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Design and Development of a Foldable Multifunction Travel Hanger Using the Rational Product Design Method

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ABSTRACT

The growing mobility of modern society has increased the demand for innovative travel accessories that offer practicality, efficiency, and multifunctionality. This study seeks to meet these demands by designing a foldable travel hanger that maximizes storage space while ensuring clothing remains neat, addressing the needs of both business and leisure travelers. The design process follows Nigel Cross's Rational Product Design and Development Method, a systematic approach that involves clarifying objectives, defining functions, establishing requirements, identifying key features, generating design alternatives, and selecting the best solutions. The final solution effectively reduces the risk of wrinkled clothing during travel and speeds up the drying process, offering dual benefits. Its compact and user-friendly design ensures long-term usability, making it a sustainable and cost-effective option for modern travelers. The product contributes to enhancing users' professional image by providing reliable and efficient clothing management, thus addressing critical customer needs. The study emphasizes the importance of incorporating user feedback to improve product usability and satisfaction. By aligning technological innovation with consumer needs, this work establishes a benchmark for future travel accessory development, demonstrating how structured design methodologies can resolve user challenges and drive innovation in consumer products. The results of this study show that the Multifunctional Foldable Hanger with a built-in heating system can help smooth out clothes easily during travel, weighing only 700g and featuring 7 folding hinges. With a portable design, heat-resistant ABS material, and 3 adjustable temperature settings, this product innovation has also been tested using von Mises stress analysis to assess its strength.

Keywords:
Product Development,
Foldable Hanger, Travel,
Clothing Management,
Clothing Heater

1. INTRODUCTION

The need for travel continues to rise each year, both for personal and professional purposes. In 2022, business or professional travel saw a significant increase, reaching 20.02 percent, up 3.98 percentage points compared to the previous year [1], see Table 1.

Table 1 - Percentage of travel for Indonesians

Category	2019	2021	2022
Vacation/Recreation	47.61%	20.79%	28.87%
Visiting Friends/Family	31.44%	29.98%	24.93%
Profession/Business	0.97%	16.04%	20.02%
Festive Homecoming	7.24%	4.58%	5.99%
Religion	6.74%	3.26%	2.26%
Health	1.08%	1.61%	1.22%
Shopping	1.18%	1.87%	1.39%
Congress/Seminar	0.35%	8.21%	5.46%
Others	3.39%	13.68%	9.86%

Many Indonesians undertake round trips of 100 kilometres [2] or more for work purposes, with varying percentages across different regions. This frequent mobility demands efficiency and readiness, especially when it comes to maintaining a professional appearance. Short business trips, such as one-day travels, are often undertaken with time and cost efficiency in mind. Official vehicles play an essential role in supporting efficient and responsive business activities and ensuring a neat appearance is important during formal meetings [3].

A polished appearance, including neat and well-pressed clothing, is essential in professional settings as it shapes first impressions and fosters positive perceptions [4]. Consumer Behavior Theory explains that consumer decisions are influenced by personal preferences, cultural norms, and social situations [5]. To maintain the neatness of clothing, portable irons are often chosen to smooth out wrinkles while traveling. However, their use can be impractical as they require time and a reliable power source, which may not always be available at every location. Additionally, ironing can consume valuable time, especially when there is limited time before attending a meeting.

In the early 20th century, coat hanger design began to evolve, closely resembling the form we recognize today. In Jackson, Mississippi, a man named Albert J. Parkhouse, who worked at the Timberlake Wire and Novelty Company, discovered that strong wire could be shaped to create a useful tool for hanging clothes, particularly coats. The design, patented under US787559A [6] as in Figure 1, consisted of two ovals at each end, twisted in the middle with a hook shape on top, allowing it to hang on a rod, wall hook, or other places. As Parkhouse's design gained popularity, various companies and individuals began making improvements to the coat hanger. These hangers, which are easy to carry and help maintain the neatness of clothing, allow garments to stay wrinkle-free. By hanging clothes immediately upon arrival, gravity naturally helps reduce creases without requiring electricity or additional equipment.

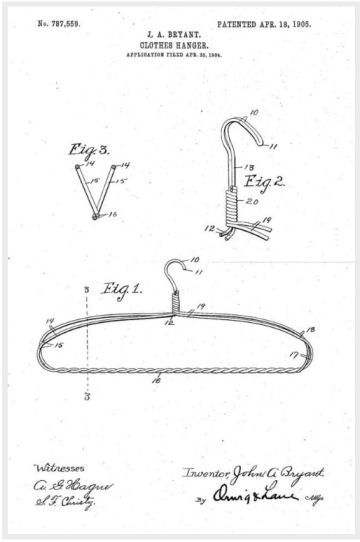

Figure 1 – History of Hanger

Current folding hangers lack the necessary practicality and multifunctionality, which highlights the need for an innovative design. This research aims to develop a folding hanger that addresses these gaps, specifically designed to benefit travelers, particularly business professionals. The proposed hanger simplifies the travel experience by incorporating a unique feature that not only allows it to fold compactly but also effectively smooths and organizes clothes, ensuring they remain neat and wrinkle-free throughout the journey. Professions that often involve extensive travel and necessitate a professional appearance include business owners, bankers, corporate leaders, students, and government representatives [19]-[21]. There are several folding hangers available in the market, but unfortunately, none of them are designed to smooth out wrinkled clothes and make them neat, nor can they be folded together with the clothes. Below are the existing folding hanger products on the market.

