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Strategic Framework for Extended Producer Responsibility of Used Beverage Carton Packaging Using Analytical Hierarchy Process

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Abstract

The rapid expansion of urban populations and changing consumption behaviors have intensified solid waste challenges, particularly in developing countries like Indonesia. Used beverage cartons (UBCs), composed of layered paper, plastic, and aluminum, are among the most difficult packaging materials to recycle. Extended Producer Responsibility (EPR) is increasingly promoted as a policy mechanism to shift waste management responsibilities from local governments to producers. However, the implementation of EPR in Indonesia remains limited due to weak infrastructure, low market incentives, and fragmented stakeholder coordination. This study aims to identify strategic priorities for EPR implementation in managing UBC waste by applying the Analytical Hierarchy Process (AHP), integrated with a penta-helix stakeholder framework. Conducted in East Jakarta between March and November 2023, the research engaged five expert informants representing government, academia, industry, civil society, and waste management sectors. Through structured pairwise comparisons, the study evaluated five sub-criteria: stakeholder participation, regulatory framework, financial incentives, market access for recycled UBCs, and recycling technology. The AHP analysis revealed that stakeholder participation holds the highest priority weight (48.31%), followed by the regulatory framework (34.57%) and financial incentives (9.64%). Market and offtaker availability (5.63%) and recycling technology advancement (1.85%) were identified as lower-priority but still necessary components. These results indicate that socio-economic considerations dominate strategic decision-making in UBC waste management. The study offers a data-driven and context-sensitive framework for EPR implementation that can inform policymakers and industry actors. Furthermore, the AHP model demonstrates potential for replicability in other complex waste streams requiring coordinated multi-stakeholder engagement.

Keywords: Used Beverage Carton (UBC), Extended Producer Responsibility (EPR), Analytical Hierarchy Process (AHP), waste management, recycling, sustainability

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INTRODUCTION

The accelerating pace of global population growth and rapid urbanization have significantly altered consumption patterns, resulting in mounting environmental pressures particularly in the domain of solid waste management. This issue is especially critical in urban areas where high population density and increasing consumerism contribute to complex and often unsustainable waste generation dynamics (Pramiati et al., 2021). The volume of urban waste continues to expand, posing significant threats to environmental quality, climate stability, and public health. These concerns are exacerbated by ineffective waste management systems, most notably in densely populated developing countries where infrastructure and regulatory oversight remain underdeveloped (Mahmud, 2021).

Global estimates from the World Bank (2020) project that annual waste generation will rise from 2.01 billion metric tonnes in 2016 to approximately 3.4 billion metric tonnes by 2050. This projection underscores a direct relationship between economic expansion, consumer behavior, and increasing volumes of waste. In Indonesia, waste generation reached 33.1 million tonnes in 2020, with 40.64% remaining unmanaged and disposed of in landfills without processing (MoEF, 2021). According to Charles (2022), the escalation in consumption fueled by economic growth has led to a disproportionate increase in packaging waste, particularly plastic and paper-based materials. Of this, packaging waste constitutes roughly 6.7%, or 2.22 million tonnes, annually (MoEF, 2021).

Among the most environmentally challenging categories of packaging waste is the Used Beverage Carton (UBC). These multilayer cartons composed of polymer-coated cardboard, aluminum foil, and sometimes polyethylene are widely used for beverages such as milk and juice due to their durability and barrier properties. However, their complex material composition significantly impedes recycling processes (Robertson, 2021). The tightly bonded layers make separation technologically demanding and economically unattractive, particularly in settings lacking advanced recycling facilities. UBCs typically consist of 75% paper and 25% aluminum/plastic film. Unlike conventional packaging such as PET or glass, UBCs possess minimal resale value, making them less desirable for informal recyclers and more likely to be discarded or landfilled.

The challenge of UBC waste is not unique to Indonesia. In Europe, where circular economy models are more mature, UBCs remain a problematic waste stream. While materials like glass, metal, and paper are effectively recycled, beverage cartons often end up incinerated or landfilled due to inadequate separation technologies (Brouwer et al., 2019; Varžinskas et al., 2012). In Lithuania, for instance, ineffective collection and limited market value of recycled UBC components hinder their recovery, despite growing environmental awareness (Varžinskas et al., 2012).

In Indonesia, the Ministry of Environment and Forestry has attempted to tackle this issue through Regulation No. P.75/Menlhk/Setjen/Kum.1/10/2019, which mandates producers to reduce and manage the waste of their products, including packaging. However, practical implementation remains limited. Despite regulatory provisions, UBCs continue to be improperly disposed of, primarily due to systemic shortcomings such as limited recycling infrastructure, absence of economic incentives, and lack of stakeholder coordination.

