Opsi p-ISSN 1693-2102

Vol. 18, No. 2, December 2025 e-ISSN 2686-2352

Comfortable and efficient laundry room design using design thinking and jobs-to-be-done

Elty Sarvia *, **Novi Soesilo, Joanna Patricia, Alena Augustin**
Industrial Engineering Bachelor Program, Universitas Kristen Maranatha, Jl.Surya Sumantri No. 65, Bandung, 40164, Indonesia

Corresponding Author: elty.sarvia@eng.maranatha.edu

Article history:
Received: 4 January 2025
Revised: 24 November 2025
Accepted: 26 December 2025
Published: 30 December 2025

Keywords:
Laundry room design
Design thinking
Jobs-to-be-done
User comfort
Ergonomics

ABSTRACT

Optimal laundry room design is essential for efficiency and comfort in washing, drying and ironing clothes. This research identifies people's need for a functional and comfortable laundry room, along with increasingly busy lifestyles. Non-ergonomic designs can reduce efficiency and comfort. Therefore, this research aims to provide a design solution that suits the preferences of users in Indonesia. A total of 123 respondents participated in the survey, of which 100 met the inclusion criteria through purposive sampling. The design thinking and jobs-to-be-done approaches were applied to explore an in-depth understanding of user needs. The results show that all respondents (100%) agreed that the proposed laundry room design is comfortable, functional, and ergonomically suitable, particularly in the height arrangement of the washing machine, accessibility of the drying area, and ironing layout. Dry room integration was also identified as a significant need. Based on the analysis, the recommended minimum size for an ergonomic laundry room is 220 cm x 300 cm, which supports efficient workflow and user comfort. This study emphasizes the importance of a user centered and ergonomic approach in residential space design to enhance daily comfort and productivity.

DOI:
https://doi.org/10.31315/opsi.v18i2.14327

1. INTRODUCTION

Every individual desires a pleasant home, including every part of it, and one of them is the laundry room. The laundry room is considered one of the most essential spaces in a house, serving the purposes of washing, drying, and organizing clothes and other household textiles such as dresses, , towels and bed sheets. Therefore, the planning of a laundry should be carried out carefully so that users can perform activities comfortably without being disturbed or hampered by other household activities.

People now demand housing that is not only functional, but also has aesthetic value and meaning [1], and is able to provide a healthy and comfortable environment for its residents. One of the critical aspects of space design involves the integration of ergonomic principles. Ergonomics is a field of science that systematically utilizes a number of information about human nature, abilities, and limitations to design a safe,

healthy, productive and comfortable work system [2], [3]. Applying human-centered ergonomic principles yields significant benefits for workplace design [4]. To create a user-centered design, an ergonomic approach must integrate considerations of aesthetics, safety, comfort, ease-of-use, and productivity [5].

In laundry room design, ergonomics, particularly anthropometry, plays a crucial role in determining the appropriate dimensions and proportions of design elements such as working heights, reach distances, and equipment placement. These considerations are essential because laundry activities involve frequent physical interaction between users and equipment. The proper application of anthropometric data allows users to perform washing, drying, and ironing tasks with greater comfort, efficiency, and safety. Assessing anthropometric suitability in laundry room design is a crucial step to ensure that all components can be used comfortably and effectively by the user.

Recent studies have shown that ergonomic and anthropometric based designs can enhance comfort and reduce physical strain during laundry activities. Research on washing and ironing stations shows that designs suited to human body measurements can reduce fatigue and the risk of health risks [6]–[8]. Laundry work itself is physically demanding, involving repetitive movements and awkward postures that often cause discomfort and injury [9]. The most important factors affecting a person's work performance are room temperature, furniture arrangement, and repetitive tasks [10].

This study is important as the laundry process which includes lifting of load involves significant physical work and repetitive activity, leading to fatigue and discomfort when the workspace provided has no ergonomic consideration. These activities are routinely done for 1-3 hours during each visit, depending on the number of household members and workload.

Although washing machines can reduce manual effort, improper placement and poorly planned layouts can still cause discomfort and musculoskeletal issues. Fatigue can have a negative impact on performance achievements, with a decline in quality being one of the implications [11]. Prolonged fatigue can affect not only physical endurance but also mental and behavioral health, which may eventually lead to illness and reduced productivity [12]–[14]. Applying ergonomic principles can therefore improve safety, quality, and efficiency in these activities [15], [16]. Hence, it is necessary to design a laundry room that suits the needs and comfort of its users.

Several studies have discussed the ergonomic challenges related to laundry tasks. One study proposed an electroless manual washing machine that improves posture, reduces musculoskeletal strain, and enhances working conditions for women [17]. Other studies examined the difficulties faced by elderly users when operating washing machines and recommended design improvements to enhance functionality and user-friendliness [18], research that produced six dimensions of Generation Z user expectations and provided a design framework that can serve as an innovation guide for laundry product designers and developers [19], environmental impacts associated with laundry activities influenced by a series of related tasks ranging from sorting, drying, ironing, storing, to social norms [20], the reuse of wastewater by separating laundry wastewater according to washing machine cycle stages (wash, rinse, spin) in order to minimize treatment needs and optimize reuse potential [21], effects of manual washing and machine washing with liquid and powder detergents on the quantity and quality of wash water [22]. energy-saving behavior of electric washing machine users[23], and water use efficiency in households based on gender [24].

Research related to design thinking has explored its influence on product development, particularly in enhancing creativity and innovation [25], the design of therapy wheelchairs for stroke patients [26], educational escape rooms [27]–[29], temperature recording system for medication room [30] and the combination of digital technology and physical products to create innovative digital products [31]. In addition, investigations into the design thinking method with Quality Function Deployment (QFD) in product design have also been carried out [32], the Reverse Engineering method integrated with VDI 2222 in designing multi-feature engine carbon cleaning maintenance tools [33], living room design using the Kansei engineering method [34], and smart living room design for dementia patients [35], breastfeeding chair for maternity room [36] using the Kano Model, Analytic Hierarchy Process (AHP), and QFD.

Laundry room design also needs to consider the daily behavior of its users. Research conducted in Finland and Switzerland found that laundry habits are greatly influenced by social norms, family dynamics, as well as the condition of the home space and appliances [37]. With the implementation of Jobs-to-be-Done (JTBD), users' deep needs can be identified properly, enabling the design of innovative product concepts that suit their preferences [38], but also helps minimize the risk of product innovation failure from the early stages

[39]. Furthermore, the JTBD framework has recently been recognized as a structured method to understand user goals and support human centered innovation, making it valuable when integrated into the design process [40]. Although JTBD is widely used in marketing and digital innovation, for example in fashion retail studies to identify customer needs and barriers [34]), its application in product and interior design is still rarely [41].