Table 2 – Features of Existing Foldable Hanger

No.	Product Name	Product Image	Features
1	Pinmoo Folding Hanger [39]		Has 1 swivel hinge in the center and 2 swivel hinges on the right and left to fold the hanger.
2	KOHI - Portable Folding Hanger [40]		Has 1 foldable hinge in the center, and 2 clips on the right and left ends of the hanger.
3	Gogoland - Portable Folding Hanger [41]		Has 1 foldable hinge in the center, and clothing hooks on the right and left sides of the hanger.
4	Marya - Folding Clothes Hanger for Travel [42]		Has 1 foldable hinge in the center with a pressable lock to open or close it.
5	2 in 1 Multifunctional Folding Clothes Hanger [43]		Has 1 hinge in the center, 2 swivel hinges on the right and left sides, and 2 clips on the right and left ends of the hanger.

Based on the design of existing folding hangers, the first hanger's advantage is its ability to fold, making it compact for storage or travel. The second hanger offers the benefit of folding and includes clips for clothes. The third hanger, in addition to folding, features hook for sleeveless clothing. The fourth hanger has a lock to secure the fold, ensuring stability during use. The fifth hanger, besides being foldable, also has hooks and clips for clothes. However, the main drawback of these hangers is that none can be folded together with the clothes, nor can they easily maintain or smooth out the

clothes. Therefore, there is a need for an innovative travel foldable hanger that makes it easier to organize and maintain the neatness of clothes.

Another tool that can help tidy clothes during travel is portable irons. It is often chosen to make clothes neat and wrinkle-free [7]. On the other hand, travel garment bags, although specifically designed to keep formal clothing neat, are large and take up considerable space in luggage [8]. Foldable hangers offer a simpler and more effective solution. Foldable hangers provide a practical alternative, as they are lightweight, compact, and require no additional equipment. By using gravity to keep garments neat, these versatile hangers are ideal for travel and can be easily used in hotel rooms or meeting spaces.

The global hanger market was valued at USD 1.9 billion in 2023 and is projected to reach USD 2.9 billion by 2033, growing at a compound annual growth rate (CAGR) of 4.6% from 2024 to 2033. Plastic hangers dominate the market, accounting for 40% of the total share, due to their durability and cost-effectiveness. Household use leads the market, representing 70% of the demand, highlighting the significant need for personal clothing organization. Regionally, Europe holds a dominant 55% market share, driven by high consumer spending on home organization products. Additionally, there is a growing opportunity to develop eco-friendly and biodegradable hanger options to cater to environmentally conscious consumers, which could further fuel market expansion [9].

Using the Rational Product Design and Development Method, this will result in a design for a foldable clothing hanger for travel that meets both the practical and aesthetic needs of users. With the aim of innovating a travel foldable hanger that makes it easier to organize and maintain the neatness of clothes, this process involves stages such as clarifying objectives, establishing functions, setting requirements, determining characteristics, generating alternatives, and evaluating alternatives [22]. Prototyping and product testing are also conducted to ensure functionality and user comfort during the development process. Considering the complexity of travel activities and user needs, this research is expected to contribute to the development of better foldable hanger products. The resulting product is expected to provide practical and effective solutions for travellers in overcoming storage and clothing care issues. Therefore, this research has the potential to make a positive impact in the field of product design and improve the quality of users' travel experiences.

2. METHOD

2.1. Rational Product Development by Nigel Cross

The rational method is one of the product design techniques described by Nigel Cross in his book "Engineering Design Methods: Strategies for Product Design." This method offers a more systematic approach to product design compared to creativity-based methods, which are typically used to broaden the search for potential solutions or facilitate teamwork and decision-making [10]. The stages of the product design process are shown in the following diagram. [11] This method consists of seven systematic stages, each with its specific methods as:

1. Clarifying Objectives
2. Establishing Functions
3. Setting Requirements
4. Determining Characteristics
5. Generating Alternatives
6. Evaluating Alternatives
7. Improving Details

2.1.1. Clarifying Objectives

This stage is used to determine the objectives of the design [12]. The function of this method is to identify the primary and secondary objectives of a product design and the relationship between them. This relationship is known as an objectives tree. The following are the steps in creating an objectives tree:

1. List the design objectives.
2. Organize the objectives from the highest level to the lowest level.
3. Create an objectives tree diagram to show the hierarchical relationship.

2.1.2. Establishing Function

The function-setting stage aims to determine the required functions and the limitations of the design system for the new product [13]. In this stage, the functional analysis method is used. The following are the steps in conducting functional analysis:

1. Organize the system functions in the form of input-to-output transformations.
2. Group several sub-functions.
3. Draw a block diagram.

4. Define the system boundaries.
5. Identify components suitable for generating sub-functions and the interactions between these sub-functions.

The black box is made transparent so that the sub-functions and their interactions can be clearly seen. The transparent black box is used to identify all sub-functions separately, placing them into interconnected boxes via input and output, ensuring that the overall function of the product or equipment being designed is met.

