited involvement of older adults throughout the design and validation process [11], [12], [13]. As a result, many existing products fail to accommodate anthropometric variability and real-world usage conditions, which may reduce user satisfaction and compromise safety [13]. These limitations indicate the need for a more systematic, user-centered development approach that integrates ergonomic principles from the early design stages. Therefore, this study applies Quality Function Deployment (QFD) and Concurrent Engineering (CE) to translate user needs into measurable technical specifications while embedding ergonomic, technical, and manufacturing considerations across the product development process. It is hypothesized that a mobility aid developed using this integrated approach will demonstrate improved safety, usability, and user satisfaction compared to conventional designs.

2. METHOD

2.1 Research Design

This study adopted a user-centered product development approach integrating Quality Function Deployment (QFD) and concurrent engineering. QFD was employed to systematically translate user needs into technical design requirements, while concurrent engineering was applied to support parallel development of ergonomic design, technical evaluation, and prototyping [14]. The methodology consisted of four main phases: (1) identification of user needs, (2) quantification and prioritization of needs using QFD, (3) derivation of technical responses and construction of the House of Quality (HoQ), and (4) ergonomic design and validation through concurrent engineering [15].

2.2 Study Population and Sample

The study population comprised older adults aged 60 years and above who experience mobility limitations and regularly use or require walking assistance devices. Participants were recruited from Panti Sosial Tresna Werdha Budi Pertiwi. Two participant groups were involved:

1. **Preliminary needs identification stage (QFD input):**
   Ten older adults participated in interviews and observations to elicit initial user requirements. The use of 10 respondents in the need statement identification stage was considered adequate, as QFD focuses on identifying dominant user requirements rather than inferential statistical analysis. Previous studies indicate that 8–12 users are sufficient to capture more than 80% of usability and requirement issues in early design phases [16]. Therefore, the selected sample size was deemed representative for identifying key user needs relevant to the design of the mobility assistive device.
2. **Questionnaire and anthropometric data collection stage:**
   Thirty older adults participated in the structured survey and anthropometric measurements used for design validation and ergonomic modeling.

2.3 Study Variables and Research Instruments

The study variables consisted of user needs related to safety, ergonomics, usability, and functionality of the mobility assistive device. These variables were operationalized into need statements. Data were collected using a structured questionnaire based on a four-point Likert scale to assess customer satisfaction and perceived importance. The questionnaire was constructed through a literature review, preliminary observation, and semi-structured interviews to ensure content validity.

2.4 Data Collection Procedure

Data collection was conducted in three stages: (1) observation and interviews to identify user needs, (2) questionnaire distribution to evaluate satisfaction and importance levels, and (3) field validation involving direct use of the prototype. Surveys were administered using Google Forms, while observations were conducted on-site to capture real-time user interactions.

2.5 Data Analysis Technique

Quantitative data were analyzed using Weighted Average Performance (WAP) calculations to determine satisfaction and importance levels for each variable. The results were further mapped using the Klein Grid Matrix to classify attributes into Expected, High Impact, Low Impact, and Hidden categories. Descriptive statistics were applied during the validation phase to evaluate usability outcomes and support design conclusions.

2.6 Quality Function Deployment

This study employed the Quality Function Deployment (QFD) method. The primary objective of QFD is the translation of customer needs into specific, measurable product characteristics while identifying priority areas to be addressed during the design and development process. Data processing in this study was conducted through the construction of one or more matrices known as the House of Quality (HOQ). The following describes the HOQ stages applied in the design of the mobility aid.

2.6.1 Need Statement

The identification of customer needs served as a critical initial stage in the design of the mobility aid, forming the foundation for subsequent development phases and increasing the likelihood of product acceptance. This process involved gathering comprehensive information on desired characteristics, attributes, and features through surveys, observations, and secondary data analysis [17]. Surveys were used to collect structured responses via online questionnaires (Google Forms) for ease of access, while observations provided systematic records of actual behaviors and conditions without direct interaction. Attributes identified through these methods were defined as customer needs and subsequently incorporated into the House of Quality (HoQ) matrix [18].

