

Repurposing Humanitarian Packaging Waste: A Framework for Material Transformation and Value Creation

Nizar Shbikat ¹, Omar M. Bwaliez ^{2,*}, Emad Alzubi ³ and Bassam Maali ⁴

¹ Logistics Sciences Department, Business School, German Jordanian University, Amman 11180, Jordan; nizar.shbikat@gju.edu.jo

² Management Sciences Department, Business School, German Jordanian University, Amman 11180, Jordan

³ Transport Systems and Logistics Department, Faculty of Engineering, University of Duisburg-Essen, 47058 Duisburg, Germany; emad.alzubi@uni-due.de

⁴ International Accounting Department, Business School, German Jordanian University, Amman 11180, Jordan; bassam.maali@gju.edu.jo

* Correspondence: omar.bwaliez@gju.edu.jo

Abstract

This study aims to systematically investigate packaging waste repurposing in humanitarian logistics. It aims to bridge the theory–practice gap by providing a consolidated evidence-based analysis of how packaging is repurposed, the driving motivations, and the design characteristics that enable such transformations. A systematic review and thematic analysis of 34 documents from well-known international relief organizations was conducted. The documents were thoroughly reviewed, and codes were extracted and grouped into themes. The findings reveal that packaging repurposing is a widespread practice driven by three interconnected streams: (1) designer-led (top-down) initiatives rooted in Non-Governmental Organizations (NGOs) policies and design innovation, (2) user-led (bottom-up) initiatives that are induced by the survival and livelihood of affected communities, and (3) hybrid initiatives that involve the participation of the NGOs and affected people. Moreover, repurposing is highly dependent on specific design enablers, such as structural and material properties, to facilitate it. Lastly, a hierarchy of material transformation is proposed, ranging from low-energy mechanical adaptations to high-energy physio-chemical processes. This paper provides a novel integrated framework that links material, drivers, and design enablers for packaging repurposing in humanitarian logistics. It proposes a transformation spectrum to guide repurposing strategies based on resource and tool availability. This study consolidates fragmented knowledge across different sources and offers practical insights into the applicability of repurposing in various domains such as procurement, packaging design, and logistics planning.

Keywords: humanitarian logistics; packaging waste; circular economy; repurposing; upcycling; sustainable operations; post-disaster recovery



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1. Introduction

The last decades have witnessed an increase in natural and man-made disasters driving displacement to record-high levels and exerting pressure on humanitarian organizations to meet the increased demand for relief items [1]. The humanitarian supply chain is inherently resource intensive, which generates a vast quantity of solid waste in regions that often lack the municipal infrastructure and policies to manage it [2]. Among various waste streams, packaging is the most common type. According to a joint report by multiple relief

organizations, 33,000 metric tons of primary and 35,600 metric tons of secondary packaging were used to package food and non-food items for the humanitarian emergency response in 2021 [3,4].

The central problem addressed in this research is the disconnect between the designed intent of packaging (single-use protection) and the actual needs of the beneficiaries (long-term survival resources). Consequently, a critical blind spot remains about what happens to packaging waste on-site in the immediate aftermath of distribution. There is a lack of systematic understanding of how these materials are repurposed by displaced populations (user-led) or intentionally redesigned by aid agencies (designer-led) to serve secondary functions [4]. Without this knowledge, the humanitarian sector misses an opportunity to turn waste into useful items [5,6]. Recent scholarship highlighted that integrating circular economy principles into humanitarian operations could transform packaging waste into valuable resources [7]. Moreover, sustainable humanitarian supply chains require frameworks that explicitly address waste minimization and value creation [8]. Finally, value co-creation approaches in humanitarian logistics demonstrate that beneficiaries themselves can play a pivotal role in transforming discarded packaging into survival assets [5].

Existing literature on humanitarian logistics often frames sustainability through the lens of green supply chain management that focuses on reducing carbon footprint and improving transportation efficiency with very limited studies on waste management [2]. In fact, there is a distinct scarcity of research on on-site repurposing, where the lifecycle of the packaging is closed locally by the beneficiary [8]. Furthermore, academic research on this specific niche is limited, with the bulk of practical knowledge from relief organizations as presented technical reports and field manuals that have not yet been synthesized into a coherent theoretical framework [1]. This study seeks to bridge this gap by reaching such reports and informing our understanding of the possible opportunities for repurposing package waste in a relief operations context [9]. The research is guided by the following central question:

RQ: How is packaging waste from humanitarian relief operations repurposed, and what mechanisms drive these transformations in crisis settings?

To structure the presentation of the findings, the central research question was decomposed into four sub-questions that correspond to the emergent themes. These sub-questions serve an organizational function and were not used as a priori hypotheses:

Sub-RQ1: What types of packaging materials are repurposed in humanitarian settings, and into what new functional applications are they transformed?

Sub-RQ2: Who initiates the repurposing of packaging waste (designers, users, or both), and what motivates these actions?

Sub-RQ3: What design characteristics enable packaging to be effectively repurposed?

This research offers both theoretical and practical contributions to the field of humanitarian logistics. Theoretically, it proposes a new operational framework of circularity for crisis settings, distinguishing between “survival repurposing” (driven by scarcity) and “innovation repurposing” (driven by design). This moves the discourse beyond simple waste management toward value creation [5]. Practically, it guides relief organizations to consider material repurposing in product design and procurement [10]. Furthermore, the consolidated examples can help beneficiaries explore alternatives for reusing packaging in a non-conventional manner to reduce the impact of resources deprivation [8].

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature on humanitarian logistics and waste management. Section 3 details the methodology, explaining the systematic search strategy. Section 4 presents the results of the thematic analysis, categorizing the findings into material transformations, drivers, and design features. Section 5 discusses these findings, interpreting the tension between user-led and

designer-led approaches. Finally, Section 6 concludes with implications for policy and practice, alongside suggestions for future research.

2. Literature Review

The scale, urgency, and cyclical nature of humanitarian aid logistics generate a massive amount of packaging waste. Packaging has several vital functions, such as protecting relief items, especially critical food and medical supplies that go through complex and often harsh transit routes, facilitating efficient handling and storage, and displaying vital information [11]. However, upon the distribution and unpacking of relief items, this essential packaging is frequently rendered redundant, rapidly amassing as waste within camps where formal waste management infrastructure is typically weak or entirely absent [12]. This accumulation creates a set of interconnected operational, environmental, and protection risks that can quickly undermine response effectiveness, including increasing fire load in densely populated shelters and blocking distribution routes.

Humanitarian packaging systems traditionally adhere to conventional commercial logistics classifications, comprising primary, secondary, and tertiary layers [11]. Primary packaging is the immediate packaging that directly contains and touches the product. Its core functions are to protect the product from damage, contamination, and spoilage, and to provide information for the end-user, such as labeling, instructions, and nutritional facts [13]. Primary packaging often determines shelf presentation and is usually designed for consumers or final points of use. Secondary packaging groups one or more primary packages together to facilitate handling, storage, and transportation within the humanitarian supply chain [14]. It typically does not reach the consumer in the form it is shipped and is removed before individual use. Tertiary packaging (e.g., pallets and containers) aims to facilitate transport and store bulky products [15].