2.1.3. Setting Requirements

The requirement-setting stage aims to create accurate performance specifications for the required design solution [14]. The steps in this stage are as follows:

1. Consider various levels of solutions that can be applied.
2. Define the operational levels.
3. Identify performance attributes.
4. Define the performance requirements for each attribute.

2.1.4. Determining Characteristic

This stage aims to determine the characteristics and targets needed to achieve improvement goals. The method used is Quality Function Deployment (QFD) [15], which is a method to improve product or service quality by understanding customer needs and linking them to technical specifications. The steps in creating QFD are:

1. Identify user needs in product attributes.
2. Determine the relative importance of each attribute.
3. Evaluate attributes of competitor products.
4. Create a matrix that links product attributes to technical characteristics.
5. Identify the relationship between technical characteristics and product attributes using the "house of quality."
6. Identify relevant interactions among technical characteristics.
7. Set targets to be achieved for each technical characteristic.

2.1.5. Generating Alternatives

The purpose of the generating alternatives stage is to create several design concepts that can solve the problem being researched. The method used is the morphological chart [16]. The steps in creating a morphological chart are:

1. List the important elements of a product that cover all functions at the appropriate level of generalization.
2. Specify each function to be achieved by identifying the necessary components.
3. Draw and create a chart that lists all possible solutions.

2.1.6. Evaluating Alternatives

The evaluating alternatives stage aims to select the best alternative from the available options, resulting in an optimal design that meets consumer preferences [17]. The steps in evaluating alternatives are:

1. List the design objectives.
2. Organize the list of objectives and sub-objectives from the highest to the lowest level.
3. Assign relative weights to each objective.
4. Determine the implementation parameters and the utility values for each objective.
5. Calculate and compare the relative values of each design alternative by multiplying each parameter score by its weight. The best alternative is the one with the highest total value.

2.1.7. Improving Details

This stage aims to modify or develop an existing product, such as detailing the performance, costs, or updating its appearance [18]. This development focuses on detailed design, material selection, shape, manufacturing methods, and cost for the product manufacturing.

3. RESULT AND DISCUSSION

3.1 Identification of Customer Needs

Based on surveys and focus group discussions (FGDs) with professionals who frequently travel for business and prioritize maintaining a polished appearance, there was a strong validation of the need for solutions that streamline their workflow, enhance time management, and ensure their clothing remains in optimal condition for a professional look. Professions that often require frequent travel and need formal appearance include entrepreneurs, bankers, students, CEOs, and government representatives [19]-[21]. The need statement is developed based on customer needs gathered from the data collection in this study, see Table 3.

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Table 3 – Need Statement and Customer Needs

No.	Need Statement	Customer Needs
1	The foldable hanger must be easy to carry during travel or be stored in limited spaces (easy to fold and unfold).	Portability and space efficiency: The hanger should be easy to fold, unfold, and practical to carry.
2	The foldable hanger must be usable for various types of clothing and fabrics.	Flexibility of use: The hanger should be compatible with various types of clothing and fabrics.
3	The foldable hanger should have a heating feature to speed up the removal of wrinkles or creases from clothing.	Innovative features for garment care: The hanger should be equipped with a heater to remove wrinkles.
4	The foldable hanger must be made of strong and durable materials (heat and rust-resistant).	Durability and material quality: The hanger should be made of strong, durable, heat-resistant, and rust-resistant materials.
No.	**Need Statement**	**Customer Needs**
5	The foldable hanger should be able to fold along with the clothes (to simplify and speed up clothing storage).	Ease of clothing storage: The hanger should make it easier to fold and store clothes.

Based on customer needs, there are varying levels of urgency for such solutions, see Table 4.

Table 4 – Level of Urgency for each Customer Needs

Customer Needs	Level of Urgency
The product is easy to carry while traveling or store in limited spaces.	5
The product can be used for various types of clothing and fabrics.	4
The product features a heater to remove clothing wrinkles.	5
The product is made of durable and strong materials.	4
The product can be folded together with clothing.	3

The level of urgency is as follows: 5 is highly necessary, 4 is necessary, 3 is not highly necessary but would be good to have, 2 is unnecessary, and 1 should be removed. The next stage involves designing the product by following the rational product design methodology.

3.2. Clarifying the objectives

Customer needs are necessary to ensure the product design aligns with the expectations and requirements of the target audience [12]. In clarifying Objectives, the design of the foldable hanger aims to achieve several key goals. First, portability must be a priority, ensuring the hanger is lightweight, compact, and easy to fold for convenience during travel. Durability is also important, with the hanger made of high-quality materials that can withstand frequent use and the demands of travel. The design must also be cost-effective, providing an affordable solution without compromising on quality or functionality. Additionally, the hanger should be user-friendly, allowing for easy folding and unfolding while effectively smoothing out wrinkles and maintaining the neatness of clothes. Multifunctionality is essential, as the hanger must accommodate various types of clothing, from shirts to dresses, and be adjustable for different garment sizes. The hanger should also include a clothing heating feature to reduce creases on clothes that have been folded. Lastly, the hanger should be space-saving, easily fitting into luggage without taking up much space.

