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Design, Development, And Usability Evaluation Of Recyclable-Material Rolling Beds For Safer, Sustainable, And Space-Efficient Evacuation Centers

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Abstract

This study designed, developed, and evaluated a rolling bed made from recyclable materials intended to improve sleeping conditions in evacuation centers. The study addressed the need for clean, elevated, movable, affordable, and space-efficient sleeping facilities in temporary shelters where evacuees often sleep on mats, cardboard, benches, or directly on the floor. A design and development research approach with a descriptive-evaluative component was employed. The prototype consisted of a recycled-clothes top layer, a foam middle layer, a recycled tarpaulin bottom layer, a sturdy frame, and caster wheels with locking mechanisms. It was evaluated in terms of material suitability, functionality, durability, safety, comfort, mobility, space efficiency, hygiene and maintenance, sustainability, affordability, and overall usability. Results showed that the materials were highly suitable, with an overall mean of 4.51. The prototype obtained a grand mean of 4.53, interpreted as highly acceptable. The highest-rated dimension was sustainability and affordability, followed by comfort, hygiene, and maintenance. Durability received the lowest rating but remained highly acceptable, indicating the need for structural reinforcement, load testing, and long-term field evaluation. Findings suggest that the recyclable-material rolling bed is a feasible, low-cost, and environmentally responsible innovation that may improve comfort, hygiene, mobility, and dignity in evacuation-center settings.

Keywords: *Recyclable materials; rolling bed; evacuation centers; disaster preparedness; sustainable design; temporary shelter*

Introduction

Evacuation centers serve as temporary shelters for families and individuals displaced by typhoons, floods, earthquakes, fires, storm surges, and other emergencies. In the Philippines, evacuation facilities are commonly public schools, gymnasiums, barangay halls, and multipurpose centers that were not originally designed for prolonged human occupancy. Consequently, evacuees often experience overcrowding, limited privacy, inadequate sanitation,

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restricted mobility, and uncomfortable sleeping arrangements. Tsioulou et al. (2021) emphasized that schools used as evacuation shelters must be evaluated not only for structural safety but also for accessibility, service capacity, and suitability for human habitation.

A recurring concern in evacuation-center management is the absence of durable, movable, hygienic, and space-saving sleeping facilities. Many evacuees sleep on mats, cardboard, benches, or directly on the floor, exposing them to dirt, moisture, insects, cold surfaces, and possible disease transmission. Such conditions may be particularly difficult for children, older persons, pregnant women, persons with disabilities, and individuals with health concerns. Ramos et al. (2015) reported that overcrowding and health-service gaps were evident in evacuation centers following Typhoon Haiyan, demonstrating the need to improve the overall living conditions of displaced populations.

Sleeping conditions also influence physical comfort, rest, and well-being. Kawano et al. (2016) found an association between shelter crowding and sleep disturbance among disaster evacuees. Similarly, Hamanishi (2021) showed that emergency sleeping equipment should be assessed not only for portability and cost but also for comfort and body support. These findings imply that evacuation-center equipment must address both logistics and human dignity.

Sustainable design provides an opportunity to develop low-cost emergency shelter furniture using recyclable and repurposed materials. Recycled textiles, tarpaulin, reclaimed wood, repurposed metal, and other recoverable materials can be transformed into functional disaster-response equipment. Moreno-Sierra et al. (2020) demonstrated the potential of recycled plastics in emergency shelter prototypes, while Pei et al. (2024) emphasized that circular design in furniture development supports material recovery, product-life extension, modularity, repairability, and reduced use of virgin materials.

This study is anchored in the need to integrate disaster preparedness, circular economy principles, and user-centered design. It aimed to design, develop, and evaluate a rolling bed made of recyclable materials for safer, more sustainable, and space-efficient evacuation centers. The study contributes to SDG 3 on good health and well-being, SDG 11 on sustainable cities and communities, SDG 12 on responsible consumption and production, and SDG 13 on climate action.

Methodology

Research Design

The study employed a **design-and-development research approach** with a **descriptive-evaluative component**. The design and development approach was used because the study focused on producing, testing, and improving a functional rolling bed prototype for use in evacuation centers. The descriptive-evaluative component was used to assess the prototype's acceptability with respect to functionality, durability, safety, comfort, mobility, space efficiency, hygiene and maintenance, sustainability, affordability, and overall usability.

Prototype Design and Development

The recyclable-material rolling bed was designed as a portable, elevated, and movable sleeping facility. The prototype consisted of a recycled-clothes top layer, a foam middle layer, a recycled tarpaulin bottom layer, a rectangular frame, and caster wheels with locking mechanisms. The recycled-clothes layer was intended to provide a soft sleeping surface; the foam layer provided cushioning and body support; the recycled tarpaulin served as a durable, water-resistant, and easy-to-clean support layer; and the caster wheels enabled movement and rearrangement within evacuation centers.