Theoretically, repurposing and upcycling align closely with circular economy principles, specifically the aims of closing material loops and extracting maximum value from resources [16]. While reuse implies repeated use of a product or material without alteration, upcycling involves creative transformation that creates new value or function [17]. Recent scholarship has extended these principles to humanitarian contexts, arguing that circular economy approaches could transform packaging waste from a disposal burden into a valuable resource [7,10]. Unlike reuse, repurposing involves alteration in packaging form and leveraging physical characteristics like strength, flexibility, and insulation capacity to serve new functions [18]. This perspective aligns with broader definitions of upcycling, which focus on enhancing the value or utility of discarded materials rather than prolonging their lifespan in the same form [19]. In fact, the added value of repurposing is measured in terms of its ability to address the needs of affected people rather than its monetary value [20].

The circular economy paradigm has gained traction in humanitarian logistics to address the growing environmental footprint of relief operations. Rocheteau [10] examined how circular economy adoption can be driven in temporary humanitarian organizations. However, repurposing in humanitarian logistics remains constrained by emergency time pressure, donor procurement policies, and operational priorities, which reveal a persistent theory–practice gap [16]. This gap underscores the need for frameworks that translate circular economy principles into actionable strategies for packaging waste management in crisis settings.

A niche body of literature has documented specific repurposing applications suited to low-resource and post-disaster environments. These studies, while valuable, remain fragmented across material types and application domains, lacking a unified framework. Cardboard has been thoroughly investigated as material that can be used for both daily use

and shelter. Its structural potential has been examined in creating affordable housing panels, frequently in conjunction with other repurposed materials like wood [21]. On a smaller, more immediate scale, cardboard is converted into lightweight furniture, stools, slippers, and carton cradles, all of which directly address needs in camp environments [12,22]. Higher-value transformation pathways exist outside of structural applications, such as upcycling cardboard and wastepaper into textile fibers and yarns for knitting clothing, demonstrating substantial material revalorization [23]. Regattieri et al. [24] suggested a design for a portable solar cooker integrated into a kitchen set box enclosed with humanitarian aid.

Tertiary packaging, including freight containers and pallets, constitutes another major repurposing stream. Previous studies highlighted the potential uses of containers as modular components and blocks for secure and weather-resistant shelters and temporary storage facilities that can be quickly deployed in emergency situations [25,26]. Similarly, pallets have been repurposed for constructing shelters and designing beds due to their standard dimensions and load-bearing capability [27]. These design rethinking ideas reframe logistical assets into humanitarian infrastructure alternatives, specifically in cases of supply shortages. However, the literature primarily focuses on technical feasibility rather than the operational and logistical enablers required for widespread adoption.

Durable plastic packaging waste has also attracted significant research attention. Local recycling of plastic packaging such as bottles into 3D-printing filament presents a localization strategy for manufacturing spare parts and tools, which enhances supply chain resilience [28]. Recycling High-Density Polyethylene (HDPE) caps into new bottles has been a common practice for decades [29]. Other approaches have investigated the use of plastic in construction materials like bricks, tiles, and concrete as a substitute for scarce traditional inputs for constructing shelters [30,31]. However, recycling healthcare plastics is considered non-viable due to their impact on human health and the environment [32]. Although these applications require specialized technologies to transform materials [33], they open the door for more advancements and affordable innovations in this path.

Several recent systematic reviews have examined sustainability in humanitarian supply chains, providing a foundation for situating the present study. Anjomshoae et al. [8] conducted a comprehensive review of sustainable humanitarian supply chain management, identifying themes such as supply network configuration, coordination, partnership, and performance measurement. Their analysis revealed that theoretical studies typically do not integrate all sustainability dimensions, with social sustainability factors largely absent from current models. Ramirez-Villamil and Jaegler [34] systematically reviewed green practices in humanitarian logistics, finding increasing adoption of emissions monitoring, waste reduction, and resource-efficient transportation, but also identifying barriers such as operational complexity, inadequate digital infrastructure, and the absence of standardized environmental frameworks. Garcia et al. [35] examined the integration of reverse logistics with humanitarian operations, identifying four roles of reverse logistics: environmental, operational, institutional, and technological. The authors noted that reverse logistics remains “a latent and non-formalized capability” in humanitarian contexts.

Academic literature and institutional gray literature operate in parallel but rarely intersect. On one hand, academic research has developed conceptual frameworks for sustainable humanitarian supply chains [8], circular economy principles [7,17], and innovation typologies [24]. However, these frameworks are rarely grounded in field-level evidence of packaging repurposing practices. The academic literature tends to treat packaging waste as a peripheral issue within broader sustainability discussions, rather than as a distinct phenomenon worthy of dedicated investigation.

On the other hand, relief organizations produce extensive gray literature such as field manuals, technical reports, case studies, and procurement guidelines that document specific

repurposing practices in detail. These documents contain rich empirical evidence of how packaging is repurposed on-site, the drivers of these practices, and the design characteristics that enable them. However, this knowledge remains fragmented, organization-specific, and largely inaccessible to academic audiences. It has not been systematically synthesized, theorized, or integrated into a coherent framework. Therefore, the lack of systematic evidence on how packaging waste is physically repurposed in humanitarian settings justifies the need for the present study.

3. Methodology

3.1. Research Design

Content analysis is used in this research to answer the research questions and provide evidence-based applications of the extended value of used packages. The approach is suitable for extracting meaningful patterns, symbolic qualities, and expressive contents from unstructured data [36]. It is academically sound and rigorous since it is a systematic and rule-guided technique used to analyze informational contents of texts [37]. Manual coding is adopted to extract categories due to its systematic rigor and contextual sensitivity [38]. This research is registered in the Open Science Framework (<https://osf.io/8eqnr/overview>, register date: 24 May 2026).

3.2. Sample Selection

To collect practical applications of packaging repurposed in the humanitarian context, we initially performed a pilot literature review to define possible sources for documents. The following sources were determined based on their widely accepted role in relief operations: World Food Program (WFP), United Nations High Commissioner for Refugees (UNHCR), United Nations International Children's Emergency Fund (UNICEF), International Committee of the Red Cross (ICRC) [35,36], and the digital platform Environment and Humanitarian Action Connect (EHA-Connect), which provides resources for humanitarian workers to integrate environmental considerations into disaster response, preparedness, and recovery [39]. This deliberate scope limitation is justified by the leading role of these organizations in humanitarian packaging procurement and waste management, and their extensive publicly available documentation on field-level practices.

The following search string was used to locate studies on the Google search engine.