All of those objectives collectively aim to provide a compact, efficient, and practical solution for travelers, addressing the need for clothing organization and care while on the go. Therefore, the sub-goals for designing this foldable travel hanger are as follows:

1. The product is easy to carry while traveling or store in limited spaces.
2. The product can be used for various types of clothing and fabrics.
3. The product features a heater to remove clothing wrinkles.
4. The product is made of durable and strong materials.
5. The product can be folded together with clothing.

The next step involves arranging the objectives from higher to lower levels and illustrating a goal or diagram tree to show the hierarchical relationships as follows.

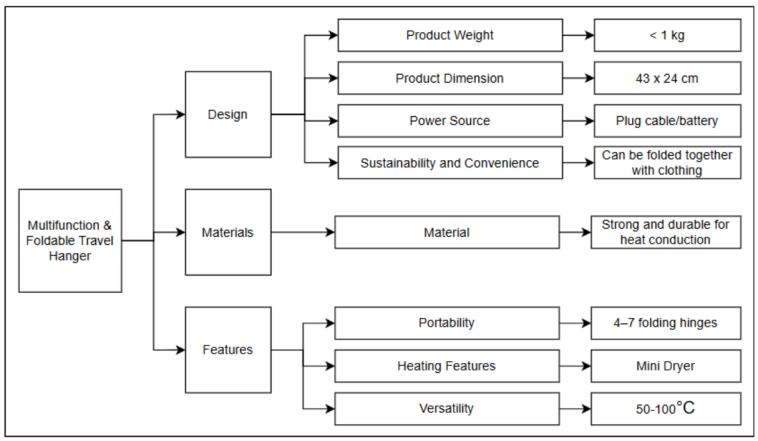


Figure 2 – Diagram Tree

3.3. Establishing Function

The establishing function stage is the phase where functions and constraints in product design are determined using a black box [13]. The black box is used to identify the main functions of the drying machine in terms of input, process, and output.

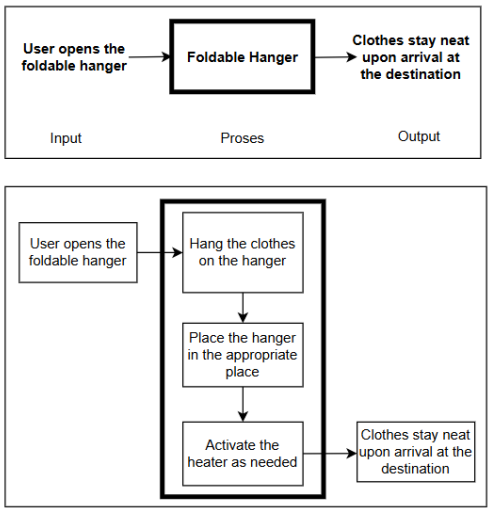


Figure 3 – Level of Urgency for each Customer Needs

Sub-functions such as the folding mechanism, stability when hung, and user comfort during storage and access should be considered separately but remain interconnected. With this approach, the foldable travel hanger can meet the user's needs for comfort and functionality during travel, while maintaining a compact size that is easy to carry.

3.4. Setting Recruitment

In the design process of this multifunctional foldable travel hanger, it is essential to establish clear design requirements and constraints, as outlined by Nigel Cross in *"Engineering Design Methods*" [22]. These constraints include aspects such as acceptable product size and weight, as well as performance specifications like power consumption and temperature settings. These design constraints not only ensure that the product meets functional needs but also guide researchers toward optimal solutions, avoiding designs that are too narrow or too broad. Therefore, the Table 5 outlines the technical characteristics and targets of this multifunctional foldable travel hanger.

Table 5 – Setting Recruitment

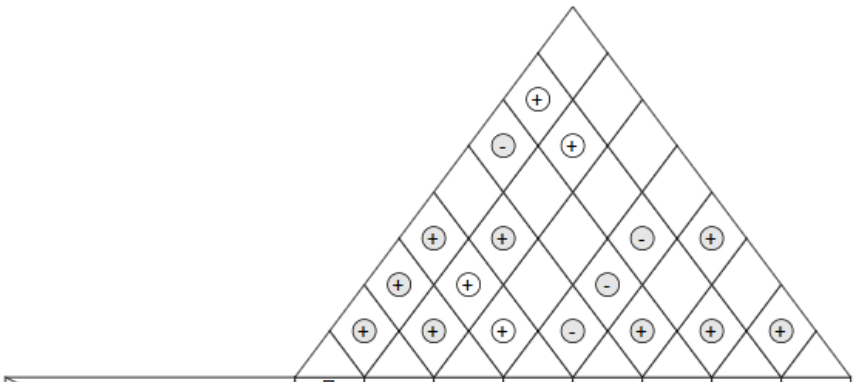
Attribute/Criteria	Technical Characteristics	Target	D/W
Product is easy to carry or store in limited space	Design and portability	Can be folded	W
	Product weight	500 - 1000 gram	D
Product can be used for various types of clothing and fabric	Product dimensions	43 x 24 cm	W
	Temperature control	3 Adjustable temperature setting	D
Product has a heating feature to remove clothing creases	Dryer	Has a dryer feature	W
	Product power source	(Rechargeable) Battery	D

Attribute/Criteria	Technical Characteristics	Target	D/W
Product has strong and durable material	Heat-resistant material	Acrylonitrile Butadiene Styrene (ABS)	W
Product can be folded along with the clothes	Number of hinges	7 Foldable hinges	W

From the data analysis, characteristics and targets have been discussed with users. It was found that "D" refers to *consumer demand*, which represents what consumers want or need from a particular product or service. This includes preferences, expected features, or solutions to problems they face. Meanwhile, "W" refers to *accuracy with consumer expectations*, which indicates how well the product or service design aligns with consumer expectations. This reflects the level of alignment between what consumers desire and what is offered by the design [22].

