

Designing a Sustainable Business Model through Supply Chain Integration: A Business Model Canvas Approach for Disposable Baby Diaper Waste Management

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Abstrak

Limbah popok bayi sekali pakai telah berkembang menjadi krisis lingkungan perkotaan di Indonesia akibat tingginya volume timbulan, kompleksitas material, serta keterbatasan sistem pengelolaan yang masih berorientasi linier. Data nasional menunjukkan bahwa limbah popok merupakan salah satu komponen terbesar sampah residu rumah tangga dan berkontribusi signifikan terhadap kelebihan kapasitas Tempat Pemrosesan Akhir (TPA), emisi gas rumah kaca, serta risiko kesehatan masyarakat. Meskipun berbagai penelitian telah mengkaji pengolahan limbah popok dari sisi teknis, sebagian besar belum mengintegrasikan aspek tata kelola multi-aktor, kelayakan ekonomi, dan nilai sosial-etis dalam satu kerangka sistemik. Penelitian ini bertujuan untuk merancang model bisnis berkelanjutan dalam pengelolaan limbah popok bayi sekali pakai melalui integrasi rantai pasok dengan menggunakan pendekatan Business Model Canvas (BMC). Penelitian ini menggunakan metode studi kasus kualitatif dengan pengumpulan data melalui wawancara semi-terstruktur, observasi lapangan, dan studi dokumentasi yang melibatkan pemangku kepentingan utama dalam rantai pasok pengelolaan limbah. Data dianalisis secara tematik dan dipetakan ke dalam sembilan elemen BMC. Hasil penelitian menunjukkan bahwa integrasi rantai pasok antara rumah tangga, penyedia layanan pengumpulan, fasilitas pengolahan, dan mitra daur ulang berperan penting dalam meningkatkan efisiensi operasional, mengurangi beban lingkungan, serta menciptakan nilai ekonomi dan sosial. Model bisnis yang diusulkan menekankan pada penciptaan nilai bersama, penguatan kemitraan strategis, dan diversifikasi sumber pendapatan dengan tetap mempertimbangkan prinsip ekonomi sirkular dan tanggung jawab moral terhadap lingkungan. Penelitian ini berkontribusi dalam menyediakan kerangka model bisnis terintegrasi yang relevan untuk pengelolaan limbah popok bayi di konteks negara berkembang.

Kata kunci : Business Model Canvas; limbah popok bayi; integrasi rantai pasok; model bisnis berkelanjutan; ekonomi sirkular.

Abstract

Disposable baby diaper waste has evolved into an urban environmental crisis in Indonesia due to its high volume, complex materials, and the limitations of waste management systems that remain predominantly linear in orientation. National data indicate that diaper waste is one of the largest components of household residual waste and contributes significantly to overcapacity at final disposal sites (landfills), greenhouse gas emissions, and public health risks. Although numerous studies have examined diaper waste treatment from a technical perspective, most have not integrated multi-actor governance, economic feasibility, and social ethical values within a single systemic framework. This study aims to design a sustainable business model for managing disposable baby diaper waste through supply chain integration, using the Business Model Canvas (BMC) approach. A qualitative case study method is employed, with data collected through semi structured interviews, field observations, and documentation studies involving key stakeholders in the waste management supply chain. The data are analyzed thematically and mapped into the nine elements of the BMC. The results indicate that supply chain integration among households, collection service providers, processing facilities, and recycling partners plays a crucial role in improving operational efficiency, reducing environmental burdens, and creating economic and social value. The proposed business model emphasizes shared value creation, strengthening strategic partnerships, and diversifying revenue streams, while adhering to the principles of the circular economy and moral responsibility toward the environment. This study contributes by providing an integrated business model framework for managing disposable baby diaper waste in developing countries.

Keywords: Business Model Canvas; management of baby diaper waste; supply chain integration; sustainable business models; circular economy.