A promising policy instrument for addressing this issue is Extended Producer Responsibility (EPR). EPR holds producers accountable for the environmental impacts of their products throughout the entire lifecycle from production and use to post-consumer disposal (Stansbury, 2012; Waste4Change, 2021). EPR shifts waste management costs and responsibilities from municipalities to producers, thereby incentivizing better product design, sustainable materials, and improved recyclability (Maitre-Ekern, 2021). EPR policies are aligned with the principles of a circular economy, offering a framework that promotes reuse, recycling, and material recovery while minimizing environmental harm (Colelli et al., 2022).

However, despite its potential, the implementation of EPR in Indonesia remains in its infancy and is fragmented across sectors. The key challenge lies in designing a framework that accommodates the local socioeconomic context, infrastructure limitations, and diverse stakeholder interests. Previous studies have highlighted that multi-stakeholder integration, involving government, industry, consumers, and waste managers, is crucial to the success of EPR frameworks, especially in countries with nascent recycling systems (Gui et al., 2016; Widyarsana & Nurawaliah, 2023).

Recent empirical studies emphasize that collective EPR schemes where multiple producers collaborate to share costs and logistics are particularly effective in emerging economies (Yao et al., 2024; Kunz et al., 2018). In Indonesia, this collective model could significantly enhance the financial feasibility of UBC recycling initiatives, especially when

combined with public-sector support. At the same time, regulatory enforcement, public awareness campaigns, and market incentives must be developed in tandem to ensure system-wide compliance and success (Rahmani et al., 2021; Fauzi et al., 2024).

A notable research gap exists in the structured prioritization of the key elements required for effective EPR implementation for UBC waste in Indonesia. While EPR models have been explored globally such as in the EU and selected ASEAN countries no prior study has explicitly applied the Analytical Hierarchy Process (AHP) to evaluate stakeholder-driven priorities for EPR development in the context of Indonesia's UBC packaging waste. The current study addresses this critical gap by introducing a structured, data-informed, and participatory decision-making model using AHP, integrated with a penta-helix stakeholder framework.

The novelty of this study lies in its unique approach: integrating expert judgment from five major sectors government, industry, academia, civil society, and waste practitioners to systematically evaluate the most effective strategic components for implementing EPR in UBC packaging waste. By applying AHP, the study ranks these strategies in terms of sustainability, feasibility, and impact, providing an evidence-based framework that can inform both policy formulation and private-sector action.

The use of AHP is particularly appropriate in this context. As a multi-criteria decision-making tool, AHP allows for the incorporation of both qualitative judgments and quantitative data, making it well-suited for policy analysis in complex, multi-stakeholder environments (Saaty, 2012; Gautam et al., 2023). Previous studies in packaging waste management have demonstrated AHP's ability to prioritize strategies based on environmental, economic, and social dimensions (Koçak & Tırkolaee, 2025; Joltreau, 2022). For instance, in evaluating flexible packaging alternatives or selecting municipal waste treatment technologies, AHP has successfully guided governments and institutions toward more sustainable waste management practices (Radu et al., 2020; Pongpimol et al., 2020).

Within the ASEAN region, the implementation of EPR has shown varied progress. Countries such as Vietnam have recently launched EPR frameworks for electronic waste, but continue to face challenges related to enforcement, consumer engagement, and coordination across sectors (Tran et al., 2023; Chaerul & Indrapta, 2024). A study by Choi et al. (2021) indicates that the informal waste sector often neglected in formal policies plays a major role in material recovery across ASEAN cities, further complicating EPR execution. While Indonesia has begun to explore EPR in electronic and packaging sectors, integration with existing waste management systems remains weak and under-researched (Soudachanh et al., 2024; Cecchin et al., 2019).

Moreover, the recycling of multi-layer packaging, such as UBCs, poses additional technical challenges. In developing countries, recycling technologies capable of separating bonded layers of paper, plastic, and foil are scarce (Hossain et al., 2023; Seier et al., 2023). Enzymatic and solvent-based methods show potential, but remain prohibitively expensive or underdeveloped for mass deployment (Šleiniūtė et al., 2023; Waszczyłko-Miłkowska et al., 2024). This technological constraint underscores the need for both policy and market mechanisms to support investments in advanced recycling infrastructure.

This study aims to address the complexities of managing used beverage carton (UBC) waste by evaluating the relative importance of various criteria such as regulation, technology, incentives, stakeholder engagement, and market support in the successful implementation of Extended Producer Responsibility (EPR). By applying the Analytical Hierarchy Process (AHP), the study systematically ranks strategic actions based on expert judgments from key stakeholder groups, allowing for a nuanced understanding of priority areas. These insights contribute to the development of a strategic framework that integrates these critical factors and can be adapted by Indonesian policymakers and industry actors to operationalize EPR in a way that is both contextually relevant and environmentally sustainable.

