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Moderation Effect of Coping Behavior on the Engagement Model Implementation in Reverse Logistics Activities to Improve Green E-Waste Business Performance

Hesti Maheswari
School of Business and Economics, Universitas Prasetiya Mulya, Indonesia
Email: hesti.maheswari@prasetiyamulya.ac.id (*Corresponding Author)*

Christiana Yosevina; Fati Ramadhanti
School of Business and Economics, Universitas Prasetiya Mulya, Indonesia
Email: yosevina.tercia@prasetiyamulya.ac.id; fati.ramadhanti@prasetiyamulya.ac.i

Agung Sigit Santoso
Psychology Faculty, Mercu Buana University, Indonesia
Email: agung.sigit@mercubuana.ac.id

Prameshwara Anggahegari
National Research and Innovation Agency (BRIN), Indonesia
Email: prameshwara.anggahegari@brin.go.id

ABSTRACT

Environmental pollution caused by conventional reverse logistics practices conducted by marginalized communities in developing countries is concerning. However, governments recognize this group's potential to independently improve their welfare through e-waste processing i.e., informal e-waste businesses. This research aims to develop an engagement model for reverse logistics and evaluate the moderating effect of coping behavior on informal e-waste businesses' performance by employing partial least-squares structural equation modeling . A sample of 474 informal e-waste businesses is used to test the model and the interrelationships. Findings reveal that the engagement model positively and significantly enhances business performance though coping behavior does not reveal a notable negative impact. Business performance measurement requires a balance among financial, environmental, and social impacts on society. Collaboration models can take the form of coaching programs; provision of low-tech machines; and bridging collaboration between OEMs and informal recyclers. Empowering them as business partners for OEMs and large-scale recyclers, having e-waste component shredders and air filter machines can also be implemented. The engagement model, coping behavior, and green business performance standardized and proposed in this research can be used as a reference for incubating informal e-waste businesses. Further research should focus on the role and commitment of governments in developing the e-waste business and identify factors that can improve coping behavior. This study contributes to the operations management literature by aligning reverse logistics practices with government policies on green business performance. Using a second-order SEM, this study explores engagement, collaboration, and empowerment models that can improve informal e-waste businesses' performance.

Keywords: *engagement model; reverse logistics; coping behavior; green performance*

1. INTRODUCTION

Developed countries have successfully conducted reverse logistics (RL) practices to address the growth of waste generated by people's households and originating from industry, commercial areas, public facilities, schools, offices, and street life (Abdissa *et al*., 2022). RL is very reliable as part of supply chain management in developed countries (Waqas *et al*., 2018). The lack of government intervention and the high involvement of informal groups in RL practices has resulted in ineffective and inefficient management and utilization of waste, especially electronic waste, which typically has high economic value (Maheswari & Simangunsong, 2023; R. R. Srivastava & Pathak, 2020). In contrast to developed countries, in developing countries, the management and utilization of electronic waste (e-waste) are predominantly carried out by informal groups (Damanhuri & Padmi, 2012; Maheswari *et al*., 2017). Limited capital, machine tools, ability to manage and process, and other physical facilities create difficulties for this group to maintain a balance between profit goals and environmental sustainability, along with social demands in

community life (Abdulrahman *et al*., 2014). Businesses' awareness of environmental issues from their RL practices is still very low (Giunipero *et al*., 2012), even in regard to health issues for themselves, their families, and their surrounding community. In several areas, environments around which a business operates were found to have quite high levels of air and water pollution (Xu & Yang, 2022), thus triggering public complaints. This document provides a template for authors to prepare manuscripts for submission to the OSCM Journal. The template is provided to meet the requirements of the OSCM Journal submissions. Please prepare your manuscript without modifying the underlying template file. Figures are best included in high-resolution format. Tables should be included as part of the main text. Please refrain from using any other template files when preparing your manuscript.

The government operates on many big agendas to solve urgent problems that need to be executed immediately, such as poverty, unemployment, stunting, quality of education, flooding, and traffic jams. Thus, problems related to e-waste are often neglected. Government policies that encourage people to switch from using oil-fueled to electric vehicles is a new intensive trigger to environmental problems (Ghulam & Abushammala, 2023). Governments in developing countries tend to consider finding solutions after a problem occurs rather than anticipating it (Sindhuja & Narayanan, 2018).

For informal groups to carry out green reverse-logistics practices (GRP), a government needs to standardize an engagement model (EM) that is not only the best but also appropriate to the situations and conditions of various businesspeople. Adjusting the application of the EM model is necessary because each region is considered to have different problems. For example, Batam-Riau Islands obtains raw materials (scrap) easily. Meanwhile, businessmen in Lampung, Banten, and Central Java are faced with unhealthy competition to obtain scrap. Moreover, locations of businesses in some areas are quite far from densely populated areas, and there are fewer complaints from the community to address. Meanwhile, businesspeople in the Tangerang–Banten area operate in locations with a fairly high population density, which means smoke from combustion processes that are very dangerous to health will quickly reach people's homes. With the diversity of problems in each region and considering the intensity and duration of the activities carried out, a well-matched and potential EM is needed (Appiah, 2023; Carter, 2015). Freeman *et al*. (2016) divided three engagement models based on these considerations: involvement; collaboration; and empowerment.

Collaboration is reflected in the existence of cooperation between informal e-waste processing business activists, with the government and original electronic manufacturers (OEM), or with certified and licensed waste-processing companies, and perhaps in the form of synergy in operation (Cricelli *et al*., 2021; Rebehy *et al*., 2019). Moazzeni *et al*. (2024) suggested a collaborative model among small and medium/big-size electronic enterprises for handling e-waste generated from manufacturing processes. According to Mahadeva (2019), only collaboration between large manufacturers of electronic products and informal e-waste businesses can reduce illegal e-waste processing activities. Collaboration is impossible if there is no awareness among informal businesses to be involved in environmentally friendly e-waste processing. Most scavengers in Nigeria ignore the health and safety impact of e-waste processing activities (Ibifunmilola, 2024). A collection model under a membership-based community, as one of the involvement models, can be developed to address illegal activities that damage the environment (Chu *et al*., 2024). The involvement model is identified by voluntarily engaging in e-waste management and utilization activities in accordance with the rules (Maheswari & Simangunsong, 2023). Kaynak *et al*. s(2014) suggested the concept of logistics centers in villages to organize, operate, coordinate, consolidate, and function as administrative hubs. Another consideration is the integration mechanism from the formal to informal sector to convert e-waste into various types of valuable material (Li & Tee, 2012). With the large profits, IEB groups in Indonesia can be empowered to have low-tech equipment or machines for overcoming air, water, and soil pollution (Maheswari & Simangunsong, 2023). Empowerment can be seen from the willingness of e-waste businesspeople, either independently or collectively, to have their own machines for faster and greener processes (Manzauri *et al*., 2010; Rehman *et al*., 2025; Thio *et al*., 2021). Most studies only focus on the collaboration model and pay little attention to the empowerment model of IEBs to meet sustainability goals. Meanwhile, researchers believe that only the implementation of all engagement models can improve not only the financial performance but also the environmental and social performance of e-waste businesses.