A survey was conducted to assess customer satisfaction and the perceived importance of ten identified need statements related to the mobility aid. Thirty respondents participated in this evaluation, representing potential end users and stakeholders. Each statement was rated using a four-point Likert scale, where a score of 1 indicated very dissatisfied or very unimportant, 2 indicated dissatisfied or unimportant, 3 represented satisfied or important, and 4 denoted very satisfied or very important. The collected responses were processed to calculate the Weighted Average Performance (WAP) for both satisfaction and importance parameters. The weighted average for each variable was calculated by multiplying the number of responses at each scale level by the corresponding score, summing these products, and dividing the result by the total number of respondents. This process produced the WAP (Customer Satisfaction) chart, which ranked user satisfaction across the identified need statements.

2.6.2 Create Technical Response

Technical responses were defined using measurable parameters that describe how product attributes could be fulfilled [19]. These responses were obtained through a combination of literature review and direct observation. Several technical responses were obtained during the identification process.

2.6.3 Determine Relationship

The relationship between need statements and technical responses was established by mapping the connections between them. Each relationship was evaluated and assigned a corresponding value to indicate the strength of association.

2.6.4 Determine Technical Correlations

The technical correlation matrix was developed to analyze interrelationships among the identified technical responses. This matrix supports the identification of synergistic or conflicting interactions between product attributes, thereby guiding design trade-offs and integration strategies [11]. Positive correlations, indicated by a “+” symbol, suggest that improvements in one technical aspect may enhance another. Conversely, negative correlations, denoted by a “–” symbol, highlight potential design conflicts. These technical correlations were qualitatively assessed based on engineering judgment and user-centered design principles to ensure that the development process addresses user needs without compromising key performance attributes [20].

2.6.5 House of Quality (HoQ)

At this stage, the House of Quality (HOQ) was constructed by integrating multiple matrices to identify and prioritize design specifications that served as the primary reference for developing the mobility aid interface [21]. The HoQ framework comprises user requirements (product attributes), technical responses, the relationship matrix, and the technical correlation matrix [22]. In this study, the planning matrix was intentionally excluded from the QFD phase, as the study objective was centered on addressing the needs of internal stakeholders rather than performing competitive benchmarking. This decision aligns with Hariri et al. (2023), who emphasized the adaptability of QFD to the specific nature and objectives of each project. Because the design was tailored exclusively for internal users, prioritization based on competitive analysis and relative importance weights was unnecessary. Consequently, the next step involved prototype development guided by the technical responses derived from the HoQ [24].

2.7 Concurrent Engineering

In this study, concurrent engineering was applied to enable the simultaneous development of multiple aspects of the mobility aid, from ergonomic handle design to integrated braking systems. This method promotes collaborative and parallel workflows across various stages such as planning, design, simulation, manufacturing, sales, and support. During the planning phase, the needs of older adult users with mobility limitations were identified. A crucial part of the planning process involved the collection and analysis of anthropometric data from 30 older adult participants to guide the design process. The anthropometric data were then directly integrated into the design phase using Autodesk Inventor to develop the initial 3D model of the mobility aid. Following the design stage, the product underwent simulation testing to evaluate its stability and comfort under realistic usage scenarios. The validated components were subsequently transitioned into the manufacturing phase for prototyping. The sales team provided input to ensure that the product aligns with market expectations regarding cost and functionality. The support phase included developing user manuals and collecting feedback for future improvements.

3. RESULT AND DISCUSSION

3.1 User Need Evaluation Using QFD

User needs related to the mobility aid were evaluated using a four-point Likert scale questionnaire administered to 30 respondents. Weighted Average Performance (WAP) values were calculated to assess both customer satisfaction and perceived importance for each of the ten need statements (V1–V10), as shown in Table 1. The results of customer satisfaction analysis are presented in Figure 2.

Table 1 - Connecting User Needs to Technical Responses

Variable	Need Statement
V1	The product must be safe.
V2	The product must have a reliable hand brake feature.
V3	The product must be adjustable in height.
V4	The product must have comfortable, non-slip handles.
V5	The product must be stable during use.
V6	The product must be made of lightweight yet strong materials.
V7	The product must have a foldable seat.
V8	The product must have a comfortable armrest
V9	The product must have non-slip wheels.
V10	The product must have a basket feature.