METHOD

Research Design

This research employed a qualitative-exploratory approach integrated with the Analytical Hierarchy Process (AHP) to identify strategic priorities for implementing Extended Producer Responsibility (EPR) in managing Used Beverage Carton (UBC) packaging. Conducted between March and November 2023, the study spanned five main phases: preparation, stakeholder identification and engagement, data collection, AHP structuring, and strategic synthesis. The study location was East Jakarta, a strategic urban area within DKI Jakarta Province, bordered by Bekasi, South Jakarta, and Tangerang. This location was selected for its representative urban waste challenges and dynamic inter-municipal activity.

The design was guided by the Penta-Helix model, incorporating perspectives from five key stakeholder groups government, industry, academia, civil society, and the waste management community to ensure a multi-sectoral and systemic understanding of the EPR ecosystem. The research design process is illustrated in Figure 1, showing sequential steps from secondary data analysis to stakeholder scoring and final strategy formulation.

Participants

Five expert informants were purposively selected using a non-random, stakeholder-representative sampling strategy. Selection criteria included institutional authority, technical competence in waste policy or recycling systems, and experience in EPR implementation. As shown in Table 1 (Expert Profiles), participants represented key institutional actors such as the DKI Jakarta Environmental Agency, University of Indonesia, Indonesia Solid Waste Association (InSWA), a UBC packaging producer, and a collection partner (PT A).

Table 1. Respondent's Identity of Origin

No	Institution	Qualification	Number of Expert
1	Government: DKI Jakarta Environmental Agency	Official with expertise in waste and recycling assessment	One person
2	Academic: University of Indonesia	Academic or lecturer with knowledge of waste management	One person
3	Indonesia Solid Waste Association (InSWA*)*	Official from a packaging recycling organization in Indonesia with expertise in implementing extended producer responsibility (EPR)	One person
4	UBC Packaging Producer Management	Official with authority and expertise to represent the company in EPR implementation	One person
5	Collection Partner (PT A)	Organization that applies the EPR concept in the field	One person

Data Collection Technique

The research began with the collection of secondary data, followed by an analysis of the current recycling flow for used beverage carton (UBC) packaging. This analysis laid the foundation for developing sustainable strategies to improve producer responsibility in waste management. To develop a strategy for expanding producer responsibility for UBC packaging, the study utilized the Analytical Hierarchy Process (AHP) method. This technique relied on expert informants as primary sources of data. The criteria and sub-criteria used in the analysis were derived from insights gained through interviews and focused discussions with these selected experts. The selection process was designed to ensure that the experts involved had a deep understanding of the practical implementation of extended producer responsibility (EPR) strategies.

Data Analysis and AHP Calculation

The Analytical Hierarchy Process (AHP) is a decision-making tool that measures ratio scales, applicable to both discrete and continuous pairwise comparisons (Darmanto et al., 2014). AHP is fundamentally based on human judgment and perception. The "hierarchy" in AHP refers to the restructuring of a complex and unstructured problem into a multi-level structure that is easier to analyze and assess (Marsono, 2014). The method facilitates decision-making by identifying the best possible alternatives through a process that includes question restructuring, alternative identification, value assessment, and risk specification.

The development of strategies to broaden producer responsibility in managing UBC waste was carried out using the AHP framework. The process involved gathering input from expert informants, whose responses informed the formulation of relevant criteria and sub-criteria. These informants were chosen carefully, considering their knowledge and expertise related to the implementation of extended producer responsibility. AHP was used to generate alternative solutions and to evaluate the sustainability of EPR-based strategies. Prior to applying the AHP method, which involves five core sectors essential for driving innovation and sustainability. These sectors included government, industry, academia, civil society, and the waste management community. This inclusive approach ensured a balanced and comprehensive perspective in the formulation of strategies (Saaty, 2012).

The Analytical Hierarchy Process (AHP) was selected due to its ability to accommodate both qualitative and quantitative inputs in complex multi-criteria environments (Marsono, 2014; Koçak & Tırkolaee, 2025). The method was operationalized using five sequential steps:

1. Problem Structuring: Based on stakeholder input, the problem was framed as: “What strategic actions are most critical for sustainable UBC waste management through EPR?”
2. Hierarchy Development: Three tiers were defined: Goal → Criteria → Sub-criteria.
3. Pairwise Comparisons: Experts rated each criterion and sub-criterion relative to one another.
4. Priority Weighting and Synthesis: Scores were normalized to produce final priority rankings.
5. Consistency Validation: The Consistency Ratio (CR) was computed to ensure logical coherence in the judgments. As per Saaty (2012), a CR value below 0.1 was considered acceptable.