1. Introduction

The issue of disposable diaper waste is not just a household hygiene issue, but an environmental crisis that

impacts urban ecosystems in Indonesia. Indonesia is estimated to use 17,4 million disposable diapers every day, equivalent to 3488 tons of daily waste entering

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landfills (TPA) (Badan Riset dan Inovasi N, 2024). The KLHK stated that Indonesia produces around 175,000 tons of diaper waste per year, with urban households as the main source (Kementrian Lingkungan Hidup dan Kehutanan, 2024). The data show that disposable diapers are the second-largest component of non-organic waste after plastic packaging, with an average contribution of 7–11% of total household waste (Budiarto *et al.*, 2023). A recent study from the Bandung Institute of Technology found that 63% of landfills in Java have exceeded capacity, with diapers being the main contributor (Fauziyah & Putri, 2025)

Disposable diapers consist of 30–50% plastic (polypropylene/polyethylene), 30% wood pulp, and 20–30% superabsorbent polymer (SAP). These components are estimated to persist in the environment for 500–800 years (United Nations Environment Programme, 2024). In Indonesia, less than 10% of plastic waste is successfully recycled (Bussines Indonesia, 2024; Yuyun Ismawati *et al.*, 2022), and baby diapers are excluded from waste bank programs and existing domestic waste management schemes due to concerns about biological contamination (Badan Riset dan Inovasi N, 2024). Conventional waste management approaches are inadequate, as diapers are typically disposed of in landfills or incinerated, resulting in methane emissions from landfills, a greenhouse gas with a global warming potential 30 times greater than CO₂ (Rinesti, 2021). This limited management capacity highlights a significant research gap that warrants further investigation.

The impact of diaper waste encompasses not only environmental concerns but also significant social and public health issues. When diaper waste is disposed of in sewers or rivers, it provides a favorable environment for the proliferation of pathogenic bacteria, including *E. coli* and *Salmonella*. Data from the Ministry of Health (Badan Riset dan Inovasi N, 2024). indicate a significant correlation between the density of diaper waste in residential areas and the incidence of diarrhea among toddlers. This issue also raises important ethical and spiritual considerations. Furthermore, diaper waste contaminates soil and groundwater through leachate containing ammonia, heavy metals, and microplastics.

Islamic teachings affirm that humans serve as khalifah fil ardh (God's representatives on earth) and are obligated to maintain the balance of nature (Hasibuan, 2021). Surah Al-A'raf, verse 56, states, "...and do not cause corruption on the earth after (Allah) has set it in order..." This verse establishes a normative foundation for waste management, including diapers, framing it as both a moral obligation and an act of social worship rather than solely a technical responsibility.

The national waste management system continues to operate under a linear economic model characterized by the sequence of take, make, and dispose. This approach presumes unlimited resources and treats landfills as the final destination for waste, despite the

finite carrying capacity of the Earth. Although national regulations promote waste reduction and the adoption of a circular economy, there is a lack of specific business models addressing non-conventional domestic waste streams such as diapers. In the context of increasing global demands for net-zero emissions and circular economic practices, Indonesia remains deficient in infrastructure for processing non-organic waste. Currently, only 3% of diaper waste is managed using environmentally friendly methods such as pyrolysis or incineration, while the majority is either landfilled or openly burned (Sistem Informasi Pengolahan Sampah Nasional, 2025)

The circular economy has emerged as a solution oriented framework derived from the development of the green economy (Suyandari, 2024). In contrast to the linear economy, the circular economy treats waste as a secondary resource, reintegrating it into the value chain through the principles of reduce, reuse, recycle, and recover (4R). Recent global innovations include biopolymer-based recycled diapers, separate collection systems, and thermal conversion technologies that convert diapers into alternative fuels, such as Refuse-Derived Fuel (RDF). In Japan and Sweden, diaper-to-energy programs have reduced landfill waste by 90% since 2020 (IVL, 2021).

Several developed countries have introduced innovative solutions to address these challenges. In Japan, thermal sterilization and mechanical separation technologies are being implemented through a Diaper Recycling project, which converts diaper waste into raw materials for particleboard and solid fuel (Shokubai, 2020). In Europe, a subscription-based collection system integrates a circular economy approach with both producer and consumer engagement (ARN BV, 2020). Startups in Malaysia and India have developed prototypes for converting diapers into lightweight bricks or alternative fuels (Patel *et al.*, 2023). However, the economic feasibility, scalability, and social context of these global innovations have not yet been evaluated in Indonesia.