3.5. Determining Characteristic

The results of the House of Quality (HOQ) illustrate the relationship between customer needs and the technical features of the product, highlighting the interactions between the two. This table provides an overview of the priorities and influence of each feature on customer satisfaction, which is crucial for designing product development strategies and continuous improvement. [22] The numbers in the table represent the level of interaction: 9 indicates a high level of interaction, 3 indicates some interaction, 1 indicates minimal interaction, and 0 indicates no interaction. Thus, the table offers insights into the impact of each technical characteristic on customer needs, helping to design products that are more effective and focused on customer satisfaction. The following are the results of determining the characteristics of this product design.



Technical Characteristic / Customer Needs	Design and Portability	Product Weight	Product Dimensions	Number of Hinges	Heat Resistant Material	Temperature Control	Product Power Source	Dryer
Product is easy to carry or store in limited space	9	9	9	3	0	0	1	1
Product can be used for various types of clothing and fabric	9	1	3	1	0	0	0	3
Product has a heating feature to remove clothing creases	3	1	1	0	9	9	9	9
Product has strong and durable material	1	1	1	3	9	1	3	1
Product can be folded along with the clothes	9	1	3	9	1	0	0	0
Units	Binary	g	cm	Unit	Binary	Binary	Binary	Binary
Target / Value	Can be folded	500-1000	43 x 24	7	Yes	Yes	Yes	Yes

⊕	Strong Positive Impact
+	Positive Impact
⊖	Strong Negative Impact
-	Negative Impact

Figure 4 – Determining Characteristics

The top section (triangle) of this HOQ illustrates the relationships between technical characteristics. In the middle section, it shows the connection between customer needs and their corresponding technical characteristics, along with the target/values for the proposed product. After that, component or material options for the proposed product will be created and grouped into several alternatives in the generating alternatives phase. It is based on the targets from this HOQ.

3.6. Generating Alternatives

3.6.1. Temperature Tolerance and Fabric Care in Drying Clothes

Different types of fabrics have varying levels of temperature resistance and maximum temperature tolerance. Most fabrics can be dried up to 100°C, with cotton and synthetic fabrics tolerating up to 120°C, although this is not recommended as it approaches the fabric's burning point [23]. Exceeding this temperature may lead to the fabric catching fire. The dryer's temperature should be adjusted based on the fabric type to prevent damage, such as color fading or stiffness.

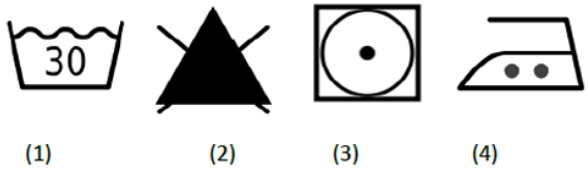


Figure 5 – Textile Care Labeling Standards

The figure above shows the symbols from the textile care labeling standards, which define five basic symbols for textile care: washing, bleaching, drying, ironing, and dry cleaning. A label for cotton fabric care includes the following symbols:

1. The first symbol indicates that the garment can be machine washed at a maximum water temperature of 30°C.
2. The second symbol warns that bleach should not be used.
3. The third symbol permits drying using a low-temperature dryer (below 50°C).
4. The fourth symbol shows that the garment can be ironed at a medium temperature (up to 150°C).

3.6.2. Material Selection

Acrylonitrile Butadiene Styrene (ABS) is an excellent material for use in foldable hangers with heating dryers due to its high mechanical strength, thermal stability, and dimensional stability [24]. With a thermal deformation temperature around 90–100°C, ABS can withstand the heat from the dryer without warping, making it more durable than Polypropylene (PP), which can only withstand 60–80°C and is prone to warping [25]-[27]. Additionally, ABS has superior impact strength compared to Nylon (Polyamide) and is more cost-effective, as it does not absorb moisture, preventing shape deformation in humid environments. These properties make ABS the ideal choice for foldable hangers with heating dryers, offering cost-efficiency and performance.