Laundry workers in healthcare facilities often experience musculoskeletal injuries and other workplace hazards, underscoring the importance of ergonomic interventions in laundry room design [42]. While previous studies have discussed the ergonomic aspects of separate laundry activities, research that examines the interrelation between washing, drying, and ironing areas within a single study remains limited. Moreover, studies that combine the design thinking and JTBD approaches in guiding ergonomic home design are still rare. Therefore, this research integrates both approaches to better understand user needs and develop an ergonomic laundry room layout suited to Indonesian users, enabling them to perform laundry activities comfortably, safely, healthily, and efficiently. This integration provides a new perspective by connecting human-centered innovation methods with ergonomic principles to generate practical design insights for household environments that have not been widely explored in previous research.

2. MATERIALS AND METHODS

The research began by identifying the problems faced by current users. In this initial stage, difficulties faced by users were identified using questionnaires and interviews. Design thinking is a human centered approach to innovation, which integrates user needs, technological possibilities, and business requirements, as well as framing problems and understanding user needs to be incorporated into processes and systems [43], [44]. This approach was applied through five iterative stages: Empathize, Define, Ideate, Prototype, and Test. JTBD is a method that categorizes and manages user requirements. It explains how users judge success in completing tasks and helps innovations to address the problems and barriers that hinder their success. JTBD focuses on understanding users' needs and motivations for doing a job, often without realizing it. In addition, this method also solves problems related to the work that needs to be done. Users pay more attention to the solution offered by the product to solve a problem or achieve a goal, rather than the product itself [45], [46]. The framework has been recognized for capturing user goals and translating them into actionable design insights, particularly in innovation driven contexts [47], [48].

A total of 123 respondents initially participated in the survey, but only 100 met the inclusion criteria: (1) actively performing washing, drying, and ironing activities at home, and (2) using a washing machine for at least one of these processes. These respondents represented a range of household contexts, including small and medium sized families living in urban housing. Participants were selected using a purposive sampling method to ensure diverse user characteristics and experiences.

The design thinking method is used to explore the needs of users who frequently wash, dry and iron at home, through five stages: Empathize, Define, Ideation, Prototype, and Testing. Data were collected through open ended questionnaires and semi structured interviews focusing on users' experiences, challenges, and expectations regarding comfort and efficiency in performing laundry tasks. To enhance the exploration of user needs and ensure the resulting design is aligned with real user behavior, the JTBD framework was integrated into the design thinking process. This study adopted a qualitative approach by integrating the design thinking and JTBD frameworks. The JTBD framework was incorporated into the empathize and define stages of the design thinking process to identify users' functional and emotional needs. During the empathize stage, user insights were obtained through surveys and interviews, which were then organized using the JTBD framework to determine key goals related to laundry activities. The responses were then structured into empathy maps and analyzed using the JTBD pattern (When…, I want to…, So I can…) to identify users' main goals and challenges. These insights were synthesized into need statements, which informed the define and ideate stages in generating ergonomic design concepts.

These findings were further developed in the define and ideate stages to generate user requirements and ergonomic design solutions. Data were analyzed through pattern and needs analysis, enabling a structured interpretation of user behavior and expectations to create an efficient, ergonomic, and user-centered laundry room design. In addition, the JTBD approach helped identify what users genuinely aim to achieve during their laundry activities and the main difficulties they encounter. These insights became the foundation for creating

flexible and adaptive design solutions that respond to users' real needs and make their daily laundry tasks easier and more comfortable.

3. RESULT

The findings presented in this section are based on data obtained from 100 respondents who met the inclusion criteria outlined in the previous section. In designing the physical facilities for the laundry room, the design thinking method was applied through several structured stages. This section presents the results of the design thinking process carried out to develop a comfortable and efficient laundry room. This process follows the stages of the design thinking framework, with the JTBD approach not applied as separate method but integrated into the early stages to explore user needs, which subsequently serve as the basis for generating solution oriented and innovative design concepts.The following subsections describe each stage of the process start from emphatize, define, ideate, prototype, and testing.

3.1. Stage 1: Emphatize

The focus of empathy is to deeply understand the user's perspective [49], [50]. By integrating design thinking and JTBD, the laundry room design can be aesthetically pleasing and meet users' needs in washing, drying, and ironing clothes. Design thinking encourages creative ideas through an iterative process, while JTBD helps understand how users meet their needs [51]. In the laundry room design, the work includes washing the family's clothes and saving time and energy. The application of JTBD allows us to formulate user needs and create more effective solutions. JTBD is one of the emphatize methods. By understanding the needs of users who have not been understood using the JBTD theory, we can develop more effective solutions and better meet their needs [52]. In this study, JTBD framework was integrated as an essential part of the design thinking process, rather than applied separately. It provided a structured approach to capture and interpret user insights within the empathize and define stages. Data were collected through Google Form questionnaires and in-depth interviews to explore users' functional and emotional needs. Findings from the surveys and interviews were expressed in the form of "When…, I want to…, so I can…" statements to represent users' goals, motivations, and challenges in performing washing, drying, and ironing activities. These statements were then organized into empathy maps to visualize patterns of behavior and expectations, which also helped identify two primary user personas: housewives and employees with busy daily schedules. The insights derived from the empathy maps were subsequently refined into design requirements in the define stage to guide the development of ergonomic laundry room concepts. This process ensured that user needs were accurately translated into actionable ergonomic design insights that aligned with the overall objectives of the study. The results of the empathy stage, which summarize the users' observations and expressed needs, are presented in Figure 1 as an empathy map that illustrates the key insights obtained from this process.

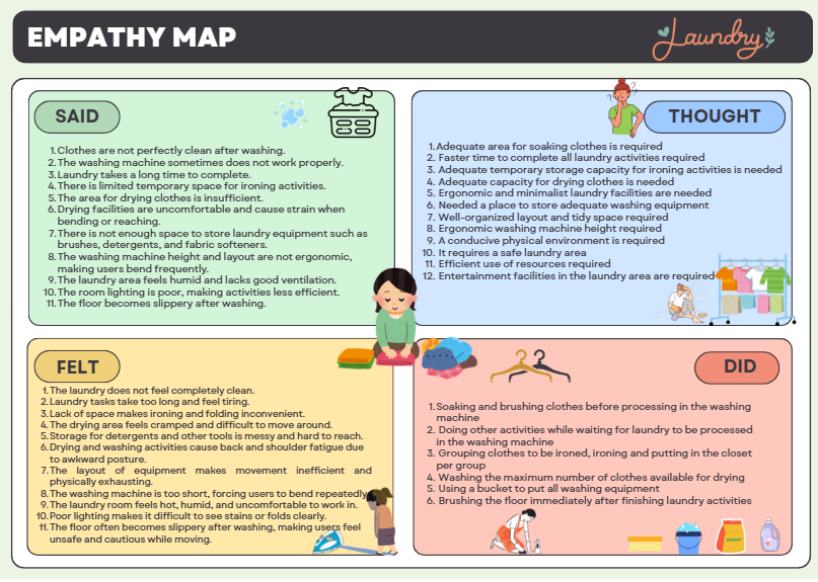


Figure 1. Laundry room design empathy map

3.2. Stage 2: Define

In the Define stage, the approach used is personas, which are representative profiles developed from real user data obtained through questionnaires. These personas help to understand the behavior, needs, and main challenges faced by the user group, and help to formulate more precise problems in designing an ergonomic laundry room.