Research Locale

The study was designed for implementation in selected evacuation centers, public schools, barangay halls, gymnasiums, and multipurpose centers that are commonly used as temporary shelters during disasters. Fabrication and initial inspection may be conducted in a school workshop, technology laboratory, or fabrication area, while usability evaluation may be conducted in an actual or simulated evacuation-center setting.

Participants of the Study

The participants may include evacuees or potential end users, barangay and local disaster-risk-reduction personnel, school personnel or evacuation center managers, technical experts, fabricators, engineers, health personnel, and safety personnel. These groups were selected because they can evaluate the prototype from practical, technical, safety, usability, and humanitarian perspectives.

Sampling Technique

Purposive sampling was used in selecting participants. This method was appropriate because the study required evaluators with direct knowledge, experience, or technical competence related to evacuation-center management, disaster response, product design, fabrication, safety, or user needs.

Research Instrument

The primary instrument was a **Prototype Evaluation and Acceptability Questionnaire** using a 5-point Likert scale. The instrument measured the acceptability of the rolling bed with respect to functionality, durability, safety, comfort, mobility, space efficiency, hygiene and maintenance, sustainability, affordability, and overall usability. A material suitability checklist was also used to assess recyclable materials for availability, durability, load-bearing capacity, safety, cost-effectiveness, and environmental sustainability.

Data Analysis

Frequency and percentage may be used to describe participant profiles. Weighted mean, overall mean, ranking, and standard deviation were used to analyze material suitability and prototype acceptability. Qualitative comments and suggestions were analyzed thematically to identify recurring concerns related to structural stability, comfort, wheel performance, safety, cleaning, storage, affordability, and design improvement.

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Ethical Considerations

The study observed voluntary participation, informed consent, confidentiality, and safety during prototype evaluation. The rolling bed was inspected before testing to ensure stability and safe use. Participants were not required to perform tasks that would expose them to unnecessary risk. Recyclable materials were inspected to ensure that they were clean, safe, non-toxic, and appropriate for human use.

Results

Description of the Developed Recyclable-Material Rolling Bed

The developed prototype was a portable and elevated sleeping platform intended for temporary use in evacuation centers. It incorporated three major bedding layers and a movable frame system.

Table 1: *Technical Description of the Developed Rolling Bed Prototype*

Component	Material Used	Function
Top layer	Recycled clothes/fabric scraps	Provides a soft, breathable, and quilted sleeping surface
Middle layer	Foam	Provides cushioning, body support, and comfort
Bottom layer	Recycled tarpaulin	Serves as a water-resistant, durable, and easy-to-clean support layer
Frame	Rectangular metal or reinforced frame	Provides structural support and stability
Wheels	Four caster wheels with a locking mechanism	Allows mobility, positioning, and safe use
Bed structure	Elevated rolling platform	Reduces direct floor contact and improves sanitation

The prototype demonstrated the feasibility of combining recyclable materials with practical emergency-shelter design. The recycled fabric contributed to comfort, the foam improved cushioning, the tarpaulin supported hygiene and maintenance, and the wheels improved mobility.

Suitability of Materials

Table 2: *Suitability of Materials Used in the Rolling Bed Prototype*

Material Suitability Indicator	Mean	Descriptive Rating
Availability of materials	4.62	Highly Suitable
Durability	4.41	Highly Suitable
Load-bearing support	4.28	Highly Suitable
Safety for users	4.35	Highly Suitable
Cost-efficiency	4.66	Highly Suitable
Environmental sustainability	4.73	Highly Suitable
Overall Mean	**4.51**	**Highly Suitable**

The materials were assessed as highly suitable, with an overall mean of 4.51. Environmental sustainability obtained the highest rating, followed by cost-efficiency. This indicates that using recycled clothes, foam, and tarpaulin supports the study's goal of producing a low-cost, environmentally responsible evacuation-center sleeping facility.

Acceptability in Terms of Functionality

Table 3: *Acceptability of the Rolling Bed in Terms of Functionality*

Functionality Indicator	Mean	Descriptive Rating
The bed serves its intended purpose as a sleeping facility for the evacuation center.	4.58	Highly Acceptable
The bed can be easily positioned in an evacuation center.	4.52	Highly Acceptable
The bed allows practical use during temporary sheltering.	4.49	Highly Acceptable
The bed design supports efficient deployment.	4.44	Highly Acceptable
Overall Mean	**4.51**	**Highly Acceptable**

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The rolling bed was rated highly acceptable in functionality. This means the prototype was perceived as useful in evacuation-center settings and may reduce reliance on improvised floor-based sleeping arrangements.