RESULTS AND DISCUSSION

Hierarchical Strategy Structure and AHP Approach

The strategy for recycling used beverage carton (UBC) packaging is structured through a hierarchical model, as illustrated in Figure 1. This model adopts a multi-criteria decision-making framework using the Analytical Hierarchy Process (AHP), integrating three primary criteria environmental, stakeholder, and socio-economic considerations. These overarching criteria are further broken down into five interconnected sub-criteria: (1) UBC packaging recycling technology, (2) regulatory development for the expansion of producer responsibility, (3) stakeholder participation including communities and supply chain actors, (4) the availability of offtakers and market access for processed UBC products, and (5) financial incentives. The model captures the interdependence among these factors, emphasizing that successful EPR implementation requires a synergistic approach that aligns technical, institutional, and social dimensions.

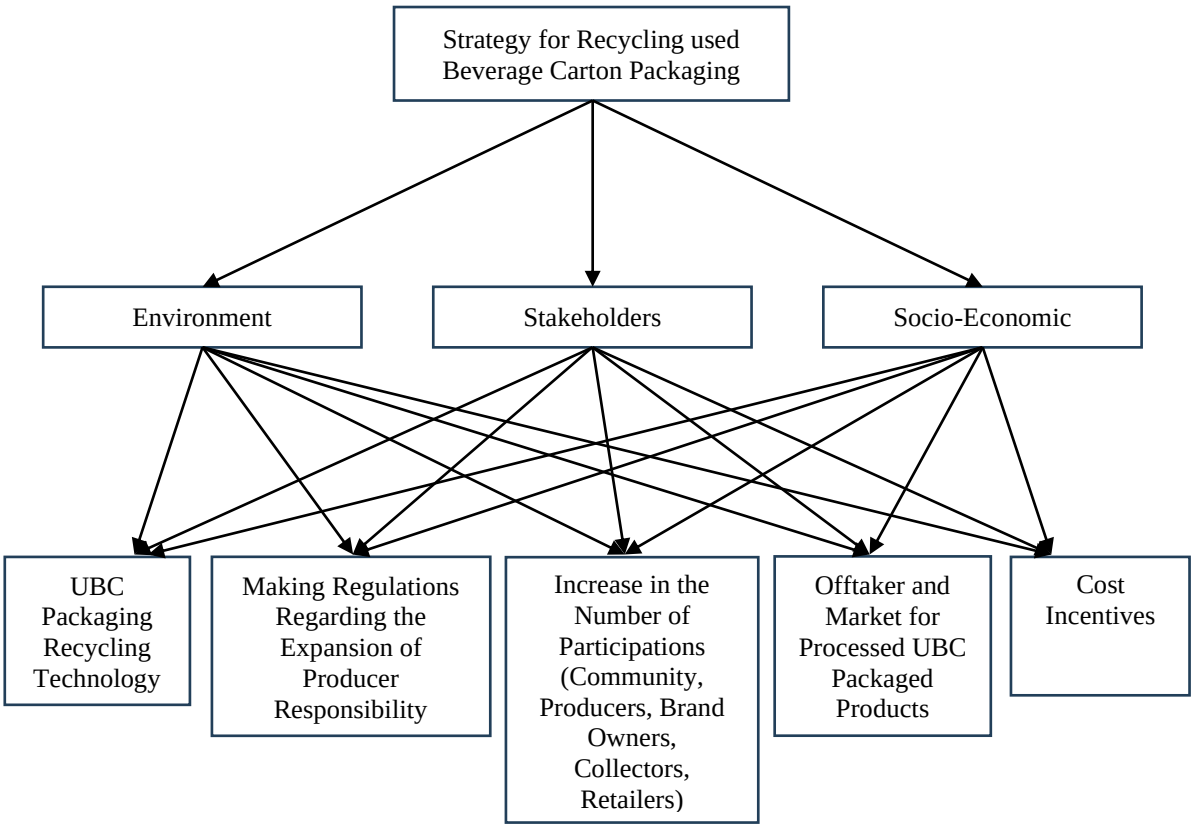

Figure 1. Sustainability hierarchy for extended producer responsibility used beverage carton

The application of the Analytic Hierarchy Process (AHP) within the Extended Producer Responsibility (EPR) framework represents a structured approach to designing waste management strategies, particularly for used beverage cartons (UBCs). As a form of Multi-Criteria Decision Making (MCDM), AHP enables stakeholders to assess various policy alternatives through a systematic and tiered hierarchy. This is especially important in the context of EPR, which requires a balance between social, economic, technological, and environmental dimensions.