The search was restricted to key humanitarian organization domains: (site:wfp.org OR site:unhcr.org OR site:unicef.org OR site:icrc.org OR site:ehaconnect.org) AND ("repurposing" OR "reuse" OR "secondary use" OR "upcycling") AND ("packaging" OR "containers" OR "cartons" OR "boxes" OR "bags" OR "sacks"). It was not restricted by publication year. A preliminary restricted search (2010–2025) yielded very few relevant documents, reflecting the under-documented nature of packaging repurposing in humanitarian settings. An unrestricted search was therefore conducted to capture all available evidence. Peer-reviewed academic databases (Scopus, Web of Science) were tested with the same search strings but produced only one document meeting the inclusion criteria. Most academic literature on humanitarian waste focuses on policy, decarbonization, or general waste management, without documenting the physical repurposing of packaging materials. Consequently, this study draws primarily on organizational gray literature (NGO reports, field manuals, and case studies), which represents the most direct and practical source of evidence on repurposing practices. This yielded 739 results, from which 412 sources were initially excluded due to inaccessible content (password-protected, broken links), event announcements, and duplicates. Then, an additional screening for topic relevance was undertaken for the remaining 327 items. A total of 293 items were excluded because of their focus on non-packaging waste streams (e.g., organic/bio-waste, general decarbonization

policy) rather than the physical repurposing of packaging materials. At this stage, strict inclusion criteria: Context, Component, and Concept (3-Cs) were established to ensure the relevance of the gathered dataset. These criteria were implicitly derived from the research question itself to ensure transparency and systematic application during the final selection stage. While the criteria were made explicit at this stage, they had implicitly guided the screening process from the beginning. The formalization step was a methodological measure to enhance rigor and reproducibility, consistent with best practices in qualitative content analysis [36]:

- Context: documents must pertain to humanitarian operations (conflict, disaster relief, or displacement settings);
- Component: the focus must be on any type of packaging material (primary, secondary, and tertiary);
- Concept: documents must provide evidence or policy guidance on the repurposing, functional reuse, or upcycling of these materials, excluding standard disposal methods like landfilling or incineration.

Figure 1 shows the selection flow process. Eventually, 34 documents were included in the full review and coding (see Table A1 in Appendix A).

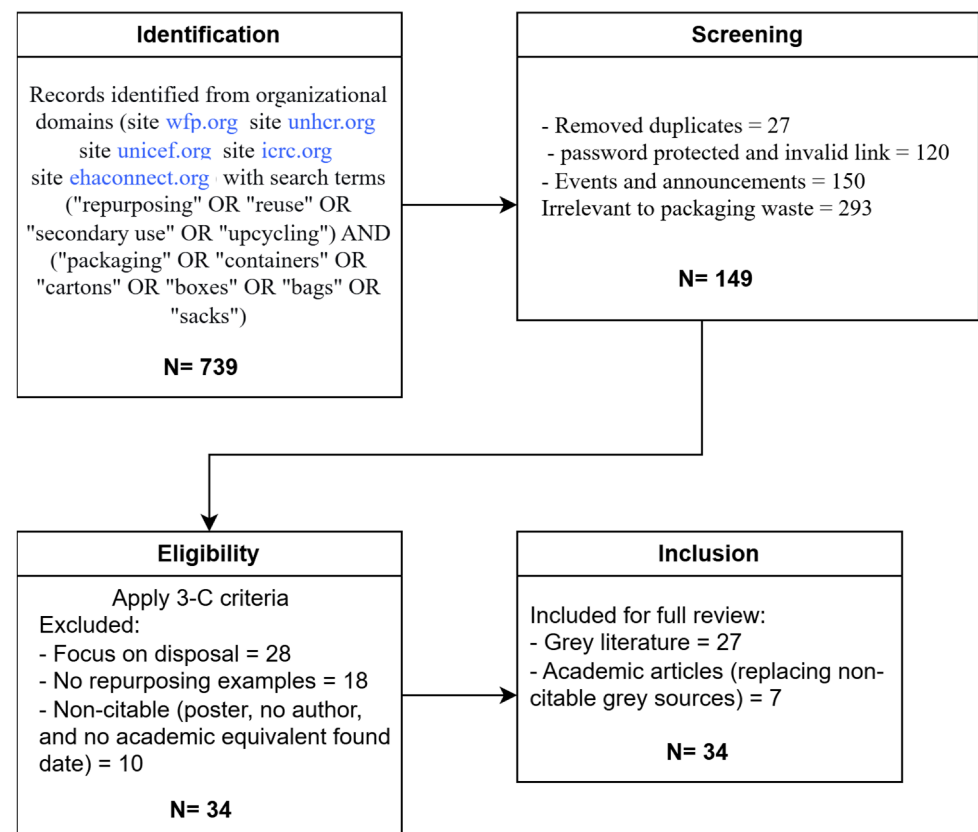


Figure 1. PRISMA flowchart.

3.3. Coding Method

The included documents were manually reviewed and coded following the steps proposed by Lyhne et al. [40] as illustrated in Figure 2. A meaning unit or coding unit refers to the constellation of words or sentences that relate to a central meaning [41]. Condensed meaning units represent a shortened text of the meaning units to simplify the coding.

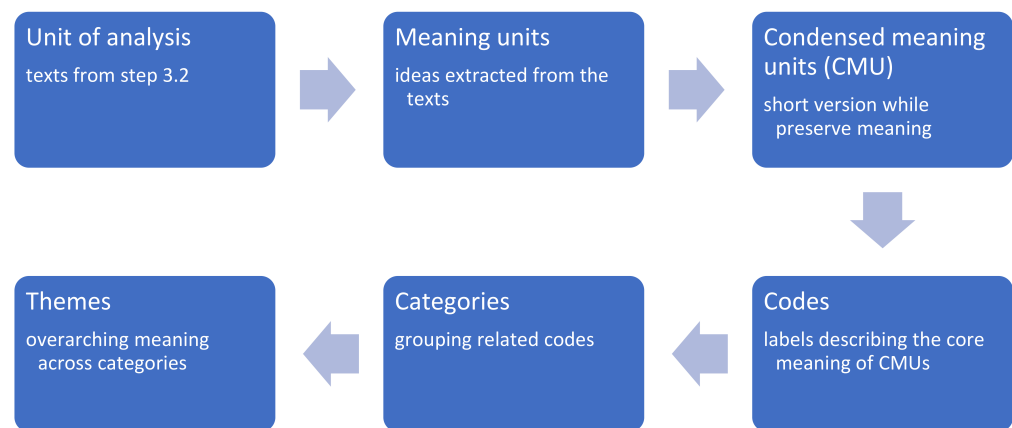


Figure 2. Coding method.

