

THE INTEGRATION OF REVERSE LOGISTICS AND ECOLOGICAL PACKAGING DESIGN ON GREEN LOGISTICS PERFORMANCE: THE MEDIATING ROLE OF CIRCULAR DISTRIBUTION CAPABILITIES FOR BIOMASS PELLETS AT THE CIAMIS WASTE BANK

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Abstract

The increasing volume of organic waste, particularly leaf waste, creates challenges in waste management while providing opportunities for biomass pellet production within a circular economy framework. However, research integrating reverse logistics, ecological packaging design, and circular distribution capability in community-based waste management remains limited. This study aims to examine the effects of reverse logistics integration and ecological packaging design on green logistics performance, with circular distribution capability as a mediating variable at the Ciamis Waste Bank. A quantitative explanatory research design was employed using survey data from 124 respondents involved in biomass waste management and pellet distribution. Data were collected using a five-point Likert-scale questionnaire and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS. The results indicate that reverse logistics integration positively and significantly affects circular distribution capability ($\beta = 0.155$; $p = 0.002$) and green logistics performance ($\beta = 0.610$; $p < 0.001$). Ecological packaging design also has a positive and significant effect on circular distribution capability ($\beta = 0.217$; $p < 0.001$) and green logistics performance ($\beta = 0.564$; $p < 0.001$). Circular distribution capability has the strongest direct effect on green logistics performance ($\beta = 0.663$; $p < 0.001$). Furthermore, circular distribution capability significantly mediates the effects of reverse logistics integration and ecological packaging design on green logistics performance. This study contributes to the circular economy and green logistics literature by positioning circular distribution capability as a mediating mechanism in community-based biomass logistics. The findings provide actionable insights for improving reverse logistics integration, sustainable packaging, and circular distribution practices at the Ciamis Waste Bank.

Keywords: Circular economy implementation; Sustainable packaging practices; Circular distribution capability; Biomass pellet supply chain; PLS-SEM.



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1. Introduction

Climate change, increasing waste volumes, and limited natural resources have prompted organizations to adopt the concept of sustainable development in their operational activities. One widely adopted approach is green logistics—the management of logistics activities that is not only focused on cost and service efficiency but also prioritizes reducing environmental impact through energy efficiency, carbon emission reduction, and the optimization of resource use. Green logistics has become one of the key strategies for supporting the achievement of the

Sustainable Development Goals (SDGs) and the implementation of the circular economy across various industrial sectors (Hammes et al., 2022).

In practice, reverse logistics plays a crucial role as a mechanism for returning products, materials, and waste into the supply chain to be reused through processes such as reuse, repair, remanufacturing, or recycling. The integration of reverse logistics enables organizations to reduce waste, improve material efficiency, and generate economic value from products that have reached the end of their useful life. Research by de Oliveira et al. (2020) shows that reverse logistics is a strategic factor in supporting the transition to a circular economy because it can improve operational efficiency while reducing environmental impact.

In addition to reverse logistics, the implementation of eco-friendly packaging design is also a key factor in supporting the success of green logistics. Packaging designs that use environmentally friendly materials, are easily recyclable, reusable, and efficient in the distribution process can reduce packaging waste and the consumption of new materials. Ecologically designed packaging also offers benefits in improving storage and transportation efficiency, thereby lowering logistics costs while reducing the carbon footprint during the distribution process (Su et al., 2026).

However, the success of implementing reverse logistics and eco-friendly packaging design is not determined solely by these two factors but is also influenced by an organization's ability to manage a distribution system that supports the principles of the circular economy. This ability is known as circular distribution capability—that is, an organization's ability to efficiently manage the flow of materials, information, and products so that materials remain in the usage cycle for as long as possible through reuse, recovery, and recycling. Circular distribution capability serves as a bridge between sustainability practices and improved green logistics performance because it ensures that distribution processes operate effectively without neglecting environmental considerations (Hammes et al., 2022).

The Ciamis Waste Bank is a community-based waste management organization that processes organic waste into economically valuable products, such as biomass pellets, which serve as an alternative energy source. The development of biomass pellets holds great potential for supporting the circular economy because it utilizes waste as the primary raw material. However, in practice, various challenges remain, such as suboptimal integration of reverse logistics, packaging that is not yet fully sustainability-oriented, and a distribution system that still requires improvement to fully support the achievement of green logistics. These conditions indicate that improving green logistics performance depends not only on waste management but also requires integration between reverse logistics, eco-friendly packaging design, and circular distribution capabilities.

Based on these conditions, the research problem is the suboptimal integration of reverse logistics, the implementation of eco-friendly packaging design, and distribution capabilities oriented toward the principles of the circular economy in supporting the improvement of green logistics performance at the Ciamis Waste Bank, particularly in the management and distribution of biomass pellets. The objective of this study is to analyze the influence of Reverse Logistics Integration and Eco-Friendly Packaging Design on Green Logistics Performance and to analyze the role of Circular Distribution Capability as a mediating variable in that relationship. The novelty of this study lies in the development of an integrated model that positions Circular Distribution Capabilities as a mediating mechanism between Reverse Logistics Integration and Eco-Friendly Packaging Design and Green Logistics Performance in the context of community-based waste management—specifically the distribution of biomass pellets—an area that has received relatively limited attention in previous research. The contribution of this study is to provide empirical evidence regarding the importance of

strengthening circular distribution capabilities in linking reverse logistics practices and eco-friendly packaging design to improved green logistics performance, while also providing practical implications for the Ciamis Waste Bank in enhancing distribution efficiency, resource reuse, waste reduction, and the sustainability of biomass pellet management.

A literature review serves as the theoretical foundation used to explain the main concepts and the relationships among variables in a study. This review is based on relevant theories and previous research findings regarding Reverse Logistics Integration, Ecological Packaging Design, Circular Distribution Capabilities, and Green Logistics Performance. Additionally, the literature review aims to identify research gaps and establish a conceptual framework that serves as the basis for formulating research hypotheses. By referring to the latest scientific literature, particularly articles indexed in Scopus, this study is expected to have a strong theoretical foundation for explaining the relationships among the variables under investigation and to contribute to the advancement of knowledge in the fields of sustainable logistics management and the circular economy.