Persona is an idealized user representation that reflects the behavior and motivations of real users, based on research, not assumptions [53]. Personas are helpful in empathizing with and understanding users' perspectives on the problems they face [54]. The personas chosen should reflect fictional characters with traits that represent the specific target group, and should be based on real data, not just generalizations [55]. Empathy and personas are effective tools for understanding user needs and desires, as well as identifying challenges and opportunities that exist in the design process [56]. The study involved participants recruited using a purposive sampling approach, focusing on individuals who routinely perform domestic laundry activities. Based on questionnaire results, a dominant user profile emerged and has been translated into a primary persona to represent typical needs and behaviors in the design process. The personas found in this study are :

Persona 1: Housewife

- Description: Housewives who are responsible for washing and drying clothes, need an organized space for laundry supplies.
- Requirements: Adequate storage space for detergents and supplies, and sufficient drying capacity.
- Challenges: Narrow space, insufficient drying capacity, and unergonomic drying facilities.
- Problem defined: The design of the laundry room should be ergonomic, with adequate storage and efficient drying facilities.

Persona 2: Employee with a Busy Schedule

- Description: Busy employees who need a quick and efficient laundry process.
- Requirements: Fast laundry process with easy-to-use equipment.
- Challenges: Limited time and less ergonomic workspace.
- Problem defined: The laundry room design should support speed and efficiency, with ergonomic equipment layout.

By using these personas, the research focuses on concrete problems according to user needs. These personas help formulate specific solutions in the design of a more ergonomic and efficient laundry room, which includes aspects of space limitations, user comfort, and ease of use of equipment.

The definition stage is a step to identify problems based on the results obtained from the previous stage. The results of the interview will be poured into an empathy map for each user. The information obtained from this empathy map will then be summarized into a need statement, as shown in Table 1 in column 2 and column 3. The results from the empathy map were examined to find patterns in what users think, feel, and do during their laundry activities. These patterns helped identify what users genuinely experience as their main challenges and expectations. The findings were then interpreted and written as clear need statements that describe what users truly need to make their laundry activities more comfortable and efficient. For example, when users often mentioned back pain or discomfort while bending, this was understood as a need for better working height and posture support. Through this process, the qualitative data from users were gradually shaped into specific ergonomic design criteria that guided the layout and features of the laundry room. The defined user needs then served as the foundation for generating creative ideas and possible design solutions in the ideation stage.

3.3. Stage 3: Ideate

At this stage, based on the summarized need statement, the design team will start developing ideas and potential solutions to address the need. Brainstorming will be done to generate innovative and effective ideas. From the list of need statements obtained in the previous stage, alternative design ideas that can be a solution to the problem are created, as shown in Table 1 in column 4.

Table 1. Needs statement and laundry room design idea

No.	User Need	Technical Statement	Idea
1	The results of the washing are not completely clean, requiring soaking and brushing before washing.	Need for an adequate soaking area equipped with scrubbing support to improve washing results and reduce manual effort.	Design a soaking zone with an integrated scrubbing board that can be used in either standing or sitting posture.
2	Laundry activities take a long time to complete.	Need for an efficient spatial layout that allows smoother workflow and reduces task completion time.	Design the layout of the laundry area with the arrangement of the laundry triangle and provide storage.
3	Poor layout of washing machine and other facilities leads to fatigue.	Need for an ergonomic and efficient workspace layout to minimize unnecessary movement and physical strain.	Rearrange the placement of washing, drying, and ironing areas according to workflow sequence and ergonomic principles.
4	Insufficient temporary storage for ironing activities	Need for adequate temporary storage near the ironing area to organize clothes before and after ironing.	Provide temporary racks or shelving in the ironing area for folded or ready-to-iron clothes.
5	Lack of place to dry clothes especially during rainy season	Need for a flexible drying facility with sufficient capacity and adaptability for different weather conditions.	Design a multilayer clothesline system that can be expanded during rainy days or folded to save space.
6	Drying facilities are inconvenient and not height-adjustable.	Need for a movable and adjustable drying rack to improve comfort and flexibility in daily use.	Develop a foldable drying rack with height-adjustable features for different clothing types.
7	Inadequate or inaccessible storage for laundry tools and materials	Need for easily reachable and organized storage for equipment such as brushes, detergents, and softeners.	Install modular storage units at reachable height in each laundry area.
8	The height of the washing machine is not suitable (too short) so that it hurts when washing	Need for washing machine placement that corresponds to user anthropometry to prevent back strain and awkward posture.	Adjust the height of the washing machine base according to anthropometric data of Indonesian users.
9	Humid room and poor lighting	Need for proper ventilation and adequate lighting to improve comfort, visibility, and air circulation.	Use glass roofing or skylight panels in drying area, add ventilation gaps, and install task lighting in washing and ironing zones.
10	Slippery floor surfaces cause safety risks during washing activities.	Need for a non-slip and slightly sloped floor design to ensure safety in wet conditions.	Design a 2-degree sloped floor using anti-slip materials, rubber mats, or textured paving in washing and drying areas.

3.4. Stage 4: Prototype

This stage aims to develop more ideas based on empathy and create prototype designs that serve to reduce errors before the final product is produced [57], [58]. Once these ideas are developed, they will be evaluated and selected based on their potential effectiveness and feasibility. Prototypes of the selected solution will be created and tested in the next stage. The prototyping process helps designers better understand the physical aspects of the product such as form, function, and structure [59]. Through this process, a laundry room design was developed that combines aesthetic appeal with functionality while maximizing space efficiency. The final design, illustrated in Figure 2, organizes the washing, drying, and ironing areas according to ergonomic principles to support users' daily activities comfortably and effectively.