The analysis showed that height adjustability (V3) and non-slip wheels (V9) achieved the highest satisfaction scores (3.57), indicating that these features were the most valued by users. In contrast, product stability during use (V5) obtained the lowest satisfaction score (2.90), suggesting that users perceived stability as an area requiring further improvement. These results indicate that users tend to prioritize directly experienced functional attributes, such as adjustability and wheel grip, over less visible structural characteristics, although both remain essential for safe and effective use.

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Customer Satisfaction WAP (Weighted Average Performance)

CUSTOMER SATISFACTION WAP CALCULATION											
	Score	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Total Number of Respondent Answered	1	0	0	0	0	0	0	0	0	0	0
	2	0	2	1	1	11	0	0	0	0	0
	3	22	28	11	16	11	19	14	19	13	14
	4	8	0	18	13	8	11	16	11	17	16
TOTAL		30	30	30	30	30	30	30	30	30	30

	Score	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Performance Weighted	1	0	0	0	0	0	0	0	0	0	0
	2	0	4	2	2	22	0	0	0	0	0
	3	66	84	33	48	33	57	42	57	39	42
	4	32	0	72	52	32	44	64	44	68	64
TOTAL		98	88	107	102	87	101	106	101	107	106

Weighted Average Performance (Customer Satisfaction)									
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
3,27	2,93	3,57	3,40	2,90	3,37	3,53	3,37	3,57	3,53

Figure 2 – Weighted Average Performance (Customer Satisfaction)

Similarly, the perceived importance of each need statement was analyzed, as shown in Figure 3. The highest importance scores were recorded for lightweight yet strong materials (V6) and basket feature (V10), reflecting users' emphasis on practicality and daily usability. In contrast, stability (V5) and armrest comfort (V8) were rated lower, indicating that these attributes are considered baseline expectations rather than differentiating features.

Customer Importance WAP (Weighted Average Performance)

CUSTOMER IMPORTANCE WAP CALCULATION											
	Score	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Total Number of Respondent Answered	1	0	0	0	0	1	0	0	0	0	0
	2	0	1	0	0	7	0	1	0	0	0
	3	17	17	16	14	9	12	13	19	14	12
	4	13	12	14	16	13	18	16	11	16	18
TOTAL		30	30	30	30	30	30	30	30	30	30

	Score	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Performance Weighted	1	0	0	0	0	1	0	0	0	0	0
	2	0	2	0	0	14	0	2	0	0	0
	3	51	51	48	42	27	36	39	57	42	36
	4	52	48	56	64	52	72	64	44	64	72
TOTAL		103	101	104	106	94	108	105	101	106	108

Weighted Average Performance (Customer Importance)									
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
3,43	3,37	3,47	3,53	3,13	3,60	3,50	3,37	3,53	3,60

Figure 3 – Weighted Average Performance (Customer Importance)

3.2 Klein Grid Matrix Classification

The satisfaction and importance results were further interpreted by plotting the WAP values using a Klein Grid Matrix, which classifies attributes into four categories: Expected (EXP), High Impact (HIM), Low Impact (LIM), and Hidden (HID). The classification results are presented in Figure 4. The analysis revealed that V1 (product safety), V2 (hand brake reliability), V4 (handle comfort), V6 (material weight and strength), and V8 (armrest comfort) were classified as Expected attributes, indicating that users generally anticipate these features as standard. Meanwhile, V3 (height adjustability), V7 (foldable seat), V9 (non-slip wheels), and V10 (basket feature) were categorized as High Impact attributes, demonstrating their strong influence on user satisfaction and overall product performance. V5 (product stability) was placed in the Low Impact category, indicating that although stability is essential, it is perceived as a fundamental requirement rather than a source of added value.

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Weighted Average Performance (Customer Satisfaction)									
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
3,27	2,93	3,57	3,40	2,90	3,37	3,53	3,37	3,57	3,53
Intersection Point (X) :		3,34							

Weighted Average Performance (Customer Importance)									
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
3,43	3,37	3,47	3,53	3,13	3,60	3,50	3,37	3,53	3,60
Intersection Point (Y) :		3,45							

Figure 4 – Klein Grid Matrix results

3.3 Relationship Analysis Between User Needs and Technical Responses

The relationships between user needs and technical responses were analyzed using the House of Quality framework, as illustrated in Figure 5. The results showed that the need for product safety (V1) had a strong relationship with product stability during use and a moderate relationship with the overall level of product safety, highlighting the importance of structural stability in ensuring safe operation.