The success of IEBS in implementing an integrated EM model will also depend greatly on their behavior in overcoming the complexity of problems and unfavorable situations (coping behavior) (Nasution *et al*., 2021; Rehman *et al*., 2025). Coping behavior can be measured based on problem-focused coping (developing abilities and learning new skills to deal with situations or problems), emotion-focused coping (controlling emotional responses to stressful situations), and dysfunctional coping (seeking social support for advice on problems encountered) (Lazarus & Folkman, 1984). Langenhof and Komdeur (2018) stated that business actors who have adequate coping behavior capabilities are able to overcome the negative impacts of a business on the environment. Therefore, this study predicts also that having these three behavioral competencies can significantly improve the performance of IEBs when they implement an integrated EM.

2. LITERATURE REVIEW

This section is a general review of the literature related to reverse logistics, coping behavior, and business performance. By examining existing research, this section aims to identify gaps in the current knowledge as a basis for formulating hypotheses.

2.1 Reverse Logistics

In a linear economy, raw materials are produced, sold to users, and then discarded. These discarded used products will maintain economic value if they are recycled, remanufactured, reconditioned, and conditioned with other activities known as "reverse logistics practices." In reality, many such resources are discarded rather than used optimally

(Mallick *et al*., 2023). Maheswari and Simangunsong (2023) defined reverse logistics (RL) as an activity to maximize the utilization of products after use. RL research in developing countries is still very much needed because its activities are closely related to social, economic, and environmental problems (Sonar *et al*., 2024). The involvement of informal businesses in RL practices is huge and extensive (Li & Tee, 2012; Maheswari et al., 2020). On the one hand, the social and economic problems of marginalized communities have been resolved; on the other hand, environmental problems have increased (Damanhuri & Padmi, 2012)

The implementation of the RL concept in developing countries is quite different from that in developed countries (see Table 1). In developed countries, the actors are the government, licensed waste processing companies, and OEMs. Meanwhile, in developing countries, informal groups, namely, marginalized communities, dominate this business. In terms of types of activities, RL in developing countries focuses on manual processes, starting from collecting, sorting, dismantling, recycling, and exporting (for components that are difficult to extract, e.g., gold, silver, palladium, copper). The informal groups that perform these activities are divided into three groups: collectors; merchants; and recyclers (Chu *et al*., 2024). Unlike in developing countries, in developed countries, the government plays an active role in several aspects, namely, creating extended production responsibility regulations for OEMs, assessing the feasibility, and then granting operating permits for waste-processing companies. The process of collecting waste from the community is carried out by officers who determine a disposal schedule based on the type of waste. The government regulates that organic waste is not mixed with electronic-product waste so that the recapturing value and recycling processes are easier and more economical.

2.2 Another Subsection Example

The sustainable reverse logistics (SRL) capability of an OEM is measured by several indicators (Morgan *et al*., 2016): 1) integration of SRL issues into strategic planning process; 2) quality is related to reducing the negative environmental impact; 3) interrelation of SRL with corporate goals; and 4) emphasizing SRL activities in company ads. These capabilities give greater impact to sustainable business performance if a company adopts a sustainability culture (Saglam, 2023). The characteristic of a business that implements a sustainable culture is that they conduct RL practices to achieve good business processes and corporate reputation, which then provides them with a competitive advantage. However, previous studies have focused only on evaluating RL performance in general without considering the RL process (Banihashemi *et al*., 2019). In fact, environmental pollution occurs frequently during the process of converting e-waste into gold, palladium, etc. The most critical obstacles in implementing sustainable culture on RL practices in developing countries are: high cost of adopting reverse logistics (finance and economics); lack of skilled professionals (knowledge and experience); poor business culture (management); lack of human resources (infrastructure and technology); lack of environmental legal awareness (environment); lack of societal pressure (market); and company policies (reverse logistics in policy) (Waqas *et al*., 2018). SRL will only increase performance if a business has high resource commitment, such as technology, financial, and management (Hyder *et al*., 2022), i.e., having a sustainable culture. Meanwhile, IEBs as the main actors in RL activities are difficult to comply with it. Therefore, by considering the critical obstacles, the sustainability culture, and sustainable business performance, the research developed business performance indicators for IEBs into six dimensions (Maheswari *et al*., 2020; Shaik & Abdul-Kader, 2012). Dimensions 2, 3, and 4 measure the performance in the process converting e-waste into valuable products (gold, silver, palladium, etc.).

1) The financial performance of recyclers is measured by five factors, i.e., giving greater profit than other informal businesses; having big margins; efficient operational cost; high business productivity with adequate equipment; and fast material turnover.
2) Internal business process: A good business process is determined by work accident rate, following regulations, skilled and experienced workers, availability of waste disposal site, and certainty that the product is no longer functioning.
3) Stakeholders' value: The values provided to stakeholders include providing a safe working process for workers, helping the government reduce e-waste, creating jobs, and providing benefits for investors.
4) Innovation and Growth: A business's ability to grow through innovation is measured by six factors: using low-tech machines; creatively creating efficient and safe operating processes; business turnover increases and meets the targets; business turnover is faster than other businesses; and facilitating workers to improve skills.
5) Social: Social impact is reviewed on the basis of four aspects, i.e., reduction in unemployment rates, reduction criminality rates, formation of the habit of collecting and sorting one's own waste, and well-managed e-waste.
6) Environmental: Environmental performance is measured by five indicators, i.e., clean around the business; green environment, no complaints from the surrounding community; and business activities do not pollute air, water, and land.

2.3 Stakeholder Theory

Reverse logistics activities can be conducted if at least two parties are involved. Stakeholder engagement in RL should continue to be conducted because waste will continue to be produced, and recyclers need the waste for raw materials. Parties (stakeholders) who are willing to be involved have clear goals and expect benefits for themselves. The level of involvement depends greatly on the diversity of the communication process and the nature of the relationships between the parties (Mahajan *et al*., 2023). The communication that occurs between businesspeople will be very deep and diverse. They will discuss price, quality, quantity, delivery process, and sometimes even more intensely if delivery problems occur. They also need to discuss procurement of low-tech machines (Sun *et al*., 2022), raw materials, and equipment. Under these conditions, the most appropriate engagement model includes involvement (learning on all sides but stakeholders and recyclers act

independently), collaboration (cooperation between organization and stakeholders), and empowerment (stakeholders do something relevant) (Freeman, 2016). Implementation of these engagement models is expected to increase e-waste business performance. Collaborative RL among SMEs significantly thus reduces operational costs (Moazzeni *et al*., 2024).