A national research study identified at least seven researchers who have examined waste management (Afriliana *et al.*, 2024); (Prasetyo *et al.*, 2021); (Karunianto *et al.*, 2024); (Purwati *et al.*, 2023); (Sakti, 2025) (Purwati *et al.*, 2024) For example, (Purwati *et al.*, 2023) focused on processing waste into resin, (Budiarto *et al.*, 2023) explored conversion into fertilizer, and both (Karunianto *et al.*, 2024) (Purwati *et al.*, 2024) investigated the production of paving blocks. However, these studies remain limited in scope. While several works emphasize the technical aspects of recycling, they have not addressed multi-actor governance or the integration of ethical values. Furthermore, these solutions have not been effectively implemented in developing countries, primarily due to high technology costs and limited infrastructure. There is also a lack of business

models that incorporate local socio-economic factors. The absence of an integrated business framework involving multiple supply chain actors highlights a research gap in developing sustainable business models that combine technical, social, economic, and moral considerations within a unified systemic framework, such as the Business Model Canvas.

2. Research Methods

This research uses descriptive analysis with a qualitative approach. This method was chosen because the issue of disposable diaper waste management in Yogyakarta is still exploratory, making a descriptive approach most appropriate for mapping the actual conditions and business prospects without hypothesis testing. The objective of the research is to present a comprehensive overview of the business model structure and process flow within the diaper waste management system through the BMC framework and a SWOT analysis (Hendrawan et al., 2023).

The research stages are structured as shown in Figure: 1. First, problem identification is conducted through an initial review of the disposable diaper waste management system, specifically the limitations of the conventional system and the lack of integration of the circular economy approach. Second, data collection is conducted using secondary data (regulations, government reports, academic literature) and primary data (field observations, interviews with practitioners). Third, the BMC is designed to map the business model structure and process flow for diaper waste management. Fourth, data verification and triangulation are conducted by comparing the results of interviews, observations, and literature to ensure the validity of the findings. Fifth, the results and discussion are structured to emphasize the relevance of the business model to the policy context and business opportunities in Indonesia. The choice of this method is supported by literature, including (Villamin et al., 2024) who emphasizes descriptive analysis as a way of describing phenomena as they are, and (Irawan, 2024) who connects descriptive analysis with SWOT techniques for business strategy.

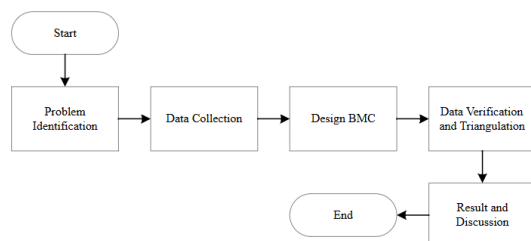


Figure 1: Methodology Flowchart

2.1 Data Collection

The data collection phase aims to obtain an initial empirical picture of the system and business processes

for managing disposable baby diaper waste. At this stage, researchers collect data through field observations, literature studies, and observations of real-world conditions in the surrounding environment relevant to the research object.

The data obtained during the data collection phase is used as a basis for understanding activity patterns, actor roles, and general mechanisms in the waste management under study. This phase does not yet include data validation; instead, it focuses on gathering information to inform business model design.

2.2 Business Model Canvas Design

The BMC design stage was conducted after initial data was collected through literature studies, observations of real world conditions, and exploration of existing service systems and practices. BMC is a management strategy that facilitates the visualisation of business ideas and their rapid implementation (Hendrawan et al., 2023). At this stage, the collected data were analyzed descriptively to map the business model into the BMC framework, which serves as a conceptual tool for profiling the business process of disposable diaper waste management.

2.3 Data Triangulation Validation

The validation stage is conducted to ensure the BMC design has adequate validity, consistency, and reliability. This validation aims to ensure that each element of the formulated BMC accurately represents empirical conditions and is supported by scientifically reliable data sources.

The triangulation process in this study involves three main categories of data sources. (1) households as primary waste generators, (2) service providers including collection and processing actors, and (3) similar businesses or industry benchmarks. These three sources were selected to represent the upstream, operational, and comparative perspectives within the diaper waste management supply chain.