AHP's strength lies in its ability to decompose complex problems into manageable subcomponents. As noted by Malinowski et al. (2021), AHP is effective in assigning relative weights to criteria used in selecting landfill sites. Similarly, Kharat et al. (2016) showed that AHP can rank waste treatment options based on environmental and cost-efficiency criteria. In Jordan, AHP was applied to develop robust solid waste systems aligned with EPR principles (Qdais & Al-Saleh, 2023). AHP is also flexible, as it can be combined with other methodologies such as fuzzy logic. Agarwal and Sharma (2024) demonstrated that the fuzzy-AHP hybrid model is useful in contexts with subjective or uncertain data, which are common in environmental policy evaluations. Even in optimizing waste transportation systems, Hmamed et al. (2023) proved that AHP can be integrated into more complex hybrid models.

From a social perspective, stakeholder involvement is a key element of successful EPR implementation, especially in developing countries. As noted by Tasaki et al. (2018), differences in stakeholder understanding of EPR principles can influence participation levels. In Indonesia, Chaerul and Indrapta (2024) highlighted that e-waste management is still carried out by informal actors working in loosely coordinated networks, requiring inclusive policy designs that accommodate this flexibility. Gupta and Dash (2023) emphasized the importance of local experience and community contributions in designing and executing EPR policies. Community engagement increases legitimacy and a sense of ownership, which are essential for program sustainability. Similarly, Widyarsana and Nurawaliah (2023) argue that the success of EPR depends heavily on the socio-political context and the alignment of stakeholder

interests. Gui et al. (2013) added that open and participatory communication channels must be established to ensure inclusive implementation and reduce resistance.

On the technical side, recycling multilayer beverage cartons such as UBCs presents significant challenges. The layered structure, made of paper, plastic, and aluminum, complicates separation and processing (Robertson, 2021). Ciawi et al. (2024) emphasized that this material complexity hinders efficient recycling. Technologies such as enzyme-based processing and hydrapulping are now being developed to address these barriers (Lomwongsopon & Varrone, 2022; Mantia & Castellani, 2022).

However, the challenge extends beyond technology. High processing costs make UBC recycling less attractive compared to more established materials like PET (Robertson, 2021). In this context, EPR functions as a mechanism to shift end-of-life product management costs to producers (Lakhan, 2016; Gong et al., 2023). This approach encourages producers to invest in technology and infrastructure that support circularity.

Collaboration between local governments, industries, and recycling facilities is essential to build effective collection and processing systems. Public awareness and educational campaigns are also needed to increase consumer participation (Bakar & Mohamed, 2024). These elements must be consolidated within the AHP framework, which should be not only technocratic but also participatory and adaptive. Therefore, AHP is a highly valuable tool in evidence-based EPR planning. It helps identify priorities and fosters integration between technical and social interests in a balanced way. An effective UBC recycling strategy will ultimately depend on the successful integration of technological, market, regulatory, and multi-stakeholder collaboration dimensions.

Sub-Criteria Priority Ranking

The criteria were selected through discussions with experts, focusing on socio-economic, environmental, and stakeholder viewpoints. The results are presented in the following table.

Table 2. Priority Ranking of Sub-Criteria for Expanding Producer Responsibility

Sub-Criteria	Priority Weight (%)	Description
Stakeholder Participation	48.31%	Increasing the number of involved parties (community members, manufacturers, brand owners, etc.)
Regulatory Framework	34.57%	Establishing supporting regulations for expanding producer responsibility
Financial Incentives	9.64%	Providing economic incentives to support EPR implementation
Market and Offtaker Availability for Processed UBC Products	5.63%	Ensuring there are buyers and markets for recycled UBC materials
Advancement in UBC Recycling Technology	1.85%	Improving technological capabilities for UBC recycling

The AHP analysis indicates that the success of Extended Producer Responsibility (EPR) implementation for used beverage carton (UBC) recycling is primarily driven by stakeholder participation, which holds the highest priority weight at 48.31%. This finding highlights the critical importance of increasing both the number and the quality of engagement from actors such as community members, manufacturers, brand owners, retailers, and waste collectors. Effective EPR systems rely heavily on inclusive stakeholder networks that facilitate collaboration, legitimacy, and public trust.

In developing countries, community involvement is not merely a complementary element but a structural component of waste management systems. Research shows that community engagement significantly enhances compliance, reinforces ownership, and legitimizes policy implementation (Faibil et al., 2022; Tindana et al., 2015). Locally tailored engagement strategies, such as working with community leaders and grassroots organizations, have proven effective in strengthening communication and policy acceptance (Kolopack et al., 2015; Gilmore et al., 2020). Therefore, the high prioritization of stakeholder participation in the AHP hierarchy reflects the pressing need for adaptive, trust-building community strategies in EPR rollouts.

