Proposed design of prosthetic arm with the integration of Kano model and TRIZ method

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ABSTRACT
Individuals with upper-limb disabilities face substantial limitations in performing daily activities. Statistics Indonesia reports that 62.59% of persons with disabilities have physical impairments, while the Special Region of Yogyakarta ranks among the three provinces with the highest prevalence of finger and hand mobility disorders, at 0.44%. However, most available prosthetic devices remain primarily cosmetic and provide limited functional performance, leaving users' needs and expectations unmet. This study aims to design a functional prosthetic hand that addresses user requirements and expectations by integrating the Kano model and the TRIZ (*Teoriya Resheniya Izobretatelskikh Zadatch*) method. The Kano model was applied to identify and classify user needs based on satisfaction levels, involving 15 individuals with upper-limb disabilities in Gunungkidul Regency. TRIZ was subsequently used to develop systematic and innovative design solutions. The proposed design emphasizes functionality, comfort, safety, ergonomics, ease of use, product quality, and aesthetic appearance. The design was validated through feedback from users and experts. Of the 13 respondents involved in the validation process, 11 agreed with the proposed design, while two recommended minor revisions to accommodate specific disability conditions. The final design consists of two prosthetic configurations: transhumeral and transradial prosthetic hands.

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1. INTRODUCTION

Upper-limb disability can substantially restrict an individual's ability to perform activities of daily living, occupational tasks, and social participation because the hand and arm are essential for reaching, grasping, manipulating objects, and performing coordinated movements [1], [2]. In Indonesia, the need for assistive technology remains considerable; a national assessment reported that approximately 60% of assistive-product needs among surveyed respondents were unmet, with affordability and limited funding identified as major barriers to access [3]. The consequences of upper-limb impairment are particularly complex because everyday activities require combinations of joint motion, strength, coordination, dexterity, and interaction with objects [1]. Consequently, the loss or reduced function of an upper limb may substantially affect personal independence, work participation, psychosocial well-being, and quality of life [2], [4].

This issue is particularly relevant in Gunungkidul Regency, Special Region of Yogyakarta, a vast, hilly, and predominantly rural region where dispersed settlements and limited access to specialized healthcare facilities may complicate prosthetic assessment, fitting, maintenance, repair, and follow-up services [5]—[7], [9]. In this context, upper-limb function is essential for personal care, household activities, and livelihood-related tasks such as reaching, grasping, lifting, carrying, handling tools, preparing food, and manipulating objects, all of which require varying levels of joint mobility, grip strength, coordination, dexterity, and force [1]. Prostheses with inadequate grip, restricted motion, excessive weight, discomfort, or difficult control may consequently reduce users' independence and capacity to perform productive daily activities [2], [8], [7]. Therefore, upper-limb prostheses for users in Gunungkidul should be designed according to actual task demands, environmental conditions, financial capacity, physical characteristics, and locally available maintenance resources. A context-specific and user-centered design emphasizing functionality, affordability, comfort, low weight, durability, ease of operation, and ease of maintenance is essential to reduce dependence on highly specialized facilities and improve suitability for activities of daily living [4], [8], [7].

Upper-limb prostheses are intended to restore part of the lost function, support independence, and improve the appearance of the affected limb. Nevertheless, many currently available devices remain limited in terms of affordability, weight, comfort, functionality, reliability, and adaptability to individual users [2], [3], [8]. Advanced myoelectric and multi-grip prostheses may provide several grasping patterns and sophisticated control options; however, their high cost, relatively heavy structure, maintenance requirements, and control complexity can restrict accessibility and sustained use [8], [9]. Conversely, simpler and lower-cost prostheses are generally more accessible and lightweight but may provide limited dexterity, grasping capability, sensory feedback, or adaptability to different daily tasks [8], [10]. These limitations contribute to continued dissatisfaction and prosthesis abandonment, with discomfort, excessive weight, inadequate control, limited functionality, and poor sensory feedback consistently reported as important factors [2], [8].

Designing an upper-limb prosthesis therefore requires balancing several competing requirements, including mechanical strength, low weight, functional range of motion, intuitive control, comfort, reliability, aesthetic acceptance, manufacturability, maintenance, and cost [1], [8], [9]. Recent studies have shown that achieving human-like functionality while maintaining an acceptable device weight remains a major engineering challenge, particularly because upper-limb activities involve different combinations of joint angles, velocities, torques, and object-related loads [1].

Although previous studies have identified general user priorities such as functionality, comfort, weight, appearance, reliability, and ease of control, these findings have primarily been presented as broad design requirements or examined in socioeconomic and healthcare contexts different from rural Indonesia [11], [12]. In Gunungkidul, prosthetic requirements are shaped not only by users' functional, physical, and psychosocial needs but also by limited access to specialized fitting, maintenance, repair, and follow-up services. Consequently, affordability, low weight, durability, simple operation, and local maintainability are essential design considerations rather than merely desirable product attributes. Previous research has either synthesized general upper-limb prosthesis user needs [11], investigated user-driven requirements in another national context [12], or applied TRIZ to the technical analysis of existing myoelectric hand concepts [13]. However, to the best of the authors' knowledge, no previous study has integrated Kano-based classification and prioritization of locally elicited user needs with TRIZ-based resolution of engineering contradictions for upper-limb prosthesis design in a low-resource rural Indonesian setting. Therefore, the specific gap addressed in this study is the lack of a structured and context-sensitive method for translating the needs of rural Indonesian users into prioritized and technically actionable prosthesis design specifications.

Considering the persistent limitations of existing upper-limb prostheses, particularly in terms of affordability, comfort, functional suitability, maintainability, and responsiveness to individual user needs, this study proposes the development of a functional hand prosthesis specifically designed for users in Gunungkidul Regency. The proposed design aims to support selected activities of daily living, particularly basic grasping and object-handling tasks, while remaining lightweight, comfortable, affordable, and practical to use. Its development considers applicable quality standards, ergonomic principles, safety requirements, usability, and conformity with the physical and functional characteristics of the target users. To ensure that user expectations are systematically incorporated into the design process, the Kano model is employed to classify user requirements according to their influence on satisfaction, while the Theory of Inventive Problem Solving (TRIZ) is applied to resolve technical contradictions and generate feasible design solutions.

The integration of these approaches provides a structured method for translating subjective user needs into prioritized technical specifications and innovative prosthetic design concepts. Accordingly, this study aims to develop and evaluate a user-centered functional hand prosthesis concept that is contextually appropriate for users in Gunungkidul Regency. To the best of our knowledge, this is the first study to integrate the Kano model and TRIZ specifically for functional hand prosthesis design targeting users in a resource constrained rural setting in Indonesia. The study is expected to provide a practical contribution by proposing an affordable, lightweight, comfortable, and maintainable upper-limb assistive device concept, as well as a methodological contribution by demonstrating how the Kano model and TRIZ can be used complementarily to classify user requirements, prioritize design attributes, and resolve technical contradictions in prosthetic product development. Furthermore, the resulting design and specifications may serve as a foundation for subsequent prototype fabrication, mechanical and ergonomic testing, usability evaluation, feature optimization, and larger-scale validation involving a broader group of users.