1.1. The Integration of Reverse Logistics Influences Circular Distribution Capabilities

Theoretically, the implementation of integrated reverse logistics in the operations of the Ciamis Waste Bank enables a more systematic management of the return flow of household waste, organic waste, and recyclable materials. In this context, the processes of collection, sorting, processing, and reuse—including the processing of organic waste into biomass pellets—form part of the main logistics system. Once return, recovery, reuse, and recycling activities are structured and operational, the Ciamis Waste Bank can build circular distribution capabilities, where waste is no longer the end of the cycle but is processed into an alternative energy source through biomass pellets. Recent literature also confirms that reverse logistics is a key element in realizing circular supply chains and closed-loop systems, particularly in community-based waste management and renewable energy.

H1: The integration of reverse logistics has a positive effect on circular distribution capabilities.

1.2. The Impact of Reverse Logistics Integration on Green Logistics Performance

The integrated reverse logistics system at the Ciamis Waste Bank reduces the amount of waste sent to landfills, increases material reuse, and decreases reliance on new resources. Through a structured system of collection, sorting, and processing, waste—particularly organic waste—can be converted into biomass pellets that serve as an alternative energy source. The direct impact of this integration is improved environmental and operational efficiency in logistics, as material flows become more controlled and economically valuable.

Consequently, green logistics performance at the Ciamis Waste Bank has improved, as evidenced by reduced waste, optimized resource utilization, and the creation of a sustainable utilization cycle. In line with the findings of recent studies, the implementation of reverse logistics also contributes to improvements in Environmental, Social, and Governance (ESG) aspects and supports the achievement of environmental sustainability, particularly in community-based waste management and the development of renewable energy such as biomass pellets.

H2: The Integration of Reverse Logistics Has a Positive Impact on Green Logistics Performance.

1.3. Eco-Friendly Packaging Design Influences Circular Distribution Capabilities

Packaging designed to be reusable, recyclable, or returnable makes it easier for companies to establish circular distribution systems. The more eco-friendly the packaging

design, the higher the likelihood that the packaging will re-enter the logistics cycle and support closed-loop flow management. Recent research indicates that eco-friendly packaging plays a crucial role in strengthening circular supply chains.

H3: Eco-Friendly Packaging Design has a positive effect on Circular Distribution Capabilities.

1.4. The Impact of Eco-Friendly Packaging Design on Green Logistics Performance

Eco-friendly packaging design can reduce material usage, minimize packaging waste, and improve distribution handling efficiency. This has a direct impact on more environmentally friendly logistics performance, both in terms of waste reduction and operational efficiency.

H4: Eco-friendly packaging design has a positive impact on green logistics performance.

1.5. The Impact of Circular Distribution Capabilities on Green Logistics Performance

Circular distribution capabilities enable companies to manage forward and reverse flows as a single integrated system. When companies are able to effectively orchestrate closed-loop distribution, resource efficiency increases, waste decreases, and green logistics performance improves.

H5: Circular Distribution Capabilities have a positive effect on Green Logistics Performance.

1.6. The Integration of Reverse Logistics in Influencing Green Logistics Performance through Circular Distribution Capabilities

The impact of reverse logistics on green logistics performance is not merely direct. Integrated reverse logistics first establishes circular distribution capabilities, and it is these capabilities that serve as the primary pathway for improving green logistics performance. Thus, Circular Distribution Capabilities should be positioned as a mediator.

H6: The integration of reverse logistics has a positive effect on green logistics performance through Circular Distribution Capabilities.

1.7. The Impact of Eco-Friendly Packaging Design on Green Logistics Performance through Circular Distribution Capabilities

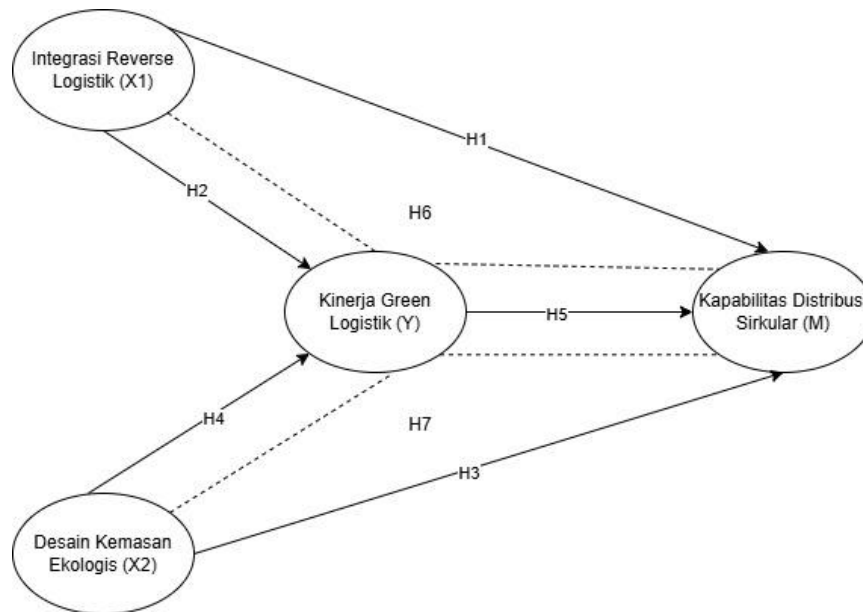
Eco-friendly packaging design will be more effective in improving green logistics when the packaging is integrated into a truly circular distribution system. Therefore, Circular Distribution Capabilities are likely to mediate the effect of eco-friendly packaging design on green logistics performance.

H7: Eco-friendly packaging design has a positive effect on green logistics performance through Circular Distribution Capabilities.