The second highest-ranked sub-criterion is regulatory framework (34.57%), which underscores the urgency of establishing clear, enforceable legal foundations for producer responsibility. Well-structured regulation provides legal certainty and accountability mechanisms that compel producers to manage products throughout their entire lifecycle. Case studies from the European Union, such as the WEEE Directive and the Packaging and Packaging Waste Directive, illustrate how firm regulatory frameworks can drive eco-design and strengthen collection systems (Gui et al., 2013; Dada et al., 2024). In Africa, Rwanda's ban on plastic bags and Kenya's integrated recycling policies exemplify how national legislation can stimulate behavioral and systemic changes (Uche, 2023).

Although financial incentives rank third in the priority hierarchy (9.64%), they remain a strategic tool in motivating industry engagement. Fiscal instruments such as subsidies, landfill taxes, and compliance cost reductions have been shown to stimulate innovation and incentivize investment in recycling infrastructure and product redesign (Shooshtarian et al., 2020; Fatmawati et al., 2022). These mechanisms act as a bridge between regulatory pressures and economic feasibility, making EPR obligations more manageable for producers.

The remaining sub-criteria availability of markets and offtakers (5.63%) and advancements in UBC recycling technology (1.85%) are weighted lower but remain indispensable. UBCs are multilayered materials combining paper, polyethylene, and aluminum, which require advanced separation and processing methods. Technologies such as solvent-based recycling and hydropulping show promise, but require further development and investment (Li et al., 2024; Samorì et al., 2023). However, even the most efficient technologies are limited without stable market demand. Therefore, market development must be pursued through multi-sector collaboration and public awareness campaigns to ensure that recycled UBC products are commercially viable (Jacob et al., 2021; Eißenberger et al., 2023).

In sum, the AHP-based priority structure illustrates that effective EPR strategies must be integrated. Stakeholder participation forms the social foundation; regulatory clarity establishes legal certainty; incentives provide economic motivation; and market and technological readiness ensure operational continuity. Without coordination across these five sub-criteria, expanding producer responsibility for UBCs is unlikely to achieve long-term sustainability or contribute meaningfully to the circular economy.

Main Criteria Analysis from AHP

The findings from the analysis indicated that the socio-economic dimension held the highest priority in determining the sustainability of extended producer responsibility implementation, scoring 0.79 on a scale of 1. The AHP method further identified several sub-criteria, which consisted of recycling technologies for UBC packaging, regulations linked to extended producer responsibility, an increase in the number of stakeholders such as community members, producers, brand owners, collectors, and retailers, the presence of offtakers and market opportunities for processed UBC packaging products, as well as financial incentives.

Tabel 3. Pair Wise Comparison Level 1

Criteria	Environment	Stakeholders	Socioeconomic	Vector Eigen
Environment	0.076923077	0.015444015	0.089285714	0.060550936
Stakeholders	0.230769231	0.115830116	0.107142857	0.151247401
Socioeconomic	0.692307692	0.868725869	0.803571429	0.788201663
Amount	1	1	1	1

The AHP results presented in the table show that the socioeconomic criterion holds the highest weight in the evaluation of strategies for implementing EPR for UBC recycling. With an eigenvector value of 0.7882, it dominates decision-making, indicating that aspects such as stakeholder participation, financial incentives, and economic feasibility are considered the most critical success factors. The stakeholder dimension ranks second, with a weight of 0.1512. This suggests that expert judgment values the active involvement of key actors such as producers, communities, and waste collectors as essential to ensuring the long-term effectiveness and coordination of EPR implementation. In contrast, the environmental aspect is given the lowest weight at 0.0606. While still relevant, it is considered less urgent in comparison to economic and social factors, likely due to the immediate practical challenges in mobilizing stakeholder engagement and financial support within existing waste management systems.

Detailed Breakdown of Each Category's Sub-Criteria

In the evaluation of environmental factors related to UBC packaging recycling, the sub-criteria were assessed with the following weights: regulation formulation for extended producer responsibility (0.5026), increased participation from stakeholders such as community members, producers, brand owners, collectors, and retailers (0.3352), market and offtaker availability for processed UBC packaging products (0.0810), incentives (0.0437), and recycling technology (0.0375).

Table 4. Environmental Sub-criteria and Their Weights

Environmental Sub-criteria	Weight	Interpretation
Regulation Formulation for EPR	0.5026	Highest among environmental factors, emphasizing the need for legal and institutional support.
Stakeholder Participation	0.3352	Inclusion of public and informal sectors is considered vital from an ecological standpoint.
Market & Offtaker Availability for Recycled UBC	0.0810	Highlights the challenge of establishing a viable end-use market for recycled UBCs.
Environmental Incentives	0.0437	Aims to increase adoption of green practices within industries.
Recycling Technology	0.0375	Necessary but currently constrained by availability and affordability.