The selection of triangulation sources was based on several criteria: (1) relevance to the research object, particularly actors directly involved in diaper waste generation or management; (2) experience and knowledge, ensuring that informants possess adequate understanding of waste management practices; (3) data accessibility and reliability, allowing consistent and verifiable information to be obtained; and (4) representation of different roles within the supply chain, to capture diverse viewpoints and reduce bias. To assess data validity, this study applies indicators of data convergence and data divergence. Data are considered consistent when similar patterns, information, or findings are repeatedly identified across different sources, indicating strong empirical support. Conversely, data are categorized as inconsistent when discrepancies arise between sources, either in terms of perceptions, practices, or reported conditions. Such inconsistencies are not

immediately discarded but are further analyzed to understand contextual differences, actor perspectives, or potential gaps in the system.

The results of this triangulation process are used to refine and validate the BMC elements, ensuring that the proposed model reflects not only conceptual assumptions but also empirically grounded and contextually relevant conditions.

3. Results and Discussion

3.1. Supply Chain Characteristics for Disposable Baby Diaper Waste Management

Disposable diapers are classified as complex waste due to their composition of plastic, paper pulp, and specialized absorbent materials, which are resistant to natural decomposition and may harbor pathogens from infant waste (Arena et al., 2015; United Nations Environment Programme, 2024; Kaza et al., 2018). The prevalence of disposable diaper use is rising in parallel with increasing birth rates and evolving urban lifestyles (United Nations Environment Programme, 2024). According to a UNEP study (2024), the accumulation of single-use plastics, including diapers, contributes significantly to land and water pollution. The World Health Organization (2019) reports that the presence of infant waste in household refuse elevates the risk of disease transmission via water sources. Addressing these challenges requires solutions that extend beyond conventional disposal methods. A comprehensive recycling approach is recommended (Iskandar Shah et al., 2025), engaging all stakeholders: families as waste generators, local governments as regulators, industries as producers and processors, and communities as partners in education and collection. Through such a recycling system, diaper waste can be converted into valuable products, such as construction materials or alternative energy sources, thereby reducing landfill dependency and mitigating associated health (Kayikci et al., 2022; Badan Riset dan Inovasi N, 2024).

Effective management of disposable diaper waste is closely linked to the spatial context in which it is produced (Patel et al., 2023). In Yogyakarta, the combination of a dense population and a high proportion of young, middle-income households generates a substantial yet fragmented stream of diaper waste. Urban waste collection systems are not equipped to separate hybrid waste types such as diapers, resulting in undifferentiated disposal at landfills (Kaza et al., 2018). Conversely, rural and peri-urban areas produce lower volumes of diaper waste, but limited access to regular collection services often leads to burning or burial of waste in residential yards (Zisopoulos et al., 2023). These contrasting geographic conditions necessitate adaptive supply chain strategies, such as modular, community-based systems for rural areas and digitally integrated logistics for urban environments.

The research results of (Sakti, 2025) recommend that the management of disposable baby diaper waste requires a reverse supply chain approach with complex and multidimensional characteristics. An illustration of the intended supply chain is shown in Figure 2. Diaper waste originates in households and flows through collection, transfer, sorting, and processing before being reused or disposed of as final residue. Unlike conventional supply chains, the material flow in this system is highly dependent on the level of participation of waste sources and the effectiveness of coordination between actors.



Figure 2: Diaper Waste Management Process

Socioeconomic factors also shape the structure of the diaper waste supply chain. Low-income households tend to be sensitive to additional costs. Municipal waste management in Japan and Sweden uses a subscription-based collection model (Technology Strategy Center (TSC), 2020; IVL, 2021). Costs are covered by local governments, producers, and households, including tax payments, at a relatively low and affordable rate.

On the other hand, the upper-middle class in urban Indonesia is beginning to show a willingness to pay for environmentally friendly services, especially when linked to social values or ecological identity (Suryawan & Lee, 2023). Meanwhile, the informal sector particularly scavengers and collectors remains dominant in Yogyakarta's recycling ecosystem; however, they have not yet addressed diaper waste because of hygiene stigma and limited processing technology. Without integrating them into the formal supply chain, large-scale efforts will lose the foundation of efficient and inclusive distribution (White et al., 2023).