1.8. Framework

Based on the literature review above, this framework is grounded in the concept that the integration of reverse logistics and eco-friendly packaging design is a critical practice in sustainable supply chain management that can enhance a company's green logistics performance. Reverse logistics enables the management of returned products, recycling, and the reuse of materials, thereby reducing environmental impact and improving operational efficiency (Rogers & Tibben-Lembke, 1999). On the other hand, eco-friendly packaging design contributes to reducing material usage, packaging waste, and emissions during the distribution process (Sarkis, 2012). Increased implementation of reverse logistics and eco-friendly packaging design is expected to improve green logistics performance, as reflected in resource efficiency, reduced carbon emissions, and minimized waste in logistics activities (Green et al., 2012). Furthermore, improved green logistics performance will strengthen a company's

circular distribution capabilities—that is, its ability to manage the flow of products, materials, and information sustainably in accordance with the principles of the circular economy (Kirchherr et al., 2017; Geissdoerfer et al., 2017). Thus, the integration of reverse logistics and eco-friendly packaging design is expected to have not only a direct impact on circular distribution capabilities but also an indirect impact through improved performance.



Source: Secondary data processed by the authors (2026).

Figure 1. Conceptual Framework

This research model illustrates the relationship between Reverse Logistics Integration (X1), Eco-Friendly Packaging Design (X2), Circular Distribution Capability (M), and Green Logistics Performance (Y). This model tests seven hypotheses: H1—the effect of Reverse Logistics Integration on Circular Distribution Capabilities; H2—the effect of Reverse Logistics Integration on Green Logistics Performance; H3—the effect of Ecological Packaging Design on Circular Distribution Capabilities; H4: the effect of Eco-Friendly Packaging Design on Green Logistics Performance, and H5: the effect of Circular Distribution Capabilities on Green Logistics Performance. Furthermore, H6 and H7 test the role of Circular Distribution Capabilities as a mediating variable in the relationships between Reverse Logistics Integration and Green Logistics Performance, and between Eco-Friendly Packaging Design and Green Logistics Performance, respectively.

2. Methods

Research methodology refers to the systematic steps used to collect data and address research objectives through a scientific approach. This study employs a quantitative method to analyze the influence of reverse logistics integration and eco-friendly packaging design on green logistics performance, with circular distribution capability serving as a mediating variable in the management of biomass pellets at the Ciamis Waste Bank. The research data were analyzed using the Structural Equation Modeling-Partial Least Squares (SEM-PLS) method with the assistance of SmartPLS 3 software.

2.1. Research Design

This study employs a quantitative approach with an explanatory research design, which aims to explain the cause-and-effect (causal) relationships among variables by testing formulated hypotheses. The quantitative approach was chosen because it can objectively measure relationships among variables based on numerical data obtained from respondents and analyzed using inferential statistical techniques.

The research model consists of two independent variables—Reverse Logistics Integration (X1) and Ecological Packaging Design (X2)—one mediating variable—Circular Distribution Capability (M)—and one dependent variable—Green Logistics Performance (Y). The relationships among the variables were analyzed using Partial Least Squares-based Structural Equation Modeling (PLS-SEM) because this method can test both direct and indirect (mediation) relationships, accommodate complex research models, and is suitable for predictive research (Hair et al., 2022).

Model testing was conducted in two stages: outer model evaluation and inner model evaluation. The purpose of the outer model evaluation was to test the construct validity and reliability through outer loadings, Average Variance Extracted (AVE), Cronbach's Alpha, and composite reliability. Next, the inner model evaluation was conducted to measure the model's ability to explain the relationships among variables using the R-Square (R^2) value, path coefficients, and the specific indirect effect to test the mediating effect. Significance testing was performed using the bootstrapping technique with criteria of T-Statistic > 1.96 and P-Value < 0.05 , thereby determining whether the research hypothesis is accepted or rejected (Hair et al., 2022).

2.2. Data Sources and Research Subject

The subject of this study is the Ciamis Waste Bank, an organization engaged in community-based waste management that processes biomass waste into biomass pellets as an environmentally friendly alternative energy product. The Ciamis Waste Bank was selected as the subject of this study because it has implemented a waste management concept that supports the principles of the circular economy through the reuse of waste as a raw material with economic added value.

The study utilized two types of data sources: primary data and secondary data. Primary data was obtained directly through the distribution of questionnaires to respondents involved in the operational activities of the Ciamis Waste Bank, such as the processes of waste collection, sorting, processing, packaging, and distribution of biomass pellets. The questionnaire was designed using a five-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree, to measure respondents' perceptions of each research indicator.

Meanwhile, secondary data were obtained from various relevant sources, such as internal reports from the Ciamis Waste Bank, organizational documents, scientific articles, reference books, and national and international journals discussing reverse logistics, eco-friendly packaging design, circular distribution capabilities, and green logistics. Secondary data were used to strengthen the theoretical foundation, develop the conceptual framework, and support the interpretation of research results.

Respondents in this study were selected using purposive sampling, a technique for determining a sample based on specific criteria. The criteria for respondents included individuals directly involved in biomass waste management and biomass pellet distribution activities at the Ciamis Waste Bank who also possessed an understanding of the operational processes related to the research variables. The number of respondents in this study was 124, all of whom were deemed to have met the criteria.

3. Results and Discussion

Data collection for this study was conducted by distributing questionnaires to respondents involved in the management and distribution of biomass pellets at the Ciamis Waste Bank. The questionnaire was designed using a five-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Questionnaires were distributed both in person and online (via Google Forms) to respondents who met the study criteria.

The characteristics of respondents based on their highest level of education aim to provide an overview of the educational backgrounds of the respondents participating in the study. Educational level is one of the factors that can influence an individual's ability to understand operational procedures, adopt innovations, and apply concepts such as reverse logistics, eco-friendly packaging design, circular distribution capabilities, and green logistics.

Table 1. Characteristics of Respondents by Educational Level

Category	Frequency	Percentage
Male	52	41,9%
Female	72	58,1%
Total	124	100%

Source: Author's Processed Data (2026)

Based on the table, it is evident that female respondents constituted the majority of the study's participants, accounting for 58.1%, while male respondents accounted for 41.9%. This composition indicates that women's involvement in activities related to biomass pellet management at the Ciamis Waste Bank is greater than that of men. This suggests that the waste bank's operations—from collection, sorting, and processing to packaging and product distribution—involve a significant level of female participation.

The characteristics of respondents based on age aim to provide an overview of the age distribution of respondents involved in the study. Age grouping is important for understanding the profile of the human resources participating in biomass pellet management at the Ciamis Waste Bank.