A group of codes can then be synthesized into a meaningful category that represents shared concepts across data points or codes. A theme is a higher-level interpretation that links categories together. For example, the raw meaning unit “In Gaza, displaced families repurpose flour and rice bags into sandbags to reinforce their shelters against rain and wind” was condensed to “Flour and rice bags repurposed into sandbags for shelter reinforcement” and coded as “Survival reuse of food aid bags for protection.” This code, together with similar codes (e.g., “Tarpaulin packaging used as sleeping mats,” “Vegetable oil containers converted into washing basins”), formed the category “User-Led Repurposing—Survival & Protection.” This category, in turn, contributed to the higher-level theme “User-Led (Bottom-Up) Drivers of Repurposing.”

The coding was conducted by a single researcher (the first author). A single-coder approach was adopted to ensure interpretive consistency across all 34 documents, particularly given the exploratory nature of this study and the descriptive, field-report style of the gray literature sources, which minimized ambiguity in identifying meaning units. To prepare for the coding process, the coder first engaged in an extensive familiarization phase, which included a comprehensive review of the humanitarian logistics and packaging waste literature, as well as a thorough reading of all 34 included documents to gain a holistic understanding of the content and context. A codebook was developed inductively from the first five documents, with codes refined iteratively as additional documents were analyzed. To enhance reliability, a second researcher (the corresponding author) independently reviewed a random sample of 20% of the coded documents to verify the consistency of code application and thematic interpretation. Discrepancies were discussed and resolved through consensus, and the codebook was adjusted accordingly. Microsoft Excel was used to tabulate data and facilitate the thematic analysis process.

4. Results

The systematic review and thematic analysis of the 34 selected documents yielded a detailed dataset covering the geographic scope, organizational sources, and specific mechanisms of packaging repurposing in humanitarian contexts. The findings are presented in two parts: first, a descriptive statistical analysis of the dataset’s composition; and second, a qualitative thematic analysis detailing the material transformations, drivers, and design features identified.

4.1. Geographic Distribution of Packaging Repurposing

The data in Figure 3 show clear regional clusters where specific site interventions are most often recorded. Many repurposing activities concentrate on Sub-Saharan Africa, South Asia, and the Middle East. Sierra Leone ($n = 4$) and Bangladesh ($n = 4$) appear

most often because long-standing refugee operations exist. Other countries affected by conflicts, such as Yemen, Uganda, Pakistan, Kenya, India, and Ethiopia ($n = 3$ each), also appear often, which shows that repurposing usually occurs as a response to long-term displacement crises and poverty.

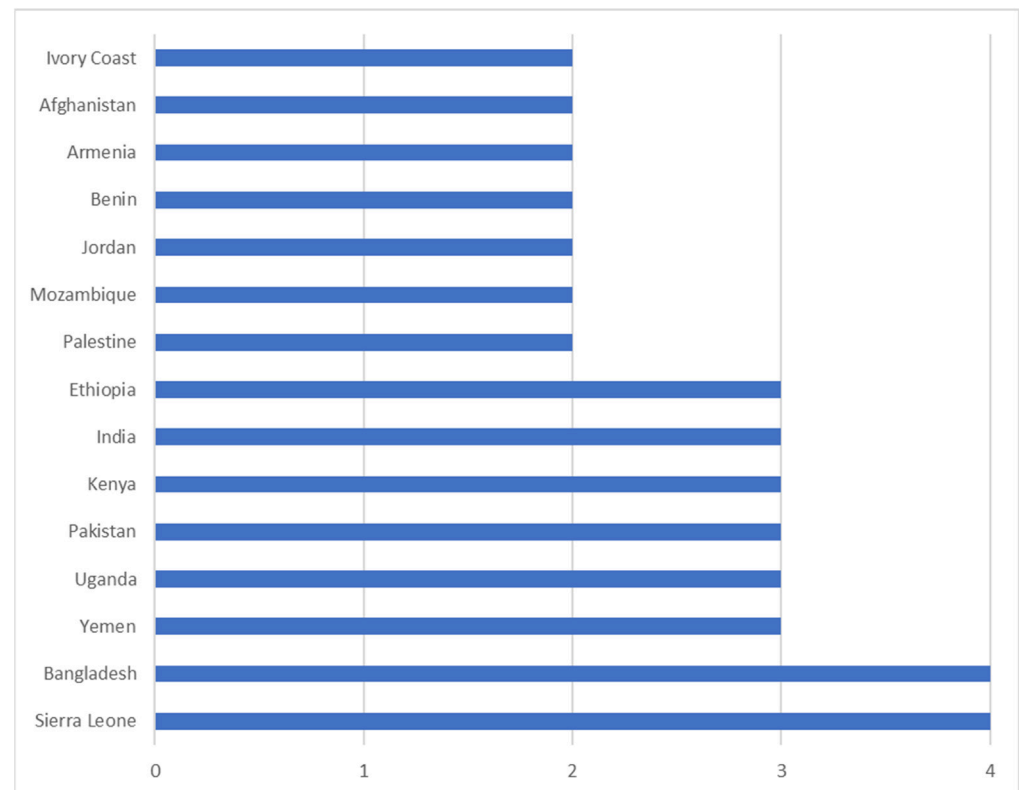


Figure 3. Frequency of countries mentioned in reviewed items.

4.2. Thematic Analysis Findings

The thematic analysis is organized around the three sub-questions: (1) repurposing examples and applications (Section 4.2.1, addressing Sub-RQ1); (2) repurposing drivers (Section 4.2.2, addressing Sub-RQ2); and (3) design enablers (Section 4.2.3, addressing Sub-RQ3).

4.2.1. Theme 1: Repurposing Examples and Applications

The data confirm that packaging in humanitarian settings rarely reaches an end-of-life state immediately after delivery. Instead, the reviewed documents provide multiple examples of materials being transformed into new functional objects (see Table 1). These examples span diverse application domains, including education, shelter, water, sanitation, and hygiene (WASH), and livelihood support.

These transformations are determined largely by the material composition of the packaging. Cardboard packaging is the most frequently repurposed material and is used in several domains such as education, logistics, and shelter. Notable examples include RUTF (Ready-to-Use Therapeutic Food) cartons being printed and pre-cut to function as educational toys, and larger boxes being refolded into school desks. Another example is using woven Polypropylene (PP) sacks (used for flour and grain) in Gaza as flood dikes by filling them with sand.

Table 1. Summary of packaging materials and their documented secondary applications.