Geographical differences require adaptive supply chain systems. Socioeconomic factors shape public acceptance of service costs. Technological barriers require investment in sterilization facilities and material separation. Institutional barriers demand collaboration among stakeholders (Zisopoulos et al., 2023; Schenck et al., 2024). These factors create opportunities for circular business models that transform diaper waste into valuable materials and energy. In a circular framework, producers, governments, and communities share responsibility to generate sustainable economic, social, and environmental value (Zisopoulos et al., 2023). Multi-stakeholder collaboration is essential for a sustainable diaper waste supply chain; producers participate through extended producer responsibility, local governments

regulate, and communities use the services. Without integrating spatial, economic, and socio-cultural dimensions, diaper waste management initiatives will likely remain small and fail to scale (Kayikci et al., 2022; Schenck et al., 2024).

These findings indicate that failed supply chain integration leads to inconsistent waste supply, high logistics costs, and low added value. Therefore, supply chain integration is a key prerequisite for designing a sustainable business model for diaper waste management.

3.2. Business Model Canvas Design Based on Supply Chain Integration

The BMC design was carried out by integrating the supply chain perspective into the nine main elements. Supply chain integration is achieved by connecting key actors, from households as waste generators, through

collection and transfer units, sorting and processing facilities, to recycling partners and final residue managers. This approach enables a more efficient and controlled flow of materials, information, and economic value. The application of the BMC resulted in a mapping of nine integrated business model elements. The resulting business model design is visually presented in Table 1, which illustrates the interrelationships between elements in the disposable diaper waste management system. In terms of customer segments, this system involves not only households and daycares as diapers manufacturers, users of baby diapers, but also local governments, MSMEs, and processing industries as part of the value ecosystem. This approach enables the flow of materials, information, and economic value to move more planned and measurable along the supply chain.

Table 1: Business Model Canvas

<u>Key Partnerships</u>	<u>Key Activities</u>	<u>Value Propositions</u>	<u>Customer Relationships</u>	<u>Customer Segments</u>
- Diaper Manufacturers - Local government authorities and the Environmental Agency - Waste banks and environmental community organizations - Daycare centers - Universities and research institutions - Recycling industry stakeholders and purchasers of processed products - Sponsoring companies and corporate social responsibility (CSR) partners	- Collection and transport of diaper waste - Sorting and sterilizing	- Offers a practical and hygienic method for the disposal of disposable diapers. - Contributes to the reduction of environmental pollution. - Includes scheduled residential trash collection and offers incentive points.	- Monthly subscription-based membership for diaper pickup services - Reward points system designed to incentivize active depositors - Provision of transparent recycling reports to members - Customer service	- Households with babies - Childcare centers - Managers of waste banks - Local governments - Industries involved in the recycling of organic and non-organic materials
<u>Key Resources</u>			<u>Channels</u>	
- Human Resources (recycling operators, field staff, technicians) - Application - Website			- Development of an application or mobile web platform to facilitate pickup requests - Deployment of waste bank agents - Utilization of social media platforms - Implementation of educational programs in schools and health facilities	
<u>Cost Structure</u>			<u>Revenue Streams</u>	
- Transportation operations expenses - Labor compensation - Application development and maintenance expenses - Training and education expenditures			- Subscription fees collected from households for diaper collection services - Corporate social responsibility contributions from environmentally conscious companies	

The resulting value proposition is multidimensional, encompassing practical and hygienic solutions, environmentally friendly waste management services, reduced landfill burden and associated environmental pollution, and economic value from previously unused diaper waste. This value serves as the basis for establishing a business model oriented towards

economic, social, and environmental sustainability. This economic value can take the form of incentive points or rewards for loyal customers of diaper waste suppliers. The primary value of this model is reducing the environmental burden caused by diaper waste while simultaneously creating economic value through the reuse of valuable materials. This finding aligns with the

circular economy concept, which emphasises the use of waste as a resource (Kirchherr et al., 2017).