Table 6 – Materials Selection

Property	Acrylonitrile Butadiene Styrene (ABS)	Polypropylene (PP)	Nylon (Polyamide)
Thermal Deformation Temperature	90-100°C	60-80°C	120°C
Tensile Stress	32Mpa	37Mpa	40Mpa
Resistance to Warping	Excellent	Prone to warping	Good
Cost	Cost-effective	Lov-cost	Higher cost
Suitability for Hanger with Heating Dryer	Ideal	Less suitable	Suitable but costly

3.6.3. Power Source Selection

Lithium-ion batteries are a superior choice compared to conventional batteries and plug-in cables as a power source for portable devices such as foldable hangers with dryers. Conventional batteries, such as single-use alkaline batteries, have limited power capacity and cannot be recharged, resulting in higher electronic waste and increased long-term usage costs. On the other hand, plug-in cables require direct access to a power source, which reduces the flexibility and portability of devices, particularly in locations without electricity access. According to research in various scientific journals, lithium-ion batteries have high energy density, enabling greater power storage in a smaller and lighter form factor, making them ideal for portable devices [28]. Additionally, this technology has a long cycle life with efficient recharge capabilities, making it more environmentally friendly compared to single-use batteries by reducing battery waste production [29]. Lithium-ion batteries also exhibit a low self-discharge rate, ensuring optimal battery performance even when not in use for extended periods [30]. With these characteristics, lithium-ion batteries provide stable and sustainable power for

efficient clothes drying while supporting flexible use in various conditions, including travel or locations without electricity access.

3.6.4. Option for Generating Alternatives

There are three alternatives for the design, material, weight, dimensions, temperature settings, and power source for developing a foldable hanger with a dryer, see Table 7.

Table 7 – Generating Alternatives (1)

Function	Alternative 1	Alternative 2	Alternative 3
Design and Portability	Foldable	Foldable and detachable	Foldable and detachable
Product Weight	700g	800g	850g
Product Dimensions	43 x 24 cm	43 x 24 cm	43 x 24 cm
Number of Hinges	4	6	7
Heat-resistant Material	Acrylonitrile Butadiene Styrene (ABS)	Polypropylene (PP)	Polyamide (Nylon)
Dryer	Yes	Yes	Yes
Temperature Settings	80°C and 100°C	50°C, 70°C, 100°C	50°C, 80°C, 120°C
Product Power Source	Battery	Plug cable	Rechargeable Battery

Based on the Table 7, two development options for the foldable hanger with a dryer can be narrowed down. The options are as in Table 8.

Table 8 – Generating Alternatives (2)

Function	Option 1	Option 2
Design and Portability	Can be folded and detached	Can be folded and detached
Product Weight	700g	700g
Product Dimensions	43 x 24 cm	43 x 24 cm
Number of Hinges	7	7
Heat-Resistant Material	Acrylonitrile Butadiene Styrene (ABS)	Acrylonitrile Butadiene Styrene (ABS)
Dryer	Available	Available
Temperature Control	50°C, 70°C, 100°C	50°C, 70°C, 100°C
Product Power Source	Rechargeable Battery	Plug Cable

3.7. Evaluating Alternatives

This process aims to select the best alternative from the available options, resulting in an optimal design that meets consumer preferences. Concept screening is conducted to narrow down the number of concepts or quickly eliminate unsuitable ones, as well as to improve the remaining concepts [22]. The table below shows Option 1 and Option 2 are feasible for development. In this process, the evaluation criteria are assigned with the following notations:

- **(+)** indicates the concept performs better than the reference.
- **(0)** indicates the concept is equal to the reference.
- **(-)** indicates the concept performs worse than the reference.

The Table 9 presents the final total scores derived from the assessment of each concept during the screening phase. This score highlights the strengths and weaknesses of each concept compared to the reference, providing a foundation for further refinement and development.

Table 9 – Concept Screening

Selection Criteria	Concept A	Concept B
Design and Portability	+	+
Product Weight	0	0
Product Dimensions	0	0
Number of Hinges	+	+
Heat-Resistant Material	+	+
Dryer	+	+
Temperature Control	+	+
Product Power Source	+	0
Number of (+)	6	5
Number of (0)	2	3
Number of (-)	0	0
Final Score	6	5
Ranking	1	2
Continue?	Y	Y

Concepts A and B have been identified as viable options and can be further developed and advanced to the next stage for concept weight scoring evaluation. The weighted objectives method is a systematic approach to comparing the utility values of alternative design proposals based on their performance against objectives with varying levels of importance. The process begins with listing the design objectives, which may need to be adjusted or reorganized using an objectives tree. Next, these objectives are ranked based on their importance according to consumer input from the outset. Performance parameters or utility scores are then established for each objective, using simple point scales to evaluate both qualitative and quantitative objectives. Finally, the relative utility values of the alternative designs are calculated by multiplying each parameter score by its corresponding weight. The design with the highest total utility value is considered the 'best,' although analyzing the utility value profiles can provide deeper insights for decision-making beyond simply selecting the top option.

In this final evaluation matrix, the design objectives (selection criteria) are assigned relative weights. The remaining concepts are then assessed in comparison to this baseline: 5 points for 'much better,' 4 points for 'better,' 3 points for 'the same,' 2 points for 'worse,' and 1 point for 'much worse'.

Table 10 – Concept Weight Score

Selection Criteria	Weight (%)	Concept A		Concept B	
		Rating	Weighted Score	Rating	Weighted Score
The product is easy to carry while traveling or store in a limited space	23.81%	3	0.7143	2	0.4762
The product can be used for various types of clothing and fabric	19.05%	3	0.5715	3	0.5715
The product has a warming feature to remove wrinkles from clothes	23.81%	5	1.1905	5	1.1905
The product is made of durable and strong material	19.05%	4	0.762	4	0.762
The product can be folded together with clothing	14.29%	4	0.5716	4	0.5716
		Concept A		**Concept B**	
Final Total Score		**3.71**		**3.47**	
Rank		**1**		**2**	
Proceed?		**Yes**		**No**	

Based on the rating and weight scores from customer requirements, Concept A has been selected for development in terms of design, material, weight, dimensions, temperature options, and power source.