Packaging Material	Repurposed Product/Application	Specific Use Case/Mechanism	Frequency (Number of Documents out of 34)
Cardboard boxes and cartons	Education and play	Foldable school bags that transform into desks [42]; RUTF (Ready-to-Use Therapeutic Food) cartons printed/pre-cut to turn into toys [43].	2
	Logistics and storage	Reused for filing/storage in offices [24].	1
	Shelter	Used as thermal insulation material or general construction aid [44].	1
PP woven bags (e.g., food sacks)	Disaster mitigation	Filled with sand to create sandbags for flood protection or to reinforce shelters [45,46].	2
Plastic bottles (PETs) and containers	Horticulture	Cut and upcycled into planting pots [47].	1
	Construction	Filled with sand or inorganic waste to create construction bricks for rigid walls and foundations [48,49].	2
Metal cans and tins	Household utility	Melted or mechanically reshaped into cooker grills, sinks, and cooking pans [50].	1
Wooden and plastic pallets	Furniture and infrastructure	Wooden pallets disassembled for construction timber [51]; metal stands reused as kitchen shelves [50].	2
	Recycled goods	Plastic pallets recycled into basins and beverage crates [50]. Plastic waste is collected and used to design and produce bags, hats, and other products across the recycling centers [52].	2
Plastic tarpaulin packaging and straps	WASH infrastructure	Baling straps and soft plastic packaging woven/assembled to create privacy walls and doors for latrines [53,54]. Plastic containers or cleaned oil drums can also be used for waste storage [55].	3
Metallized sachets	Livelihood products	Sewn or woven into tote bags, wallets, trash bins, and handicrafts [50]. Used WFP Polypropylene (PP) bags are recycled into new unbranded bags composed of 50% recycled material, for use in the local market [56].	2
HDPE plastics (rigid)	Education and infrastructure	Recycled into alphabet blocks for children and heavy-duty pavement or latrine pit slabs [50].	1
Glass	Logistics and storage	Reusing glass jars after removing the labels for storing materials and food [57].	1

Refugees in the Rohingya displacement camp reused Polyethylene Terephthalate (PET) as a construction brick through stuffing it with inorganic waste. They then stack the bottles to build walls and reinforce buildings. Also, metallized sachets, originally used to store food, were upcycled in niche livelihood projects. For example, Rohingya refugees in Bangladesh collect packaging of WFP food products such as Super Cereal sachets, which are washed, cut, and heat pressed in preparation for transforming them into other useful products such as wallets and bags [50].

4.2.2. Theme 2: Drivers of Repurposing

The analysis distinguishes between three distinct motivations for repurposing, ranging from survival necessity to high-level policy mandates, as illustrated in Table 2.

Table 2. Drivers of packaging waste in the humanitarian context.

Driver Category	Sub-Category and Mechanism	Key Examples from Data	Frequency (Number of Documents out of 34)
Designer-led (top-down)	Policy and procurement: Institutional requirements to assess the “reusability” of packaging at the sourcing stage, ensuring it is of value to the community before it is bought.	• UNHCR sustainable packaging guidelines [55]. • Reusability assessment before procurement [24]. • Joint Initiative (JI) promotion of secondary-use packaging [3].	3
	Product innovation (design for reuse): Packaging is intentionally designed with a dual purpose, turning waste into a functional item.	• UNICEF RUTF cartons converted into educational toys [58]. • Pre-cut and printed packaging designs [58,59]. • WFP packaging designed for reuse from inception [60].	3
	Technical research: Studies validating that packaging waste is structurally sound enough for construction.	• Ecobricks from PET bottles [49,61]. • Alternative construction materials [49]. • Packaging performance testing [49].	2
User-led (bottom-up)	Survival and protection: Repurposing driven by immediate, critical needs for shelter or safety in conflict/disaster zones.	• PP food bags converted to sandbags [62]. • Oil containers reused as washing basins [50]. • Tarpaulin packaging used as sleeping mats [50]. • Cardboard used for insulation and storage [63].	3
	Livelihood and income: Individuals collecting packaging waste to create saleable products.	• Decorative vases from plastic waste [64]. • Refurbished cans and bottles into flowerpots, lamps, and coffee grinders [65]. • Employment for people with disabilities through plastic upcycling initiatives [52].	3
	Others: Creative hacks to solve daily household problems using packaging.	• Child’s swing from packaging waste [66]. • Recrafted clothing and accessories [67]. • Household problem-solving through upcycling [67].	2
	Community-led design: Agencies consulting communities to find specific uses for their packaging waste.	• Tarpaulin packaging transformed into latrine doors [53]. • Community design committees [53]. • Plastic-lid keychain workshops [68].	2
NGO facilitated (hybrid)	Upcycling centers: Formal facilities established by NGOs to train refugees in converting packaging into products.	• WFP upcycling centers [50]. • Metallized sachet tote bags [50]. • Wallet production and handicrafts [50]. • Refugee-led product development [69].	2
	Local reuse networks: Logistics teams find local pathways to keep materials out of the waste stream.	• ShelterBox pallet reuse programs [70]. • Cardboard reuse for reconstruction [70]. • Local material recovery pathways [70].	1

Practices were grouped into three main categories according to who initiated the repurposing process. Designer-led repurposing initiatives are led and implemented by practitioners and researchers in the field of humanitarian operations such as institutionalizing repurposing in procurement through policing, designing packaging to be reused for other purposes by end-users, and conducting research by academics or NGOs to design and test upcycled products from packaging waste.

The second stream of applications originates from the affected people on the field whose repurposing attempts are driven by their survival instincts. This pathway is characterized by bottom-up innovation driven by immediate scarcity. In displacement settings, packaging is repurposed to meet essential needs that aid agencies have not otherwise met, for example, cardboard as thermal insulation material in houses and shelters. Moreover,

waste picking becomes an income stream, with individuals collecting and refurbishing scrap materials (e.g., turning cans into lamps) for sale.

A third stream is participatory in which relief organizations establish systems to capture waste streams for cost savings or environmental compliance and involve affected people through training, waste collection, and treatment. While NGO-supported upcycling centers offer environmental and social benefits, they face major challenges including high setup and operating costs, complex reverse logistics, and reliance on donor funding. Economic sustainability remains uncertain, as most centers function as pilot projects rather than self-sustaining enterprises, with ongoing concerns about funding continuity, product quality, and market access [71]. Consequently, these initiatives currently operate as humanitarian social enterprises rather than commercially viable waste management solutions.

4.2.3. Theme 3: Design Enablers

The analysis identified specific physical attributes of packaging that facilitate these transformations. Repurposing is rarely accidental; it relies on inherent material properties. Table 3 summarizes the design characteristics of packaging waste material that facilitates repurposing it into new products or functions. Examples of these characteristics are:

- Structural and mechanical features: pre-cut lines and perforations are essential for transforming cardboard into complex shapes (toys, desks) without tools. Disassemblability is key for wooden pallets to allow them to be broken down into construction timber;
- Material properties: the tensile strength of PP bags is the primary enabler for their use in reinforcement when filled with sand, while the rigidity of HDPE allows it to be used as pavement slabs. On the other hand, the heat-press capability of metallized laminates (used in food sachets) allows them to be bonded into new fabrics for easier transformation into other products;
- Geometric form: The shape of the packaging can facilitate or hinder its repurposing. For example, the standardized volume of food sacks and the self-standing cylindrical shape of PET bottles are critical for their use as modular building blocks (Ecobricks).