2.4 Engagement Model in Reverse logistics and Sustainable Business Performance

Quality stakeholder engagement for RL practices should be based on a commitment to the principles, i.e., a clearly defined scope; opportunities created; transparency, timeliness, flexibility, and responsiveness; a process appropriate to engage the stakeholders; and value added for the organization and its stakeholders (Freeman, 2016). Commitment forms are adjusted by stakeholder integration such as inclusivity (engaging at all level), materiality (the most relevant and significance issues), and responsiveness (decisions, actions, performance, and communications related to those material issues). Stakeholder integration embedded within the organization is an absolute requirement for effective and successful engagement (Appiah, 2023; Carter, 2015; Maheswari *et al*., 2019). For the highest quality, stakeholder engagement in e-waste processing businesses needs to be designed and implemented in a credible way, i.e., planned and systematic engagement to manage risk and return (Freeman, 2016). Then, the organization should determine the level(s) and method(s) of engaging with stakeholders. For determining level(s) of engagement, RL businesses should define the nature of the relationship, while the engagement methods should be selected to best meet stakeholders' needs, capacity, and expectations. Because RL business requires diverse communication, long-term nature of relationships, and a high level of engagement, so the appropriate engagement models are involvement, collaboration, and empowerment (Maheswari & Simangunsong, 2023).

Moazzeni (2024), Morgan (2016), and Mahadevan (2019) established a positive impact on sustainable business performance when a business collaborates with other parties for handling e-waste. Integration between formal and informal e-waste businesses or interorganizational collaboration (Wahab *et al*., 2023) have succeeded in suppressing e-waste growth and improving performance (Cricelli *et al*., 2021; Li & Tee, 2012). In a strategic breakthrough, the potential e-waste processing technology was developed by deep resource commitment effects on sustainable performance. The use of technology reduces direct contact with e-waste, speeds up work processes, and improves quality of the final product (Maheswari *et al*., 2020a; Morgan *et al*., 2016). IEB involvement model in e-waste management can be realized through a membership-based community scheme and has been proven to increase the speed of raw material acquisition, dismantling and melting processes, and conversion of environmentally friendly materials (Appiah, 2023; Chu *et al*., 2024). Based on these explanations, the following hypothesis is proposed:

H1: Implementing the engagement model in reverse logistic practices will increase sustainable business performance

2.5 Moderating Role of Coping Behavior

The success of the e-waste processing business in implementing standardized EM will depend greatly on the behavior of e-waste business actors in overcoming the complexity of problems and unfavorable situations (coping behavior/CB). Coping is a cognitive and behavioral effort aimed at meeting internal and external demands so as to be able to manage conflict (Tsaur *et al*., 2016) faced by businesspeople and their environment (Langenhof & Komdeur, 2018; Lazarus & Folkman, 1984). Three measurements of coping behavior were analyzed in this study: problem-focused coping (developing abilities and learning new skills to deal with situations or problems); emotion-focused coping (controlling emotional responses to stressful situations); and dysfunctional coping (seeking social support for advice on problems faced). Businesspeople who focus from the start on the scope of environmentally friendly RL practices and assess skills gaps and then provide training can be said to have a PFC strategy (Bag & Gupta, 2020). Businesspeople who can control their emotions when facing problems (EFC) avoid getting involved in conflicts (distancing), manage their feelings and seek a solution (self-control), accept that they are the ones who caused the problem and must be responsible (accepting responsibility), find positive meaning from the problem, and find new beliefs for personal growth (positive reappraisal) (Lazarus & Folkman, 1984; Tsaur *et al*., 2016). In addition to PFC and EFC, electronic waste business actors must also have a dysfunctional coping (DC) strategy, namely, an effort to seek social support to gather advice and a place to express emotions (Lazarus & Folkman, 1984; Srivastava & Tang, 2018). Businesspeople do not give up and focus on the difficulties experienced and report problems to decision-makers (focusing on and venting of emotions), avoid giving up and strive to achieve goals (behavioral disengagement), and divert attention to the positive side of an activity (mental disengagement) (Lazarus & Folkman, 1984; Rice & Liu, 2016; Tsaur *et al*., 2016).

Green human resource and supply chain management by assessing CB capabilities has been conducted (Jabbour & De Sousa Jabbour, 2016). Sharing responsibility for e-waste by supporting RL (Koshta *et al*., 2022) and analysis of business CB capabilities to address business impacts on the environment (Langenhof & Komdeur, 2018) has been studied; however, the studies were conducted for legal and large-scale companies. In fact, those who continue to create conflict are typically the informal e-waste activists. Therefore, it is urgent to standardize the indicators that measure CB for the informal e-waste business group. Researchers believe that CB parameters are necessary to measure the ability of e-waste businesspeople to overcome problems. Researchers believe also that having these three behavioral competencies will significantly improve the performance of e-waste businesses if standardized EM is implemented. Therefore, based on the description above, we propose the following hypothesis:

H2: Coping behavior is able to positively increase the influence of engagement model implementation to sustainable business performance.

3. METHODOLOGY

Data were collected using a survey method from 11 provinces in Indonesia. By using a convenience sampling method, this study obtained 474 respondents, as presented in Table 2. Most respondents are merchants, many of whom have been operating for more than 10 years, with business turnover in the range of 10–300 million rupiah. The majority of them have elementary education. Only 4% of business owners are undergraduates.

3.1 Moderating Role of Coping Behavior

The use of footnotes and endnotes should be avoided. Submission of the revised manuscript should be accompanied by a few pages outlining how each comment from the reviewers have been addressed. The revised paper should show the modified or revised parts, by for example, marking these new or revised parts with a different font color.

E-waste processing business performance is defined as the capability of a business to obtain profit, green internal business processes, high stakeholder values, green innovation and growth positively, social impact, and green environment. These sub-variables were adopted from Shaik (2012), Maheswari *et al*. (2020b), and Hyder *et al*. (2022), as detailed in Table 4.

Coping behavior reflects the extent to which IEBs can solve a business problem. Coping behavior was measured using three dimensions: problem-focused; emotional; and dysfunctional coping. Each dimension was measured using several indicators adopted from (Bag & Gupta, 2020; Lazarus & Folkman, 1984; Tsaur *et al*., 2016), as depicted in Table 5.