2. MATERIALS AND METHODS

This research employed interviews and questionnaires to collect data relevant to the design of a prosthetic hand for individuals with upper limb disabilities. The questionnaire was developed based on the Kano model and consisted of functional and dysfunctional questions to identify users' levels of satisfaction and dissatisfaction with various product attributes. The final questionnaire was administered to 15 respondents with hand disabilities in Gunungkidul Regency using the purposive sample. 15 respondents used in this research is due to the scarcity of data told by local government and related NGO (Non Government Organization) such as *Muhammadiyah* Disability Center, OHANA, and so on around Gunung Kidul, also the tendencies of people to hide out their related families with disabilities, nevertheless, the 15 respondents is spread across Gunungkidul with almost the same economic background, thus it could represent the demographic condition around Gunungkidul Regency. The collected responses were analyzed and used as the basis for the product design process to ensure that the proposed design appropriately reflects user needs, preferences, and expectations.

2.1 Pilot Test

Pilot testing is an important stage in instrument development because it enables researchers to evaluate the feasibility, clarity, comprehensibility, and practical administration of a questionnaire before its use in the main study [14]. A pilot study can provide an early indication of potential weaknesses in the research protocol, data-collection procedures, and respondents' interpretation of questionnaire items, thereby allowing necessary revisions before full-scale implementation [15], [16]. In the present study, instrument pretesting is done only by expert to do the content validation thus it became the limitation on this paper. Through a thorough process, starting from a two-way interview regarding the questionnaire contents to discussing the contents of every single questionnaire item, the experts assessed the relevance, clarity, and appropriateness of each questionnaire item. and a preliminary trial involving a respondent with an upper-limb disability. The expert panel comprised hand-prosthetics specialists from the Yakkum Rehabilitation Centre and Orto Syam, including practitioners with approximately 10 years of experience in prosthetics and orthopaedics.

The results of the expert assessment were evaluated through content-validity analysis and interrater agreement analysis. Content validity refers to the extent to which the items of an instrument adequately represent the construct and dimensions that the instrument is intended to measure [17], [18]. The relevance of each item was evaluated using the Item-Level Content Validity Index (I-CVI), calculated as the proportion of experts assigning an item a relevance rating of 3 or 4 on a four-point scale [17]. An I-CVI value of at least 0.78 is generally considered acceptable when an item is evaluated by three or more experts; however, complete agreement is normally expected when only two experts are involved [17]. Items that did not meet the required criterion were revised or reconsidered based on the experts' qualitative comments.

Interrater agreement was subsequently assessed using a kappa coefficient to determine whether the experts' ratings were consistent beyond the level expected by chance [19], [20]. Cohen's Kappa is appropriate when an item is assessed by two raters, whereas Fleiss' Kappa or another multi-rater agreement coefficient should be used when three or more raters evaluate the same items [20]. Following the conventional interpretation proposed by Landis and Koch, Kappa values of 0.61–0.80 indicate substantial agreement, whereas values of 0.81–1.00 indicate almost perfect agreement. The combined application of the I-CVI and an appropriate kappa statistic therefore provides complementary evidence that the questionnaire items are substantively relevant and consistently evaluated by the expert panel. Following this validation process, the revised instrument was considered appropriate for use in the main data-collection stage.

2.2 Kano Model

The Kano model is widely used to classify user requirements according to their nonlinear effects on satisfaction and dissatisfaction, thereby supporting the prioritization of product or service attributes during development and improvement [21]—[23]. Unlike conventional approaches that assume a linear relationship between attribute performance and satisfaction, the Kano model recognizes that different quality attributes influence users in different ways. The model was originally introduced by Noriaki Kano and colleagues to distinguish between attributes whose absence causes dissatisfaction, attributes whose improved performance proportionally increases satisfaction, and attributes that create unexpected user delight [24]. As illustrated in Figure 1, the two-dimensional Kano model relates the degree of attribute fulfillment to the resulting level of user satisfaction.

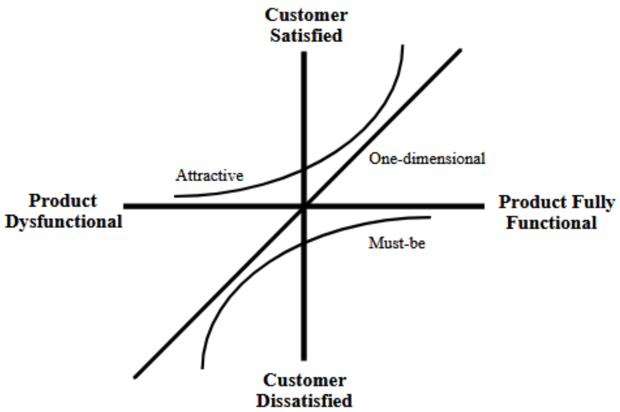

Figure 1. The kano diagram [24]

In this study, the model was applied to identify and categorize the requirements of upper-limb prosthesis users so that design resources could be directed toward attributes with the greatest influence on user acceptance and satisfaction. Understanding these quality categories provides a structured basis for determining which requirements must be fulfilled, which should be continuously improved, and which may offer opportunities for design differentiation and increased user satisfaction [21]. The Kano quality categories used in this study are described as follows:

1. Attractive (A), Attributes that significantly increase user satisfaction when present but do not cause dissatisfaction when absent.
2. One-Dimensional (O), Attributes for which user satisfaction is directly proportional to their performance; the better the performance, the higher the user satisfaction.
3. Must-Be (M), Basic attributes that must be fulfilled; their absence causes dissatisfaction, while their presence does not significantly increase satisfaction.
4. Indifferent (I), Attributes whose presence or absence has little or no impact on user satisfaction.
5. Reverse (R), Attributes that reduce user satisfaction when present, meaning users are more satisfied when these attributes are not implemented.

6. Questionable (Q), attribute where consumers demonstrate inconsistency. The level of satisfaction or dissatisfaction with the provided service depends on the presence or absence of that attribute.

The Kano model classifies user requirements through paired functional and dysfunctional questions that assess respondents' reactions to the presence and absence of each product attribute [25], [26]. The combination of responses is matched with the Kano evaluation matrix in Table 1, resulting in six categories: Attractive (A), Must-be (M), One-dimensional (O), Indifferent (I), Reverse (R), and Questionable (Q) [25]. The frequency of each category is subsequently tabulated for every attribute, and the dominant category is used to represent users' perceptions of the hand-prosthesis design requirements. This procedure distinguishes basic expectations, performance-related requirements, and attractive features, thereby providing a systematic basis for prioritizing product attributes according to their nonlinear effects on user satisfaction and for translating user needs into subsequent design decisions [22].