3.8. Improving Details

In this section, the results of creating a detailed design draft, cost, and load-bearing strength test for the folding hanger product development with this dryer are presented in Figure 6 and Table 11.

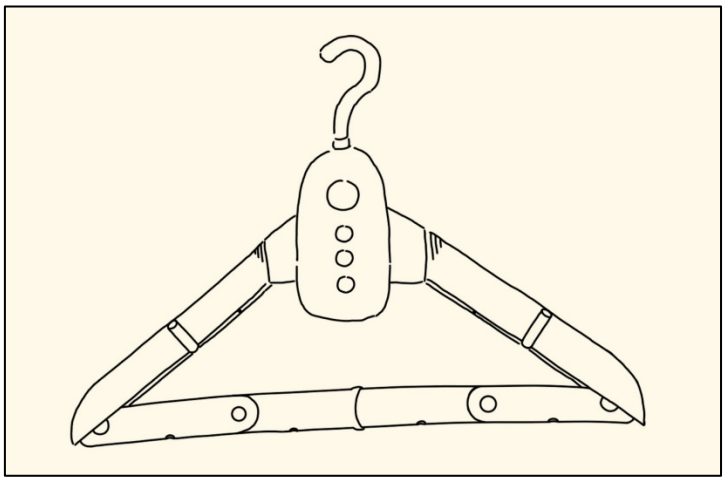


Figure 6 – Product Illustration

Table 11 – Improving Details

Materials	Price	Total Needs	References
ABS plastic pellets. For hook, main face front, main power button, right arm 1, right arm 2, right cylinder 1, right cylinder 2, right arm 1, left arm 2, left cylinder 1, left cylinder 2.	Rp17.010	1	[31]
Dryer Machine	Rp30.000	1	[32]
1000mAh Lithium Polymer Battery	Rp35.000	1	[33]
LED Light	Rp450	3	[34]
Packing	Rp8.300	1	[35], [36]
Molding Services	Rp50.000	1	[37]
Total Price	**Rp141.310**		

3.9. Prototyping and Testing

The following are the prototype and Bill of Materials (BOM) for the multifunctional travel folding hanger with a dryer.

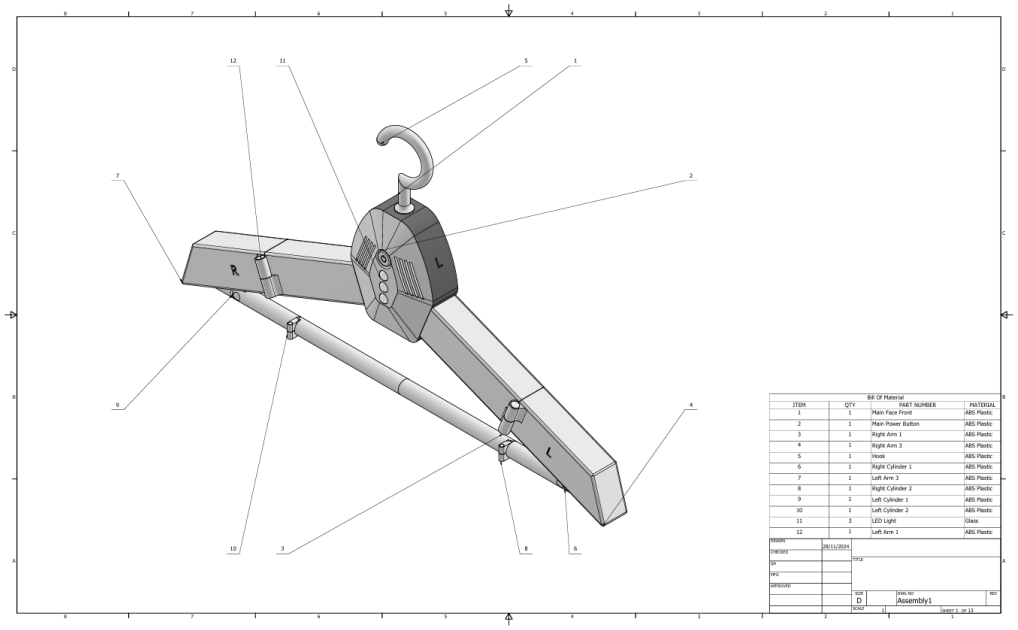


Figure 7 – Bill of Materials Product

This product has been tested using the Von Mises Stress, which shows that it can support a shirt, jacket, and pants simultaneously.