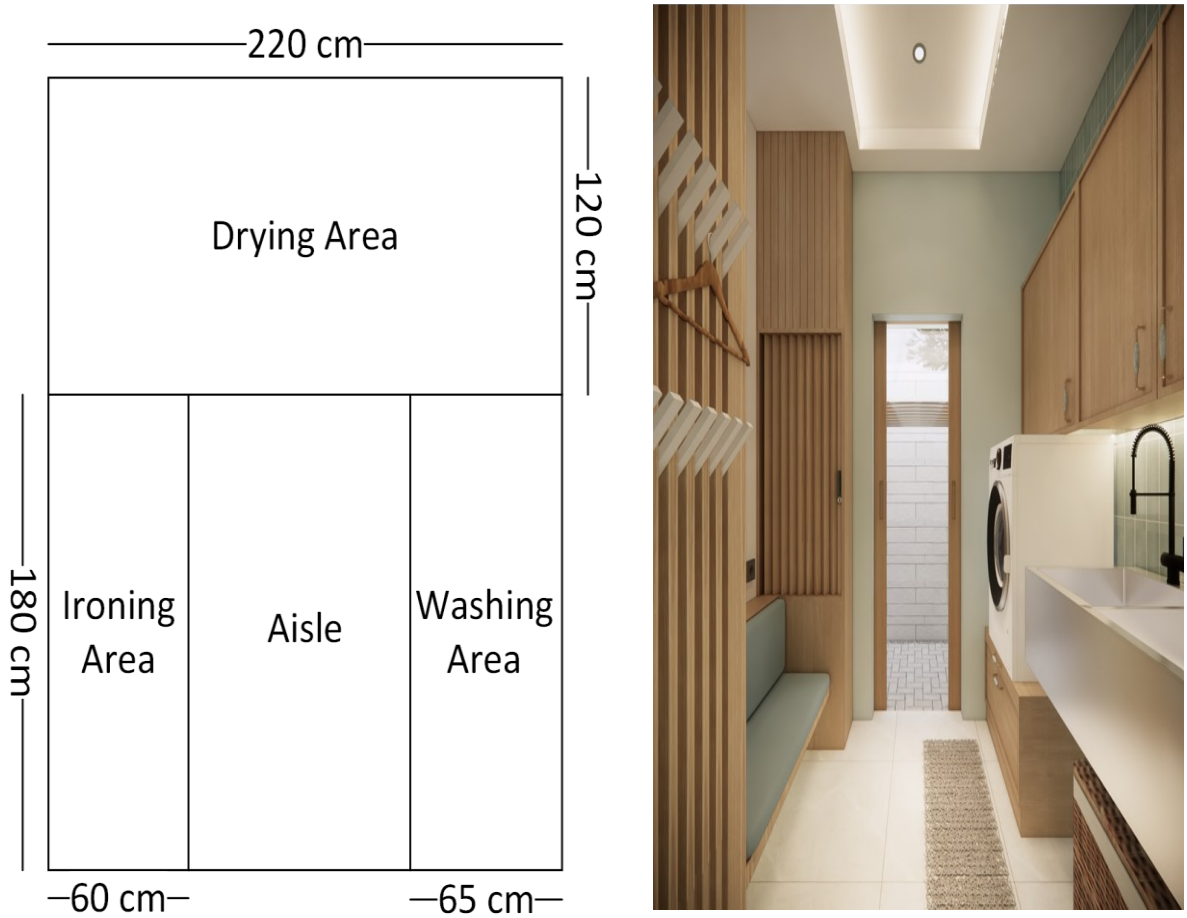
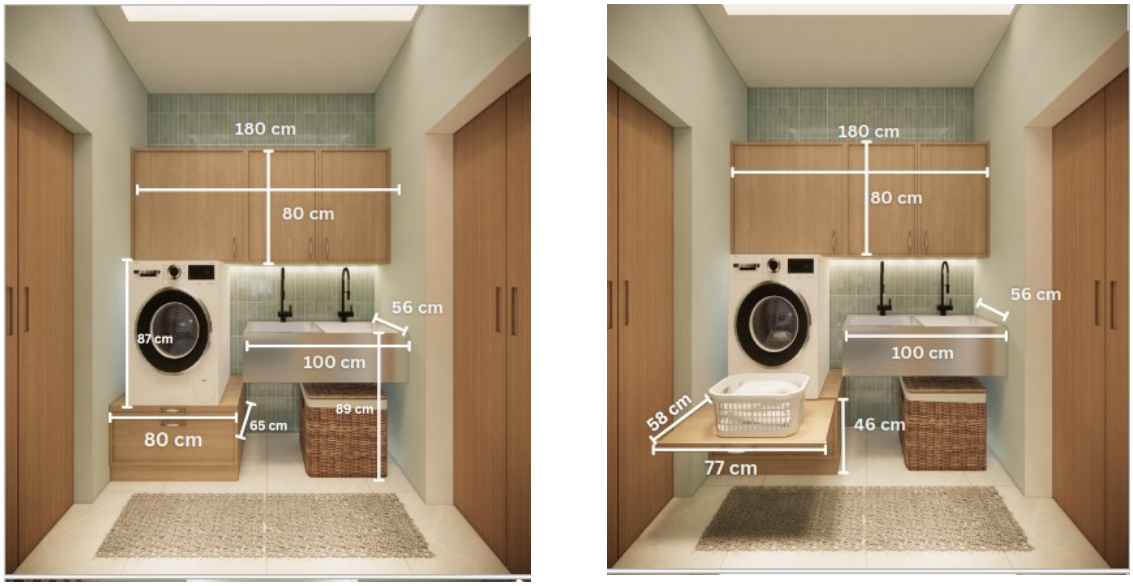


Figure 2. Laundry room layout design

The dimensions of the design product for the washing, drying and ironing area are designed by considering the anthropometric suitability of the user. Anthropometric data is the most important ergonomic information in the design process [60]. Using anthropometric data allows for ergonomic design, so that users can work more comfortably, safely, and efficiently [61–[63]. This anthropometric data refers to the body dimensions of Indonesian adult women over 17 years old, based on anthropometric data that has been collected in Indonesia [64]. In this design, the selection of dimensions and percentiles is based on user anthropometric data, with a focus on comfort and efficiency when carrying out washing, drying and ironing activities.

3.4.1. Design of Washing Area

The washing area in Figure 3, located in the right corner near the entrance, includes a sink for soaking and washing clothes before entering the front loading washing machine. The sink and washing machine are placed at a height that suits the user's anthropometry, so that the activity of washing clothes can be done without bending over. The distance between the sink and washing machine is also taken into account, making it easier for users to move from one activity to another. The sink is equipped with a dirty clothes storage area underneath and a faucet positioned within easy reach. The space above the washing machine can be used to store laundry equipment such as detergent and fabric softener. Underneath the washing machine, there is a pull-out table designed as part of its base structure, providing a practical surface for placing laundry baskets. This feature helps reduce the need to bend when loading or unloading clothes, which is particularly beneficial for housewives and elderly users who frequently perform this activity. Below the table, an additional drawer offers extra storage space for clothes or bed sheets when needed. At the very bottom, a sturdy base acts as a barrier to protect the drawer from contact with water or cleaning tools.



(a) Pull-out table in a closed position (b) Pull-out table in an extended position

Figure 3. Washing area design with adjustable pull-out table

Front loading washing machine with a capacity of 7.5 kg which has dimensions of 60 cm x 56 cm x 87 cm, ideal for small to medium household needs. This washing machine allows users to wash a number of clothes in one cycle without having to repeat the washing process. Table 2 presents information about the anthropometric suitability of the washing area design. The mismatch between product design and users' anthropometric needs can cause discomfort and fatigue [65]. The length and width of the washing machine area are determined by adding an allowance to the size of the washing machine. The addition of this allowance is very important to ensure there is sufficient space for machine access and maintenance. With a washing machine area size of 80 cm for length and 65 cm for width, this area provides adequate space for users to maneuver when using or servicing the washing machine. The door position of the washing machine is designed based on standing elbow height (D4). This aims to ensure that users can access and use the washing machine comfortably without having to bend too low, thus reducing the risk of back injury.