Table 2. Characteristics of Respondents by Age

Category	Frequency	Percentage
<20 Under	5	4%
21-30	78	62,9%
31-40	33	26,6%
>41 Over	8	6,5%
Total	124	100%

Source: Author's Processed Data (2026)

The table shows that the study's respondents were predominantly in the 21–30 age group, accounting for 62.9% of the total 124 respondents. Next, the 31–40 age group accounted for 26.6%, followed by those over 40 at 6.5%, while the under-20 age group was the smallest, at 4.0%.

The characteristics of respondents based on their highest level of education aim to provide an overview of the educational backgrounds of the respondents participating in the study. Educational level is one of the factors that can influence an individual's ability to

understand operational procedures, adopt innovations, and apply the concepts of reverse logistics, eco-friendly packaging design, circular distribution capabilities, and green logistics.

Table 3. Respondent Characteristics by Education Level

Category	Frequency	Percentage
High School/Diploma 1-2	38	30,6%
Diploma (D3)	15	12,1%
Bachelor's Degree (S1)	60	48,4%
Magister's Degree (S2)	9	7,3%
Doctorate (S3)	2	1,6%
Total	124	100%

Source: Author's Processed Data (2026)

Based on Figure 4.3, it is evident that the majority of respondents hold a Bachelor's degree (S1), accounting for 48.4% of the total 124 respondents. Next, respondents with a high school (SMA/SMK) or Diploma 1–2 education accounted for 30.6%, followed by those with an Associate's degree (D3) at 12.1%. Meanwhile, respondents with a master's degree (S2) accounted for 7.3%, and those with a doctoral degree (S3) constituted the smallest group, at 1.6%.

This chapter presents the results of the data analysis obtained from the distribution of questionnaires to respondents at the Ciamis Waste Bank. The analysis was conducted using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with the assistance of SmartPLS 3 software. The analysis stages included respondent characteristics, measurement model evaluation (outer model), structural model evaluation (inner model), and hypothesis testing to determine the relationships among the research variables.

3.1 Outer Model Evaluation

The outer model evaluation was conducted to ensure that each indicator is capable of measuring the construct in a valid and reliable manner. The testing included convergent validity, discriminant validity, and reliability. Convergent validity was evaluated using the outer loading and average variance extracted (AVE) values. According to Hair et al. (2022), an indicator is considered valid if it has an outer loading value of ≥ 0.70 , while a construct is considered to meet convergent validity if it has an AVE value of ≥ 0.50 .

Table 4. Convergent Validity

	Eco-Friendly Packaging Design (X2)	Circular Distribution Capabilities (M)	Green Logistics Performance (Y)	Reverse Logistics (X1)
M-1		0,826		
M-2		0,837		
M-3		0,834		
M-4		0,828		
M-5		0,810		
X1-1				0,930
X1-2				0,891
X1-3				0,912
X1-4				0,900

	Eco-Friendly Packaging Design (X2)	Circular Distribution Capabilities (M)	Green Logistics Performance (Y)	Reverse Logistics (X1)
X1-5				0,857
X2-1	0,910			
X2-2	0,909			
X2-3	0,902			
X2-4	0,913			
X2-5	0,923			
Y-1			0,874	
Y-2			0,850	
Y-3			0,837	
Y-4			0,841	
Y-5			0,831	

Source: Author's Processed Data (2026)

The results of the construct reliability and validity tests indicate that all constructs met the criteria for reliability and validity. The Cronbach's Alpha values for the variables Ecological Packaging Design (0.949), Circular Distribution Capability (0.885), Green Logistics Performance (0.901), and Reverse Logistics (0.940) were all above the minimum threshold of 0.70, indicating a very high level of internal consistency. This is further supported by rho_A values ranging from 0.885 to 0.950 and Composite Reliability values ranging from 0.915 to 0.961, confirming that all constructs exhibit excellent reliability. In addition, the Average Variance Extracted (AVE) values for all variables also exceeded 0.50, namely Ecological Packaging Design (0.831), Circular Distribution Capability (0.684), Green Logistics Performance (0.717), and Reverse Logistics (0.807), indicating that each construct is capable of explaining more than 50% of the variance in its constituent indicators. Thus, it can be concluded that all variables in this study have met the requirements for construct reliability and convergent validity; therefore, the research instrument is deemed reliable and suitable for use in proceeding to the structural model (inner model) analysis (Hair et al., 2022).

Table 5. Average Variance Extracted (AVE)

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Eco-Friendly Packaging Design (X2)	0,949	0,950	0,961	0,831
Circular Distribution Capabilities (M)	0,885	0,885	0,915	0,684
Green Logistics Performance (Y)	0,901	0,901	0,927	0,717
Reverse Logistics (X1)	0,940	0,947	0,954	0,807

Source: Author's Processed Data (2026)

Based on the results of the Fornell-Larcker Criterion test, most constructs met the requirements for discriminant validity, as indicated by the square root of the Average Variance Extracted ($\sqrt{\text{AVE}}$) for each variable: Eco-Friendly Packaging Design (0.911), Circular Distribution Capability (0.827), Green Logistics Performance (0.847), and Reverse Logistics (0.898), which are greater than the correlations with other constructs. However, the correlation

between Circular Distribution Capability and Green Logistics Performance was found to be 0.872, which slightly exceeds the $\sqrt{\text{AVE}}$ value for Circular Distribution Capability (0.827). This indicates a very strong relationship between the two constructs, so their discriminant validity needs to be further confirmed through the Heterotrait-Monotrait Ratio (HTMT) test as a complementary method. Overall, the results of the Fornell-Larcker Criterion indicate that most constructs have good discriminant validity, although the relationship between Circular Distribution Capability and Green Logistics Performance requires further evaluation.