Similarly, the need for a reliable hand brake (V2) exhibited a strong relationship with hand brake stopping force, confirming its critical role in controlling movement and preventing falls. Height adjustability (V3) demonstrated a strong relationship with the height adjustment range, emphasizing its significance in accommodating users with varying body dimensions. Additional strong relationships were observed between handle comfort (V4) and the handle friction coefficient, foldable seat functionality (V7) and ease of seat folding**,** non-slip wheels (V9) and the wheel friction coefficient, as well as basket functionality (V10) and basket capacity. These findings indicate that the identified technical responses appropriately represent the functional requirements expressed by users.

Variable	Need Statements \ Technical Responses	Level of product safety	Hand brake stopping force	Height adjustment range	Handle friction coefficient	Product stability level during use	Product weight	Ease of seat folding operation	Armrest comfort level	Wheel friction coefficient	Basket capacity
1	The product must be safe to use.	●	○		▽	●	▽		▽	○	
2	The user must be able to stop the product easily and safely.	○	●			○					
3	The product must accommodate users of different heights.			●							
4	The user must be able to grip the product comfortably and securely.				●						
5	The product must remain stable during use.	○	▽			●	▽			▽	
6	The user must be able to move or carry the product easily without it breaking.	▽				▽	●				
7	The user must have a place to sit when needed.							●			
8	The user must be able to rest their arms comfortably.								●		
9	The product must move smoothly without slipping.	▽	▽			▽				●	
10	The user must be able to carry personal items while using the product.										●

Figure 5 – Relationship Analysis Between User Needs and Technical Responses

3.4 Technical Correlation Analysis

The technical correlation matrix presented in Figure 6 illustrates the interrelationships among the defined technical responses. Positive correlations were identified between product safety, product stability, and handle friction coefficient, suggesting that improvements in grip quality can enhance overall stability and safety. Negative correlations were observed between product weight and both product stability and ease of seat folding, indicating potential design trade-offs. While increased weight may contribute to greater stability, it can negatively affect portability and folding

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convenience. These findings highlight the importance of balancing ergonomic performance and structural design during product development.

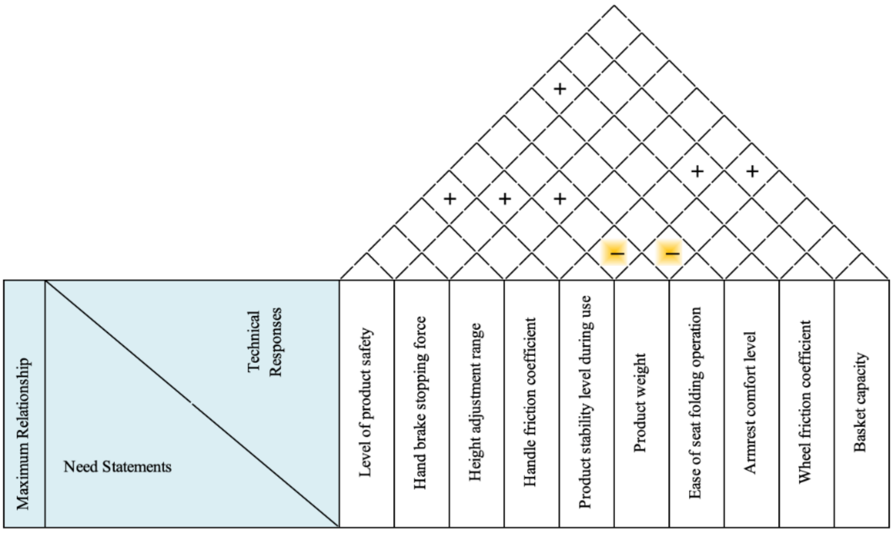
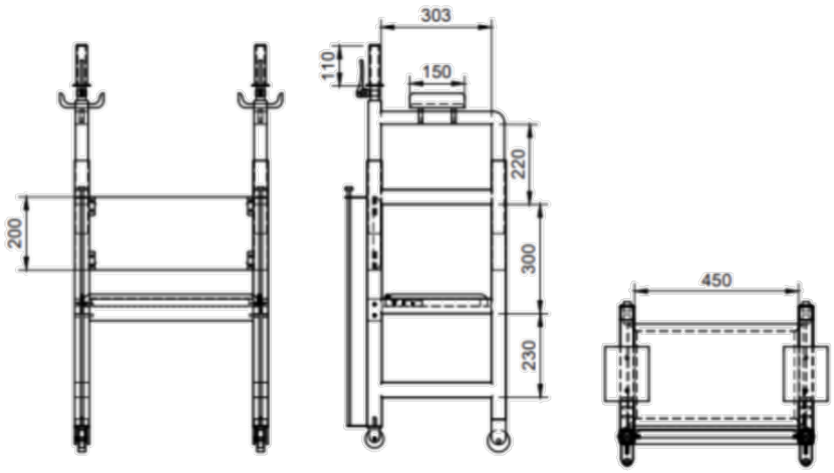