For the the dimensions of the sink, the length of the sink area was determined to be double the length of the sink at 100 cm, while the width of the sink area was based on the measured forward arm span length (D24) of 56 cm, taking into account the 5th percentile to ensure easy forward reach. Thus, users can comfortably reach the farthest part of the sink. This size results in a sink area large enough to perform washing activities without feeling restricted, so that the user's reach area can be optimized for various activities such as washing, drying, and preparing utensils. This ensures that users can move freely and comfortably while performing daily tasks in the area. In addition, the height of the sink is also adjusted to the standing elbow height (D4) at the 5th percentile, which helps prevent discomfort when using the sink, especially for users with below average height. These considerations are important to promote a more ergonomic user experience and reduce the risk of injury due to improper posture. The 15-degree slope of the scrubbing board is designed to make it easier for users to perform scrubbing activities, as well as ensure that water can flow properly downward. This slope has several important effects compared to a straight scraping board. Firstly, this slope promotes better water flow down the drain, reducing waterlogging and preventing the accumulation of dirt and soap residue, thus keeping the washing area clean. In addition, the inclined scrubbing board is designed for an ergonomic position that is more comfortable for the user while washing, reducing strain on the back and arms, and allowing access to deeper areas without having to bend over. With more efficient water flow and a comfortable position, users can complete washing tasks faster and reduce the chance of errors in the washing process. In terms of design, the sloped scraping board not only offers a more modern and functional look, but also requires consideration of different materials and construction techniques to ensure strength and durability. As such, the slope of the scraping board is an important element in designing a functional and convenient washing area.

Table 2. Anthropometric suitability for washing area

Design Product Dimensions	Anthropometry/Other Reference Data	Anthropometric Dimension	Percentile	Size Benchmark (cm)
Length of Washer Area	Washing Machine Length + allowance			60+20=80
Washer Area Width	Washer Width + allowance			56+9 = 65
Washing Machine Height				87
Washing Machine Pedestal Height				4
Washing Machine Cot Height				10
Drawer Height	Elbow stand height - 1/2 washing machine height - washing machine base height - cot height	D4	5	89 - (1/2x87) - 4 - 10 = 32
Drawer Length	Washing Machine Length + allowance			60+20=80
Drawer Width	Washing Machine Width + allowance			56+9 = 65
Washing Machine Top Cabinet Length	Washing Machine Length + allowance			60+20=80
Washing Machine Top Cabinet Width	Washing Machine Width + allowance			56+9 = 65
Washing Machine Top Cabinet Height				80
Height of Washing Machine Top Cabinet Bulkhead				40
Sink Area Length	2x Sink Length			2x50 = 100
Width of Sink Area	Length of forward hand span	D24	5	56
Sink Height	Standing elbow height (15 degree tilt of the rolling board)	D4	5	89
Sink Depth				30
Sink Top Cabinet Length	2x Sink Length			2x50 = 100
Width of Sink Top Cabinet	(1/2 x Sink Width) + allowance			(1/2 x 56) + 2 = 28
Height of Top Cabinet Pedestal from floor	Standing Eye Height - allowance	D2	5	136 - 3 = 133

The cabinet above the sink and washing machine follows the same principle, with a length that is double the length of the sink and a width that is half the width of the sink. This provides ample storage space without interfering with the workspace in the lower area. The basket for holding dirty laundry is placed under the sink, making efficient use of the space. The use of the 5th percentile in some of the measurements indicates that the design is intended to meet the needs of users with smaller body sizes, so that more people can access it. This approach reflects inclusive ergonomic design. Overall, the selection of dimensions and percentiles in the design of this washing area is based on ergonomic principles that aim to improve comfort, accessibility and efficiency of use. Good design will help users perform daily activities more easily and reduce the risk of injury due to improper body positioning.

3.4.2. Design of Drying Area

The design considers comfort and efficiency in the clothes drying process, with various features specifically designed to meet user needs. Figure 4 is the design of the elements in the drying area.

(a) in extended position (b) in folded position

Figure 4. Design of drying area

There are 3 areas of clothesline poles in the drying area, namely those located on the left and right sides with a height according to the height of the elbow standing and a clothesline pole located in the center. The clothesline poles in the drying area in the center of the laundry room can be adjusted in height according to user comfort. The clothesline poles located on the left and right sides are intended for shorter garments such as shirts and small towels, while the clothesline pole in the center is designed for longer items such as dresses, blankets, and bed sheets. The entire roof in the drying area is designed using glass material with a thickness of 1 cm. With the use of glass, sunlight can be used optimally to help the drying process of clothes. The drying area is designed to be a closed space so that on all three sides of the drying area a dehumidifier can be installed. This tool is very useful in helping the drying process especially when the weather is cloudy. There is one fluorescent lamp in the center of the room as a source of lighting so that drying activities can still be carried out even at night. The floor in the drying area uses pavement blocks to speed up the water absorption process and avoid stagnant water on the floor.

In designing the clothesline area, it is important to consider the anthropometric suitability of users so that the drying process becomes more comfortable and efficient. Table 3 presents the information about anthropometric suitability in the design of the clothesline area. The height of the clothesline is adjusted to the user's anthropometry, especially the height of the upward hand grip in a standing position (D34) so as to ensure that users can hang and pick up items easily without having to us additional tools. There are two alternatives for the height of the middle clothesline pole, namely 160 cm (for users with a short height) and 200 cm (for users with a tall height). The length of the clothesline also needs to be considered to be sufficient to accommodate large items without impeding the airflow required for effective drying. The minimum width required is 200 cm, enough to dry a single blanket or bed cover. In this design, the clothesline is 220 cm wide, following the width of the room, so it can accommodate large items easily. This size also allows the center clothesline to be used for drying blankets or bed covers comfortably. Meanwhile, the clotheslines on the left and right sides are designed with a height of 108 cm, based on 95th percentile anthropometric data for standing elbow height (D4), ensuring user comfort, particularly for taller individuals. This design allows users to hang and retrieve clothes without having to reach too high or low, and pays attention to the spacing between hangers to prevent clothes from overlapping, improve air circulation, and drying effectiveness. With a percentile data based approach, the design meets the needs of the majority of users, improving the overall comfort and functionality of the clothesline. By designing two types of clotheslines that suit the needs and

anthropometric characteristics of users, the drying process can become more efficient and comfortable. A design fit that considers the height, reach, and type of clothes being dried will improve the user experience and effectiveness of clothes drying.

Table 3. Anthropometric suitability for the clothesline area

Design Product Dimensions	Anthropometry/Other Reference Data	Anthropometric Dimension	Percentile	Size Benchmark (Cm)
Height of Middle Section Clothesline	Hand grip height up in standing position	D34	5	160
	Body Height (Male) +allowance		95	186+14 = 200
Length of Middle Section	Room Length			220
Pipe Diameter				2,5
Height of side clothesline	Standing Elbow Height	D4	95	108
Distance between each side of the pole				10
Length of side clothesline	Room width – distance from each edge of the pole			120 – (2x10) = 100

The drying area is designed to maximize the drying process of clothes. The use of a solar flat canopy allows optimal sunlight to enter, while dehumidifiers placed on three sides of the drying area serve to reduce humidity during cloudy weather. To ensure sufficient lighting, both during the day and night, the space is equipped with UV and fluorescent lights. The availability of adequate electrical resources is also a major concern in this design. There is one socket for the washing machine in the washing area, three sockets for the dehumidifier in the drying area, and an additional socket for UV lamps or other lighting systems. Thus, all necessary equipment can operate properly and efficiently.