Table 3. Design characteristics enabling packaging waste repurposing.

Design Feature Category	Specific Characteristic	Enables Repurposing for...	Frequency (Number of Documents out of 34)
1. Structural and mechanical design	Pre-cut lines and perforations	Allows cardboard cartons (e.g., RUTF boxes) to be easily punched out and assembled into toys without tools [58].	1
	Foldability and transformability	Enables cardboard boxes to be refolded into new functional forms, such as a school bag that unpacks into a desk [42].	1
	Disassemblability	Allows items like wooden pallets to be taken apart so the timber can be reused for construction [51].	1
2. Material properties	Tensile strength and tear resistance	Critical for PP woven bags so they can be filled with heavy sand/earth and used as sandbags for flood protection or shelter reinforcement [62].	1
	Rigidity and load bearing	Allows cardboard to support weight (e.g., as a desk) and HDPE plastics to serve as durable pavement slabs or pallets [42,51].	2
	Durability and flexibility	Enables plastic tarpaulin packaging and baling straps to be woven or stretched to create walls and privacy doors for latrines [53].	1
	Heat-press and woven capability	Allows multi-layered metallized sachets (which are hard to recycle) to be sewn or heat-bonded into durable textiles for tote bags and wallets [3].	1

Table 3. Cont.

Design Feature Category	Specific Characteristic	Enables Repurposing for...	Frequency (Number of Documents out of 34)
3. Geometric and physical form	Self-standing shape	The cylindrical, stable shape of PET bottles allows them to be stacked vertically and filled with sand to create rigid walls (Ecobricks) [49].	1
	Standardized volume	The uniform size of food sacks (flour/rice) makes them ideal standardized “building blocks” when filled with sand [62].	1
4. Informational and visual design	Printed reuse instructions	Printing “how-to-use” guides or reuse suggestions directly on the box (e.g., “turn this box into a bed”) encourages users to repurpose the item [58].	1
	Inclusive graphics	Using high-contrast colors and tactile features on packaging (like the UNICEF toy cartons) ensures the repurposed item is accessible to children with disabilities [58].	1
5. Composition and safety	Mono-materiality	Using a single material type (e.g., 100% PE or PP) makes it easier to melt down and mold packaging into new items like bricks or crates [50,72].	2
	Material safety	Ensuring packaging is free from toxic coatings or hazards is a prerequisite for safe reuse by families [47,60,73].	3

In more detail, Table 4 synthesizes the design enablers of packaging repurposing with thresholds and observed failures documented in the selected humanitarian documents. The table highlights how materials performed under stress in real-world applications, for example, cardboard collapsing under modest loads, PP bags tearing when overfilled, or PET bottles deforming under sunlight. By anchoring these insights in empirical evidence and linking them to specific references, Table 4 provides a rigorous engineering perspective on the conditions that enable or constrain repurposing practices in crisis settings. This integration ensures that the framework moves beyond descriptive intuition toward actionable guidance for packaging design, procurement, and logistics planning.

Table 4. Design enablers of packaging repurposing with thresholds.

Packaging Material	Design Enabler	Observed Thresholds/Failures in Field Reports
Cardboard cartons	Rigidity, compressive strength	RUTF cartons used as desks collapsed under ~25 kg load; moisture absorption in Bangladesh reduced strength within 48 h in humid conditions [42–44].
PP woven bags	Tensile strength, seam durability	Gaza reports: sandbags burst when filled beyond ~40 kg; UV exposure caused fiber brittleness after 3–4 months outdoors [45,46].
PET bottles	Structural integrity under compression	Rohingya camps: walls collapsed when bottles underfilled (<70% volume); direct sun exposure caused deformation and loss of rigidity [48,49].
Wooden pallets	Load-bearing capacity	Uganda shelters failed when stacked > 3 tiers without bracing; wood warped under prolonged rain exposure [51].
Plastic tarpaulin straps	Flexibility, weave strength	Kenya latrine walls tore under wind loads > 60 km/h; straps frayed after repeated knotting [53,54,74].
Metal cans	Thermal resistance, malleability	Yemen reports: cooker grills warped after repeated heating cycles; thin-gauge cans cracked under hammer reshaping [50].
Metallized sachets	Barrier properties, flexibility	Bangladesh livelihood projects: wallets delaminated after ~3 months; heat-press seams failed under repeated folding [50,56].

4.2.4. Theme 4: The Hierarchy of Material Transformation

The fourth theme emerges to conceptualize the degree of transformability of packaging waste into new uses. Figure 4 suggests a transformation spectrum depicting two ends: low energy required to upcycle, and high energy or processes required to integrate the packaging material into new products.

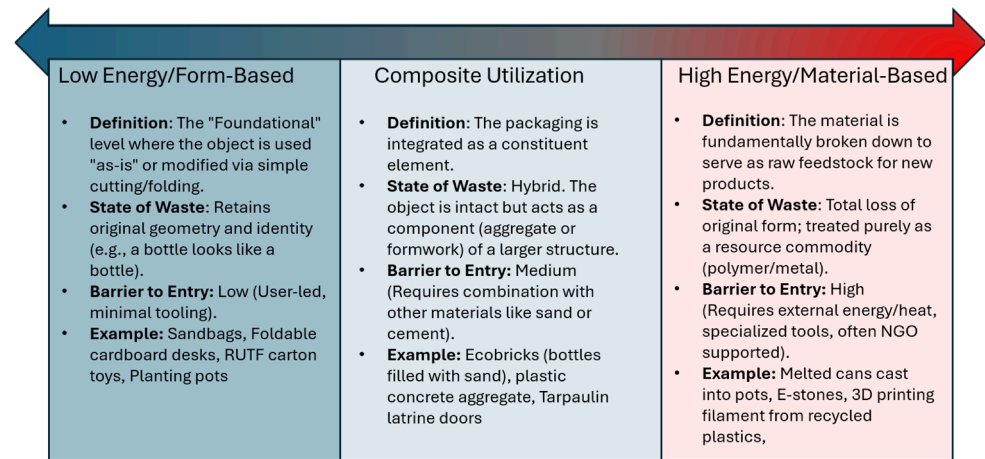


Figure 4. Spectrum of complexity and material alteration.

The left side of the diagram represents the most accessible form of waste repurposing that requires mechanical intervention. In this zone, the packaging material is used "as-is" or modified through simple steps like cutting or folding. The value here lies in the object's original geometry such that a sack remains a sack and a bottle remains a bottle. This level serves as the foundational entry point for repurposing in disasters because it requires zero external energy and minimal tooling, which allows immediate and spontaneous adoption by affected people for their survival needs.

The center of the diagram, which represents the composite utilization phase where packaging becomes a constituent element of a larger matrix or construct. This section represents a sub-level of integration. Ecobricks can fit in this category in which plastic is physically broken down but not chemically altered. The application here uses an external binder (cement) to hold plastic and other materials together. This middle tier bridges the gap between simple reuse and industrial processing, which requires specialized treatment operations.

