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Innovative Redesign of Traditional Stilts (Egrang)

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Abstract

Traditional stilts (*egrang*), once a popular form of children's play in Indonesia, are now rarely used due to safety issues, poor durability, and limited adaptability to modern needs. This research focuses on developing a redesigned stilt that features an extendable stilt pole for adjustable height and sturdy, non-slip footrests, using an integrated approach of Quality Function Deployment (QFD) and the Theory of Inventive Problem Solving (TRIZ). QFD was used to capture and translate consumer needs into technical requirements. TRIZ was applied to solve design contradictions, while AHP determined the best alternative concept. The newly designed stilt was specifically engineered to meet user needs for lightweight construction, portability, strength, appropriate size, and operational safety. This study demonstrates that combining QFD and TRIZ provides a comprehensive, user-centered framework for innovative redesigning traditional play equipment, supporting safer and more enjoyable active play for children.

Keywords: QFD; TRIZ; Egrang; Traditional stilts; Product design

1. Introduction

Traditional games are an essential part of Indonesia's cultural heritage, reflecting communal spirit, creativity, and intergenerational knowledge transfer. Among these, egrang (traditional stilts) represent a game that not only challenges children's physical strengths, such as balance and coordination, but also fosters teamwork and resilience. Egrang (traditional stilts) is a well-known traditional Indonesian game in which players walk on two long poles, typically made of bamboo or wood, equipped with footrests that allow the user to balance and move while elevated above the ground, as shown in Figure 1.a. The poles—usually about 1.5 to 3 meters in length—have foot platforms positioned between 30 cm to 1 meter high, depending on the player's skill and the game's purpose. To play, users step securely onto the footrests and grip the upper part of the poles with both hands, maintaining their balance as they move forward in a rhythmic pattern.

However, dramatic changes in childhood leisure patterns have occurred in recent decades, primarily due to proliferation in digital technology. Children increasingly favor screen-based activities, resulting in decreased opportunities for engaging in physically demanding and socially interactive games. The cultural importance of egrang is compounded by their use in festivals, community gatherings, and as a practical tool in the past for navigating flooded fields. Despite these benefits, surveys reveal that traditional stilts suffer from safety limitations, heaviness, and a lack of modern ergonomic features. Parents and children are understandably concerned about injury risks, and as a result, egrang are less present in daily play.

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(a) (b)

Figure 1 (a) traditional stilts (egrang) and (b) An egrang develop by Rinawati and Dei (2015)

Reinvigorating traditional games such as egrang is crucial, not only to preserve intangible cultural heritage but also to address the alarming trend of physical inactivity among Indonesian children. According to the World Health Organization (WHO), regular moderate- to vigorous-intensity physical activity is essential for healthy development. Embedding traditional play into contemporary lifestyles can confront issues of declining motor skills, poor emotional regulation, and weakening social bonds. Previous studies show that participation in traditional games significantly boosts social intelligence, emotional well-being, and cooperative skills among children. Previous study characterizes traditional games strengthen muscles, improve cardiovascular health and flexibility, and promote overall fitness, while also reducing stress [1]. Another research [2] demonstrated that incorporating traditional games into daily routines significantly boosts children's social intelligence, especially skills in communication, teamwork, and conflict resolution. Ozcan & Sakiz [3] found that participation in traditional child games directly improves social-emotional competencies, cooperation, and inclusivity in school contexts.

To facilitate a resurgence of traditional play, the physical product itself must evolve to meet the expectations and requirements of modern users. This study builds upon the folding stilt prototype developed by Rinawati and Dei [4]. Their design, shown in Figure 1b, featured innovations such as hinged foldability and adjustable footrest heights, enabled by an integrated application of ECQFD, TRIZ, and AHP methods. While these features enhanced flexibility and adaptability, the prototype still presented technical challenges, particularly in terms of structural strength, overall weight, and user safety. To address this drawback, this study aims to evaluate and improve that design. By integrating robust engineering methodologies—QFD and TRIZ—the redesign strives to produce stilts that are safe, lightweight, ergonomic, and culturally relevant, ensuring their place in both play and preservation for future generations.

2. Methodology

The research employed an integrated framework involving two major steps: (1) identifying consumer needs through QFD and (2) generating design alternatives using TRIZ. This research adopting integrated QFD and TRIZ approach as applied by previous studies [5]–[7].