Table 1. Evaluation table

Customer Requirements		Dysfunctional				
		Dislike	Live with	Neutral	Must-Be	Like
Functional	Like	Q	A	A	A	O
	Must-Be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Initial classification of each attribute was obtained based on responses to the questionnaire items. This evaluation aimed to generate quantitative scores for each attribute. However, relying solely on simple statistics based on response counts or frequencies was considered insufficient, as it did not fully capture the distribution of responses across the various Kano categories. To overcome these limitations, a quantitative approach was developed by calculating the better (Satisfaction Index) and worse (Dissatisfaction Index) values. In the calculation of the Better and Worse indices, only responses categorized as Attractive (A), One-dimensional (O), Must-be (M), and Indifferent (I) were included, while Reverse (R) and Questionable (Q) responses were excluded from the analysis. Conceptually, the Satisfaction Index (SI) represents the degree to which the presence of an attribute increases user satisfaction, whereas the Dissatisfaction Index (DI) reflects the level of dissatisfaction resulting from the absence of an attribute, thereby quantifying the influence of each attribute on user satisfaction. Mathematically, SI and DI are formulated as Eqs. (1) and (2).

$$Better\ (SI) = \frac{A + O}{A + O + M + I} \tag{1}$$

$$Worse\ (DI) = -\frac{O + M}{A + O + M + I} \tag{2}$$

2.3 *TRIZ (Theory of Inventive Problem Solving)*

TRIZ is a knowledge-based and structured methodology that supports innovative problem solving by identifying recurring patterns of technological development and resolving contradictions within a system [27], [28]. A technical contradiction occurs when improving one design characteristic causes another characteristic to deteriorate, such as increasing strength at the expense of weight or improving functionality while increasing complexity. To address such conflicts, the problem is translated into an improving parameter and a worsening parameter, which are mapped onto the TRIZ contradiction matrix. The classical matrix consists of 39 engineering parameters and recommends relevant solutions from the 40 inventive principles [27], [29]. These principles serve as generalized solution directions rather than ready-made answers and must therefore be interpreted and adapted to the specific design context. Recent studies continue to use the contradiction matrix and inventive principles to systematically generate alternative solutions for engineering and product-design problems [27], [29].

In this study, TRIZ was implemented through three main stages. First, in the problem-definition stage, prioritized prosthetic-hand attributes obtained from the Kano analysis were examined to identify design requirements and potential technical contradictions. Second, in the problem-resolution stage, each contradiction was translated into appropriate improving and worsening engineering parameters and mapped onto the contradiction matrix to obtain recommended inventive principles. Third, during solution evaluation, the recommended principles were interpreted in relation to the functional, ergonomic, manufacturing, and user-related constraints of the hand prosthesis, and the most feasible design alternatives were selected. The alternatives were assessed with reference to the concept of ideality, which seeks to maximize the useful functions and benefits of a system while minimizing harmful effects, complexity, and resource requirements[30]. However, a higher theoretical ideality does not automatically demonstrate user acceptance; the selected solution must still be evaluated against user requirements and practical design constraints.

The integration of Kano and TRIZ provides complementary support for the prosthetic-hand design process. The Kano model identifies how individual attributes influence user satisfaction and establishes which requirements should receive priority, whereas TRIZ translates the prioritized and potentially conflicting requirements into structured technical problems and inventive solution directions. Thus, Kano answers the question of which attributes should be prioritized, while TRIZ supports decisions regarding how those attributes can be technically realized without unnecessarily compromising other design characteristics. This integration enables qualitative user expectations to be systematically transformed into engineering parameters, inventive principles, and proposed design features for the hand prosthesis.

3. RESULTS

3.1. Instrument Validation

The questionnaire instrument used in this study underwent content validity and inter-rater reliability assessments. Content validity refers to the appropriateness and comprehensiveness of the instrument items in relation to the conceptual definition of the research variables [31], It is typically evaluated through expert judgment to ensure that each item is relevant. The content validity assessment was conducted using the Content Validity Index (CVI), which involves six steps [32], The results indicated that all items achieved an I-CVI > 0.80 and an S-CVI/Ave of 0.85, suggesting that the items' relevance is categorized as good [33]. Inter-rater reliability was examined using Cohen's Kappa to ensure consistency among expert ratings [34]. Kappa values range from -1 to 1, where values approaching 1 indicate excellent agreement and values near 0 indicate low agreement. The test results yielded a Kappa value of 0.615, which is considered good according to Landis and Koch's interpretation [35]. As a result of the instrument validation, two items required revision, specifically items 5 and 7, prior to data collection. Table 2 presents the data used to classify customer requirement attributes obtained through the Kano questionnaire, which consists of paired functional (positive) and dysfunctional (negative) questions for each attribute:

Table 2. Kano model questionnaire

	Functional	Dysfunctional
X1	The prosthetic design resembles a natural human hand (capable of grasping and holding objects).	The prosthetic design does not resemble a natural human hand (incapable of grasping and holding objects).
X2	The prosthetic design displays a color that matches the user's skin tone, providing a natural appearance.	The prosthetic design does not display a color that matches the user's skin tone, resulting in an unnatural appearance.
X3	The prosthetic design appears elegant, enhancing the user's confidence in public.	The prosthetic design does not appear elegant, reducing the user's confidence in public.
X4	The prosthetic design features an easy and practical attachment system.	The prosthetic design does not feature an easy or practical attachment system.
X5	The design appears neat, detailed, and of high quality.	The design does not appear neat, detailed, or of high quality.

	Functional	Dysfunctional
X6	The design is tailored to the user's arm shape, providing comfort.	The design is not tailored to the user's arm shape, resulting in discomfort.
X7	The prosthetic is designed in accordance with quality standards (precision and safety).	The prosthetic is not designed in accordance with quality standards (precision and safety).
X8	The prosthetic includes strong and secure locking or fastening components during use	The prosthetic does not include strong or secure locking or fastening components during use.
X9	The prosthetic design features a ventilation system to prevent skin moisture.	The prosthetic design does not feature a ventilation system, allowing skin moisture.
X10	The prosthetic includes padding or layers for enhanced comfort.	The prosthetic does not include padding or layers for comfort.

3.2. Kano Model

The analysis of user requirements in this study was conducted using the Kano method based on questionnaire data obtained from individuals with upper limb disabilities. Attribute classification in the Kano model was performed by combining respondents answers to functional and dysfunctional questions. After collection, the combination of respondents' answers from both types of questions was processed using the Kano evaluation table [36], allowing each attribute to be classified into one of the following categories: must-be, one-dimensional, attractive, indifferent, or reverse. A Kano tabulation table was constructed to summarize the total responses for each attribute from 15 respondents. This tabulation provides the basis for calculating the SI and DI using Eq. (1) and Eq. (2). which will be used and transformed into a Kano quadrant to determine which attribute goes to which quadrant. Therefore, the Kano tabulation serves as a quantitative foundation for assessing the contribution of each attribute to user satisfaction and dissatisfaction, as well as for determining priorities in prosthetic hand design development. Table 3 presents the Kano tabulation results used to classify each attribute into user requirement categories based on the Kano method.