Table 1 Comparison of RL Implementation in Developing and Developed Countries

	Developed Countries	Developing Countries
Actor	• Government • Formal e-waste processing business • Original electronic manufacturer	Marginalized communities
Activities	• Return to supplier • Resell • Recondition • Refurbish • Remanufacture • Reclaim materials • Recycle • Landfill	• Collecting • Sorting • Dismantling • Exporting • Recycling
Business Status	Legal	Illegal Informal

Table 2 Respondents profile

PROVINCE	BUSINESS GROUP			BUSINESS AGE		
	Collector	Merchant	Recycler	< 5 Years	5 – 10 Years	> 10 Years
South Sulawesi	14	52	16	2	8	72
Jakarta	-	18	1	5	4	10
Banten	-	14	18	5	9	18
West Java	-	69	28	4	15	78
Central Java	6	18	7	6	2	24
East Java	27	17	21	15	13	37
Lampung	7	27	8	2	4	36
Riau Island	2	22	12	6	10	22
East Kalimantan	8	3	2	5	6	2
Yogyakarta	1	10	2	-	1	12
West Nusa Tenggara	10	25	6	10	8	72
	TURNOVER/MONTH					
	< 10 M	10 – 100 M	100 – 300 M	> 300 M		
South Sulawesi	4	18	58	2		
Jakarta	-	12	6	1		
Banten	8	14	8	2		
West Java	-	43	43	11		
Central Java	9	11	10	2		
East Java	28	31	5	2		
Lampung	5	21	14	1		
Riau Island	2	14	13	9		
East Kalimantan	9	2	2	-		
Yogyakarta	2	3	8	-		
West Nusa Tenggara	7	1	1	2		
	EDUCATION					
	Elementary	Jr. High School	Senior High School	Undergraduate		
Number	179	161	114	20		

Table 3 Engagement model for reverse logistics

Construct	Indicator	Item
Involvement Model (IM)	Green goals	IM1
	Compliance with environmental regulations	IM2
	Obey to use gloves	IM3
	Obey to use mask	IM4
	Obey to wear boots	IM5
	Provide a unique place	IM6
	Seriousness in reducing direct contact with e-waste	IM7
Collaboration Model (CM)	Capacity building training for improving environmental performance	CM1
	Business management and development coaching to maximize the economic value of waste	CM2
	Provision of low-tech machines to improve worker safety	CM3
	Provision of microfinancing facilities to accelerate business growth	CM4
	Pioneering collaboration between OEMs and informal recyclers	CM5
	Profit sharing system between OEMs and informal recyclers	CM6
	Collaboration between SMEs and large recyclers	CM7
Empowerment Model (EM)	Partners with OEMs or large-scale recyclers	EM1
	Having component shredders	EM2
	Using air filter machines	EM3
	Investments in green business development	EM4
	Sharing knowledge on green e-waste processing	EM5

Table 4 Sustainable business performance

Construct	Indicator	Item	Construct	Indicator	Item
Financial (F)	Having bigger profit than other business	F1	Innovation & Growth (IG)	Innovate by using low-tech machines	IG1
	Getting low cost of materials	F2		Create efficient and safe oprt. processes	IG2
	Low operational cost	F3		Grow by innovation and creativity	IG3
	High productivity with adequate equipment	F4		Business turnover reaches target	IG4
	Profit ensures business continuity	F5		Business turn. rotates faster than others	IG5
Internal Business Process (IBP)	Low accident rate	IBP1		Workers are facilitated and encouraged to improve their skills	IG6
	Compliance with SOP	IBP2	Social (S)	Reduce unemployment	S1
	Skilled and experienced workers	IBP3		Reduce crime rates	S2
	Availability of waste material disposal sites	IBP4		Empower communities as a partner	S3
	Unfunctional electronic product guarantee	IBP5		Manage waste to reduce env. problems	S4
Stakeholders' Value	Providing safety for workers and the environment	SV1	Environment (E)	The env. around the business is cleaner	E1
				No complaints from community	E2
	Successfully reducing e-waste	SV2		The business does not pollute the air	E3
	Creating jobs	SV3		The business does not pollute the water	E4
	Providing benefits for investors	SV4		The business does not pollute the land	E5

Table 5 Coping behavior

Construct	Indicator	Item
Problem Focused Coping (PFC)	Green business focus	PFC1
	The green process focuses	PFC2
	Consistent partnering in green business	PFC3
	Self-development	PFC4
	Conscientious in decision-making	PFC5
Emotion Focused Coping (EFC)	Solution-finding awareness	EFC1
	Negative invitations	EFC2
	Self-limitation in green business	EFC3
	Responsibility in green process creation	EFC4
	Open-minded and willing to consult	EFC5
	Individual growth encouragement	EFC6
	Understanding deficiencies and seeking other opportunities	EFC7
Dysfunctional Coping (DC)	Joint the RL association	DC1
	Switch to a green RL business	DC2
	Problem counteract ability	DC3
	Divert attention from stressors	DC4
	Placing problems as business challenges	DC5

3.2 Moderating Role of Coping Behaviour

The control variables for this research are 1) business groups, i.e., merchants and e-waste processing businesses (recyclers) and 2) business turnover of more than 10 million/month. The electronic waste collector group was excluded from the data analysis because many of their answers were outliers. The collecting group has a very different interest from the other two groups. For example, they are willing to switch to another business as long as the government provides jobs. However, merchants and recyclers refuse to switch to another business because this business gives a high turnover compared to an informal business (Damanhuri & Padmi, 2012).

3.3 Method of Data Analysis

This research uses the partial least-squares structural equation modelling (PLS-SEM) technique because the variables cannot be measured directly. It is possible that measurement errors will need to be corrected, and there will be testing at Stage 2 because each variable has several

dimensions, and each dimension has several indicators. The bootstrapping approach was used to make statistical inferences (Hair *et al*., 2021). Before testing the hypothesis, a second-order confirmatory factor analysis (CFA) is required to ensure that each indicator is valid. In the SEM-based analysis, SmartPLS 4,0 software was used because the PLS approach is a powerful method of analyzing the minimal demand on measurement scales (Chin, 1998). By using SmartPLS software, the latent variable score that will be used for the structural model evaluation stage is easily formed after clicking "create data file." With the presence of this latent variable score, each variable is measured by dimensions rather than by indicators. The steps taken before testing the two hypotheses are as follows.

3.3.1 Measurement Model Evaluation (Outer Model)

The measurement model was tested in three stages:

1. Convergent validity indicates whether a test designed to measure a particular construct correlates with other tests that assess the same or similar construct. Chin (1998) explained that an indicator is valid if the factor loading is ≥0.70. The factor loading of an indicator 0.70 should be removed from the model (Chin, 1998).
2. Construct reliability and validity were tested by calculating composite reliability, namely, testing the reliability of the instrument in the research model. The composite reliability between 0.6 and 0.7 is considered to have good reliability (Sarstedt *et al*., 2021). An item is reliable if the Cronbach alpha is greater than 0.6 (Hair *et al*., 2013). The closer the Cronbach's alpha to 1, the higher the internal consistency.
3. Discriminant validity of a measurement model, i.e., testing of the average variance extracted (AVE) value, which must be greater than 0.50; heterotrait monotrait ratio (HTMT) should be lower than 0.90; and the Fornell–Larcker criterion (1981), the square root of the AVE by a construct, must be greater than the correlation between the construct and any other construct.