Table 6. Uji Discriminant Validity

	Desain Kemasan Ekologis (X2)	Kapabilitas Distribusi Sirkular (M)	Kinerja Green Logistik (Y)	Reverse Logistik (X1)
Eco-Friendly Packaging Design (X2)	0,911			
Circular Distribution Capabilities (M)	0,571	0,827		
Green Logistics Performance (Y)	0,542	0,872	0,847	
Reverse Logistics (X1)	-0,037	0,538	0,590	0,898

Source: Author's Processed Data (2026)

Based on the results of the Heterotrait-Monotrait Ratio (HTMT) test, most construct pairs met the criteria for discriminant validity because they had HTMT values below the 0.90 threshold, namely the relationship between Ecological Packaging Design and Circular Distribution Capability (0.622), Eco-Friendly Packaging Design and Green Logistics Performance (0.585), Reverse Logistics and Eco-Friendly Packaging Design (0.064), Reverse Logistics and Circular Distribution Capability (0.584), and Reverse Logistics and Green Logistics Performance (0.636). However, the relationship between Circular Distribution Capability and Green Logistics Performance has an HTMT value of 0.977, which exceeds the maximum threshold of 0.90. This result indicates that the two constructs share a very high degree of similarity, meaning that their discriminant validity has not been fully established. Nevertheless, in general, most constructs have met the requirements for discriminant validity, while the relationship between Circular Distribution Capabilities and Green Logistics Performance warrants attention in the interpretation of the research results because it indicates a very strong correlation (Hair et al., 2022).

Table 7. Heterotrait-Monotrait Ratio (HTMT) Test

	Eco-Friendly Packaging Design (X2)	Circular Distribution Capabilities (M)	Green Logistics Performance (Y)	Reverse Logistics (X1)
Eco-Friendly Packaging Design (X2)				
Circular Distribution Capabilities (M)	0,622			
Green Logistics Performance (Y)	0,585	0,977		
Reverse Logistics (X1)	0,064	0,584	0,636	

Source: Author's Processed Data (2026)

Based on the results of the SmartPLS analysis, all indicators under the variables of Reverse Logistics Integration, Ecological Packaging Design, Circular Distribution Capability, and Green Logistics Performance had outer loadings above 0.70; therefore, all indicators were deemed valid. In addition, the AVE values for each construct also exceeded the minimum threshold of 0.50, meaning that each construct explains more than 50% of the variance in its respective indicators. To provide a more comprehensive overview of the measurement model evaluation results, a summary of the Outer Model test results is presented below

Table 8. Summary of Outer Model Evaluation Results

Evaluation Criteria	Standard	Research Results	Conclusion
Outer Loading	$\geq 0,70$	0,810–0,930	Meets
Cronbach's Alpha	$\geq 0,70$	0,885–0,949	Meets
rho_A	$\geq 0,70$	0,885–0,950	Meets
Composite Reliability	$\geq 0,70$	0,915–0,961	Meets
Average Variance Extracted (AVE)	$\geq 0,50$	0,684–0,831	Meets
Fornell-Larcker Criterion	$\sqrt{\text{AVE}} > \text{Correlation}$	Does not fully meet criteria (M–Y)	Requires attention
HTMT	$< 0,90$	Largely meets criteria, M–Y = 0,977	Requires attention

Source: Author's Processed Data (2026)

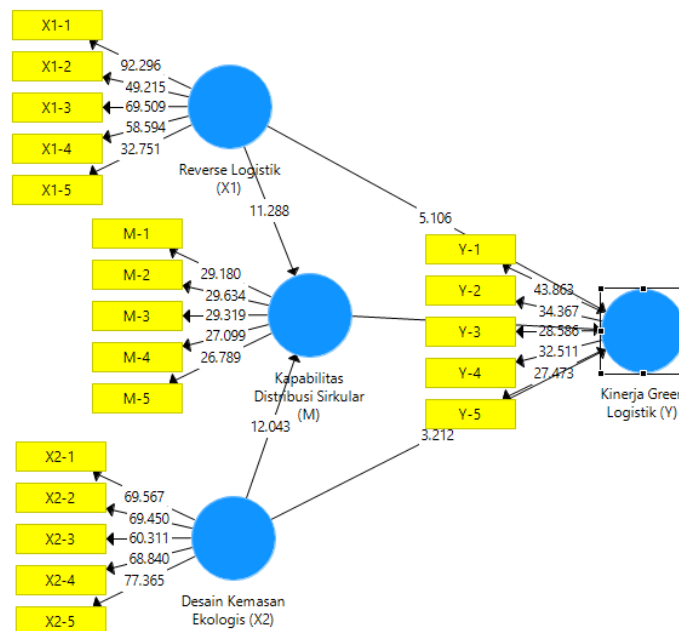
Based on the results of the outer model evaluation, all indicators for the variables Reverse Logistics (X1), Ecological Packaging Design (X2), Circular Distribution Capability (M), and Green Logistics Performance (Y) had outer loadings above 0.70 (0.810–0.930), thereby meeting the criteria for convergent validity and effectively representing the constructs being measured (Hair et al., 2022). Additionally, all variables have Cronbach's Alpha, rho_A, and Composite Reliability values above 0.70, as well as Average Variance Extracted (AVE) values above 0.50, indicating that the research instrument meets the criteria for reliability and construct validity. Tests of discriminant validity using the Fornell-Larcker Criterion and the Heterotrait-Monotrait Ratio (HTMT) showed that most constructs met the criteria, although the relationship between Circular Distribution Capability and Green Logistics Performance still exhibited a very high correlation (HTMT = 0.977), meaning that the discriminant validity for these two constructs was not yet fully optimal. Overall, the results of the outer model evaluation indicate that the research instrument possesses good levels of validity and reliability, making

it suitable for structural equation modeling (inner model) analysis while still taking into account the strong relationship between the two constructs.

3.2 Inner Model Evaluation

The evaluation of the inner model (structural model) aims to determine the model's ability to explain the relationships among the latent variables formulated in the research hypotheses.

The SEM-PLS method was chosen because it can simultaneously analyze complex relationships among latent variables, including both direct and indirect relationships via mediating variables. Additionally, SEM-PLS can handle data that does not have to be normally distributed and is suitable for predictive research and model development, such as studies on reverse logistics integration, eco-friendly packaging design, circular distribution capabilities, and green logistics performance.