Table 3. Kano evaluation

Instrument	A	M	O	R	Q	I	Total	Maximum Value
X1	1	2	9	0	0	3	15	9
X2	1	8	0	0	0	6	15	8
X3	2	3	2	0	0	8	15	8
X4	2	6	0	0	0	7	15	7
X5	4	2	0	0	0	9	15	9
X6	1	6	7	0	0	1	15	7
X7	8	4	0	0	0	3	15	8
X8	2	5	6	0	0	2	15	6
X9	7	1	4	0	0	3	15	7
X10	2	2	10	0	0	1	15	10

The SI and DI values provide a quantitative representation of each attribute's contribution to user satisfaction, where positive values approaching 1 indicate a strong impact on increasing satisfaction, while negative values approaching -1 indicate high dissatisfaction when the attribute is not fulfilled. For instance, the functional attribute has a SI value of 0.67, which is close to 1, indicating that fulfillment of the functional attribute significantly enhances user satisfaction. Meanwhile, the DI value of −0.71, which is close to −1, indicates that the absence of this attribute would lead to a high level of user dissatisfaction. Based on the combination of a high SI value and a strongly negative DI value, the functional attribute exhibits a direct relationship with both user satisfaction and dissatisfaction, thereby indicating that this attribute represents a high-priority requirement in the design process. Table 4 presents the calculated SI and DI values used to assess the impact of attribute fulfillment and non-fulfillment on levels of user satisfaction and dissatisfaction.

Table 4. SI and DI value based on kano evaluation calculation

No	Instrument	Better (SI)	Worse (DI)
1	Functional	0.67	-0.73
2	Color Matching	0.07	-0.53
3	Elegant Appearance	0.27	-0.33
4	Ease of Attachment	0.13	-0.40
5	Product Quality	0.27	-0.13
6	Comfort	0.53	-0.87
7	Quality Standardization	0.53	-0.27
8	Safety	0.53	-0.73
9	Presence of Ventilation	0.73	-0.33
10	Presence of Padding/Lining	0.8	-0.8

Based on this analysis, the identified contradiction represents real design conditions, enabling the effective use of inventive principles from the contradiction matrix in formulating design solutions. The inventive principles obtained were then translated into innovative solutions in the form of technical concepts or design ideas aimed at optimally improving system performance without compromising other aspects. In the final stage, the most relevant inventive principles were selected for the development of prosthetic designs for individuals with upper-limb disabilities. Table 5 presents the results of the application of the contradiction matrix, which led to the selected solutions for the attributes to be developed.

Table 5. TRIZ results

<table>
<tr><th>No</th><th>Requirement</th><th>Contradiction Matrix</th><th>Inventive Principles</th><th>Principle Explanation</th><th>Selected Solution and Explanation</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Functional</td><td rowspan="3">Reliability (27) >< Volume of stationary object (8)</td><td>2 Taking Out</td><td>Change color to match natural human hand</td><td rowspan="3">Solution: 35 Parameter Change – design a prosthetic hand that fulfills hand functions Explanation: Principle 35 is the closest in answering the “functional” requirement, by doing a parameter change. One of the definition based on TRIZ method, parameter change means change on the degree of flexibility, thus it could make the hand, compared to existing product, become more functional</td></tr>
<tr><td>35 Parameter Change</td><td>Create a functional prosthetic hand</td></tr>
<tr><td>24 Intermediary</td><td>add a layer to prevent irritation</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Elegant Appearance</td><td rowspan="2">(Shape (12) >< Measurement Accuracy (28))</td><td>28 Replace Mechanical System</td><td>Use hidden magnetic lock</td><td rowspan="2">Solution: 32 Color Change, - Color matches natural hand Explanation : color change in TRIZ itself means a different color, in this case, to make it</td></tr>
<tr><td>32 Color Change</td><td>Color matches natural hand</td></tr>
</table>

No	Requirement	Contradiction Matrix	Inventive Principles	Principle Explanation	Selected Solution and Explanation
					more like human skin, thus it is chosen as the principle in order to answer the requirement
			1 Segmentation	outer part resembles skin, inner part focuses on comfort	Solution: 1 Segmentation, - outer part resembles skin, inner part focuses on comfort Explanation : the problems of existing prosthetic hand is there are no differentiation between each limb, thus segmentation is chosen in order to differentiate each part, and to make it to have an elegant appearance
3	Ease of Attachment	Loss of Time (25) >< Power (21)	35 Parameter Change	Design flexible for easy stretching	Solution: 35 Parameter Change, – flexible design for easy attachment/removal Explanation : same goes with this requirement, choosing parameter change means the design should have a change of flexibility, compared to existing product
			20 Continuity of Useful Action	Prosthetic hand with elastic spring system	
			10 Prior Action	provide a flexible socket	Solution: 6 Universality, - Design allows easy attachment/detachment Explanation: The aliases for this principle is “multi functionality”, by choosing this principle, the designated design should be easier to be used, attach and even de-attach after usage.
			6 Universality	Design allows easy attachment/detachment	
4	Product Quality	Reliability (27) >< Shape (12)	35 Parameter Change	Designed according to anthropometric dimensions	Solution : 11 Cushion in Advance, – precise and detailed structure Explanation: Definition wise, cushion in
			1 Segmentation	Design divided into multiple parts	

No	Requirement	Contradiction Matrix	Inventive Principles	Principle Explanation	Selected Solution and Explanation
			16 Partial or Excessive Action	Trim unnecessary parts for precise and aesthetic finish	advance means to compensate the reliability of an object by taking countermeasure, in creating a "quality product", by giving a cushion, surely elevate the design to be better than current existing product, which almost always not having an extra cushion to prevent the possibility of scratch
			11 Cushion in Advance	Precise and detailed structure	
5	Comfort	Measurement Accuracy (28) >< Shape (12)	6 Universality	Provides comfort during use	Solution: 6 Universality, - Provides comfort during use Explanation: in order to achieve comfort, 6th principle plays an important part. By definition, Universality means the object could perform multi-function, on context of this design, the prosthetic not only functionally works, but also provide comfort for the users
			28 Replace Mechanical System	Replace with automated mechanism	
			32 Color Change	modify color appearance	
6	Standardized Quality	Reliability (27) >< Device Complexity (36)	13 The Other Way Round	Wrist design allows movement	Solution: 13 The Other Way Round, – movable wrist design **Explanation:** based on the contradiction matrix, there are 3 inventive principle found. 13th principle is being chosen, because based on definition, the other way around means the designated prosthetic, moreover in the wrist area, could move unlike the existing product.
			35 Parameter Change	Design conforms to established standards	
			1 Segmentation	Design divided into multiple parts	
7	Safety	Strength (14) >< Object-generated	15 Dynamics	Flexible joint	Solution: 35 Parameter Change, – hook designed according to standard
			35 Parameter Change	Hook designed according to standard	

