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Development of a Scaled Buoyant Baby-Cot for Emergency Flood-Aid

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Abstract

Malaysia is one of the regions in southeast Asia prone to monsoons. During this period, flooding often displaces communities. Most household furniture is not designed for emergency use. One furniture which has the potential to be used during emergencies is the baby cot. However, standard baby-cots are heavy and not buoyant, making them unsuitable for carrying items during flood evacuation. This study involves the design and fabrication of a buoyant baby-cot that can be used during normal and emergency situations. The prototype was designed using SolidWorks and built using PVC pipes and 5 mm acrylic sheets. The total cost for the prototype was RM303.10. Simulation using Finite Element Analysis (FEA) under 50 N showed a maximum displacement of 5.206×10^{-3} mm, indicating that the frame is structurally stable. When used in normal situations, testing showed that the prototype can support up to 10 kg, while when tested for flood situation, testing showed that the prototype can float while supporting loads up to 6 kg and remain watertight for more than 30 minutes. The results clearly show that the prototype is structurally stable and affordable, and it can be used as a simple emergency response solution during floods.

1. Introduction

In Southeast Asia, Malaysia often experiences seasonal monsoon floods, which force people to leave their homes [1]. During these emergencies, there is a need for portable storage to carry important items safely. Guidelines from the National Disaster Management Agency (NADMA) Malaysia recommend preparing a “Beg Kecemasan” (Ready-to-go Bag) with food, water, first-aid supplies, and important documents before evacuating to a temporary shelter (PPS) [2]. Most storage boxes are not buoyant and must be carried through floodwater, which can be physically demanding [1]. One furniture which has the potential to be used during emergencies is the baby cot. Baby-cots and bassinets are commonly used to provide safe sleeping for infants [3]. However, once the infant outgrows the cot, it often takes up unnecessary space, especially in small urban areas. Some modern and patented designs include features such as adjustable height mechanisms, detachable side barriers, and built-in storage [4 – 9]. However, these products are still intended for normal home use only. Premium models which are commercially available cost between RM2,700 – RM4,999. They are often made from materials such as European beechwood, which makes them heavy and difficult to move around [6], [7]. Beyond residential space and cost constraints, a critical gap exists in the functional adaptability of household furniture during natural disasters. Table 1 shows the comparison of existing commercial baby-cots against their emergency flood capability.

Table 1 *Benchmarks existing commercial baby-cots against their emergency flood capability*

Product / Model	Primary material	Estimated price (RM)	Weight / Mobility	Emergency flood capability
Sniglar (IKEA) [6]	Beech wood	399	Heavy / Fixed structure	None (non-buoyant)
Kaylula Sova 5-in-1 [7]	European beechwood	4,999	Heavy / Castor-assisted mobility	None (non-buoyant)
Next2Me Pop Up [8]	Metal frame with fabric	2,700	10.4 kg / Portable	None (non-buoyant)
Gonatt [9]	Solid beech	1,000	20 kg / Portable	None (non-buoyant)

The objective for this study is to design and fabricate a dual-use baby-cot that can be used as both household furniture and emergency equipment. The study includes the design and fabrication, and testing of a scaled prototype for both normal and emergency storage during floods. The prototype uses a lightweight PVC frame and a watertight acrylic box allowing the prototype to float.

2. Methodology

This study underwent various phases for it to be completed as shown in Fig. 1. Starting with the background study to identify the current need for an emergency storage product and product benchmarking to evaluate existing products. Next, the prototype was modelled using SolidWorks [10] to define its dimensions for a scaled design. The overall dimensions for the prototype were 630 mm (length), 500 mm (width), and 800 mm (height). Each part used for the prototype was drawn and later assembled to ensure a securely fit product.

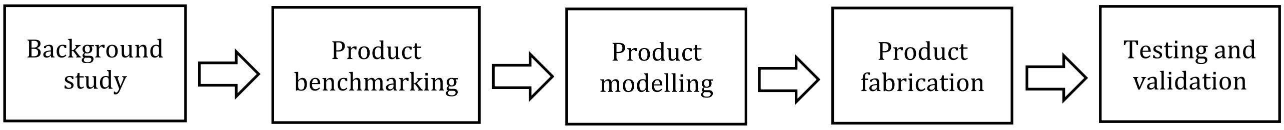

Fig. 1 *Project flow chart*

Before proceeding with the fabrication stage, a static structural analysis based on the criteria in Table 2 was performed using the finite element analysis (FEA) feature in SolidWorks to evaluate the strength of the PVC frame. The fixtures and force direction are shown in Fig. 4 indicated by the green and purple arrows respectively. For boundary conditions, the load is distributed uniformly across the spans of the two inner structural floor members as shown in Fig. 2 and the material properties [10] for PVC used for the simulation are shown in Table 3. For the analysis, a downward force of 50 N, which represents the expected load for the storage box or bassinet was applied to the base of the cot.