3.3.2 Structural Model Evaluation (Inner Model)

The second step in SEM using SmartPLS is

1. Goodness-of-fit test refers to the evaluation of how well a model fits the observed data, typically calculated using the SRMR and NFI. The SRMR should be lower than 0.08, and the NFI should be greater than 0.70 (Bentler & Bonett, 1980; Sarstedt *et al*., 2021).
2. R-square statistics explains the variance in the endogenous variable explained by the exogenous variable(s). Hair *et al*. (2013) suggested that R2 values of 0.75, 0.50, or 0.25 for endogenous latent variables can be described as substantial, moderate, or weak, respectively. The path coefficient test is a value that is useful for showing the direction of the relationship in a variable, whether a hypothesis has a positive or negative direction. The path coefficient value ranges from 1 to -1. The closer to 1 or -1, the stronger the relationship (Hair *et al*., 2013)

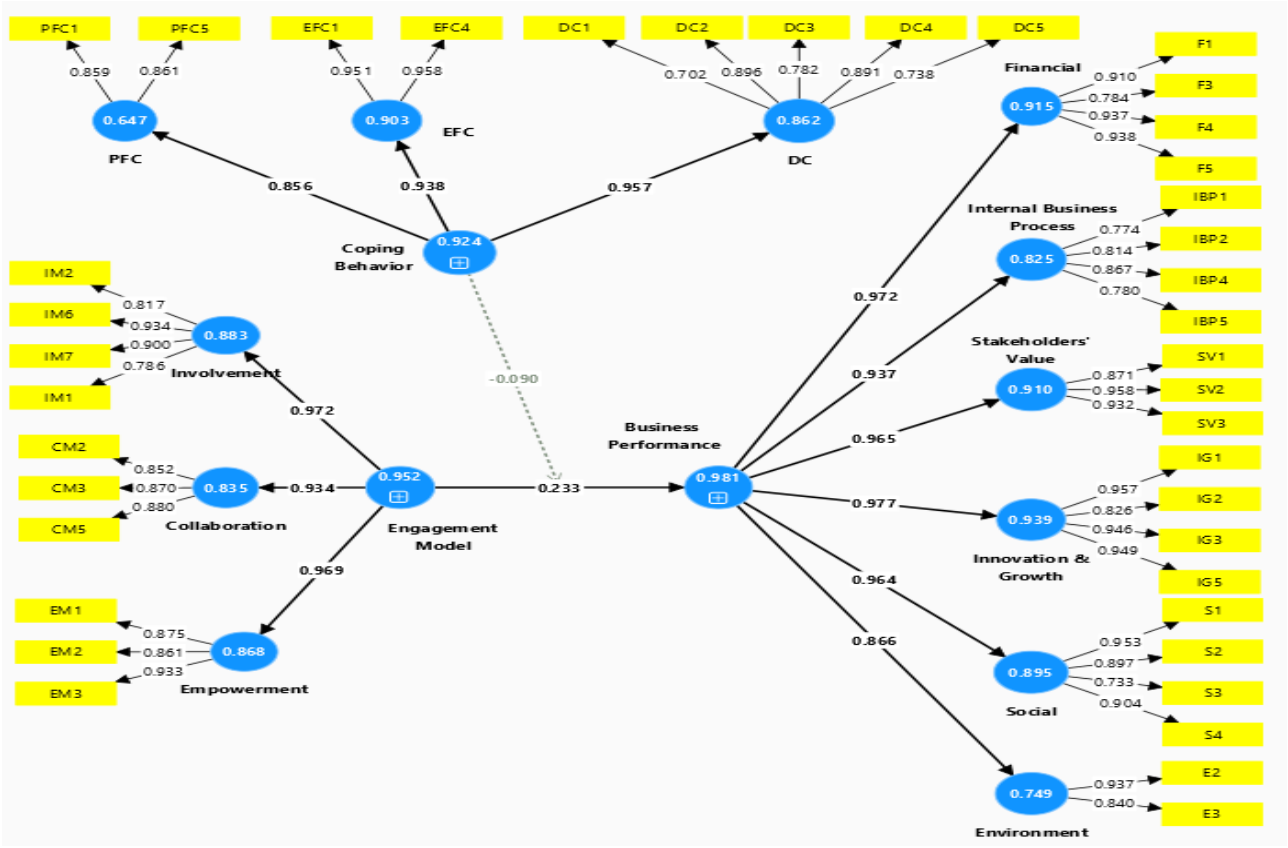

Figure 1 Measurement Model

4. RESULTS AND DATA ANALYSIS

The study employed partial least squares-structural equation modeling (PLS-SEM) for analysis, emphasizing its versatility in handling the interplay between theory and data. We used SMART PLS 4.0 to test our hypotheses. As explained in Section 3, the first step before using a model for testing hypotheses is evaluating the measurement model.

4.1 Measurement Model

The first stage of the measurement model is the factor loading calculation. The factor analysis model used in this study is the second-order confirmatory factor analysis (second CFA) because, in this study, each construct is composed of several latent variables, each of which consists of several indicators. Factor loading values less than 0.70 must be removed from the model to test the hypothesis (Hair *et al*., 2014).

4.1.1 Factor loading

Several indicators in the coping behavior variable for the PFC and EFC dimensions have a factor loading value of less than 0.70. If an indicator has a factor loading value below 0.70, it indicates that the indicator is not valid for measuring its latent variable (Bentler & Bonett, 1980; Jayashree *et al*., 2021). In addition, several indicators are often perceived by respondents as the same; thus, multicollinearity occurs. After the 26 indicators were removed, the final model was fit and could be continued to the next stage of testing (Fig. 1).

4.1.2 Construct reliability and validity

Construct reliability and validity tests were conducted by considering the Cronbach's alpha, rho_a, roach, and average variance extracted (AVE). The results of these tests, obtained using SmartPLS software, are presented in Table 6. The AVE value for all variables and dimensions exceeded 0.50, indicating that the requirements were met. Similarly, the composite reliability value (rho_c) for all dimensions and variables is far above 0.80. The Cronbach's alpha and composite reliability (rho_a) values for the problem-focused coping dimension are 0.647 (See Figure 1). However, based on Sarstedt *et al*. (2021), this item is still reliable because it is greater than 0.6. Similarly, the rho value of 0.6–0.7 is considered to have good reliability.