The *Stakeholders* table, derived from the pairwise comparison analysis using the AHP, illustrates the extent to which stakeholder involvement is prioritized in the strategy for recycling UBC under an EPR framework. The weight value of 0.2308 when compared to the *Environment* criterion indicates that experts moderately consider stakeholder engagement to be more important than environmental factors. This reflects the belief that effective environmental management requires the active involvement of various actors, including government agencies, producers, waste collectors, community members, and non-governmental organizations. Conversely, the weight value of 0.1071 when compared to the *Socioeconomic* criterion shows that the socioeconomic aspect is still regarded as more critical, particularly in terms of incentives, community participation, and the financial feasibility of recycling systems.

Table 5. Stakeholders Pairwise Comparison and Eigen Value

Compared Criteria	Stakeholders Judgement Value	Interpretation
Environment	0.2308	Stakeholders are moderately more important than Environment
Stakeholders (self)	0.1158	Self-comparison (normalized)
Socioeconomic	0.1071	Socioeconomic is slightly more important than Stakeholders

The eigenvector value of 0.1512 suggests that the *Stakeholders* criterion contributes approximately 15.12% to the overall strategic decision-making process within the AHP model. Although not the highest priority, this position emphasizes that the success of EPR implementation heavily depends on coordinated multi-stakeholder collaboration, from policy formulation and program execution to oversight and market development for recycled products. Therefore, UBC management strategies must be designed to ensure structured and continuous stakeholder engagement, enabling technical, social, and economic aspects to function synergistically in support of a circular economy.

Table 6. Socioeconomic Sub-criteria and Their Weights

Socioeconomic Sub-criteria	Weight	Interpretation
Stakeholder Participation	0.7134	Most important sub-factor under the socioeconomic domain; includes producers, communities, retailers, and others.
Financial Incentives	0.1984	Encourages producer and waste sector engagement by lowering participation barriers.
EPR Regulation	0.0387	Regulatory clarity is important but less impactful without supportive socio-economic mechanisms.
Recycling Technology	0.0171	Technologically necessary but not seen as an immediate socioeconomic driver.
Market & Offtaker Availability	0.0230	Low priority suggests current limitations in downstream market readiness.

For the socio-economic aspect, the sub-criteria received these respective importance values: increased stakeholder participation (0.7134), incentives (0.1984), regulations on producer responsibility expansion (0.0387), recycling technology (0.0171), and the market and offtaker for processed UBC packaging products (0.023).

The application of Extended Producer Responsibility (EPR) in managing used beverage cartons (UBC) involves a range of interconnected components. This approach not only assigns responsibility to producers for the entire lifecycle of their products but also emphasizes multi-sectoral collaboration, adaptive regulation, effective incentives, and technological and market support. This discussion outlines how five key EPR sub-criteria work together to support sustainable UBC management, without explicitly citing quantitative rankings.

Stakeholder Engagement as the Core of EPR

Stakeholder engagement is a central element in the success of EPR strategies. In the context of UBC recycling, collaboration among producers, distributors, government bodies, communities, informal waste collectors, and private sector actors forms the foundation of an inclusive and resilient waste management system. Effective systems must accommodate the diverse interests and capacities of all involved parties (Lau & Wong, 2024; Chaerul & Indrapta, 2024). Each stakeholder has different motivations and barriers to participation. Collaborative strategies should therefore be built through transparent communication and mutual understanding of each actor's role. As literature shows, good coordination fosters the creation

of practical, results-oriented policies with long-term impact (Gupta & Dash, 2023; Umuhoza et al., 2019). When all stakeholders are engaged from planning to implementation, EPR outcomes tend to be more sustainable.

Regulation as the Legal and Institutional Backbone

Without a strong regulatory framework, EPR implementation lacks direction and enforcement. Regulations are essential to ensure producer accountability and provide the legal basis for waste collection, processing, and reporting mechanisms. In the European Union, policies such as the Packaging and Packaging Waste Directive demonstrate how producer responsibility can be institutionalized (Cruz et al., 2012; Gui et al., 2013). In developing countries, the challenges lie in limited institutional capacity and legal uncertainty. Nevertheless, successful examples—like Rwanda's plastic bag ban—show that decisive policy measures can significantly improve environmental outcomes (Uche, 2023). For EPR to function systemically, regulations must be adaptive, inclusive, and capable of stimulating innovation in the industrial sector.