2.1. Customer Needs Identification using QFD

QFD is a structured, customer-driven methodology for product and process development, widely applied to ensure that customer requirements are systematically translated into prioritized engineering characteristics for maximum user satisfaction. Developed in Japan in the late 1960s by Yoji Akao, QFD centers on capturing the "Voice of the Customer" (VOC) and mapping it to technical solutions throughout the product's lifecycle, most often through a tool known as the House of Quality (HOQ). The HOQ matrix systematically compares customer needs with engineering solutions, measures the strength of their relationships, and helps product teams focus on the most critical attributes to drive competitive differentiation and customer value [8].

QFD method was utilized to translate user requirements into technical characteristics that designers can act upon. QFD ensures that the final design aligns with consumer expectations. Forty respondents—parents of children aged 6–9 years—were surveyed using a structured questionnaire to determine their perceptions and preferences.

The QFD analysis followed the traditional “House of Quality” structure consisting of four steps:

- Identify and prioritize customer requirements (“Whats”).
- Define corresponding technical characteristics (“Hows”).
- Determine the relationship matrix between “Whats” and “Hows”.
- Evaluate and rank technical priorities.

According to Masui et al. [9], this process consists of four phases:

2.1.1. Phase I

In Phase I, the customer’s voice for a product is translated into technical environmental characteristics to clarify the positioning of these customer requirements. Customers assign weights to each requirement: a value of 5 for very important, 3 for important, and 1 for less important. Designers also evaluate the strength of the relationship between each customer requirement and technical characteristic ($a_{i.j}$) by assigning 5 if the relationship is very strong, 3 for strong, 1 for not very strong, and 0 if there is no relationship.

2.1.2. Phase II

In Phase II, the relationship between technical characteristics and product components is clarified. Designers assess the linkage between each technical characteristic and product component ($b_{j.k}$), using the same scoring format as in Phase I: 5 for very strong, 3 for strong, 1 for not very strong, and 0 if there is no relationship.

2.1.3. Phase III

Phase III involves calculating the impact of various design changes based on technical characteristics. Designers typically develop several design alternatives. There are two approaches for designers to determine design focus: concentrating on customer requirements and evaluating the most critical product components calculated in Phase II. The improvement value of environmental technical characteristics (mr_j) can be calculated using Equation 1.

$$mr_j = \frac{\sum_{k=1}^{k}(b_{j1.k1}c_{j.k})}{\sum_{k=1}^{k}(b_{j.k})}\ (j = 1, 2, 3, \dots, j) \qquad \dots\dots \quad (1)$$

Where,
mr_j =value of improvement in environmental technical characteristic
k =number of components
$b_{j1.k1}$=relationship value between environmental technical characteristic j and component k after change
$b_{j.k}$ =relationship value between environmental technical characteristic j and component kb_j
$c_{j.k}$ =improvement value of environmental technical characteristic j on component k, 0 if no improvement can be made, 1 if improvement is possible

2.1.4. Phase IV

The purpose of Phase IV is to translate the effects of design changes from technical characteristics back into customer requirements. The weight values for customer requirements and the relationship values between customer requirements and technical characteristics are the same as those used in Phase I. The improvement in value of customer requirements (vr_i) can be calculated using Equation 2.

$$vr_i = \frac{\sum_{j=1}^{j}(mr_j a_{i.j})}{\sum_{j=1}^{j}(a_{i.j})}\ (i = 1, 2, 3, \dots, i) \qquad \dots\dots\dots\dots \quad (2)$$

Where,
vr_i =improvement value of customer requirements
mr_j=improvement value of technical characteristics
a_ij =relationship between customer requirement i and technical characteristic j, obtained from Phase I

2.2. Concept Development through TRIZ

TRIZ, or the Theory of Inventive Problem Solving, has rapidly become a fundamental method both in academic research and industry for tackling complex and conflicting problems in product development [5], [10], [11]. Originating from the pioneering work of Genrich Altshuller in 1946, TRIZ was derived from a comprehensive analysis of interdisciplinary invention patents, revealing repeated problem-solving patterns across industries. This technique includes the development of the contradiction matrix—an organized tool for mapping technical conflicts—and the identification of 40 inventive principles that guide creative approaches to resolving these contradictions systematically.

The TRIZ framework has since been refined by multiple scholars and practitioners, including Ilevbare and others, who codified both the contradiction matrix, detailed the 40 principles, and expanded TRIZ with new models and analytical tools for wider engineering and business applications [5], [10], [11]. Its versatility enables innovators to identify underlying system-level dilemmas and generate solutions not only for engineering but also for fields as diverse as tourism, digital commerce, education, and the sharing economy.