No	Requirement	Contradiction Matrix	Inventive Principles	Principle Explanation	Selected Solution and Explanation
		harmful factors (31)			**Explanation:** as it mentioned before, one of the features of parameter change in flexibility. The existing product, mostly are not as flexible as this designated prosthetic, by doing so, it could to any unwanted move that could hinder the disabled. By designing this prosthetic, hopefully it could reduce the possibility of the unwanted move and condition
			22 Blessing in Disguise	Avoid using hazardous hooks	Solution: 22 Blessing in Disguise – no hazardous hooks used **Explanation:** in line with the previous explanation, 22nd principle is being implemented by creating a safer hooks. The existing product, usually used a not-so-proper hooks, thus the possibility of hazard could happened
			2 Talking Out	Separate obstructive locking parts	
8	Ventilation	(Shape (12) >< Device Complexity (36))	16 Partial or Excessive Action	Increase number of ventilation holes	Solution :16 Partial or Excessive Action, – increase ventilation holes **Explanation** : giving a lot of ventilation, could make the product to be less tough, in order to do the trade off, 16th principle is chosen. To give several spot on the designated prosthetic a ventilation, could help the user to get fresh air or change of air.
			29 Pneumatics and Hydraulics	Use air pump design	
			1 Segmentation	Design divided to match structure	Solution: 1 Segmentation, – design divided to match structure
			28 Replace Mechanical System	Fan or pump-based ventilation system	

No	Requirement	Contradiction Matrix	Inventive Principles	Principle Explanation	Selected Solution and Explanation
					Explanation: in line with the previous explanation regarding the 1st principle, to provide a better ventilation, it is better for the design to have a segmentation.
9	Padding/Lining	Device Complexity (36) >< Shape (12)	29 Pneumatics and Hydraulics	Replace lining with hydraulic material	Solution: 29 Pneumatics and Hydraulics, – Replace lining with hydraulic material **Explanation:** in order to comply with the required attribute, choosing the 29th is required. The definition of pneumatic and hydraulic means replacing the solid parts with air cushions. In this design, the cushion is added to differentiate with current product, and using a better cushion
			13 The Other Way Round	replace automatic padding system	
			28 Replace Mechanical System	Replace automatic padding system	Solution: 15 Dynamics, – inner design adjusted for pressure Explanation : To strengthen the previous principle, the cushion of the designated prosthetic should be able to adjust with user's condition, thus choosing 15th principle is the correct way in order to answer the requested attribute
			15 Dynamics	Inner design adjusted for pressure	

Based on the calculated SI and DI values, which represent respondents' satisfaction levels, the attributes were subsequently mapped into the four quadrants of the Kano model [37], quadrants 1 (Attractive), 2 (One-Dimensional), and 3 (Must-Be) were identified as having a significant contribution to user satisfaction and the functional performance of the product as it shown in Figure 2. Therefore, these three categories were prioritized for the next stage of design development. The attributes selected for design development included X1 (Functional), X3 (Elegant Appearance), X4 (Ease of Attachment), X5 (Product Quality), X6 (Comfort), X7 (Quality Standardization), X8 (Safety), X9 (Presence of Ventilation), and X10 (Presence of Padding/Lining).

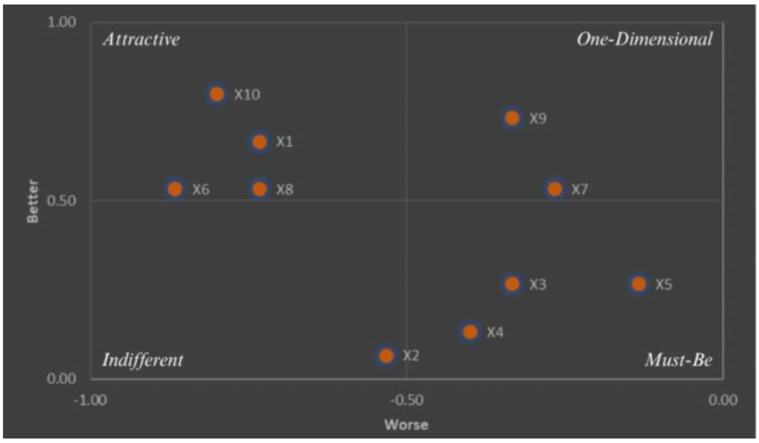

Figure 2. Kano quadrant

3.3 TRIZ

Based on the results of the SI and DI in the Kano method, the mapping of user requirement attributes and their effects on satisfaction and dissatisfaction levels was obtained. Attributes with significant SI and DI values indicate requirements that play an important role in enhancing user satisfaction. These selected attributes were subsequently integrated into the TRIZ method as the basis for formulating innovative solutions.

The results of the Kano method analysis identified nine user requirement attributes, which were subsequently integrated into the TRIZ method. The initial stage of TRIZ implementation began with the determination of the improving parameter and the worsening parameter for each attribute. The identification of these parameters aimed to reveal the technical contradictions present in the system. The selection of parameters in the TRIZ contradiction matrix is carried out by identifying the design aspects to be improved (improving parameters) and the worsening parameters, namely the aspects that must not deteriorate or change as a result of the improvement efforts applied to the improving parameters, based on the characteristics of the requirements for each attribute to be developed. Each pair of parameters was then mapped into the TRIZ contradiction matrix, which consists of 39 technical parameters. This process generated recommendations for several alternative solutions based on the 40 inventive principles [38],[39]. As an example of the application of requirement attribute No. 1, namely functional requirements, improvements in the design of prosthetic hands that resemble the shape of real hands and are capable of performing functions such as holding and grasping aim to increase the reliability parameter (27) by performing the designed functions. However, improving the reliability parameter should not result in changes to the volume of stationary objects (8) because changes in volume have the potential to interfere with the comfort and ease of use of the device when stationary.

3.4 Design Development

The design development in this study was carried out through an integrated framework combining the Kano and TRIZ methods. The inventive principles selected from the TRIZ analysis were interpreted into applicable innovative solutions, including improvements in structural configuration, geometry, functional performance, and component shape optimization. These solutions were subsequently realized in the design development process to accommodate user requirements while addressing existing technical constraints. Therefore, the proposed design represents a direct transformation of user needs identified using the Kano method into innovative technical solutions derived from TRIZ. The transformation of user's requirement to TRIZ model is shown in Table 6.