Table 2 *FEA static structural analysis criteria*

Criteria	Details
Type of analysis	Static
Type of mesh	Beam elements
Boundary condition	Uniformly distributed load
Fixtures	Fixed geometry
Force direction	Normal to plane

J. Adv. Mech. Eng. Appl. Vol. 7 No. 1 (2026) p. 65-71

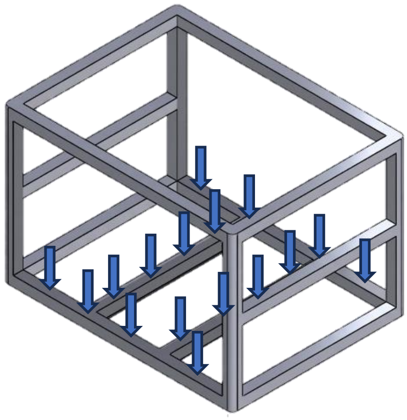

Fig. 2 *Boundary condition for finite element analysis*

Table 3 *Material properties for PVC [10]*

Property	Value (Units)
Elastic modulus	6 MPa
Poisson’s ratio	0.47
Shear modulus	2 MPa
Mass density	1290 kg/m^3
Tensile strength	13 MPa

The prototype was fabricated in several steps to ensure proper load support and water resistance. The frame was constructed using PVC pipes to provide sufficient strength while allowing the structure to float. The cot box was made from 5 mm acrylic sheets due to their transparency and water resistance [11]. A jigsaw was used to cut the PVC pipes and acrylic panels. This method helps reduce burrs and deformation before assembly. A telescopic leg design was used to allow height adjustment. The inner PVC legs slide into the outer leg and are secured using M5 x 40 bolts and nuts. This design allows the height to be adjusted from 800 mm to 830 mm to improve stability during different floating conditions.

For the assembly process, PVC T-joints and 3-way elbow joints were used to connect the PVC parts for the frame. PVC solvent cement was applied to all joints to ensure the frame formed a rigid structure [12]. The 5 mm acrylic panels were arranged to form the cot box. Silicone sealant was applied along all inner and outer edges. After curing, the silicone sealant forms a watertight seal that prevents water from entering the box [13]. Table 4 shows the bill of materials (BOM) for the scaled buoyant baby-cot.

Table 4 *Bill of materials (BOM) for scaled buoyant baby-cot prototype*

No.	Component description	Specification / Material	Qty	Estimated Cost (RM)
1	Transparent containment panel	5 mm solid polycarbonate/acrylic	1	150.00
2	Primary structural tubing	20 mm, 50 mm, and 80 mm PVC pipes	1 Set	65.50
3	Structural nodes	PVC T-joints and 3-way elbows	1 Set	35.00
4	Height adjustment fasteners	M5 × 40 mm steel bolts and nuts	8	12.60
5	Hydrodynamic sealant	Industrial-grade silicone sealant	2	25.00
6	Polymer adhesive	Heavy-duty PVC solvent cement	1	15.00
			Total cost (RM)	303.10

Tests were conducted to evaluate the performance of the scaled buoyant baby cot. The tests include operations under normal use as a baby-cot, and its condition when floating in water. For normal use, the prototype was placed on a flat surface. Weights up to 10 kg were added gradually into the acrylic box. The main goal for the test was to observe how the adjustable legs and PVC joints responded under load. To evaluate the prototype during flood conditions, a hydrostatic test was conducted. The prototype was placed in a water basin, loads of 1.5 kg and 3 kg were added and its stability were observed.

3. Results & Discussion

The CAD model defined the structure and confirmed that all components, including the adjustable legs and 80 mm PVC floats, fit without interference. Fig. 3 shows the isometric view of the 3D CAD model using SolidWorks.

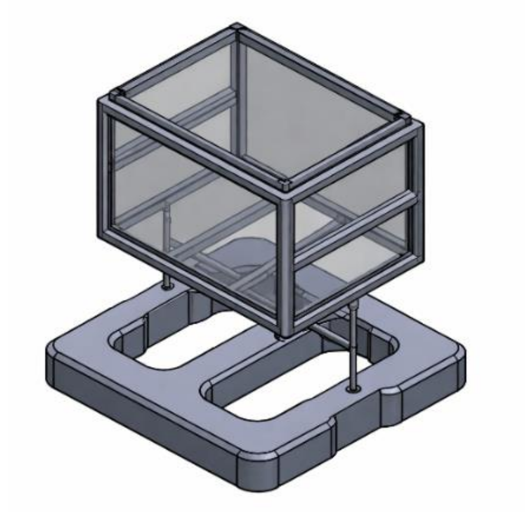

Fig. 3 *Isometric view of the final 3D CAD model in SolidWorks*

From Fig. 4, The Von Mises stress analysis [14] showed that the stress on the frame was low and well distributed across the joints. A maximum central deflection of 5.206×10^{-3} mm for the displacement analysis, which is very small indicating that the frame can support the expected load without structural failure [15].