Table 6 Reliability and validity test

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Business _Performance	0.981	0.983	0.983	0.741
Collaboration	0.835	0.835	0.901	0.752
Coping_behavior	0.924	0.933	0.939	0.660
Dysfunctional Coping	0.862	0.880	0.902	0.649
Environment	0.824	0.862	0.894	0.738
Emotion-focused coping	0.903	0.907	0.954	0.912
Empowerment	0.868	0.869	0.919	0.792
Engagement	0.952	0.954	0.959	0.700
Financial	0.915	0.923	0.941	0.800
Innovation and Growth	0.939	0.945	0.957	0.849
Internal business processes	0.825	0.836	0.884	0.656
Involvement	0.883	0.892	0.920	0.742
Problem-focused coping	0.647	0.647	0.850	0.739
Social	0.895	0.909	0.929	0.767
Stakeholders' Value	0.910	0.911	0.944	0.849

4.1.3 Discriminant Validity

Discriminant validity evaluation was conducted using three tests: heterotrait monotrait ratio (HTMT) (Table 7); Fornell–Larcker criterion; and cross loading. If two constructs or variables in a study have a very strong correlation, the HTMT value will tend to be high, indicating that they may not really be conceptually distinct. If research concludes that there is a relationship between two constructs that is not actually conceptually distinct, the researcher may draw incorrect conclusions. The discriminant validity test was carried out on stage 2 of the model. If the measurement model testing at stage 1 has met the criteria, then at stage 2, this measurement model will usually be more fit (Nguyen-Phuoc *et al*., 2022). Only one variable has an HTMT value slightly above 0.90, namely, the relationship between the engagement model and business performance (0.902). In fact, this condition is not excellent. It is necessary to determine whether indicators are irrelevant and need to be removed or replaced with other better indicators. By correlating the indicators on these two variables, selecting the indicator that has the highest average value, and then removing the highest average, the same steps are repeated for other indicators until the HTMT results meet the requirements. If the HTMT value is not too far beyond the cut-off point, the existing model can still be used for hypothesis testing. To make the results more convincing, it is necessary to check the goodness-of-fit of the second-stage model.

The second discriminant validity test was conducted by evaluating the cross-loading, as presented in Table 8. Cross-loading in the context of data analysis, especially in PLS-SEM, refers to the correlation value between an indicator (question item) and a construct (latent variable) other than the construct that the indicator is

supposed to measure. Discriminant validity using the cross-linking relation between items meets the requirements. All items of the parent construct for factor loading are greater than the correlation of factor loading of other correlation constructs.

The final discriminant validity test aims to satisfy the Fornell–Larcker criterion. The results of the Fornell–Lacker criterion suggest that the square root of the AVE is significantly higher than the correlation matrix of the constructs. The Fornell–Larcker criteria are also not very well met because it still maintains the PFC subvariable (dimension), which has a Cronbach's alpha and rho_a value slightly lower than 0.70. The researcher allows this condition because, in the SmartPLS output table, the correlation between coping behavior and business performance was 0.955 (see Table 9) and was not colored red. Thus, without removing one of the PFC indicators, the measurement model in this study can still be maintained

Table 7 Discriminant Validity-Heterotrait Monotrait Ratio

	Business Performance	Coping Behavior	Engagement Model	Coping Behavior x Engagement Model
Business Performance				
Coping behavior	0.889			
Engagement Model	0.902	0.875		
Coping behavior x engagement model	0.737	0.760	0.673	

Table 8 Discriminant validity–cross loading

	Business Performance	Coping Behavior	Engagement Model	Coping Behavior x Engagement Model
Collaboration	0.900	0.880	0.945	-0.650
Involvement	0.814	0.839	0.964	-0.606
Empowerment	0.830	0.837	0.967	-0.637
Dysfunctional _Coping	0.913	0.940	0.826	-0.699
Emotion-focused coping	0.947	0.948	0.909	-0.683
Problem-focused coping	0.756	0.879	0.714	-0.630
Environment	0.922	0.878	0.734	-0.567
Financial	0.961	0.947	0.916	-0.708
Innovation and Growth	0.967	0.961	0.888	-0.762
Internal business process	0.950	0.908	0.803	-0.718
Social	0.965	0.878	0.830	-0.720
Stakeholders' _Value	0.967	0.898	0.902	-0.706
Coping behavior x engagement_model	-0.731	-0.727	-0.659	1.000

Table 9 Discriminant validity of fornell–larcker test

	Business _Performance	Coping Behavior	Engagement_Model
Business _Performance	0.955		
Coping Behavior	0.955	0.923	
Engagement_ Model	0.887	0.890	0.959

4.2 Structural Model Evaluation and Hypothesis Testing

To analyze the extent to which empirical data support the theoretical model, a structural model test is necessary. Based on Hair *et al*. (2021), the first two steps in evaluating the structural model were taken to test the goodness-of-fit and R-squared values. R-squared is a statistical analysis that shows how well the independent variable predicts the dependent variable. Others stated that R-squared is a statistical measure that indicates the proportion of variance for a dependent variable that is explained by the independent variables. The overall model fit is acceptable (see Table 10 and 11), such as the standardized root mean square residual (SRMR) is 0.056, lower than the threshold of 0.08 (Benitez *et al*., 2020); the normed fit indices (NFI) is 0.796, greater than 0.70 (Bentler & Bonett, 1980); the variance inflation factors (VIF) were checked for all dimensions lower than 0.50 (Thompson *et al*., 2017), as presented in Table 12; and the R-square for business performance variable (endogenous) in the model was 0.921, giving the large effect size (Hayes, 2021). A bootstrapping approach using 5,000 subsamples was used to compute the standard errors and t-statistics of the estimated model to determine statistical significance (Sarstedt *et al*., 2014).

The results of hypothesis testing in the second stage as presented in Table 13 and Figure 2, indicate a positive and significant relationship between the implementation of the engagement model (involvement, collaboration, dan empowerment) in doing RL activities and e-waste processing business performance with β = 0.171; T-test = 2,074; and p-value = 0,038. Hypothesis 1 is accepted.

Table 10 goodness of fit

	Saturated Model	Estimated Model
SRMR	0.056	0.056
d_ULS	0.241	0.244
d_G	1.097	1.243
Chi-square	430.558	435.612
NFI	0.796	0.793

Table 11 Second stage: *R*-squared

	***R*-square**	***R*-square adjusted**
Business _Performance	0.921	0.918

Table 12 Second stage: variance inflation factors (VIF)

	VIF
Business performance -> Environment	1.000
Business performance -> Financial	1.000
Business performance -> Innovation and growth	1.000
Business performance -> Internal business process	1.000
Business performance -> Social	1.000
Business performance -> Stakeholder value	1.000
Coping behavior -> Business performance	4.884
Coping behavior -> DC	1.000
Coping behavior -> EFC	1.000
Coping behavior -> PFC	1.000
Engagement model -> Business performance	4.588
Engagement model -> Collaboration	1.000
Engagement model -> Empowerment	1.000
Engagement model -> Involvement	1.000
Coping behavior x Engagement model -> Business performance	1.930

Table 13 Hypotheses testing

	Original sample (O)	**Sample mean (M)**	**Standard deviation (STDEV)**	***T*-statistics (|O/STDEV|)**	***P*-values**
Coping behavior -> Business performance	0.750	0.750	0.077	9.682	0.000
Engagement model -> Business performance	0.171	0.176	0.083	2.074	0.038
Coping behavior x Engagement model -> Business performance	-0.049	-0.046	0.023	2.085	0.037