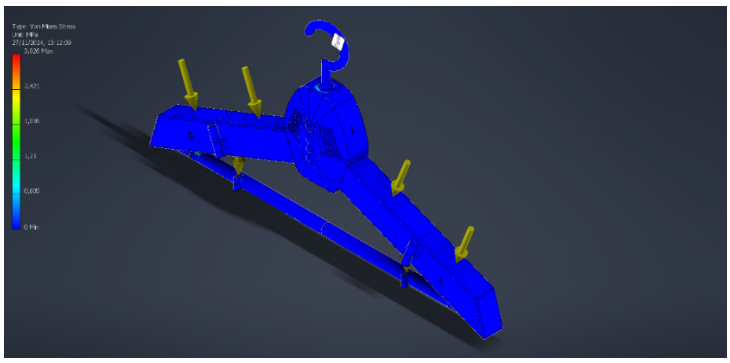


Figure 8 – Von Mises Stress

The results confirm the hanger's suitability for handling typical loads during travel scenarios, such as shirts, pants, and suits, with a total weight of around 5 kg, without significant deformation [38]. The Finite Element Analysis (FEA) results show stress and deformation distribution on the tested structure. The model volume is 379.955 mm³ with a mass of 0.892764 lbm. The maximum Von Mises stress is 3.01579 MPa, occurring in the area with the highest load, while the minimum stress is nearly zero. The maximum 1st principal stress is 2.68674 MPa, and the 3rd principal stress ranges from -3.3007 MPa to 0.681556 MPa. The maximum deformation is 0.528652 mm, indicating minimal shape change. The safety factor is 6.63177, indicating the structure can withstand 6.63 times the applied load. The results conclude that the design is safe and can handle the load with controlled stress and deformation.

Name	Minimum	Maximum
Volume	379955 mm^3	
Mass	0,892764 lbmass	
Von Mises Stress	0,000000000000556483 MPa	3,01579 MPa
1st Principal Stress	-0,434208 MPa	2,68674 MPa
3rd Principal Stress	-3,3007 MPa	0,681556 MPa
Displacement	0 mm	0,528652 mm
Safety Factor	6,63177 ul	15 ul

Figure 9 – Von Mises Stress Summary

The following are the specifications and battery testing for the dryer hanger. The specification requires temperatures starting from 50°C, 70°C, and 100°C. With a power consumption of 20 watts and an operating voltage of 220 volts. It is powered by a lithium-ion battery with a voltage of 3.7V, a capacity of 3500 mAh (3.5 Ah), and a charging voltage of 4.2V.

- Battery Energy

  $E = Capacity\ x\ Voltage$

  $E = 3.5\ Ah\ x\ 3.7V = 12.95\ Wh$

- Effective Power Consumption

  $P_eff = \frac{P}{Efficiency}$

  $P_eff = \frac{20}{90\%}$

- Usage time

  $$Usage\ time = \frac{Battery\ energy}{Effective\ power\ consumption}$$

  $$Usage\ time = \frac{12.95}{22.22} = 0.58\ hours$$

Usage time ≈ 35 minutes

- Battery energy (charging):

  $E = Capacity\ x\ Charging\ Voltage$

  $E = 3.5\ Ah\ x\ 4.2\ V = 14.7\ Wh$

- Charging Power

  $P\ charging = Voltage\ x\ Current$

  $P\ charging = 5V\ x\ 1A = 5W$

- Charging Time

  $$Charging\ Time = \frac{Battery\ energy}{Charging\ power}$$

  $$Charging\ Time = \frac{14.7}{5} = 2.95\ hours$$

Charging time ≈ 3 hours

The dryer hanger operates at 220V with a power consumption of 20W. It is powered by a 3.7V, 3500mAh lithium-ion battery with a charging voltage of 4.2V. The estimated usage time is approximately 35 minutes per full charge, assuming 90% efficiency in the step-up converter. Charging the battery using a 5V, 1A charger requires around 3 hours.

4. CONCLUSION

The development of a multifunctional foldable travel hanger equipped with a built-in dryer is a strategic response to the increasing demand for portable, efficient garment care solutions among professionals who frequently travel. Through a systematic design process, including the identification of customer needs, technical requirements, and evaluation of alternatives, a final concept "A" has been selected as the optimal solution. Concept A offers a blend of portability, functionality, and durability, featuring a foldable and detachable design, lightweight construction (700g), heat-resistant Acrylonitrile Butadiene Styrene (ABS) material, adjustable temperature settings (50°C, 70°C, 100°C), and a rechargeable battery. These features align with key customer needs, such as ease of transport, compatibility with various clothing types, and effective wrinkle removal without reliance on external power sources. Rechargeable batteries have the disadvantage of needing to be charged and can only be used for 35 minutes (while the device is on). The incorporation of innovative materials, compact design, and user-friendly features positions this product as a practical and sustainable solution for professionals striving to maintain a polished appearance during travel. The findings and methodology outlined in this study provide a foundation for future development and market introduction of travel accessories that meet the evolving demands of a globalized and mobile workforce. The results validate the hanger's ability to manage standard loads in travel situations, including shirts, pants, and suits, weighing approximately 5 kg, without noticeable distortion.

Although the findings show the potential of this product to meet the specific needs of frequent travelers, future research should focus on further developing the energy source, such as exploring more efficient battery technologies or alternative power options. Additionally, it is crucial to validate the product's performance in real-world conditions, especially when exposed to varying environmental factors such as humidity or temperature. For further refinement, it is recommended to test the product under different stress conditions and explore potential improvements in the power system and durability. This will ensure that the product can meet the diverse needs of users in various travel environments.

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