Table 6. Requirement and TRIZ principle plot

No	Requirements	TRIZ Principle	Explanation
1	Functional	Parameter change	To comply with the needs, the prosthetic should be able to fully

No	Requirements	TRIZ Principle	Explanation
			function and flexible, using the 35th principle should gives an idea in creating one.
2.	Elegant Appearance	Color change & segmentation	To differentiate and to gives feels for the prosthetic both principle could help to gives an idea how do the product should be designed.
3	Ease of Attachment	Parameter change & Universality	To help the easiness while using the prosthetic the designated product should be flexible and multi function, thus this 2 principle is chosen.
4	Product Quality	Cushion in advance	The difference between the designated product with the current product is the quality, one of the impacting factors is the cushion of the new design, by choosing the principle, the newly design should have a better cushion than the current one, it is also aligned with the previous principle
5	Comfort	Universality	Idem ditto, to give comfort, the designated design should have a high universality (multi-function)
6	Standardized Quality	The other way around	Another features in the design that will be implemented, is the ability of the product that could move freely, and it will be standardized, thus the designated principle is chosen in order to differentiate with existing product
7	Safety	Parameter change & Blessing in Disguise	Safety factor plays an important, in order to complete the requirement, both flexibility and advanced cushion and hooking system is represented in both principle
8	Ventilation	Partial/Excessive Action & Segmentation	To answer the needs of a better ventilation without sacrificing the power of the designated product, both this principle is chosen
9	Padding/Lining	Pneumatics and Hydraulics & Dynamics	Idem ditto, to fulfill the needs of padding, the designated prosthetic will use a airfilled cushion and have the ability to move freely

Using the mapping in Table 6, the final design concept, is then implemented into a three-dimensional model using *SolidWorks* software by integrating anthropometric data as the basis for dimensional determination [40]. The design process involved defining the dimensions and proportions of each component and configuring the structural layout to ensure functional performance and user comfort. *SolidWorks* was used to generate detailed three-dimensional visualizations, enabling preliminary analysis of component interactions, dimensional compatibility, and the range of motion of the mechanism.

The three-dimensional model was utilized to evaluate the feasibility and functionality of the movement mechanism and the structural integrity of the design. The resulting design is intended for users with upper-limb disabilities who have experienced transhumeral amputation. Figure 3 (a) (b) (c) below are the results of design development using *SolidWorks* software, adapting innovative principles.

(a) Isometric view (b) Side view (c) Top view

Figure 3. (a) Isometric view of transhumeral prosthesis (b) Side view of transhumeral prosthesis (c) Top view of transhumeral prosthesis

3.5 Design Validation

Design validation was conducted by presenting the results of the prosthetic hand design in the form of three-dimensional visualizations to users and prosthetic experts to obtain feasibility assessments. The evaluation was performed based on the conformity of the design with user requirement attributes previously identified through the Kano analysis. This validation stage aimed to ensure that the final design met user needs, preferences, and expectations, while also satisfying technical and functional aspects from the perspectives of both experts and individuals with upper-limb disabilities. Therefore, the validation process served as a critical evaluation phase prior to further development or large-scale production

The validation process is done to 13 respondents with 11 respondent from the previous step and 2 experts from the pilot test. 11 out of 13 respondents agrees on the proposed design, while 2 out of 13 asking for revision for the proposed design. Both of the experts, out of 11 person that agrees with the design, agreed with design. The low number of respondent in this process is the main limitation and suggestion for future research. The main feedback emphasized the need to differentiate designs based on the level of amputation, namely upper-arm (transhumeral) and forearm (transradial) amputations, as well as to adjust the design according to differences in residual limb anatomy, load-bearing points, and functional requirements. Based on that, thus the proposed design from Figure 3 is still used, and authors creates another design that focused on the development of transradial prosthetic hand design.

The respons from users and the expert provided a crucial basis for design improvements in the subsequent stage, leading to the development of two more inclusive design variants: one for transhumeral and another for transradial amputations. Thus, the validation process not only assessed the suitability of the initial design but also served as a critical step in guiding product development to be more responsive to actual user needs.

3.6 Design Improvement

Design improvements were carried out based on feedback from respondents and the prosthetics expert, resulting in the development of two more specific prosthetic variants tailored to the users' level of amputation: transradial and transhumeral. The development of these two types of designs allows for better adaptation to differences in residual anatomical structures, range of motion, support points, and user preferences for each amputation condition. The improvement efforts aimed not only to enhance functional suitability but also to ensure that the final design effectively addresses user needs.

At this steps, the TRIZ method continued to be applied as a systematic approach for design refinement. As shown in Figure 4. Modifications were made by reviewing the innovative solutions formulated in the previous stage and aligning them with the design validation results obtained from respondents and the prosthetics expert. Consequently, the design modifications were guided not only by TRIZ inventive principles but also by direct user feedback, resulting in a final design that more accurately meets the needs of individuals with hand disabilities.

(a) Isometric view (b) Side view (c) Top view

Figure 4. (a) Isometric view of transradial prosthesis (b) Side view of transradial prosthesis (c) Top view of transradial prosthesis

4. DISCUSSION

Based on the results of the prosthetic hand design development for individuals with upper-limb disabilities, the integration of the Kano and TRIZ methods proved effective in identifying user needs and generating functional design concepts. The Kano analysis successfully classified user requirements into must-be, one-dimensional, attractive, and indifferent attributes, thereby providing a clear prioritization framework for design development. The results of the Kano analysis were consistent with the initial hypothesis that product design outcomes should emphasize comfort, safety, and functionality.

The application of the Kano method identified nine key, the attribute itself are aligned from an expert judgement and a previous research. The 9 attributes that has been checked and corrected based on expert judgement, are the one that being asked to respondent, and it is found that the result itself correlate with what user needed, shown from Table 3, Table 4 and Figure 1 on Kano Quadrant. These findings indicate that user needs extend beyond basic functional aspects of prosthetic devices to include ergonomics, safety, and overall quality of user experience. The integration of Kano results into the TRIZ method yielded a significant contribution to this study, demonstrating that each category of user requirements can be systematically translated into targeted innovative solutions aligned with user expectations and design development objectives. The translated attribute from Kano to TRIZ also correlate with what the users needs, such as functionality of the design, but still maintaning the looks of the prosthesis, this is aligned with Han et al [41] on his finding regarding the relation between creativity, aesthetic and function on designing of a product.

Based on the finding from the previous section, it is known that integrating both Kano from quantitative perspective based on collected data from respondents and TRIZ model from qualitative aspect based on Kano model result, to create the designated prosthesis, really does help the researchers to identify and also solving the problem, this aligned with Rong et al [41] finding that showed Kano helps the researcher in finding innovating the product by giving not only a more efficient way on finding what the respondent wants, but also more systematic on re-creating a new yet better product . Furthermore, based on Yao's et al [42] research on redesigning an ergonomic bicycle saddle design, it is known that it is easier to find what the customer's/respondent wants on creating or recreating the newer product by aiming and finding the attractive section of the aimed product, followed by translated the needs found by Kano model to TRIZ to define how the product will be. From the prosthetic redesigning point of view, functionality remains an important part of a product, it does correlate with Widasari's finding on bionic prosthetic development [43], that focused on improving the functionality, although this paper does not focusing on producing the product, but, it aligns with the concept of focusing in functionality while designing or redesigning a product, followed by aesthetic or make up which could help boosting the confidence of the users.

The design validation process, which involved respondents with upper-limb disabilities and prosthetic experts, resulted in an approval rate 11 out of 13 respondents that agreed with the proposed design, while the other 2 asking for a revision in design to accommodate person with lower hand disability. The feedback highlighted the importance of developing prosthetic designs that are more specific to the level of amputation, leading to the differentiation of designs into transhumeral and transradial prostheses. This study contributes to the development of user-oriented prosthetic hand designs through the integration of the Kano and TRIZ methods as a systematic analytical approach. The proposed approach is effective in identifying key functional requirements, prioritizing user attributes, and formulating technical solutions that result in design outcomes aligned with user needs. This research gives a new finding in prosthetic world, by redesigning a more-needed prosthetic hand for a specific user namely Gunungkidul residents through integrating both Kano and TRIZ which complement both qualitative and quantitative aspects, although it still in design state. Future research is expected to extend the development process by fabricating physical prototypes, enabling more comprehensive testing and optimization of implementation under real user conditions.