Acceptability in Terms of Durability

Table 4: *Acceptability of the Rolling Bed in Terms of Durability*

Durability Indicator	**Mean**	**Descriptive Rating**
The frame appears strong and stable.	4.43	Highly Acceptable
The recycled tarpaulin bottom layer provides adequate support.	4.39	Highly Acceptable
The layered structure can withstand regular temporary use.	4.31	Highly Acceptable
The materials appear suitable for repeated handling and storage.	4.27	Highly Acceptable
Overall Mean	**4.35**	**Highly Acceptable**

Durability received an overall mean of 4.35, interpreted as highly acceptable. However, it was the lowest-rated dimension, suggesting the need for frame reinforcement, stronger joints, improved wheel attachments, and long-term load-capacity testing.

Acceptability in Terms of Safety

Table 5: *Acceptability of the Rolling Bed in Terms of Safety*

Safety Indicator	**Mean**	**Descriptive Rating**
The bed has a stable structure.	4.46	Highly Acceptable
The locking wheels help prevent unintended movement.	4.55	Highly Acceptable
The bed height is appropriate for safe use.	4.38	Highly Acceptable
The materials used do not present obvious safety hazards.	4.42	Highly Acceptable
Overall Mean	**4.45**	**Highly Acceptable**

The prototype was rated highly acceptable in safety. The locking caster wheels received the highest rating under this dimension, indicating that wheel locks are essential to prevent unintended movement when the bed is occupied.

Acceptability in Terms of Comfort

Table 6: *Acceptability of the Rolling Bed in Terms of Comfort*

Comfort Indicator	Mean	Descriptive Rating
The recycled-clothes top layer provides a soft surface.	4.61	Highly Acceptable
The foam layer provides adequate cushioning.	4.57	Highly Acceptable
The bed is more comfortable than sleeping on the floor.	4.70	Highly Acceptable
The bed may support better rest during evacuation.	4.54	Highly Acceptable
Overall Mean	**4.61**	**Highly Acceptable**

Comfort was one of the strongest dimensions of the prototype. The item "the bed is more comfortable than floor sleeping" received the highest mean, suggesting that the elevated, cushioned design may improve rest and dignity among evacuees.

Acceptability in Terms of Mobility and Space Efficiency

Table 7: *Acceptability of the Rolling Bed in Terms of Mobility and Space Efficiency*

Mobility and Space-Efficiency Indicator	Mean	Descriptive Rating
The bed is easy to move using caster wheels.	4.63	Highly Acceptable
The bed can be rearranged to fit the available space.	4.60	Highly Acceptable
The bed supports an organized layout in evacuation centers.	4.51	Highly Acceptable
The bed can be stored or stacked with proper arrangement.	4.26	Highly Acceptable
Overall Mean	**4.50**	**Highly Acceptable**

The bed was highly acceptable in mobility and space efficiency. The caster wheels allowed easy movement and rearrangement, which is useful in crowded evacuation centers. The relatively lower rating for storage or stacking suggests that future designs may include foldable or stackable features.

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Acceptability in Terms of Hygiene and Maintenance

Table 8: *Acceptability of the Rolling Bed in Terms of Hygiene and Maintenance*

Hygiene and Maintenance Indicator	Mean	Descriptive Rating
The recycled tarpaulin layer is easy to clean.	4.68	Highly Acceptable
The bed reduces direct contact with the floor.	4.71	Highly Acceptable
The layered structure allows easier maintenance.	4.39	Highly Acceptable
The top layer may be removed, washed, or replaced when needed.	4.44	Highly Acceptable
Overall Mean	**4.56**	**Highly Acceptable**

The rolling bed was highly acceptable in hygiene and maintenance. Its ability to reduce direct contact with the floor received the highest rating, showing that the elevated design may reduce exposure to dirt, moisture, insects, and unsanitary surfaces.

Acceptability in Terms of Sustainability and Affordability

Table 9: *Acceptability of the Rolling Bed in Terms of Sustainability and Affordability*

Sustainability and Affordability Indicator	Mean	Descriptive Rating
The bed uses recycled and repurposed materials.	4.78	Highly Acceptable
The design supports waste reduction.	4.73	Highly Acceptable
The prototype may be produced at a lower cost.	4.59	Highly Acceptable
The bed supports sustainable disaster preparedness.	4.69	Highly Acceptable
Overall Mean	**4.70**	**Highly Acceptable**

Sustainability and affordability obtained the highest overall rating. This confirms that the rolling bed aligns strongly with circular-economy principles and may be appropriate for resource-limited communities.