The right side of the diagram depicts the highest level of complexity: "physio-chemical transformation". Unlike the previous stages, this process completely decouples the material from its original form through heat or chemical treatment (melting or dissolving) to become a raw material for other uses. For example, e-stones are made by melting plastic and rubber into a pasty liquid in a drum, then sand is added while they are heated to reinforce the brick [52]. This end of the spectrum requires significant energy input and specialized equipment and needs the involvement of different stakeholders such as relief organizations and local economic actors.

In more detail, Figure 5 illustrates the comparative energy requirements and recovery potential across different packaging repurposing and recycling pathways. The horizontal axis represents the transformation continuum—from low-energy mechanical adaptations (e.g., folding cardboard, reusing PP bags) to high-energy physio-chemical recycling (e.g., melting HDPE or reprocessing PET). The vertical axis compares the processing energy input (kJ/kg) required for recycling with the material's inherent calorific value (kJ/kg) if used for controlled incineration with energy recovery. Data points show that cardboard (1–2 MJ/kg vs. ~16 MJ/kg), PP bags (3–5 MJ/kg vs. ~46 MJ/kg), PET bottles (10–12 MJ/kg

vs. ~ 22 MJ/kg), and HDPE plastics (8–10 MJ/kg vs. ~ 40 MJ/kg) exhibit distinct trade-offs between recycling feasibility and heating potential. The figure emphasizes that in low-resource humanitarian contexts, energy recovery through controlled combustion may be more efficient than high-energy recycling, while in infrastructure-supported settings, advanced recycling yields durable outputs such as 3D-printing filament or pavement slabs.

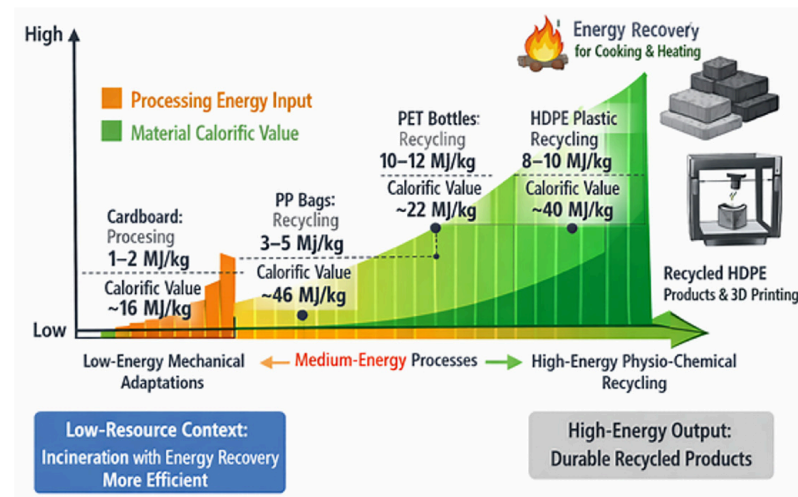


Figure 5. Energy-balance spectrum of packaging material transformation.

5. Discussion

The findings of this study demonstrate and extend the existing body of literature on packaging waste in humanitarian logistics and relief operations. While prior research has established the scale of the problem and the theoretical foundations for repurposing [11,12], the analysis here provides a consolidated evidence-based mapping of how repurposing occurs on field, its drivers, and material characteristics that enable repurposing. The results bridge the theory–practice gap by highlighting and elaborating on hands-on examples of repurposing beyond theoretical and conceptual frameworks [16].

The descriptive analysis confirms that repurposing of waste, specifically packaging, is practiced across regions in which resources are scarce. The recent reports from major agencies such as the WFP underscore that packaging waste is a pressing operational byproduct issue, especially in large-scale commodity distribution. This aligns with previous observations of weak waste management in refugee camps [12] and highlights the urgent and practical impetus behind the search for secondary uses and the extended lifetime of packaging material.

The thematic analysis offers a nuanced framework for understanding repurposing initiatives. First, Table 1 provides an empirical validation and extension for the current niche literature of packaging repurposing in humanitarian logistics. For instance, the documented use of cardboard for educational toys and desks operationalizes the conceptual suggestion that packaging can be designed for extended utility [12,42]. Similarly, the transformation of PET bottles into Ecobricks [49] exemplifies the material revalorization discussed by Ma et al. [23], which proves that waste can be repurposed into a functional value item in low-resource settings.

Second, the analysis of repurposing drivers outlined in Table 2 addresses a gap in prior research by providing insights into the motivations behind these practices. The designer-led initiatives, such as procurement policing, mandate reusability assessments to shift from single-use to value-retaining, which aligns with circular economy principles to reduce waste [17]. On the other hand, user-led repurposing is driven by the survival needs and livelihood of affected communities and highlights agency and innovation in this

regard. However, user-led initiatives can create serious health and environmental risks when packaging containing hazardous residues is reused for food or water storage, or when plastics are melted and release toxic emissions. Therefore, humanitarian organizations should design safer packaging, provide clear repurposing guidance, and integrate safety education into distribution and upcycling programs. This finding contextualizes the “emergency time pressure” constraint and illustrates that scarcity itself can be a catalyst for circular practices even if unplanned [16].

Third, the identification of specific design enablers, as shown in Table 3, moves the discussion from what can be done to how it can be encouraged. For example, a structural feature of cardboard is foldability, which supports the concept of design for reuse [60]. Although the results provide a modest characterization of material properties, this underscores the need for an interdisciplinary collaboration between logisticians, designers, and material scientists to develop and test possible designs for repurposing in the product development phase.

The proposed hierarchy of material transformation, illustrated in Figure 4, offers a novel conceptual tool for assessing and planning repurposing strategies. It reconciles the different technological pathways noted in the reviewed documents, from simple cardboard folding requiring low technological infrastructure to more advanced technological-based applications, such as 3D printing from plastic waste. The findings provide a foundation for developing an integrated and operational framework to transition ad hoc packaging waste repurposing into a more proactive and strategic component of humanitarian logistics, especially in the preparedness phase.

Existing humanitarian logistics literature often distinguishes between top-down (agency-driven) and bottom-up (community-driven) approaches to innovation and resource management [20]. While this dichotomy has provided a useful lens for analyzing organizational versus beneficiary agency, it remains limited in explaining how material properties and design enablers mediate the interaction between these streams. Our framework advances this discourse by embedding the material transformation spectrum within the top-down/bottom-up continuum, thereby demonstrating that repurposing is not simply a matter of organizational policy or community improvisation, but a dynamic process shaped by packaging design affordances and contextual resource constraints.