5. CONCLUSION

This study solely proposing a newly redesign prosthetic hand for the disabled, especially people around Gunungkidul Regency although, the numbers of respondent relatively small due to scarcity of data both based on survey and government data and the finding is still in 3D model phase . By integrating both Kano and TRIZ, it is known that several attribute plays an important role in this research. Functionality, along with comfort and safety, become the most prominent attribute identified in this research followed by the likes of ease of use, and aesthetics. This finding suggests that there are several problems with existing products on the market. Using the newly-found needs using Kano, and to fully understand the latent needs of user, it is being translated into TRIZ's inventive principle, thus helping on to fully understand what and how researcher should react and design the prosthetic hands. This design than being consulted to expert, which has been working in the same field namely prosthetic and orthopedic, and to the targeted customers or respondent, in this case is the disabled people in Gunungkidul, and found that it match with their needs and requirement from expert although there are several points from expert such as to differentiate types of prosthetic hand into 2 types : a) transhumeral and b) transradial. The transhumeral design, was the first design that based on the Kano_TRIZ integration, while after the validation process it is found that there are another insight given by respondent regarding disabled condition, thus, the transradial design emerge, using the same attribute like the former design. The innovative solutions generated were then applied to the design of the prosthetic hand using SolidWorks software, resulting in a form that aligns with user expectations.

Based on that finding, the 3D prosthesis model created in this research is accepted by the respondent, although in a small group. This claim is based on the finding that 11 out of 13 accepted the prosthesis design. Not only that, although there are revision given by respondents, it gives a new insight in creating a new prosthetic design, thus the second 3D model appeared, which focused on another types of hand disability, namely the transradial prosthetic design. Future research of this paper should focus on several aspects such manufacturing process to material testing on the design that could create a better yet affordable prosthetic hand especially for the disabled people around Yogyakarta.

REFERENCES

[1] C. Herneth, A. Ganguly, and S. Haddadin, "Functional kinematic and kinetic requirements of the upper limb during activities of daily living: a recommendation on necessary joint capabilities for prosthetic arms," *2024 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 191–198, 2024, [Online]. Available: https://api.semanticscholar.org/CorpusID:271957484

[2] L. C. Smail, C. Neal, C. Wilkins, and T. L. Packham, "Comfort and function remain key factors in upper limb prosthetic abandonment: findings of a scoping review," *Disabil. Rehabil. Assist. Technol.*, vol. 16, no. 8, pp. 821–830, Nov. 2021, doi: 10.1080/17483107.2020.1738567.

[3] S. Ardianuari, E. Pasaribu, G. Amannullah, A. Prana, and E. Widiyanta, "Assistive technology unmet need in Indonesia: challenges and opportunities for enhancing equitable access," *Disabil. Rehabil. Assist. Technol.*, vol. 19, no. 5, pp. 2026–2037, Jul. 2024, doi: 10.1080/17483107.2023.2244996.

[4] A. Caldas, D. Matos, A. de Eyto, and N. Martins, "Redefining Prosthetic Needs: Insights from Individuals with Upper Limb Loss—A Systematic Review," *Sensors*, vol. 26, no. 2, p. 734, Jan. 2026, doi: 10.3390/s26020734.

[5] Government of Gunungkidul Regency, "General Overview of Gunungkidul Regency," https://gunungkidulkab.go.id/gambaran-umum.

[6] G. R. Department of Health, "Overview of Gunungkidul Regency," https://dinkes.gunungkidulkab.go.id/about.

[7] S. C. Henao, S. Cuartas-Escobar, S. Salazar-Salgado, and A. M. Posada-Borrero, "Upper-limb prosthetic requirements from the healthcare providers, end-users and relatives' perspectives," *Journal of Hand Therapy*, vol. 39, no. 1, pp. 147–155, Jan. 2026, doi: 10.1016/j.jht.2025.04.006.

[8] R. Collu, E. Ferrazzano, V. Murgia, C. Salis, and M. Barbaro, "The Technological and Psychological Aspects of Upper Limb Prostheses Abandonment: A Narrative Review," *Prosthesis*, vol. 7, no. 6, p. 167, Dec. 2025, doi: 10.3390/prosthesis7060167.

[9] M. Mohebbian *et al.*, "A Comprehensive Review of Myoelectric Prosthesis Control," Jun. 2021. doi: 10.48550/arXiv.2112.13192.

[10] T. Triwiyanto, S. Luthfiyah, L. Forra Wakidi, and B. Utomo, "Design and Implementation of a Low-Cost and Functional Prosthetic Hand Using 3D Printing Technology for a Member of the Association of Physical Disabilities Indonesia," *Frontiers in Community Service and Empowerment*, vol. 2, no. 3, pp. 60–65, Sep. 2023, doi: 10.35882/ficse.v2i3.51.

[11] F. Cordella *et al.*, "Literature Review on Needs of Upper Limb Prosthesis Users," *Front. Neurosci.*, vol. 10, May 2016, doi: 10.3389/fnins.2016.00209.

[12] N. Ju, K.-H. Lee, M.-O. Kim, and Y. Choi, "A User-Driven Approach to Prosthetic Upper Limb Development in Korea," *Healthcare*, vol. 9, no. 7, p. 839, Jul. 2021, doi: 10.3390/healthcare9070839.

[13] R. I. Flores-Luna, J. M. Dorador-González, and A. Espinosa-Bautista, "Prosthesis Analysis Based on TRIZ," *Key Eng. Mater.*, vol. 572, pp. 135–138, Sep. 2013, doi: 10.4028/www.scientific.net/KEM.572.135.

[14] J. A. Teresi, X. Yu, A. L. Stewart, and R. D. Hays, "Guidelines for Designing and Evaluating Feasibility Pilot Studies," *Med. Care*, vol. 60, no. 1, pp. 95–103, Jan. 2022, doi: 10.1097/MLR.0000000000001664.

[15] E. R. van Teijlingen and V. Hundley, "The importance of pilot studies," in *social research UPDATE*, vol. 35, United Kingdom: Department of Sociology University of Surrey Guildford, 2001.

[16] M. A. Bujang, E. D. Omar, D. H. P. Foo, and Y. K. Hon, "Sample size determination for conducting a pilot study to assess reliability of a questionnaire," *Restor. Dent. Endod.*, vol. 49, no. 1, 2024, doi: 10.5395/rde.2024.49.e3.

[17] D. F. Polit, C. T. Beck, and S. V. Owen, "Is the CVI an acceptable indicator of content validity? Appraisal and recommendations," *Res. Nurs. Health*, vol. 30, no. 4, pp. 459–467, Aug. 2007, doi: 10.1002/nur.20199.