By addressing innovation at the root cause and system level, TRIZ strikes a balance between apparently conflicting goals in design, such as maximizing safety while minimizing weight or cost, leading to more robust and inventive products. Numerous case studies and design projects have demonstrated its effectiveness in supporting systematic ideation and proven design advancement [5], [10], [11].

3. Results and Discussion

3.1. Identification and Translation of Customer Needs using QFD

The results of the questionnaire distributed to respondents indicate that customers require stilts (egrang) that are lightweight, portable, strong, appropriately sized, constructed from safe and durable materials, and secure to use. The traditional stilt design proposed by Rinawati and Dei (2015), hereafter referred to as Egrang_1, was evaluated by 40 respondents. Of these, 90% stated that Egrang_1 is heavy, lacks stability due to insufficient hinge strength at connection points, and poses an injury risk because the footrest is made of steel plate material, which can easily cause harm to the user’s feet.

3.1.1. Phase I

The first phase of QFD aims to rank the most critical environmental technical characteristics for the product by analyzing the relationship between customer needs and technical attributes, weighted by the importance scores assigned by customers. Table 1 presents the results of the QFD Phase I calculation for the egrang.

The total score is derived by multiplying the customer weight by the relationship value between each customer need and technical characteristic for each technical attribute. The relative weight for Phase I is then obtained by dividing each technical attribute’s total score by the sum of scores across all attributes. Based on Table 1, it can be concluded that mass, strength, ergonomics, and low volume are the most critical technical criteria for fulfilling customer needs regarding lightness, strength, good fit, and portability in a stilt.

3.1.2. Phase II

The relative weights from Phase I are used to determine the importance of each product component in meeting customer needs according to their priority. The stilt’s components in this research include the stilt pole, handgrip, footrest, sole, and supporting structures. The total score for each component is calculated by multiplying the relative weight from Phase I by the relationship value between each technical attribute and product component. The results of QFD Phase II are shown in Table 2. Based on these results, the most important component is the stilt pole, followed by the footrest, handgrip, supporting structure, and sole.

Table 1 QGD of Egrang phase 1

No	Customer Needs	Weight	Technical Characteristics						
			Mass	Volume	Strength	Ergonomics	Hazardous Chemical Content	Product Lifespan	Usage Safety
1	Light	5	5	5	5	1	0	0	1
2	Portable	3	5	5	0	1	0	0	1
3	Strong	5	3	1	5	5	0	3	3
4	Appropriate dimension	3	3	5	3	5	0	0	3
5	Made from safe materials	5	1	1	1	3	5	1	5
6	Durable	3	1	1	5	1	3	5	0
7	No sharp edges	5	1	1	1	3	0	0	5
Total score			77	73	84	81	34	35	82
Relative weight Phase I			0.165	0.157	0.180	0.174	0.073	0.075	0.176
Rank			4	5	1	3	7	6	2

Table 2 QGD of Egrang phase 2

No	Customer Needs	Weight	Technical Characteristics				
			Stilt Pole	Handgrip	Footrest	Sole	Supporting
1	Mass	0.165	5	0	3	0	3
2	Volume	0.157	5	3	3	0	1
3	Strength	0.180	5	3	5	0	3
4	Ergonomics	0.174	5	5	5	3	3
5	Hazardous Chemical Content	0.073	5	1	3	0	0
6	Product Lifespan	0.075	5	3	5	3	3
7	Usage Safety	0.176	5	5	5	3	5
Total score			5.000	3.058	4.210	1.275	2.820
Relative weight Phase I			0.306	0.187	0.257	0.078	0.172
Rank			1	3	2	5	4

3.1.3. Phase III

Based on the results from Phases I and II, there are two possible focal points for the design: prioritizing either voice of the customer or the most critical product components. Both design options share similar characteristics and advantages, with the primary difference being portability—Option 1 is portable, while Option 2 is not. Table 3 summarizes the technical attributes for both design options, combining several key technical criteria.