In the channels element, supply chain integration enables the simultaneous use of physical and non-physical channels. Physical channels include material collection and distribution systems through waste bank agents. Meanwhile, non-physical channels include applications, mobile websites, and social media, which serve as educational, coordination, and communication platforms for actors, such as requesting diaper waste pickup from households. The combination of these two channels increases the effectiveness of material and information flow within the system.

Customer Relationships are designed with a long-term approach through ongoing education, incentives, and community engagement. This can take the form of a monthly subscription-based diaper pickup membership and reward points for active depositors. Regular reports on recycling results are also provided in a transparent format. Furthermore, a customer service (CS) admin is provided to facilitate communication between stakeholders. This relationship strategy aims to increase household participation in waste sorting and delivery, which directly impacts the quality of raw materials in the reverse supply chain.

3.3. Benchmarking Business Models for Baby Diaper Waste Management

Effective management of disposable baby diaper waste requires a sustainable business model integrated throughout the supply chain. A study by (Zisopoulos et al., 2023) shows that practices in Brazil, Pakistan, and China have successfully integrated the informal sector into the formal system through cooperatives, regulatory support, and technology, generating significant economic value. (Kaza et al., 2018) emphasizes the importance of national policies and infrastructure investment as global benchmarks for reducing waste mismanagement. (Mendoza et al., 2019) add that eco-friendly design and efficient production processes can reduce environmental impacts while improving life-cycle cost efficiency. Furthermore, (Iskandar Shah et al., 2025) highlight that material and energy recovery at the end of the diaper life cycle substantially reduces the environmental burden compared to conventional disposal methods.

In contrast to these international benchmarks, practices in Indonesia are still limited to community-based initiatives such as waste banks. (Purwati et al., 2023) emphasize that implementing circular economy principles in baby diaper waste management is not economically feasible without adequate production scale, institutional support, and collaboration among stakeholders. (Sakti, 2025) also emphasized that while community participation through waste banks can contribute to waste reduction, their success relies heavily on the existence of a well-defined and structured business model framework. This situation indicates that the

economic value generated is still low and the integration of actors is not yet comprehensive.

The research gap arises from the difference between international benchmarks that emphasize multi-actor integration, regulatory support, and technology utilization, and Indonesia's current reliance on community initiatives without a clear business framework. Therefore, this study proposes a sustainable business model that prioritizes supply chain integration within the Business Model Canvas framework, specifically the components of key partners, value propositions, and revenue streams. This approach aims to simultaneously generate economic, social, and environmental value and is considered relevant for application in the context of a developing country like Indonesia, where institutional support and cross-actor collaboration are key to success.

Key resources include trained human resources, waste treatment facilities, logistics systems, and processing knowledge and technology. The availability and management of these resources are determining factors in the successful implementation of the business model.

3.4. Role of Key Actors and Collaboration Mechanisms

The success of the business model is influenced by the involvement of key actors, including the government and the Environment Agency (DLH), communities, childcare centers, logistics service providers, the recycling industry as buyers of processed products, and diaper manufacturers within the EPR framework.

Collaboration between parties is realized through partnership agreements, incentive schemes, information exchange, and the establishment of operational standards for collection schedules, initial sorting, controlled transportation, and compliance with environmental standards. Within the EPR framework, manufacturers play a role in providing financial support or performance-based compensation, strengthening collection/return systems, and collaborating on education and regulating waste-management regulations.

3.5. Analysis of Cost Structure and Revenue Sources

In terms of cost structure, the analysis shows that the highest operational costs are driven by waste collection and transportation, primarily due to dispersed waste sources and relatively small volumes per point. Compliance financing support can come from producer contributions through the EPR mechanism (e.g., service subsidies, collection funding schemes, or performance-based compensation). However, supply chain integration enables cost efficiencies through route consolidation, resource sharing, and strategic partnerships.

In terms of revenue streams, this business model has potential revenue sources from waste management services, sales of processed products, and public policy support in the form of environmental incentives or subsidies. This diversification of revenue sources

increases the business model's financial resilience and reduces dependence on a single source of income.