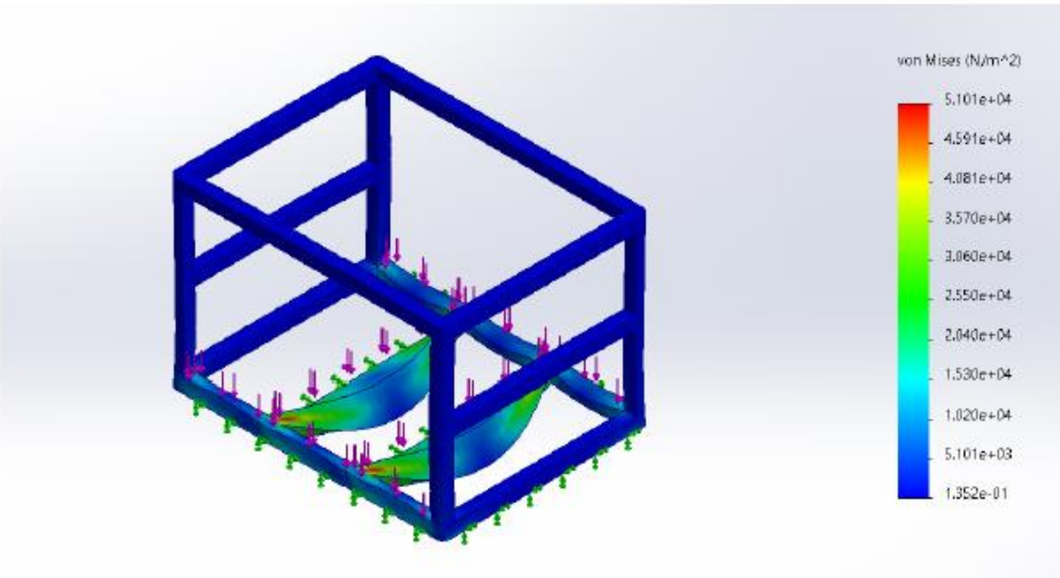

Fig. 4 *SolidWorks Von Mises stress distribution analysis*

Fig. 5 shows the completed scaled buoyant baby cot prototype. The total weight of the prototype is 7.7 kg. During normal use, the prototype supported up to 10 kg without visible deflection. The telescoping leg mechanism worked as expected. The M5 bolts allowed smooth height adjustment in increments of 10 mm.

Fig. 5 *Final fabricated dual-use baby cot prototype*

To evaluate the prototype under flood conditions, a floatation test in a water basin as shown in Fig. 6 was conducted. To ensure maximum stability, the cot legs were fully lowered to reduce its centre of gravity. Loads of 1.5 kg and 3.0 kg were added to represent real use conditions. The test results are as reported in Table 5.

Table 5 *Floatation test results for baby-cot prototype*

Applied Payload (kg)	Floatation duration (mins)	Buoyancy condition	Stability condition	Baby-cot condition
1.5	> 30	Positive buoyancy	Stable	100% Watertight
3.0	> 30	Positive buoyancy	Stable	100% Watertight

The prototype remained stable and afloat for more than 30 minutes under both load conditions. Furthermore, no water leakage was observed during the test. Further testing showed that the maximum safe load in water was 6.0 kg. Above this load, the freeboard decreases, increasing the risk of the prototype becoming unstable. The results show that the prototype can be used during floods as an emergency storage equipment.

Fig. 6 *Baby-cot prototype under a 3.0 kg payload during the 30-minute floatation test*

4. Conclusion

This study presents the design and fabrication of a scaled buoyant baby cot which can be used both as a traditional baby cot for household and emergency use. For Malaysia, being in a region where monsoon season is frequent, the prototype is intended as a low-cost solution for carrying essential items during evacuation. The prototype was built using PVC and acrylic materials, with a total cost of RM 303.10. For normal use, testing showed the structure can support up to 10 kg without failure. Flood conditions testing showed that the prototype floated for more than 30 minutes under 1.5 kg and 3.0 kg loads. The maximum safe load was 6.0 kg. Future work may include adding side supports or a wider base to improve stability. This is to ensure that the stability increases to reduce the risk of capsizing in strong currents. Overall, the prototype can function in both land and water conditions, showing its potential as a low-cost multi-purpose design.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Nabil Qayyum Roslan, Miqdad Khairulmaini; **data collection:** Nabil Qayyum Roslan; **analysis and interpretation of results:** Nabil Qayyum Roslan, Miqdad Khairulmaini; **draft manuscript preparation:** Nabil Qayyum Roslan, Miqdad Khairulmaini, Ahmad Najmie Rusli, Hasannuddin Abd Kadir. All authors reviewed the results and approved the final version of the manuscript.*

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