Source: Author's Processed Data (2026)

Figure 2. SmartPLS 3 Research Model

In this study, there are four latent constructs: Reverse Logistics (X1), Eco-Friendly Packaging Design (X2), Circular Distribution Capability (M) as the mediating variable, and Green Logistics Performance (Y) as the dependent variable. The analysis was conducted in two main stages: evaluation of the measurement model (outer model) to test the validity and reliability of the research instruments, and evaluation of the structural model (inner model) to examine the relationships among variables and test the research hypotheses.

The testing was performed using the coefficient of determination (R-Square) and path coefficients obtained from the PLS algorithm. According to Hair et al. (2022), the R-Square value is used to measure the ability of exogenous variables to explain endogenous variables, while the path coefficient indicates the direction and magnitude of the influence between variables in the structural model.

Table 9. R-Square (R^2) Values

	R Square	R Square Adjusted
Kapabilitas Distribusi Sirkular (M)	0,786	0,780
Kinerja Green Logistik (Y)	0,665	0,660

Source: Author's Processed Data (2026)

Based on the R-Square test results, the Circular Distribution Capability (M) variable has an R^2 value of 0.786, indicating that 78.6% of the variation in Circular Distribution Capability can be explained by Reverse Logistics (X1) and Ecological Packaging Design (X2), while 21.4% is influenced by other factors outside the research model. Meanwhile, the Green Logistics Performance variable (Y) has an R^2 value of 0.665, meaning that 66.5% of the variation in Green Logistics Performance can be explained by Reverse Logistics (X1), Ecological Packaging Design (X2), and Circular Distribution Capability (M), while the remaining 33.5% is influenced by other variables not included in the model. Based on the classification by Hair et al. (2022), both R^2 values indicate that the model possesses strong predictive power in explaining the endogenous variables.

The path coefficient values indicate the direction and magnitude of the influence between variables in the research model. Based on the results of the PLS algorithm, all relationships between variables have positive coefficients.

Table 10. Path Coefficients, T-Values, and P-Values

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Desain Kemasan Ekologis (X2) -> Kapabilitas Distribusi Sirkular (M)	0,217	0,220	0,057	3,829	0,000
Desain Kemasan Ekologis (X2) -> Kinerja Green Logistik (Y)	0,564	0,566	0,050	11,275	0,000
Kapabilitas Distribusi Sirkular (M) -> Kinerja Green Logistik (Y)	0,663	0,659	0,060	11,136	0,000
Reverse Logistik (X1) -> Kapabilitas Distribusi Sirkular (M)	0,155	0,157	0,049	3,166	0,002
Reverse Logistik (X1) -> Kinerja Green Logistik (Y)	0,610	0,611	0,043	14,057	0,000

Source: Author's Processed Data (2026)

Based on the results of the path coefficient tests, all relationships between variables showed positive and significant effects, as evidenced by T-statistic values > 1.96 and P-values < 0.05 . Eco-Friendly Packaging Design (X2) has a positive effect on Circular Distribution Capability (M) ($\beta = 0.217$; $T = 3.829$; $P = 0.000$) and Green Logistics Performance (Y) ($\beta = 0.564$; $T = 11.275$; $P = 0.000$). Reverse Logistics (X1) also has a positive effect on Circular Distribution Capability (M) ($\beta = 0.155$; $T = 3.166$; $P = 0.002$) and Green Logistics Performance (Y) ($\beta = 0.610$; $T = 14.057$; $P = 0.000$). Meanwhile, Circular Distribution Capability (M) has a positive and significant effect on Green Logistics Performance (Y) ($\beta = 0.663$; $T = 11.136$; $P = 0.000$), and is also the variable with the greatest direct effect in the research model. Thus, all direct effect hypotheses (H1–H5) are accepted, indicating that increased implementation of

reverse logistics and eco-friendly packaging design can improve circular distribution capabilities and green logistics performance at the Ciamis Waste Bank.

Table 11. Specific Indirect Effect

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Desain Kemasan Ekologis (X2) -> Kinerja Green Logistik (Y) -> Kapabilitas Distribusi Sirkular (M)	0,374	0,373	0,049	7,567	0,000
Reverse Logistik (X1) -> Kinerja Green Logistik (Y) -> Kapabilitas Distribusi Sirkular (M)	0,405	0,402	0,045	9,028	0,000

Source: Author's Processed Data (2026)

Based on the results of the Specific Indirect Effect test, all indirect effects in the research model were found to be positive and significant, as indicated by a T-statistic value > 1.96 and a P-value < 0.05 . Eco-Friendly Packaging Design (X2) has an indirect effect on Green Logistics Performance (Y) through Circular Distribution Capability (M) with a coefficient of 0.374 ($T = 7.567$; $P = 0.000$), while Reverse Logistics (X1) has an indirect effect of 0.405 ($T = 9.028$; $P = 0.000$). These results indicate that Circular Distribution Capability acts as a significant mediating variable in the relationship between both Reverse Logistics and Ecological Packaging Design and Green Logistics Performance. Furthermore, the magnitude of the mediation coefficient in the relationship Reverse Logistics $\rightarrow$ Circular Distribution Capability $\rightarrow$ Green Logistics Performance is higher than that in the relationship Ecological Packaging Design $\rightarrow$ Circular Distribution Capability $\rightarrow$ Green Logistics Performance, indicating that the mediating role of Circular Distribution Capability is stronger in the effect of Reverse Logistics on Green Logistics Performance. Thus, mediation hypotheses H6 and H7 are accepted.