The gap of about 15 cm between the top of the wall and the canopy is designed to allow fresh air from outside to enter the laundry area. This not only improves air circulation, but also helps to reduce humidity in the room, making the drying process of clothes more effective and faster. Good air circulation also contributes to the overall comfort and cleanliness of the laundry area. Overall, a well-designed laundry room not only serves as a place to do laundry, but also enhances the user experience. With attention to organization, lighting, and other functional elements, a laundry room can be a space that is not only efficient, but also attractive and comfortable to use.

3.4.3. Design of Ironing Area

Figure 5 shows the area designed to provide comfort and efficiency when users are ironing clothes. Within the ironing area, there are various functional elements that complement each other, such as a practical folding ironing table, a storage cabinet for storing equipment, and racks and hangers to temporarily hold clothes. In addition, an ergonomic chair is provided so that users can rest comfortably while ironing. This design also considers dimensions that are in accordance with user anthropometry, so that each element can be used optimally. Table 4 presents information on the anthropometric suitability of the ironing area design. With a good arrangement, this ironing area not only facilitates the ironing process, but also creates a pleasant and comfortable atmosphere for users.

In the ironing area, there is a folding ironing table with a storage cabinet on the right side to store the ironing table when not in use. When the user is ironing clothes, the user can use the shelves and hangers located on the left side to store clothes temporarily. A chair is provided for users to sit while ironing clothes. The chair is designed in such a way that the back of the chair will rise to support the lumbar when the user sits on the chair base. When there is no ironing activity, the chair can be placed under the left side shelf and the ironing table can be folded to the right side so that the long chair located under the ironing table can be used to sit and rest in the laundry area.

(a) Table folded and stored (b) Table opened for ironing

Figure 5. Ironing area design

The length of the ironing table was determined based on the 95th percentile standing hip height of male users (D5), with an additional allowance to ensure sufficient workspace and accommodate the adjoining cabinet structure. The total length of 115 cm provides enough surface area for various types of clothing, including longer items such as pants, allowing users to iron comfortably and efficiently without space limitations. The width of the ironing table was determined using the 95th percentile shoulder breadth of male users (D17), with a slight adjustment to provide extra working space. With a total width of 55 cm, the table offers adequate room to handle clothes while maintaining ergonomic arm movement throughout the ironing process.

These dimensions ensure that the user can easily organize the clothes on the table without feeling restricted, which is important for efficiency when ironing. The height of the ironing table uses a benchmark of sitting elbow height (D11) and popliteal height (D16), which ensures an ergonomic position when ironing in a seated position. At 78 cm high, the ironing table is designed to reduce strain on the back and arms, allowing users to iron comfortably for long periods of time. This proper position helps avoid uncomfortable postures and reduces the risk of injury. A table that is too low can force the user to slouch, while a table that is too high can make the user shrug, which can lead to fatique. The table leg height of the sofa refers to the sitting elbow height (D11), the ironing table leg height is set at 32 cm to ensure stability and comfort during use. This dimension provides good support for the ironing table, so it can be used safely and comfortably.

The use of the 95th percentile for men's shoulder side width (D17) in determining wardrobe dimensions is essential for functionality and comfort. By referring to this measurement, the wardrobe design can ensure sufficient space for storing clothes, especially men's clothes that have a larger shoulder width. With an ironing table width of 55 cm, the width of the wardrobe should add an allowance of 5 cm, bringing the total wardrobe width to 60 cm. The length of the wardrobe is calculated based on the thickness of the ironing table, iron, and allowance, the total length of 26 cm ensures that the wardrobe is enough to safely store the ironing table and iron.

The cabinet height is adjusted to match the height of the room to maximize vertical space utilization, enhance accessibility, and improve storage efficiency for users. For the section that stores the collapsible ironing table, the cabinet height is determined based on the ironing table length with an additional allowance, resulting in a total height of 100 cm. This ensures that the cabinet can accommodate the ironing table properly while still providing extra space for other storage needs.

Table 4. Anthropometric suitability for ironing area

Design Product Dimensions	Anthropometry/Other Reference Data	Anthropometric Dimension	Percentile	Size Benchmark (Cm)
Ironing Table				
Ironing Table Length	Standing Hip Height (Men) + allowance + Cabinet Length	D5	95	84 + 5=89
Ironing Table Width	Shoulder Side Width (Men) + allowance	D17	95	45 +10 = 55
Ironing Table Height	Sitting Elbow Height + Popliteal Height	D11+D16	95	32 + 46 = 78
Table Leg Height	Sitting Elbow Height	D11	95	32
Cabinet				
Cabinet Length	Ironing table thickness + iron + allowance			10 + 11 + 5 = 26
Cabinetrd Width	Ironing table width + allowance	D17	95	55 + 5 = 60
Cabinet Height	Ironing table length + allowance			89 + 11 = 100
Storage Area				
Length of temporary clothes hanging storage	Shoulder Side Width (Men) + allowance	D17	95	45 + 10 = 55
Height of temporary hanging clothes storage bin (1)	Hand grip height up in standing position	D34	5	160
Height of temporary hanging clothes storage bin (2)	Shoulder Height	D3	5	120
Sofa				
Sofa Length	Length of ironing area-length of temporary hanging clothes storage-length of closet			180 - 55 - 26 = 99
Sofa Width	Popliteal length	D14	5	37
Sofa Height	Popliteal Height	D16	5	35
Television(TV)				
TV Calculation	Eye to wall distance			55 + 15 = 70
	TV max angle (TV top (α))			23 degrees
	TV Height			30
	TV Height from Floor (Popliteal Height + Sitting Eye Height + TV Height)	D16+D9+Tinggi TV	5	35 + 61 + 30 = 126
Chair				
Seat Base Height when occupied	Popliteal Height	D16	5	35
Seat Back Height when occupied	Popliteal Height + 1/2 sitting shoulder height (backrest)	D16+D10	5	35 + (1/2x48) = 59

The dimensions of the sofa are designed to provide comfort when the user is resting. This size considers the length of the ironing area and the length of the temporary storage area. The width and height of the sofa are designed based on anthropometric data to ensure user comfort when resting. The sofa dimensions are designed by considering the popliteal length (37 cm) and popliteal height (35 cm) to ensure a comfortable sitting depth as well as proper support to the back and knees, making it easier for users to get up. The width of the sofa is optimized for space efficiency, while the appropriate height of the sofa helps maintain good

posture. With this approach, the sofa becomes more inclusive and meets the functional and comfort needs of a wide range of body size.