Table 3 Key Characteristics of Stilt Design Options

Option 1	Option 2
Reduce stilt mass	Reduce stilt mass
Increase stilt strength	Increase footrest and supporting strength
Size based on children's anthropometry	Manufacture product components according to children's anthropometry
Reduce stilt volume	Enhance operational safety on product components
Improve stilt operational safety	Reduce use of hazardous chemicals used for paintings
Reduce use of hazardous chemicals used for paintings	

Using equation (1), the improvement value (*mr*) for each technical characteristic from the new design is calculated. The *mr* values for each technical attribute from Options 1 and 2 are displayed in Tables 4 and 5, respectively.

Table 4 QFD of Egrang Phase 3 for Option 1

No	Environmental Customer Needs	Relative Weight Phase I	Stilt Pole	Hand Grip	Footrest	Sole	Supporting	Total Score	Mr
1	Mass	0.165	5	3	3	3	5	19	1.73
2	Volume	0.157	5	3	3	0	3	14	0.93
3	Strength	0.180	5	5	5	3	5	23	1.43
4	Ergonomics	0.174	5	5	5	3	3	21	1.10
5	Hazardous Chemical Content	0.073	5	0	0	0	0	5	0.56
6	Product Lifespan	0.075	3	0	3		0	6	1.2
7	Usage Safety	0.176	5	5	5	3	5	23	1.28

Table 5 QFD of Egrang Phase 3 for Option 2

No	Environmental Customer Needs	Relative Weight Phase I	Stilt Pole	Hand Grip	Footrest	Sole	Supporting	Total Score	mr
1	Mass	0.2288	5	3	3	3	3	17	1.55
2	Volume	0.1102	5	3	3	1	3	15	1.00
3	Strength	0.2203	5	1	3	3	5	17	1.06
4	Ergonomics	0.2076	5	5	5	3	3	21	1.40
5	Hazardous Chemical Content	0.0381	5	0	0	0	0	5	0.56
6	Product Lifespan	0.0636	3	0	3	0	0	6	1.20
7	Usage Safety	0.1314	5	5	5	5	5	25	1.39

Subsequent calculations in QFD Phases III and IV further quantify customer value improvements resulting from the design changes, as shown in Tables 6 and 7 for each option, supporting a transparent and evidence-based design decision process. Based on both tables, it can be seen that the total value of the effect of improvement on customer requirements for option 1 is 72.17, and for option 2 is 70.48, thus it can be concluded that option 1 is better.

The aspects of improvement implemented in the design according to the QFD results include reducing the stilt's mass, increasing the stilt's strength, sizing based on children's anthropometry, reducing stilt volume, increasing the safety of stilt operation, and reducing the use of hazardous chemicals.

Table 6 QFD Phase 4 for Option 1

No	Customer Needs	Customer Weight	Technical Characteristics							*vri*	Effect of Customer Improvement
			Mass	Volume	Strength	Ergonomics	Hazardous Chemical Content	Product Lifespan	Usage Safety		
1	Light	3	5	3	3	0	0	0	3	2.43	7.29
2	Portable	3	5	5	0	3	0	0	3	2.54	7.61
3	Strong	5	1	0	5	5	0	3	5	2.95	14.76
4	Ergonomics	3	3	3	5	1	0	3	0	2.57	7.70
5	Made from Safe Material	5	1	1	1	5	5	3	3	2.46	12.31
6	Durable	5	1	1	5	0	5	5	0	2.42	12.08
7	No Sharp or Pointed Edges	5	1	1	3	1	5	0	5	2.08	10.40
mr			1.73	0.93	1.44	1.11	0.56	1.20	1.28	8.24	
Total										17.45	72.17

Table 7 QFD Phase 4 for Option 2

No	Customer Needs	Customer Weight	Technical Characteristics							vri	Effect of Customer Improvement
			Mass	Volume	Strength	Ergonomics	Hazardous Chemical Content	Product Lifespan	Usage Safety		
1	Light	3	5	3	3	0	0	0	3	2.25	6.74
2	Portable	3	5	5	0	3	0	0	3	2.61	7.84
3	Strong	5	1	0	5	5	0	3	5	2.93	14.63
4	Ergonomics	3	3	3	5	1	0	3	0	2.37	7.12
5	Made from Safe Material	5	1	1	1	5	5	3	3	2.62	13.11
6	Durable	5	1	1	5	0	5	5	0	2.21	11.05
7	No Sharp or Pointed Edges	5	1	1	3	1	5	0	5	2.00	10.00
mr			1.73	1.55	1.00	1.06	1.40	0.56	1.20	1.39	8.15
Total										16.99	70.48

3.2. Identification of Innovative Design Alternatives Using the TRIZ Method

TRIZ method was applied to address design contradictions identified in QFD. The major contradictions were increasing strength tends to increase weight (conflict between durability and portability) and improving stability tends to reduce compactness (conflict between safety and portability).