3.6. Validation

Validation of the results and discussion in this study was conducted to ensure that the designed BMC had an adequate level of credibility, consistency, and empirical representativeness. The validation process was conducted through source triangulation by comparing research findings from various key actors in the baby diaper waste management supply chain: households as waste generators, collection and processing service providers, and similar businesses or industries as benchmarks for business practices.

The validation results indicate that the characteristics of the reverse supply chain identified in this study align with those of (Arena et al., 2015), who stated that diaper waste is a complex waste product that requires cross-actor coordination to ensure effective management. The consistency of information between field observations and the literature supports the conclusion that low integration among supply chain actors is a major factor in high logistics costs and low added value of diaper waste.

For Benchmarking with similar businesses provides further empirical validation of the proposed model. The comparison shows that most existing diaper or specialized waste management services adopt a subscription-based collection system combined with scheduled pickup mechanisms. These businesses emphasize convenience, hygiene, and environmental impact as their primary value propositions. This finding is consistent with the proposed design in this study, indicating a strong alignment between the conceptual model and real-world business practices. The value proposition element, validation was conducted by comparing the needs and perceptions of diaper-using households with existing waste management practices. The findings indicate that practicality, hygiene, and economic incentives are the primary values considered relevant by users, aligning with the concept of shared value creation in a circular economy (Kirchherr et al., 2017). This strengthens the argument that an incentive-based approach and ongoing education can increase community participation in the diaper waste management system.

The validation of the key partnerships element indicates that the roles of local governments, environmental communities, and industry partners are crucial to ensuring the operational sustainability of the business model. This finding is consistent with a study by (Hendrawan et al., 2023), which emphasized that cross-sector collaboration can improve operational efficiency and reduce the risk of failure for environmentally based business models. Regulatory and public policy support also proved to be important prerequisites for overcoming

infrastructure and technological limitations in developing countries.

Regarding cost structure and revenue streams, validation was conducted by comparing the identified cost structures with service-based waste management practices in similar sectors. The validation results indicate that the dominance of transportation and collection costs is a common characteristic of household waste management, as also reported by (Rinesti, 2021). Benchmarking findings also confirm that operational challenges mainly lie in logistics efficiency and waste supply consistency. Meanwhile, diversifying revenue sources through service fees, processed product sales, and CSR support is deemed realistic and relevant to improving the business model's financial resilience as also practiced by similar service-based waste management enterprises.

Overall, the validation process demonstrated that the results and discussion of this study exhibit a high level of convergence (fit) with empirical data, benchmarking practices, the Business Model Canvas conceptual framework, and relevant scientific literature, while also identifying several divergences (misfit) related to user behavior and financial constraints. Therefore, the proposed business model is not only conceptual but also has a strong empirical basis and is potentially adaptable to the context of baby diaper waste management in urban Indonesia.

3.7. Potential Economic and Environmental Impacts of the Baby Diaper Waste Management Business Model

3.7.1 Environmental Impact: Reducing Waste Generation and Greenhouse Gas Emissions

According to data from the National Research and Innovation Agency, baby diaper waste in Indonesia amounts to approximately 175,000 tons per year, accounting for 7–11% of total non-organic household waste (United Nations Environment Programme, 2024). If this business model were implemented in a medium-sized city, a more conservative scenario can be applied by referring to similar pilot-scale waste management initiatives. Previous studies indicate that early-stage or pilot implementations of specialized waste collection systems typically manage around 1–3% of the total waste stream, depending on participation rates and infrastructure readiness (Schenck et al., 2024; Sakti, 2025).

Diverting waste from landfills directly reduces greenhouse gas emissions. Diaper waste that degrades anaerobically in landfills contributes to methane emissions, which have a global warming potential approximately 28–30 times greater than CO₂ (Rinesti, 2021). This means that, although methane is emitted in smaller quantities than carbon dioxide, its capacity to trap heat in the atmosphere is significantly higher, making it

a major contributor to climate change. In the context of diaper waste, the presence of organic matter such as human excreta accelerates anaerobic decomposition processes, thereby increasing methane generation in landfill environments.