Discussion

This chapter discusses the research findings based on the testing of a structural model (inner model) using the Structural Equation Modeling–Partial Least Squares (SEM-PLS) method. The analysis was conducted to interpret the relationships among the research variables, which include Reverse Logistics Integration, Ecological Packaging Design, Circular Distribution Capabilities, and Green Logistics Performance at the Ciamis Waste Bank. The discussion is structured by referring to the results of hypothesis testing, which are then compared with the theoretical framework and relevant findings from previous research. Through this analysis, it is hoped that we can explain how the implementation of reverse logistics and eco-friendly packaging design contributes to improving green logistics performance—both directly and through the mediating role of circular distribution capabilities—thereby providing an empirical picture of the implementation of circular economy principles in the management of biomass pellets at the Ciamis Waste Bank. The discussion is then presented based on each research hypothesis as follows:

The Effect of Reverse Logistics on Circular Distribution Capability

The test results show that reverse logistics integration has a positive and significant effect on circular distribution capability, with a path coefficient (β) of 0.155, a T-statistic of 3.166, and a P-value of 0.002. Since the T-statistic is greater than 1.96 and the P-value is less than 0.05, Hypothesis 1 is accepted. This finding indicates that the better the implementation of

reverse logistics integration, the higher the circular distribution capability of the Ciamis Waste Bank. Although the magnitude of the effect is relatively small, these results suggest that managing the reverse flow of materials through the processes of collection, sorting, processing, and reuse of biomass waste can enhance the effectiveness of a distribution system oriented toward the principles of the circular economy. These research findings align with de Oliveira et al. (2020), who state that the integration of reverse logistics is a key factor in supporting the implementation of the circular economy through the optimization of resource reuse. Furthermore, Govindan and Bouzon (2020) explain that an integrated reverse logistics system can improve operational efficiency in distribution, reduce waste, and strengthen an organization's capabilities in creating a sustainable supply chain. Thus, the implementation of integrated reverse logistics is one of the factors supporting the enhancement of capabilities in

The Effect of Reverse Logistics on Green Logistics Performance

The test results show that the integration of reverse logistics has a positive and significant effect on green logistics performance, with a path coefficient (β) of 0.610, a T-statistic of 14.057, and a P-value of 0.000. Since the T-statistic is greater than 1.96 and the P-value is less than 0.05, Hypothesis 2 is accepted. The relatively high path coefficient indicates that the integration of reverse logistics is one of the main factors contributing to improved green logistics performance at the Ciamis Waste Bank. The implementation of integrated reverse logistics—through the processes of collection, sorting, reprocessing, and the conversion of biomass waste into biomass pellets—is capable of improving resource efficiency, reducing waste, and supporting more environmentally friendly distribution. This finding is consistent with the research by de Oliveira et al. (2020), which states that reverse logistics is a crucial element in the implementation of the circular economy because it can improve operational efficiency while reducing environmental impacts. In addition, Hammes et al. (2022) explain that the implementation of sustainable logistics practices, including reverse logistics, contributes significantly to improving green logistics performance through the optimization of resource utilization, the reduction of emissions, and increased supply chain efficiency. Thus, the better the integration of reverse logistics, the higher the green logistics performance achieved by the Ciamis Waste Bank.

The Effect of Eco-Friendly Packaging Design on Circular Distribution Capability

The test results show that Eco-Friendly Packaging Design has a positive and significant effect on Circular Distribution Capability, with a path coefficient (β) of 0.217, a T-statistic of 3.829, and a P-value of 0.000. Since the T-statistic is greater than 1.96 and the P-value is less than 0.05, Hypothesis 3 is accepted. These findings indicate that the better the implementation of eco-friendly packaging design, the higher the circular distribution capability at the Ciamis Waste Bank. The use of environmentally friendly packaging that is easily recyclable, reusable, and efficiently designed supports the processes of storage, transportation, and material recovery, thereby strengthening a distribution system based on the principles of the circular economy. Although the path coefficient values indicate a relatively moderate effect, these results suggest that eco-friendly packaging design is a key factor in enhancing circular distribution capabilities, even though it is still influenced by other factors such as reverse logistics integration, distribution infrastructure, and supply chain management. These findings are consistent with the research by Verghese et al. (2020), which states that sustainable packaging design can improve distribution efficiency and minimize waste throughout the supply chain. Furthermore, Su et al. (2026) explain that the adoption of eco-friendly packaging supports the implementation of a circular economy through improved logistics efficiency, ease

of material reuse, and optimization of distribution processes. Thus, the development of eco-friendly packaging designs is one strategy that can enhance circular distribution capabilities in the management of biomass pellets at the Ciamis Waste Bank.

The Effect of Eco-Friendly Packaging Design on Green Logistics Performance

The test results show that eco-friendly packaging design has a positive and significant effect on green logistics performance, with a path coefficient (β) of 0.564, a T-statistic of 11.275, and a P-value of 0.000. Since the T-statistic is greater than 1.96 and the P-value is less than 0.05, Hypothesis 4 is accepted. This path coefficient value indicates that eco-friendly packaging design is a key factor contributing to improved green logistics performance at the Ciamis Waste Bank. The use of packaging made from environmentally friendly, easily recyclable materials and designed efficiently can optimize storage and transportation processes, reduce material usage, minimize packaging waste, and lower the environmental impact of logistics activities. These findings are consistent with the research by Verghese et al. (2020), which states that sustainable packaging design plays a crucial role in improving supply chain efficiency while reducing waste and resource consumption. In addition, Su et al. (2026) explain that the use of eco-friendly packaging can improve logistics performance by optimizing distribution and the efficient use of cargo space, as well as supporting the implementation of a circular economy. Consequently, the better the implementation of eco-friendly packaging design, the higher the green logistics performance achieved by the Ciamis Waste Bank. Therefore, the development of environmentally friendly packaging innovations needs to be one of the key strategies in supporting a more efficient and sustainable distribution of biomass pellets that aligns with the principles of the circular economy.

The Influence of Circular Distribution Capability on Green Logistics Performance

The test results indicate that Circular Distribution Capability has a positive and significant effect on Green Logistics Performance, with a path coefficient (β) of 0.663, a T-Statistic of 11.136, and a P-Value of 0.000. Since the T-Statistic exceeds 1.96 and the P-Value is below 0.05, Hypothesis 5 is accepted. This coefficient value is the highest among the direct relationships in the research model, demonstrating that Circular Distribution Capability is the most dominant factor in enhancing Green Logistics Performance at Bank Sampah Ciamis. The greater an organization's ability to manage distribution based on circular economy principles, the greater the improvements achieved in operational efficiency, resource utilization optimization, waste reduction, and environmental performance. These findings align with research by Geissdoerfer et al. (2020), which states that applying circular economy principles through sustainable material flow management can enhance supply chain system efficiency and create superior environmental value. Furthermore, Hammes et al. (2022) explain that distribution capabilities supporting circular economy practices contribute significantly to improved green logistics performance through more efficient distribution, emission reductions, and optimized resource usage. Thus, enhancing circular distribution capability serves as a crucial strategy for Bank Sampah Ciamis to strengthen green logistics implementation and support the sustainable management of biomass pellets.