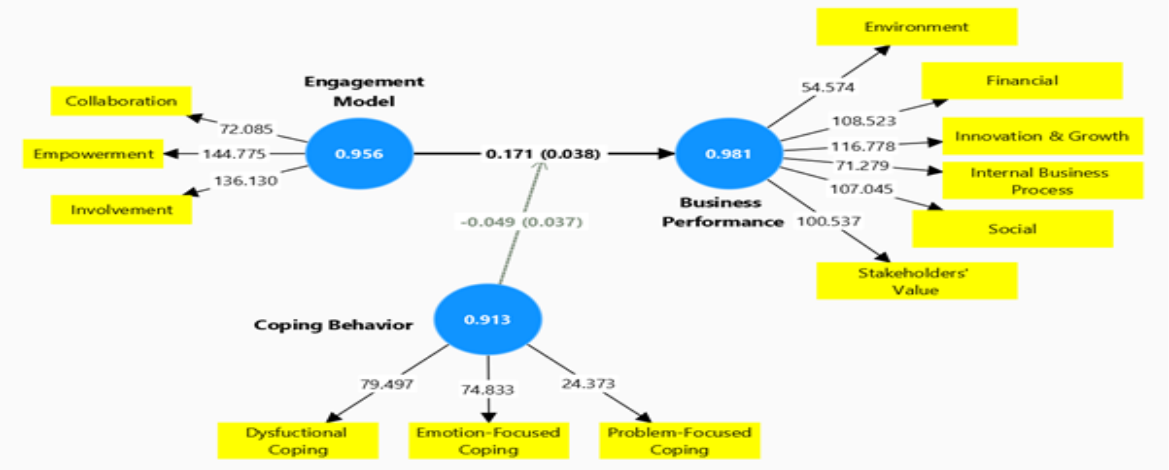

Figure 2 Structural Model Results

Meanwhile, the coping behavior variable has a significant negative moderating effect on the influence of the engagement model on business performance (4.9%). Based on these results, Hypothesis 2 is rejected. The more businesspeople comply with using personal protective equipment (PPE), only working with licensed e-waste businesses, and so on, the more business performance decreases (Anuardo *et al*., 2023). Earned profits decrease, innovation cannot be done because machines and equipment are not available, unemployment increases, crime rates are high, piles of electronic waste increase, and ultimately, the welfare of this marginal community decreases. Health and safety awareness and improving occupational hygiene practices and the work environment for informal e-waste recyclers still need to be improved (Ibifunmilola, 2024).

5. DISCUSSION

Our research has gathered interesting findings that can contribute to theories, particularly those related to the concept of reverse logistics. We have formulated an engagement model that is most applicable and appropriate to the context of a developing country like Indonesia. We have also identified the coping behaviors that e-waste processing activists must possess to improve their business performance. This study also measured the influence of engagement models on business performance and the moderating role of activists' coping behaviors.

5.1 Acceptable Engagement Models

The IEBs involvement model, applicable to developing countries like Indonesia, requires businesses to not only seek profit but also consider reducing environmental pollution by complying with environmental regulations. IEBs are willing to provide dedicated storage for used electronic components and conduct safe operations by minimizing direct contact with e-waste. Wearing masks, gloves, and boots while working is not feasible. Although workers are aware of the significant risks to health and the environment, they feel that using personal protective equipment reduces their work productivity, especially for the recycling business group. Only 25% (Munni *et al*., 2024) and 12% (Singhal & Lyngdoh, 2021) of workers in India had good e-waste awareness and were willing to use PPE. Masks are needed by recyclers but only during the chemical refinement of gold. Merchants hardly need masks when working on sorting and dismantling processes. Gloves are widely needed by merchants when dismantling components and engaging in other rough work. However, recyclers do not need gloves for engaging in the melting process. Even recyclers need to have a good sense of taste for gold (see Fig. 3). Compliance with government policies positively impacts business environmental performance. Compliance with government policies depends on business owners' behavior, willingness to obey environmental regulations (Kalubanga & Mbekeka, 2024).

Figure 3 Traditional Dismantling, Weighing, and Smelting

IEBs envision collaboration in the form of management training and business development to maximize the economic value of e-waste. Provision of low-tech machinery to improve worker safety is intended to be affordable for IEBs. In pioneering permanent collaboration between OEMs and informal recyclers, they are quite adept at processing electronic waste, so collaboration in the form of training to increase their capabilities in extracting electronic waste into valuable items such as gold, silver, palladium, and copper is not necessary for them. In fact, two respondents from Paniisan Village, Tasikmalaya, and Jakarta were found to have become waste processing instructors in Saudi Arabia and Malaysia. Although they have difficulty in terms of obtaining capital, they do not really need credit facilities from banks because large-scale collectors are willing to pay the bills of the smaller collectors with the listed selling price plus the small collectors' desired profit, such as via a profit-sharing scheme (Moazzeni *et al*., 2024). These are the reasons why providing credit facilities or financing for microbusinesses, collaborating with OEMs, and working with large-scale e-waste businesses as employees may not be attractive to IEBs. IEBs in Brazil are also unwilling to become laborers for OEMs and large-scale e-waste businesses (Aguiar & Manning, 2020), as they typically possess a strong entrepreneurial spirit (Damanhuri & Padmi, 2012; Rice & Liu, 2016).

IEBs are unwilling to invest in developing green business technology and sharing knowledge about green RL practices. Sharing knowledge about how to process electronic waste safely for the environment is highly dependent on the availability of component shredding and incineration machines. They prefer to be creative in building these machines themselves (Sun *et al*., 2022). However, the smoke filter machine built by one e-waste processing activist did not function optimally (Fig. 4). The pungent odor persisted, leading to numerous complaints from local residents (see Figure 5). Many IEBs are unwilling or hesitant to teach other businesses due to competitive reasons (Li & Tee, 2012). Furthermore, it is useless to teach small-scale businesses how to perform green process if they lack the appropriate processing machinery (Mallick *et al*., 2023). Furthermore, large businesses prefer small-scale businesses, such as collectors or small traders, who work only for sorting and dismantling, to then become suppliers (Chu *et al*., 2024).

Figure 4 Traditional Machines for Crushing, Smelting, and Filtering Toxic Fumes

5.2 Coping Behaviour of Informal e-waste Businesses

Implementation of an engagement model in conducting RL via either involvement, collaboration, or empowerment has been proven to increase e-waste processing business performance. Measuring business performance has required a balance of financial performance, environmental performance, and social impacts of the activities carried out. Coping behavior in RL context reflects the extent to which recyclers can solve societal and environmental problems through their activities. Coping behavior is divided into three models, i.e., PFC, EFC, and DC. Businesspeople who utilize coping behavior are believed to be able to improve their business performance (Nasution *et al*., 2021; Rice & Liu, 2016).