[18] V. Zamanzadeh, A. Ghahramanian, M. Rassouli, A. Abbaszadeh, H. Alavi-Majd, and A.-R. Nikanfar, "Design and Implementation Content Validity Study: Development of an instrument for measuring Patient-Centered Communication," *J. Caring Sci.*, vol. 4, no. 2, pp. 165–178, Jun. 2015, doi: 10.15171/jcs.2015.017.

[19] G. H. Poll, M. Mayes, and J. Petru, "Evidence to support test interpretation: Evaluating the content validity of a new item set for the Transition Pragmatics Interview," *Int. J. Speech. Lang. Pathol.*, vol. 26, no. 6, pp. 809–819, Nov. 2024, doi: 10.1080/17549507.2023.2287424.

[20] M. Li, Q. Gao, and T. Yu, "Kappa statistic considerations in evaluating inter-rater reliability between two raters: which, when and context matters," *BMC Cancer*, vol. 23, no. 1, p. 799, Aug. 2023, doi: 10.1186/s12885-023-11325-z.

[21] Z. Zhang *et al.*, "Automated Classification of User Needs for Beginner User Experience Designers: A Kano Model and Text Analysis Approach Using Deep Learning," *AI*, vol. 5, no. 1, pp. 364–382, Feb. 2024, doi: 10.3390/ai5010018.

[22] H. Xu and H. Song, "Key Factors Influencing Chinese Consumers' Demand for Naturally Dyed Garments: Data Analysis through KJ Method and KANO Model," *Sustainability*, vol. 16, no. 3, p. 1189, Jan. 2024, doi: 10.3390/su16031189.

[23] Y. Tandiono and H. Rau, "An Enhanced Model Using the Kano Model, QFDE, and TRIZ with a Component-Based Approach for Sustainable and Innovative Product Design," *Sustainability*, vol. 15, no. 1, p. 527, Dec. 2022, doi: 10.3390/su15010527.

[24] N. Kano, N. Seraku, F. Takahashi, And S. Tsuji, "Attractive Quality and Must-Be Quality," *Journal of The Japanese Society for Quality Control*, vol. 14, no. 2, pp. 147–156, 1984, doi: 10.20684/quality.14.2_147.

[25] Y. Tandiono and H. Rau, "An Enhanced Model Using the Kano Model, QFDE, and TRIZ with a Component-Based Approach for Sustainable and Innovative Product Design," *Sustainability*, vol. 15, no. 1, p. 527, Dec. 2022, doi: 10.3390/su15010527.

[26] Z. Zhang *et al.*, "Automated Classification of User Needs for Beginner User Experience Designers: A Kano Model and Text Analysis Approach Using Deep Learning," *AI*, vol. 5, no. 1, pp. 364–382, Feb. 2024, doi: 10.3390/ai5010018.

[27] Y. Borgianni, L. Fiorineschi, F. S. Frillici, and F. Rotini, "The process for individuating TRIZ Inventive Principles: Deterministic, stochastic or domain-oriented?," *Design Science*, vol. 7, 2021, doi: 10.1017/dsj.2021.12.

[28] Z. Guo *et al.*, "Exploring synergies between AIGC and TRIZ in the optimisation of road cone design through integrated innovation methods," *Journal of Engineering Design*, vol. 36, no. 2, pp. 256–275, Feb. 2025, doi: 10.1080/09544828.2024.2373038.

[29] G. Santoso *et al.*, "TRIZ-based method for developing a conceptual laparoscopic surgeon's chair," *Cogent Eng.*, vol. 11, no. 1, Dec. 2024, doi: 10.1080/23311916.2023.2298786.

[30] Y. Tandiono and H. Rau, "An Enhanced Model Using the Kano Model, QFDE, and TRIZ with a Component-Based Approach for Sustainable and Innovative Product Design," *Sustainability*, vol. 15, no. 1, p. 527, Dec. 2022, doi: 10.3390/su15010527.

[31] Hardi and L. Terbit, *Statistika Untuk Penelitian*. 2025.

[32] M. S. B. Yusoff, "ABC of Content Validation and Content Validity Index Calculation," *Education in Medicine Journal*, vol. 11, no. 2, pp. 49–54, Jun. 2019, doi: 10.21315/eimj2019.11.2.6.

[33] L. L. Davis, "Instrument review: Getting the most from a panel of experts," *Applied Nursing Research*, vol. 5, no. 4, pp. 194–197, Nov. 1992, doi: 10.1016/S0897-1897(05)80008-4.

[34] J. Cohen, "A Coefficient of Agreement for Nominal Scales," *Educ. Psychol. Meas.*, vol. 20, no. 1, pp. 37–46, Apr. 1960, doi: 10.1177/001316446002000104.

[35] J. R. Landis and G. G. Koch, "The Measurement of Observer Agreement for Categorical Data," *Biometrics*, vol. 33, no. 1, p. 159, Mar. 1977, doi: 10.2307/2529310.

[36] E. Sauerwein, F. Bailom, K. Matzler, and H. Hinterhuber, "The Kano Model: How to Delight Your Customers," *International Working Seminar on Production Economics*, vol. 1, Jan. 1996.

[37] C. Berger *et al.*, "Kano's Methods For Understanding Customer-Defined Quality," 1993. [Online]. Available: https://api.semanticscholar.org/CorpusID:6905614

[38] Genrich Altshuller, *The Innovation Algorithm TRIZ, Systematic Innovation and Technical Creativity*. WORCESTER, MA: Technical Innovation Center, Inc., 2007.

[39] Karen Gadd, *TRIZ For Engineers: Enabling Inventive Problem Solving*. United Kingdom: John Wiley & Sons, Ltd, 2011.

[40] Antropometri Indonesia, "Data Antropometri," https://antropometriindonesia.org/index.php/detail/artikel/4/10/data_antropometri.

[41] Hui Rong, Wei Liu, Jin Li, and Ziqian Zhou, "Product innovation design process combined Kano and TRIZ with AD: Case study," *PLoS One*, vol. 19, no. 3, pp. 1–22, 2024.

[42] K. C. Yao *et al.*, "Ergonomics in Bicycle Saddle Design: Application of TRIZ Innovation System Method with IPA-Kano Model Validation," *Designs (Basel).*, vol. 8, no. 6, Dec. 2024, doi: 10.3390/designs8060114.

[43] Edita Rosana Widasari, "Pengoptimalan Gerakan Lengan Prostetik Bionik Menggunakan Decision Based Velocity Ramp," *Jurnal Teknologi Informasi dan Ilmu Komputer*, vol. 11, no. 3, pp. 617–624, Jun. 2025.

DECLARATION OF AI-TOOL USAGE

The authors declare that AI tools were used during the preparation of this manuscript. Specifically, AI-assisted tools were employed to assist in paraphrasing and improving the clarity of the text and summarizing selected literature for easier incorporation into the manuscript. The authors confirm that all scientific ideas, data analysis, and conclusions presented in this manuscript were developed independently by the authors, without reliance on AI-generated content.