In designing the temporary storage bins for hanging ironed clothes, the dimensions used must consider anthropometric aspects so that users can access and use the storage space comfortably. The length of each storage bin was set at 55 cm, corresponding to the 95th percentile male shoulder breadth (45 cm) with an additional 10 cm of clearance, providing sufficient space to hang multiple clothes without overlap.. The height of the hanging clothes storage, which was designed in two levels, not only considered the aesthetic aspect, but also the ergonomics for the user. The topmost level, which is at a height of 160 cm, is based on the height of an upward hand grip in a standing position (D34). This height determination is ideal for hanging long dresses, ensuring that they do not come into contact with the floor, keeping them clean and tidy. Meanwhile, the second level is at 120 cm based on shoulder height (D3). This second level height is designed for shorter garments, such as shirts and blouses, allowing users to hang garments without the need to bend over. As such, users can easily access and store clothes without experiencing any discomfort, making the usage experience more efficient and enjoyable. This design not only enhances convenience, but also keeps the clothes in optimal condition, thus extending the usage period and maintaining the appearance of the clothes.

In designing the ideal television placement, ergonomic considerations are essential to ensure a comfortable viewing experience. The seated eye level (D9) and popliteal height (D16) were determined using the 5th percentile anthropometric data of Indonesian users, ensuring that the screen position remains suitable even for users with smaller body dimensions. With a seated eye level of 61 cm and a popliteal height of 35 cm, the total height from the floor to the top of the television should be approximately 126 cm. A 27-inch television has dimensions of 53.1 cm in width and 29.9 cm in height (rounded to 30 cm). Positioning the television at this height aligns the bottom of the screen with the user's eye level, preventing excessive upward viewing and reducing the risk of neck strain. The recommended viewing angle should not exceed 30 degrees from the horizontal to maintain comfort. The viewing angle was calculated using basic trigonometry, where $\tan \alpha = 30/70$, yielding an angle of approximately 23°, which is within the recommended ergonomic limit. The viewing distance is suggested to be around 70 cm, derived from the ironing table width of 55 cm and an additional clearance of 15 cm from the wall, considering spatial limitations. With this configuration, the television placement supports an optimal and comfortable viewing experience. Figure 6 provides an illustration that supports the above explanation.

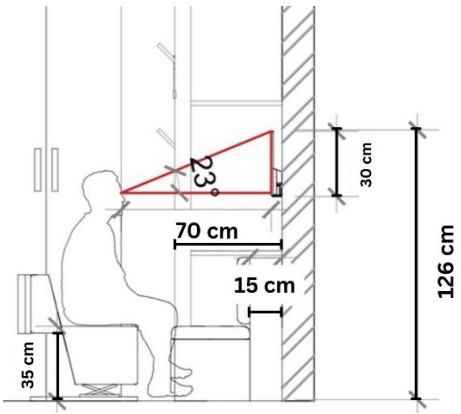


Figure 6. Illustration of viewing distance

If users need to iron for a long time, they can use a comfortable chair if needed to help support their back and reduce strain while ironing. Working in a standing position that is maintained for long periods of time (such as when folding and ironing clothes) can increase the risk of developing varicose veins in the lower limbs [66]. Understanding consumer behavior can help reduce environmental impacts and improve the quality of human life [67]. The seat base height in the occupied state is 35 cm, which corresponds to the popliteal height (D16) at the 5th percentile, ensuring that even smaller users can sit comfortably without excessive pressure on the back of the thighs. The seatback height, calculated by combining the 5th percentile popliteal height (35 cm) with half of the 5th percentile seated shoulder height (48 cm), results in approximately 59 cm. Setting the backrest at this level provides adequate support for the lower and middle back, helping to reduce muscle

strain during prolonged sitting. The use of the 5th percentile data aims to accommodate the smallest user population, ensuring that the design remains inclusive and comfortable for most individuals. Therefore, chair dimensions designed based on anthropometric percentiles can enhance comfort, support user health, and minimize the risk of discomfort from non ergonomic postures.

3.5. Stage 5: Testing

The final stage in the laundry room design process is testing and evaluation, to ensure that the resulting design can help users overcome difficulties or anxieties associated with laundry work. Based on the JBTD principle, the main goal of this innovation is to fulfill the functional, social, and emotional needs of users in the relevant context [68], such as providing a sense of comfort and convenience in their laundry room.

Since this product is only made in 3D and has not been realized in physical form, the evaluation was conducted through interviews with end users, namely housewives and office workers. Through these interviews, users provided feedback on the prototype drawings and laundry room features described by the designer. This assessment allows us to understand the extent to which the design has met their needs and preferences, as well as identify areas of improvement that may be needed.

The evaluation was conducted by distributing the design to 15 users, who then rated it based on comfort, functionality, and the suitability of the features to their expectations. Table 5 shows the evaluation results scored. All respondents (100%) agreed that each design aspect met ergonomic and functional expectations, indicating that the proposed layout successfully accommodated users' needs in comfort, accessibility, and safety.

Table 5. User evaluation of laundry design

No	Design Aspect	Evaluation Criteria	Agree (%)	Disagree (%)
1	Washing Machine Area	Ergonomic height, size appropriateness, good drainage, dirty laundry holder, ease of cleaning, detergent storage	100	0
2	Drying Area	Proper design and size, foldable clothesline, accessibility, sunlight exposure	100	0
3	Ironing Table & Storage Cabinet	Proper design and size, foldable ironing table, tool storage, easy accessibility	100	0
4	Sofa Area	Proper design and size, easy access, comfort, stability	100	0
5	Storage Area	Proper design and size, clothes hanging space, easy item access	100	0
6	Television	Ideal height and position, easy maintenance	100	0
7	Chairs	Proper design and size, ergonomic posture support	100	0
8	Overall Laundry Area	Efficient layout, adequate lighting and air circulation, sufficient power source, energy efficiency	100	0

After the initial evaluation through the user rating table, the I Like, I Wish, What If Diagram method was applied to dig deeper qualitative insights. The I Like, I Wish, and What If diagram is a summary used to gather honest, critical, yet positive feedback from users through interviews [69]. In this method, "I Like" allows users to express their preferred elements, "I Wish" encourages them to reveal aspects that need improvement, and "What If" invites creative ideas that have not yet been thought of. The combination of these two methods enriches the evaluation process by providing diverse insights into user satisfaction, encouraging creative participation, and generating new ideas. Thus, the evaluation process becomes more comprehensive, integrating quantitative results and qualitative insights for design refinements that better suit user needs.

Figure 7 presents the results of the "I Like, I Wish, What If" Diagram which reflects user feedback on the laundry room design. This diagram captures the user's expectations and desires in depth, which will guide the design refinement. By understanding user preferences and needs, it is important to create a laundry room that is not only functional, but also comfortable and enjoyable. These results emphasize the importance of collaboration between designers and users in coming up with better design solutions.

Figure 7. Diagram of I like, I wish, what if laundry room design

This research shows that a more organized and flexible laundry room design can improve work efficiency and reduce the risk of injury. These findings emphasize the importance of ergonomic layout in improving productivity and user comfort. In addition, good ventilation and natural lighting contribute significantly to creating a more comfortable and healthy working environment, supporting the overall effectiveness of laundry activities.

This research has practical implications for laundry room design, especially in space-constrained environments. The combination of daylighting through solar flat canopies and good ventilation not only supports energy efficiency, but also creates a more comfortable and healthy working environment. Other implications include the importance of flexible design to meet the needs of diverse users, such as housewives and employees with busy schedules.