Financial and Environmental Incentives as Behavior Drivers

Both financial and environmental incentives are important mechanisms for encouraging participation from producers and communities. For producers, incentives can promote eco-friendly product design and encourage investment in recycling technologies. Research suggests that assigning financial responsibility to producers increases compliance and spurs innovation (Gui et al., 2018; Portugaise et al., 2023). For communities, financial incentives also boost participation in recycling programs. Evidence from environmental initiatives shows that incentives, when paired with education, can nurture long-term motivation (Hossu et al., 2018; Molema et al., 2016). However, short-term incentives should be integrated with value-based approaches so that participation is not merely transactional.

Markets and Offtakers: Ensuring Economic Viability of Recycling

The presence of markets and buyers for recycled products is critical for the economic sustainability of the EPR system. Without a functioning end-market, producer participation may decline. In this regard, government and industry actors must work together to build robust market ecosystems through tax incentives, green procurement programs, and partnerships between producers and recycling businesses (Ciawi et al., 2024). Market development also requires consumer awareness of the importance of recycled products. Public education programs and eco-labeling can help build consumer preferences that support circular economy objectives (Kaiser et al., 2017). Business sector involvement in creating circular value chains will drive broader systemic transformation in production and consumption.

Technological Innovation: Responding to the Complexity of Multilayer Materials

UBCs are multilayer materials composed of paper, plastic, and aluminum, which makes them difficult to recycle. Thus, recycling technology plays a critical role in addressing their structural challenges. Solutions such as solvent-based recycling, hydropulping, and enzymatic depolymerization are gaining attention for their ability to effectively separate material layers (Li et al., 2024; Loukodimou et al., 2024). However, adopting these technologies faces challenges related to cost and infrastructure readiness. This underscores the need for investment in R&D by both governments and producers. Product design strategies that emphasize recyclability from the outset such as design for recycling are equally important in reducing environmental footprints (Foltynowicz, 2020; Bauer et al., 2021).

CONCLUSION

This study responds to the urgency of addressing used beverage carton (UBC) waste, a type of packaging waste that is complex and difficult to recycle, particularly in developing countries such as Indonesia. With increasing consumption and urbanization, waste volumes continue to rise, posing threats to environmental quality, public health, and climate stability. In

this context, the Extended Producer Responsibility (EPR) approach is proposed as a strategic solution that shifts waste management responsibility from the government to producers, encouraging more sustainable product design and investment in recycling infrastructure. Using the Analytical Hierarchy Process (AHP) method, this study constructs and evaluates strategic priorities for EPR implementation based on input from five main stakeholder groups (penta-helix): government, industry, academia, civil society, and waste management practitioners. The AHP results indicate that the socio-economic dimension carries the highest weight in determining the sustainability of EPR implementation, followed by stakeholder involvement, and finally the environmental aspect. This finding reflects that the success of EPR is largely determined by active community and industry participation, financial incentives, and the economic feasibility of recycling systems.

Stakeholder participation emerged as the most dominant sub-criterion (48.31%), indicating that engaging communities, producers, and informal sector actors is key to building an inclusive and adaptive system. Regulatory frameworks ranked second (34.57%), emphasizing the need for a clear legal structure to ensure producer accountability and drive systemic change. Financial incentives (9.64%) play a behavioral role, encouraging both industry and community involvement. Meanwhile, market availability for recycled UBC products (5.63%) and advancements in recycling technology (1.85%) are also important, although deemed less urgent than socio-economic factors.

In sum, the effectiveness of EPR strategies relies on the synergy between technical, economic, social, and institutional dimensions. While advanced UBC recycling technology is needed, its adoption will be limited without sufficient community involvement and financial incentives. Likewise, markets for recycled products must be developed through fiscal incentives and public awareness campaigns. This study emphasizes that a purely technocratic approach is not sufficient broad and continuous stakeholder engagement is necessary. The use of AHP as an analytical tool proves effective for structuring policy priorities in a participatory and evidence-based manner. By breaking down a complex issue into a measurable hierarchical structure, AHP provides a clearer view of the critical factors influencing EPR success. The findings of this study offer a valuable reference for policymakers and industry actors seeking to implement EPR in a more targeted and sustainable way, particularly in managing UBC waste in Indonesia. Moreover, this approach can be replicated for other types of packaging waste with similar material complexity and economic challenges.

RECOMMENDATION

Based on the findings of this study, it is recommended that future research build upon these results by conducting more comprehensive and detailed investigations into sustainable regional management development strategies. Such studies should explore a wider range of factors and practical applications to further enhance the effectiveness and sustainability of waste management systems, particularly focusing on the integration of Extended Producer Responsibility (EPR) and innovative recycling technologies. This research can serve as a valuable reference point for policymakers, industry stakeholders, and academic institutions aiming to develop more robust frameworks for environmental sustainability at the regional level.

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