Figure 6 – Correlation Matrix of Technical Responses

3.5 Product Design Based on Anthropometric Integration

Anthropometric data collected from 30 older adult participants were integrated into the design process to ensure ergonomic compatibility. Key percentile values (P50 and P95) were used as reference points for determining handle height, seat dimensions, and overall product proportions. The resulting design incorporates adjustable handles, an anti-slip wheel system, and ergonomic dimensions aligned with user anthropometry. The final product configuration is presented in Figure 7, which illustrates the front, side, and top views of the mobility aid along with its dimensional specifications.



(a) (b) (c)

Figure 7 - Product design (in mm): (a) front view illustrating the vertical dimensions and structural alignment, (b) side view depicting the depth and height proportions, and (c) top view showing the overall width and component spacing.

3.6 Discussion and Implications

The final design stage aimed to implement the concepts formulated during the design process into a prototype that fulfills user needs. In this study, the design outcome focused on the development of a mobility aid specifically designed to enhance comfort, safety, and ease of use for older adults. The design process involved translating conceptual features into a tangible design, with key elements including adjustable height, an ergonomic foldable seat, and the use of lightweight yet durable materials to ensure both reliability and efficiency in daily use. The final mobility aid is presented in Figure 8.

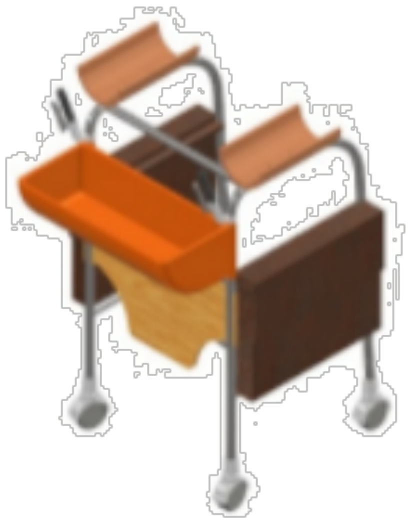


Figure 8 - Final Design of the Mobility Aid

Verification was conducted to ensure that the prototype met the predefined specifications. Table 2 presents the verification results, which confirmed that all technical criteria were fulfilled. For example, the mobility aid achieved the required handbrake force of 120 N, adjustable height range of 75–88 cm, wheel friction coefficient of 0.85, and total product weight of 7 kg. In addition, qualitative specifications such as comfort of the armrest, stability during use, and foldable seat usability were also verified and found to be consistent with the intended design goals. Similar approaches to design verification have been emphasized in ergonomics studies to ensure technical feasibility before field validation [25], [26].