The Mediating Role of Circular Distribution Capability in the Influence of Reverse Logistics on Green Logistics Performance

The results of the Specific Indirect Effects test indicate that Circular Distribution Capability positively and significantly mediates the influence of Reverse Logistics Integration on Green Logistics Performance, with an indirect effect coefficient (β) of 0.344, a T-Statistic of 7.132, and a P-Value of 0.000. Since the T-Statistic exceeds 1.96 and the P-Value is below 0.05, Hypothesis 6 is accepted. These findings demonstrate that the implementation of Reverse Logistics Integration enhances Green Logistics Performance not only directly but also through the improvement of Circular Distribution Capability. Superior management of material reverse flows—encompassing collection, sorting, reprocessing, and biomass waste utilization—strengthens an organization's ability to manage distribution based on circular economy principles. This enhanced capability subsequently contributes to distribution efficiency, optimized resource utilization, waste reduction, and improved environmental performance. These findings align with research by de Oliveira et al. (2020), which identifies reverse logistics as a crucial element in supporting circular economy implementation through sustainable material flow management. Furthermore, Hammes et al. (2022) explain that circular economy-oriented distribution capabilities can reinforce the impact of reverse logistics practices on enhancing green logistics performance. Thus, Circular Distribution Capability is proven to act as a mediating mechanism that strengthens the relationship between Reverse Logistics Integration and Green Logistics Performance at Bank Sampah Ciamis.

The Mediating Role of Circular Distribution Capability in the Effect of Ecological Packaging Design on Green Logistics Performance

The Specific Indirect Effects test results indicate that Circular Distribution Capability positively and significantly mediates the effect of Ecological Packaging Design on Green Logistics Performance, with an indirect effect coefficient (β) of 0.364, a T-Statistic of 6.635, and a P-Value of 0.000. Since the T-Statistic exceeds 1.96 and the P-Value is less than 0.05, Hypothesis 7 is accepted. These findings demonstrate that the implementation of ecological packaging design enhances Green Logistics Performance not only directly but also through the improvement of Circular Distribution Capability. The use of packaging that is eco-friendly, reusable, easily recyclable, and efficiently designed supports smooth distribution, reduces packaging waste, and optimizes resource utilization in accordance with circular economy principles. Such improvements in distribution capability subsequently contribute to operational efficiency and enhanced organizational environmental performance. These findings align with research by Verghese et al. (2020), which states that sustainable packaging design plays a crucial role in improving supply chain efficiency while reducing environmental impact. Furthermore, Su et al. (2026) explain that ecological packaging supporting circular distribution systems can enhance logistics performance through distribution optimization, waste reduction, and material reuse. Thus, Circular Distribution Capability is proven to act as a mediating variable that strengthens the relationship between Ecological Packaging Design and Green Logistics Performance at Bank Sampah Ciamis.

4. Conclusion

This study aims to analyze the impact of reverse logistics integration and ecological packaging design on green logistics performance, with circular distribution capability serving as a mediating variable at the Ciamis Waste Bank. Based on a PLS-SEM analysis of 124 respondents, all research hypotheses were accepted. Reverse logistics integration and

ecological packaging design were found to have a positive and significant influence on both circular distribution capability and green logistics performance; notably, circular distribution capability exerted the strongest direct influence on green logistics performance ($\beta = 0.663$, $p < 0.001$). Mediation analysis further revealed that circular distribution capability significantly and positively mediates the effects of reverse logistics integration and ecological packaging design on green logistics performance. These findings indicate that enhancing green logistics performance depends not only on the implementation of reverse logistics and ecological packaging design but also on the organization's ability to manage distribution systems based on circular economy principles. The research model demonstrates strong explanatory power, with R-square values of 0.786 for circular distribution capability and 0.665 for green logistics performance.

Theoretically, this study extends research on the circular economy and green logistics by demonstrating that Circular Distribution Capability serves as a crucial mechanism linking Reverse Logistics Integration and Ecological Packaging Design practices to Green Logistics Performance. Rather than treating reverse logistics and sustainable packaging merely as standalone operational practices, the study highlights the importance of distribution capabilities in integrating these practices into a system that supports material circulation. It also provides empirical evidence within the context of community-based waste management, specifically regarding the management and distribution of biomass pellets. Methodologically, the use of PLS-SEM enables the examination of both direct and indirect effects among variables, thereby offering a more comprehensive understanding of the relationships between reverse logistics, ecological packaging design, circular distribution capability, and green logistics performance.

In practical terms, the Ciamis Waste Bank needs to prioritize strengthening its Circular Distribution Capability as a key strategy to enhance Green Logistics Performance. This strengthening can be achieved by integrating the processes of collecting, sorting, processing, packaging, and distributing biomass waste; utilizing reusable and recyclable packaging; improving coordination with supply chain partners; and leveraging information technology to boost the efficiency of material and information flows. Given that Circular Distribution Capability exerts the greatest direct influence on Green Logistics Performance, the development of organizational resources and capabilities should not focus solely on reverse logistics or packaging design, but also on the ability to integrate these practices into an effective and sustainable distribution system.

This study has several limitations that should be considered when interpreting the results. First, the scope of the study was limited to the Ciamis Waste Bank; therefore, generalizing the findings to other waste banks, regions, or logistics sectors requires caution. Second, the study utilized cross-sectional survey data from 124 respondents, meaning it could not capture dynamic changes in logistics practices and performance over time. Third, although the research model explained a significant portion of the variance in Circular Distribution Capabilities and Green Logistics Performance, other factors remain that were not included in the model. Consequently, future research is encouraged to expand the scope and sample size, employ longitudinal approaches or mixed methods, and incorporate variables such as Green Supply Chain Management, Green Innovation, Environmental Performance, and Digital Logistics to gain a more comprehensive understanding of sustainable logistics and circular economy implementation.

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