The core objective of applying TRIZ is to identify contradictions inherent in each problem and match these issues to corresponding parameters defined by the 39 engineering parameters in the TRIZ contradiction matrix. In the development of the stilt (egrang), the following contradictions were identified (with # representing the TRIZ parameter number).

- Contradiction 1: Enhancing strength (#14) negatively impacts the weight of the moving object (#1).
- Contradiction 2: Increasing the volume of the moving object (#7) negatively affects both the harmful effects generated by the object (#31) and the stability of the object (#13).

Table 8 Contradictions and Related Creative Solutions

Contradiction	Parameter to Improve	Parameter to Worsen	Relevant TRIZ Creative Solution
1	Strength (#14)	Weight of moving object (#1)	#1 Segmentation – Produce stilts with components that can be easily detached #8 Anti-weight – Not applicable #15 Dynamic – Make stilts flexible and adjustable according to user needs
2	Volume of moving object (#7)	Object-generated harmful (#31) Stability of the object (#13)	#17 Another dimension – Not applicable #2 Taking out – Not applicable #1 Segmentation – Use easily detachable components #28 Mechanic substitution – Not applicable #10 Preliminary action – Not applicable #1 Segmentation – Develop portable stilts #39 Inert atmosphere – Not applicable

Based on Table 8, it can be concluded that the solution to the contradictions in the stilt design is to use composite materials, incorporate dynamic features, ensure adjustability to user needs, and design components to be easily detachable. From the TRIZ creative solutions perspective, the stilt should utilize materials that achieve both lightness and strength. The recommended material is a combination of aluminum and hard plastic. The previous design (Egrang_1) used composite material consisting of bamboo, fiber, and epoxy connected with a steel pole. However, this material presents some drawbacks when used with the connection system proposed in this design.

The improved design is shown in Figure 2. The frame joints in the new stilt design employ quick-release systems, spring-loaded buttons, and integrated locking mechanisms. These connections allow for tool-less assembly, folding, and secure attachment of the pole and footrest components. The main types of connectors include spring-ball pins that lock in place with a click.

The connector system is designed with metal connectors that use a combination of spring-loaded push buttons, quick-release levers, and locking collars. These connectors are made primarily from durable metals such as aluminum, ensuring strength, corrosion resistance, and long-term reliability. The push-button system enables users to securely attach and detach the pole or folding mechanism with an audible click. Quick-release levers allow for easy adjustment and folding, making the stilts portable and versatile. Locking collars keep the components tightly fitted, preventing wobbling or accidental release during use.

For the handgrip, foam covers the section of the stilt pole used for gripping. The footrest and supporting components are made from plastic/ polymer ABS to ensure light weight, strength, and resistance to impact and outdoor weather. The surface of the footrest is fitted with a textured or anti-slip material to ensure safety for children.

These innovations address both the structural challenges and user experience issues identified in the TRIZ contradiction analysis, resulting in a versatile, strong, and safe stilt product that meets modern user requirements.

Figure 2 Improved design of traditional stilts (egrang)

Compared with the traditional model and previous design of Egrang_1, the redesigned stilts, shown in Figure 2. demonstrated significant improvements in portability, ergonomics, and user safety. The integration of QFD ensured that user needs directly influenced design specifications, TRIZ provided innovative solutions to technical trade-offs. These results reinforce findings from prior studies (e.g., Caligiana et al., 2017; Vinodh et al., 2014) showing that integrating QFD and TRIZ improves product design quality and innovation capability.

4. Conclusion

This research demonstrates the value of systematic, user-centered redesign for traditional play equipment, exemplified by the innovative stilt (egrang) developed through the integration of QFD and TRIZ. By translating detailed consumer insights into engineering specifications, and creatively addressing technical contradictions in the design, the new foldable stilt model achieves substantial advances in safety, portability, material efficiency, and ergonomic fit.

Compared to traditional models and previous prototypes, the improved stilt offers a product that is both culturally meaningful and practically usable, supporting a healthy, active lifestyle among children. The adoption of composite materials, modular connections, and versatile adjustment mechanisms responds directly to modern user demands while respecting traditional play contexts. Ultimately, this design encourages ongoing participation in movement-based, socially constructive activities.

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