Using a conservative emission factor of 1.2 tons of CO₂-equivalent per ton of residual waste landfilled, reducing 8,750 tons of diaper waste could reduce emissions by approximately 10,500 tons of CO₂-equivalent per year. This figure demonstrates the significant contribution of this business model to local-level climate change mitigation efforts. Furthermore, reducing diaper waste also reduces the risk of soil and groundwater pollution from leachate containing ammonia, microplastics, and other hazardous compounds. By reducing landfill waste, the service life of final disposal facilities can be extended, thereby reducing the need to open new landfills with high ecological and social impacts.

3.7.2 Economic Impact: Cost Efficiency and Potential Added Value

From an economic perspective, supply chain integration in this business model can improve operational cost efficiency, particularly in waste collection and transportation. Studies on urban waste management indicate that transportation costs can account for 40–60% of a waste management system's total operational costs (Hendrawan et al., 2023). Through consolidation of collection routes, app-based scheduling, and partnerships with waste banks, this model is estimated to reduce logistics costs by 15–25% compared to conventional systems.

From a revenue perspective, this business model has the potential to generate added value from the utilization of post-consumer diaper materials. Assuming the average diaper composition is 30–50% plastic and 30% cellulose fiber (United Nations Environment Programme, 2024) the 8,750 tons of managed diaper waste could yield approximately 2,600–3,500 tons of plastic and 2,600 tons of cellulose fiber per year. If the material is processed into alternative raw materials or derived fuel (RDF) at a conservative selling price of IDR 500–1,000/kg, the potential gross revenue ranges from IDR 2.6–6.1 billion per year, depending on processing technology and market prices.

However, the economic performance of the model is subject to several limitations and external dependencies. First, the volatility of recycled material prices in secondary markets may significantly influence revenue stability. Second, the operational costs particularly for collection, transportation, and pre-processing are sensitive to fuel prices, labor costs, and geographic service coverage. Third, the model assumes a relatively stable participation rate from households, which may vary depending on willingness-to-pay and behavioral factors in urban communities.

To assess the robustness of the model, a sensitivity analysis was conducted on key economic variables. The results indicate that the system remains financially viable under moderate fluctuations. A decrease in recycled material prices of up to 20% would reduce total revenue but still maintain a positive operating margin. Similarly, an increase in collection and logistics costs of up to 20% can still be absorbed without pushing the system into financial loss, due to efficiency gains from route optimization and economies of scale. However, critical thresholds are identified when material prices decline by more than 30–40% or when operational costs increase beyond 25%, at which point the system approaches or reaches the break-even condition.

In addition to direct revenue, this model also creates indirect economic benefits by generating new jobs in the waste collection, sorting, and processing sector. Every 1,000 tons of waste managed in an integrated manner is estimated to require 5–7 operational workers; thus, managing 8,750 tons of diaper waste could create approximately 40–60 local jobs. These findings highlight that, while the model is economically promising and relatively resilient, its long-term sustainability depends on maintaining cost efficiency, stable market linkages, and adaptive operational strategies in response to market dynamics.

4. Conclusion

The findings of this study confirm that the problem of disposable baby diapers cannot be effectively solved through conventional linear and fragmented management approaches. The complexity of waste materials and the high volume of waste generation require a management model that can coordinate the roles of various actors in an integrated and sustainable system. The BMC approach enables the mapping of value relationships, resource flows, and collaboration mechanisms between stakeholders in the diaper waste management supply chain.

The analysis shows that the integration between households, collection service providers, processing facilities, and recycling partners contributes significantly to improving operational performance and reducing environmental impact. In addition, the business model developed is not only cost-efficient, but also creates social benefits and strengthens environmental responsibility through the principles of circular economy. Diversification of revenue sources and strategic partnerships are key elements in maintaining the sustainability of the proposed model. Conceptually, this study enriches the study of waste management by presenting an integrated business model framework that combines economic, environmental, and social dimensions into a single operational approach. In practical terms, this model can serve as an initial reference for policymakers and business actors in designing a diaper waste management system that is

more adaptive to urban challenges in developing countries. Further research is needed to test the acceptability of the model and its quantitative impact on a broader implementation scale.

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