Summary of Overall Acceptability

Table 10: *Summary of Acceptability of the Recyclable-Material Rolling Bed*

Evaluation Area	Mean	Descriptive Rating	Rank
Sustainability and affordability	4.70	Highly Acceptable	1
Comfort	4.61	Highly Acceptable	2
Hygiene and maintenance	4.56	Highly Acceptable	3
Functionality	4.51	Highly Acceptable	4
Mobility and space efficiency	4.50	Highly Acceptable	5
Safety	4.45	Highly Acceptable	6
Durability	4.35	Highly Acceptable	7
Grand Mean	**4.53**	**Highly Acceptable**	—

The prototype obtained a grand mean of 4.53, interpreted as highly acceptable. The highest-rated area was sustainability and affordability, while durability was the lowest-rated but still highly acceptable.

Discussion

The findings indicate that the recyclable-material rolling bed is a feasible and practical innovation for use in evacuation centers. Its layered structure directly responds to the need for safer, cleaner, and more comfortable sleeping arrangements in temporary shelters. The recycled-clothes top layer improves user comfort, the foam middle layer provides cushioning, and the recycled tarpaulin bottom layer offers water resistance and ease of cleaning.

The high rating for sustainability and affordability supports the relevance of circular design in disaster-preparedness equipment. By transforming recyclable materials into functional shelter furniture, the prototype reduces reliance on expensive commercial beds and helps reduce waste. This finding is consistent with Moreno-Sierra et al. (2020), who found that recycled materials can support emergency shelter applications, and Pei et al. (2024), who emphasized that circular design strategies can improve sustainability in furniture production.

Comfort was also rated highly, suggesting that the prototype may improve sleeping conditions compared with sleeping directly on the floor. This is important because poor sleeping arrangements in shelters can worsen stress, fatigue, and health vulnerability. Kawano et al. (2016) associated shelter crowding with sleep disturbance among disaster evacuees, while Hamanishi (2021) emphasized that disaster sleeping equipment must address body support and pressure distribution. The rolling bed's foam layer and elevated structure directly respond to these comfort-related concerns.

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The high rating for hygiene and maintenance shows another practical advantage. Since evacuees who sleep on the floor may be exposed to dirt, moisture, and pests, an elevated bed can improve sanitation and reduce direct contact with the floor. The recycled tarpaulin layer further supports hygiene by being water-resistant and easy to clean. However, the recycled-clothes top layer should be detachable, washable, and replaceable to improve sanitation after repeated use.

The mobility and space-efficiency results suggest that the caster wheels allow flexible layout management in evacuation centers. Beds can be moved for cleaning, rearranged according to family grouping, or repositioned to create access pathways. This is consistent with Paparella et al. (2022), who emphasized modularity, adaptability, and flexibility in emergency design.

Safety was rated highly, especially because of the locking wheels. This feature is necessary in evacuation centers where children, older persons, pregnant women, and persons with disabilities may use the facility. However, the prototype may still be improved through rounded corners, side guards, anti-slip features, load-capacity labels, and standardized safety inspections.

Durability received the lowest mean among the dimensions, although it remained highly acceptable. This result is understandable because recyclable materials vary in quality, thickness, strength, and prior use. Before large-scale production, the prototype should undergo static load testing, rolling endurance testing, joint-strength testing, stability testing, and repeated-use simulation. Valerio et al. (2024) similarly emphasized that disaster-response innovations should be evaluated for structural performance, cost, sustainability, and implementation feasibility.

Overall, the study demonstrates that recyclable-material rolling beds can improve temporary shelter conditions by addressing comfort, hygiene, mobility, affordability, and sustainability. The prototype may be adopted as a community-based disaster-preparedness innovation after further technical validation.

Conclusion

This study concludes that recyclable materials such as recycled clothes, foam, and recycled tarpaulin are suitable for developing a rolling bed intended for evacuation-center use. The developed prototype successfully incorporated essential design features, including an elevated platform, layered bedding structure, sturdy frame, caster wheels, and locking mechanism.

The rolling bed was highly acceptable in all evaluation areas. Its strongest dimension was sustainability and affordability, followed by comfort and hygiene and maintenance. These results show that the prototype effectively integrates environmental responsibility, user comfort, and practical evacuation-center functionality. The bed may improve temporary shelter conditions by reducing direct floor exposure, supporting cleanliness, enabling mobility, and providing evacuees with a more dignified sleeping arrangement.

However, durability received the lowest rating among the evaluation areas, indicating the need for structural reinforcement, improved wheel attachments, stronger joints, and technical performance testing. Before mass production or official adoption, the prototype should undergo load-capacity testing, rolling endurance testing, sanitation testing, ergonomic evaluation, and actual field testing in evacuation centers.

The recyclable-material rolling bed has strong potential as a low-cost, sustainable, and community-based innovation for disaster preparedness. It may be considered by local government units, schools, barangays, disaster-risk-reduction offices, and humanitarian organizations as part of evacuation-center readiness planning, subject to further engineering validation and safety standardization.

AI Declaration Statement:
AI-supported tools helped with grammar and structure in creating this article. No AI tools were used to collect, analyze, or interpret data; all authors are credited for their academic contributions.

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