The theoretical contribution of this study lies in reframing top-down and bottom-up approaches as complementary and co-creative rather than oppositional. By introducing the category of hybrid initiatives and linking them to specific design enablers, we extend existing models to account for collaborative processes where NGOs and beneficiaries jointly transform packaging waste into survival assets. This moves the literature beyond descriptive accounts of agency or community action toward a more nuanced theory of value co-creation in humanitarian logistics, grounded in circular economy principles and material transformation pathways [8,75]. In doing so, our framework provides a novel theoretical bridge between sustainability-oriented supply chain models and field-level evidence of packaging repurposing practices.

6. Conclusions

6.1. Key Findings

This study systematically examined packaging waste repurposing in humanitarian logistics reported and documented by key relief organizations. This research confirms that packaging can be reused to create secondary functional values. Based on practical examples from humanitarian agencies and groups, this paper expands our knowledge of why and how packaging repurposing occurs in crisis settings.

The findings, drawn from 34 documents across five major humanitarian organizations, demonstrate that packaging repurposing has been documented across various applications, ranging from education to sheltering (as presented in Table 1). However, the frequency and generalizability of these practices are limited by this study's scope, and the documented examples represent specific contexts that may not be universally replicable. The most common types of materials discussed in the reviewed documents are cardboard and plastic due to their large proportion in material distribution. A tripartite model of repurposing drivers is suggested to explain who initiates the reuse of packaging. Designer-led initiatives by NGOs and researchers are mainly driven by operational efficiency and innovation, while user-led initiatives are driven by the survival instinct and livelihood of the affected communities. Hybrid-led initiatives are based on a participatory approach, which involves NGOs and beneficiaries in waste valorization and upcycling.

The empirical evidence shows that repurposing packaging is highly influenced by design characteristics such as the structural and material properties of the material. For instance, the foldability of cardboard facilitates its reshaping and redesigning by beneficiaries without the need for specialized technologies. Furthermore, the tensile strength of flour bags enabled beneficiaries in some areas to use them as sandbags to reinforce shelters and protect them from flooding during rain.

The proposed hierarchy of material transformation offers a novel conceptual tool ranging from simple, immediate mechanical changes to complex, resource-intensive physiochemical processes of waste repurposing, which allows practitioners to match repurposing strategies to the specific constraints and capacities of different crisis phases and contexts.

6.2. Limitations and Future Research Directions

This study is not without limitations. The exclusion of academic databases was a deliberate scope limitation justified by the lack of field-level repurposing documentation in the peer-reviewed literature. However, future research should explore whether recent academic work (post-2025) has begun to address this gap. The results of this research are limited to packaging waste, and there is a wider application of repurposing initiatives beyond packaging. This calls for further research to include applications to other types of waste, such as biowaste and consumer goods. Another limitation is that the search scope is limited to main humanitarian NGOs and agencies. Future research can expand it to other governmental agencies and educational institutions. Additionally, more research should focus on investigating the business models that make upcycling centers economically feasible and sustainable.

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Abbreviations

The following abbreviations are used in this manuscript:

CARE	Cooperative for American Remittances to Europe
CMUs	Condensed Meaning Units
EHA-Connect	Environment and Humanitarian Action Connect
HDPE	High-Density Polyethylene
ICRC	International Committee of the Red Cross
JI	Joint Initiative
NGOs	Non-Governmental Organizations
PET	Polyethylene Terephthalate
PP	Polypropylene
RUTF	Ready-to-Use Therapeutic Food
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children’s Emergency Fund
WASH	Water, Sanitation, and Hygiene
WFP	World Food Program
3-Cs	Context, Component, and Concept

Appendix A

Table A1. Selected documents for the thematic analysis.

No.	Title	Issuer	Publication Year
1	Packaging baseline assessment based on humanitarian emergency responses in 2021	<i>Global Shelter Cluster</i>	2023
2	Made of cardboard, this Rs 10 school bag doubles as a desk for rural kids!	<i>Better India</i>	2019
3	Environmental footprint of humanitarian assistance—scoping review	<i>ReliefWeb</i>	2020
4	Actions you can take to become a climate warrior	<i>UNICEF</i>	No Date
5	Options for humanitarian packaging reuse, repurposing and recycling	<i>ReliefWeb</i>	2023
6	Decommissioning guidelines	<i>Better Shelter</i>	No Date
7	Plastic and circular economy: community solutions	<i>GEF</i>	2019
8	Finding new uses for aid packaging in Mozambique	<i>ShelterBox</i>	2024
9	WREC coalition, circular economy information session	<i>Logistics Cluster</i>	2025
10	Compendium of edition solid waste management in humanitarian contexts	<i>WASHnet</i>	No Date
11	From waste to value: a new life for WFP Polypropylene bags	<i>WFP</i>	2023
12	9 ways to reduce plastic waste at home	<i>UNICEF</i>	2020
13	Sustainable packaging: sourcing guidelines	<i>UNHCR</i>	2025
14	UNICEF supply annual report 2023	<i>UNICEF</i>	2023

Table A1. Cont.

No.	Title	Issuer	Publication Year
15	Project play: repurposing packaging into toys for play simulation	UNICEF	2024
16	Rethinking packaging, reducing waste	WFP	2018
17	Gaza humanitarian response, situation report no. 6	OCHA	2025
18	Managing packaging waste sustainably—lessons from humanitarian organizations	ICRC Blogs	No Date
19	“From zero cost to zero waste”: creative Palestinian women help save the environment	ICRC	2022
20	Syrian refugee turns trash into treasure in Jordan	UNHCR	2023
21	Upcycling for food security and fun	Medium	2018
22	How a refugee family is pioneering environmental protection in Jordan	UNHCR Jordan	2024
23	Workshops teach Ukrainian children to reuse and recycle	UNICEF	2024
24	It’s a wrap: Rohingya refugees upcycle hopes and dreams in Bangladesh	WFP	2021
25	Re-use and recycling of our aid packaging in Morocco	ShelterBox	2024
26	Design and prototyping of alternatives to Polypropylene bags.	ICRC	No Date
27	Research on properties of ecobricks and its possible applications	Highlights in Science Engineering and Technology	2022
28	Innovative portable solar cooker using the packaging waste of humanitarian supplies	Renewable and Sustainable Energy Reviews	2016
29	Thermal insulation panels fabricated using recycled cardboard for energy efficiency in buildings: retrofit performance evaluation in hot climate	International Journal of Sustainable Energy	2025
30	Sustainable flood defence using sandbags	Proceedings of the Institution of Civil Engineers-Engineering Sustainability	2025
31	Effectiveness of waste plastic bottles as construction material in Rohingya displacement camps	Cleaner Engineering and Technology	2021
32	Enhancing thermal properties of eco-bricks through integration of post-consumer plastic waste: a sustainable construction approach	Journal of Building Pathology and Rehabilitation	2025
33	Management of flood victims: Chainat Province, central Thailand	Nursing & Health Sciences	2010
34	Packaged hospital food appears safe and feasible to reuse	Nutrition & Dietetics	2023

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