4. DISCUSSION

The application of ergonomic and anthropometric principles in laundry room design was implemented in this study to improve user comfort, safety, and efficiency. The integration of the design thinking and JTBD methods enabled a more in-depth investigation of user needs and their conversion into clearer design criteria. The combination of these two methods provides a systematic approach to understanding user actions and needs, resulting in a final design that is in harmony with the natural patterns of users in carrying out washing activities.

4.1 Ergonomic and Anthropometric Considerations

The ergonomic approach in design requires the adjustment of workplace elements such as machines and workstations to the user's body dimensions [70]. This adjustment uses anthropometric data to ensure that the design can accommodate variations in users' physical characteristics, from the largest to the smallest, in order to create a safe, comfortable, and efficient environment. In ergonomics oriented design, the selection of percentile values in anthropometric data must be considered so that design dimensions directly affect user comfort and reach. P5 is used to ensure that facilities remain easily accessible to smaller users so that they do not experience difficulties due to dimensions that are too high or wide. P95 is applied to provide adequate space for larger users so that they can move around without feeling restricted by the size of the space or equipment. By considering these two body size limits, the design can accommodate most user variations. P50 is used for elements that do not require special adjustments for smaller or larger users, so that the average size can represent the general needs of users. In this study, the application of the P5, P50, and P95 percentiles was used to adjust the design of laundry rooms for the majority of users in Indonesia. The use of these percentiles ensures that the resulting design is able to accommodate a wide range of body sizes, while also increasing the comfort, safety, and effectiveness of users while washing, drying, and ironing.

The design of the washing, drying, and ironing areas demonstrates the effective application of Indonesian user anthropometric data to ensure safety, comfort, and efficiency during laundry activities. The washing

machine and sink are positioned at heights corresponding to the standing elbow height of Indonesian adult users, allowing washing and rinsing to be performed in an upright posture without excessive bending. This arrangement minimizes physical strain and supports neutral working postures in accordance with ergonomic principles.

The width of the passage between the washing and ironing areas is determined by referring to the 95th percentile shoulder width of adult Indonesian women, which is 52 cm, then adding the width of the laundry basket, which is 35 cm, and an additional 11 cm for body movement when turning or moving dynamically. The total required passage width is 95 cm so that users can move safely without the risk of bumping into surrounding furniture.

An integrated pull-out table under the washing machine provides a convenient surface for placing the laundry basket, reducing the need to bend over when loading and unloading laundry. Ergonomic adjustments for height, distance, and reach collectively contribute to efficient workflow and greater comfort, especially for housewives and elderly users who frequently do laundry at home.

In the drying area, the clotheslines on the left and right sides are adjusted to the height of the user's elbows when standing, making it easy to hang and retrieve short items such as shirts and towels. Meanwhile, the clothesline in the center is designed to accommodate longer items such as dresses or bed sheets and is adjusted to the user's upward reach. This height design allows users to dry clothes efficiently without the need to tiptoe or bend excessively, thus increasing safety and comfort during the drying process.

The ironing area design also applies ergonomic principles to support comfortable seated posture. The chair is constructed to provide sufficient lumbar support when the user sits, helping to maintain the natural curve of the lower back. This feature minimizes fatigue and discomfort during ironing activities, especially for users who perform household tasks for extended periods.

4.2 Workflow and User Efficiency

The design of this laundry room emphasizes efficiency and comfort in all laundry activities at home, such as washing, drying, and ironing. The layout of the room is designed so that the three areas are located in a sequential and close proximity to each other, allowing users to complete the process without having to move too far between areas. The sink for soaking and rinsing, washing machine, drying area, and ironing board are arranged according to the user's workflow. This arrangement makes movement more natural, reduces unnecessary body movement, and supports ergonomic principles that emphasize saving energy and distance to facilitate activities.

The placement of each element takes anthropometric data into account so that users can move comfortably between functional zones. To maximize space utilization, the laundry basket is placed under the sink so that it is easily accessible when starting the washing process. In addition, the floor area of the drying area is covered with non slip material to reduce the risk of slipping and is made a slope of about 2 degrees to avoid water pooling.

This design is also in line with the findings of the JTBD analysis, where users want a washing process that is fast, practical, and does not cause excessive fatigue. By reducing fatigue during work by minimizing the steps that must be taken and non ergonomic postures, users can complete activities more comfortably and in less time, while creating a more effective, minimalist, and ergonomic laundry space.

Optimal laundry room design is essential for efficiency and convenience in washing activities. The minimum recommended size is 220 cm x 300 cm, but a more spacious design can provide additional benefits in terms of comfort and functionality. Good lighting, both natural and artificial, creates a bright and cozy atmosphere. Strategic placement of the television can add to the comfort and entertainment while on the move. By adjusting the position of the television based on the user's anthropometry, laundry activities become more enjoyable, reduce boredom, and make the time spent in the laundry room feel lighter. Overall, a well designed laundry room not only serves as a place to wash, but also enhances the user experience. With attention to organization, lighting, and entertainment elements, a laundry room can be a functional and attractive space. A more spacious design allows for customization according to needs and preferences.

5. CONCLUSION

This research identifies the main factors that determine an optimal laundry room design based on user needs and preferences, particularly among housewives and employees with busy daily routines. By applying

the design thinking and JTBD frameworks, this research provides a clearer understanding of user expectations and translates them into practical ergonomic design solutions. The findings highlight that elements such as appropriate spatial arrangement, adequate storage, comfortable work areas, and ergonomic considerations are essential for achieving an effective and user friendly laundry room layout.

The results of the questionnaire show that users users highly prioritize good ventilation and sufficient lighting, which significantly enhance comfort during laundry activities. Users also indicated the need for a specific area to soak clothes before washing, along with efficient storage for detergents, fabric softeners, and other laundry supplies. In addition, sufficient workspace for folding and ironing, as well as an integrated drying area, were identified as key components for improving workflow and organization. The application of the I Like, I Wish, What If Diagram revealed that users appreciate designs combining aesthetics and functionality, creating laundry spaces that are both visually appealing and efficient for daily use. This participatory approach also provided deeper insights into user satisfaction and expectations regarding laundry room design.

From a practical perspective, the results of this research can be used as a reference for architects, interior designers, and homeowners in planning ergonomic and space-efficient laundry areas that suit local housing conditions. The integration of anthropometric data with user-centered findings offers a useful model for designing home environments that promote comfort, safety, and productivity.

Nevertheless, this study is limited to household scale laundry room design and relies mainly on qualitative data from a specific demographic group. Expanding the respondent pool to include more diverse users could strengthen the generalizability of the findings.

In addition, this research opens up opportunities for further studies on the influence of laundry room design on users' mental well-being, the integration of smart technology in laundry rooms to improve efficiency and personalization, and the evaluation of laundry room design at the scale of households with special needs, such as large families or residents with physical limitations. By exploring these areas, future research can provide more comprehensive and innovative solutions for ergonomic laundry room design.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Universitas Kristen Maranatha Bandung for the funding support provided for this research. We are also deeply grateful to all the respondents who participated in this study.

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