Table 2 - Product Verification Results

Product Specification	Prototype Outcome	Conformity
Product safety level > 4	The product was safe in use; no incidents were recorded.	Compliant
Hand-brake stopping force = 120 N	The hand brake achieved a stopping force of 120 N.	Compliant
Height-adjustment range 75–88 cm	The product height was adjustable within 75–88 cm.	Compliant
Wheel friction coefficient = 0.85	Wheel friction coefficient measured 0.85.	Compliant
Handle (grip) friction coefficient = 0.87	Handle friction coefficient measured 0.87.	Compliant
Product weight = 7 kg	Total product weight was 7 kg.	Compliant
Ease of folding seat > 4	Folding-seat usability rated > 4.	Compliant
Product stability during use > 4	Stability during use rated > 4.	Compliant
Armrest comfort level > 4	Armrest comfort rated > 4.	Compliant
Shopping-basket capacity = 17 kg	Basket capacity measured 17 kg.	Compliant

Following verification, validation was conducted to evaluate the safety and comfort of the mobility aid in real-life conditions. The field trial took place over two days at *Panti Sosial Tresna Werdha Budi Pertiwi*, involving 30 older adult participants. Ethical approval had been obtained prior to the trial. A mixed-method approach was applied for data collection. Quantitative data were gathered using a Likert scale survey (1–4), assessing aspects such as safety, braking performance, height adjustment, wheel and handle usability, product weight, foldable seat, stability, armrest comfort, and shopping basket capacity. The results were analyzed using descriptive statistics, including mean and standard deviation, which is a widely adopted method for usability validation in assistive product design [27], [28].

Qualitative data were obtained through direct observation during the field trial. Observations focused on older adult users' interactions with the mobility aid, spontaneous reactions, and potential issues not captured in the survey. This approach provided deeper insight into user experience, particularly regarding comfort and safety dimensions, which may not always be measurable quantitatively [29]. The validation results confirmed that the mobility aid successfully achieved the predefined design goals, as summarized in the Planning Matrix (Table 3). The majority of design variables reached high levels of customer satisfaction, importance, and goal attainment, with average scores ranging from 3.02 to 3.57 on a 4-point scale. Notably, stability (V9, mean score 3.57) and braking performance (V10, mean score 3.57) demonstrated the strongest results. These findings are consistent with previous studies highlighting the importance of stability and safety in mobility aids for older adult users [13], [30].

Table 3 - Planning Matrix

Variable	Customer Satisfaction	Customer Importance	Goal
V1	3.27	3.43	3.35
V2	2.93	3.37	3.15
V3	3.57	3.47	3.52
V4	3.40	3.53	3.47
V5	2.90	3.13	3.02
V6	3.37	3.60	3.48
V7	3.53	3.50	3.52
V8	3.37	3.37	3.37
V9	3.57	3.55	3.55
V10	3.53	3.57	3.57

Overall, the integration of ergonomic design features and user-centered considerations significantly enhanced product usability and safety for older adult users. The verification and validation outcomes provide strong evidence that the walker is a reliable mobility aid, fulfilling the study objective of developing an ergonomically optimized product to support older adult independence and well-being. Furthermore, these findings align with earlier study demonstrating that ergonomics-based design improves the usability of assistive devices [21].

Beyond product performance, this study contributes to the innovation process by demonstrating how structured, user-centered methodologies can support organizational learning in assistive product development. The integration of Quality Function Deployment (QFD) and Concurrent Engineering enables systematic knowledge capture from users and transforms tacit user experiences into explicit technical requirements. This process facilitates cross-functional collaboration among design, engineering, and manufacturing teams, reducing iterative rework and improving decision-making efficiency throughout the product development lifecycle. Moreover, the iterative feedback loops established during need identification, prototype verification, and field validation promote continuous learning, allowing organizations to refine design assumptions based on real user interactions. As a result, the proposed approach not only generates an ergonomically improved mobility aid but also strengthens organizational capability to manage innovation in a structured and replicable manner, supporting future development of user-centered assistive technologies.

4. CONCLUSION

The growing older adult population underscores the importance of mobility aids that enhance safety, comfort, and independence. This study developed and evaluated an ergonomically optimized mobility aid that integrates adjustable height, a foldable seat, and lightweight durable materials. Verification confirmed compliance with all technical specifications, while field validation with older adult users demonstrated high satisfaction in terms of stability, braking performance, and overall usability.

The results show that ergonomics-based design can significantly improve the functionality and user experience of mobility aids. The mobility aid provides a reliable solution to support older adult independence and reduce fall risk, thereby contributing to improved quality of life. Future study may expand validation with diverse user groups, integrate smart monitoring features, and explore sustainable materials to further advance assistive device design and application.

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