The coping behavior of IEBs in Indonesia is formed by behavior that always focuses on green business and being careful and thorough before making decisions. Focus on green processes (Appiah, 2023), consistently partnering only with green (certified) businesses, and development of personal abilities are not characteristics of IEBs in Indonesia. As explained, it is difficult for recyclers to focus only on green processes because the actual problem is the lack of low-tech machines for e-waste processing. The productivity of recyclers is highly dependent on the availability of three types of machines, i.e., component crushers, ovens, and smoke filters (Maheswari & Simangunsong, 2023). It is also impossible to ask IEBs to sell scrap (e-waste components) to certified merchants only because most of them are informal businesses (Aguiar & Manning, 2020). Learning from fellow businesspeople is almost impossible because of competition reasons (Cricelli *et al*., 2021; Li & Tee, 2012). They often choose to learn on YouTube.

The emotional-focused coping formed in electronic waste activists is their high awareness to find solutions and foster a responsible attitude to create environmentally friendly processes. Businesspeople in several areas prefer to use more environmentally friendly processing materials (borax and plumbum) to prevent air pollution rather than having to use PPE. Recyclers in West Nusa Tenggara only use borax, which is safer for the environment, although the process will take longer and be more expensive. Creating an air filter machine to neutralize toxic fumes from combustion should not be difficult for the government. However, there is no government support for informal e-waste businesses (Anuardo *et al*., 2023; Mallick *et al*., 2023). Consulting or learning with fellow businesspeople is almost impossible because they keep the best processing recipes a trade secret (Cricelli *et al*., 2021). Their capabilities increase due to their own processing experience (Maheswari *et al*., 2020a; Morgan *et al*., 2016; Rice & Liu, 2016). The more often they process, the more proficient they will automatically become. Compliance with the use of personal protective equipment (PPE) is still difficult to find because the use of PPE is actually troublesome and complicated and reduces their productivity, as explained by Munni *et al*. (2024) and Singhal *et al*. (2021). The majority of respondents were not willing to switch to other businesses because they felt that the turnover of money was high in this business. Reverse logistics practices provide the highest income for informal businesses (Banihashemi *et al*., 2019). Only small-scale respondents agreed to switch with the condition that the government provide jobs for them.

In contrast to PFC and EFC, all indicators in the DC dimension can be included in the measurement model: recyclers need an RL association and are willing to pay the membership fees, as mentioned by Firdous and Ramish (2023); switch to green RL business; problem counteract ability; divert attention ability from stressors; and placing problems as business challenges. IEBs actors have made efforts to seek social support to gather advice and a place to express emotions (Lazarus & Folkman, 1984; Srivastava & Tang, 2018). They typically focus on venting emotions, avoid giving up and strive to achieve goals, and divert attention to the positive side of an activity (Lazarus & Folkman, 1984; Rice & Liu, 2016; Tsaur *et al*., 2016). Optimal reverse logistics can enhance the competitive advantage of a company (Wahab *et al*., 2023)

5.3 Moderating Effect of Coping Behavior on the Influence of Engagement Models Implementation in Improving Business Performance

Coping behaviors of e-waste businesspeople result in little negative impact but are significant to the influence of implementing the engagement model when conducting RL activity to business performance. This finding contradicts the research results of Banihashemi (2019) which stated that the problem-solving abilities of informal businesspeople are very strong because they are honed by the many difficulties they face. The ability to overcome the problems is very dependent on the scale of the business (Bag & Gupta, 2020). Those with high business turnover tend to have higher coping ability (Abdulrahman *et al*., 2014), while in this research, the number of large-scale e-waste business is very small. Collaborating only with formal businesses is also impossible since most of them are informal business, as explained by Damanhuri and Padmi (2012). Most informal e-waste businesspeople still focus on profit rather than green process for maintaining sustainability of their business (Sindhuja & Narayanan, 2018). Refusing the government's call to shut down e-waste processing businesses is nearly impossible. This is the only business they can operate, and it

yields far greater profits than other informal businesses (Bag & Gupta, 2020; Kalubanga & Mbekeka, 2024; Rehman *et al*., 2025). From the three types of coping behavior, only dysfunctional coping, namely, seeking social support to obtain advice on problems faced, contributes greatly and positively to the application of the engagement model in RL activities on the performance of informal e-waste businesses. The IEBs are willing to join the RL association and conduct a green RL business. They have a high entrepreneurial spirit so they never give up (Damanhuri & Padmi, 2012; Rice & Liu, 2016), are able to divert their attention to things that make them stressed, and consider the problems they face as a challenge.

6. DISCUSSION

Waste around the world, including in Indonesia, will continue to increase. Unlike organic waste, nonorganic waste, such as e-waste, causes significant environmental pollution. Processing electronic waste into valuable metals is prone to creating pollution, especially if the process is carried out in a simple or manual way. Meanwhile, governments in many developing countries, including Indonesia, acknowledge the difficulty in overcoming the growth of electronic waste. On the other hand, the government also sees the ability of marginalized communities to improve their own welfare without depending on government assistance by conducting recycling activities and other forms of electronic waste business. The activity of reclaiming the benefits contained in waste (reverse logistics), whatever the type, is widely carried out by this group of people who have difficulty working in the formal sector due to their low level of education. The government has recognized the ability of informal businesses to maximize the use of electronic waste, which, however, requires time, energy, and costs as well as a high commitment to involve, collaborate, and empower this business to operate in optimal conditions. This research is designed to help the government start this kind of program. There are two main objectives in this research, namely, establishing an engagement model in reverse logistics activities and measuring the moderating effect of coping behavior to increase the influence of implementing the engagement model on the performance of e-waste processing businesses.

Test results demonstrate that the implementation of the engagement model in reverse logistics activities has a positive and significant effect on improving the performance of the e-waste business. However, coping behavior does not have a positive impact on the influence of the implementation of the engagement model on improving business performance.

Researchers face great difficulties when mapping the existence of businesspeople and collecting data. Their illegal status and activities are often claimed to damage the environment, making them hide from the government and close themselves off from any activities, including research. The standardized engagement models that will become guidelines in incubating this business include involvement (green goals, compliance with environmental regulation, providing a special place, reducing direct contact with e-waste); collaboration (business management and development coaching for maximizing the economic values of e-waste); provision of low-tech machines to improve worker safety and filter toxic fumes; and pioneering collaboration between OEM and informal recyclers); and empowerment (OEM and large-scale recyclers become business partners; having e-waste component shredders and air filter machines).

Further research is recommended to analyze the government's commitment and OEMs in supporting the development of informal e-waste businesses as partners that maximize the use of e-waste. The mechanism for implementing the circular economy concept, in which reverse logistics is the center of activity, is also a research theme that is still required by developing countries.

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Hesti Maheswari is currently a senior lecturer at the Management Department, School of Business and Economics, Universitas Prasetiya Mulya, BSD-Tangerang, Indonesia. She received her doctoral degree in operation and supply chain management under the research field of sustainable reverse logistics from Institut Teknologi Bandung, Indonesia. Her research interests include quality management, multicriteria evaluation, layout strategy, queuing discipline, supply chain management, and business performance. She has several publications in internationally referred journals in the operations management domain. She has published two popular book volumes with the theme of practical company management techniques. She also completed a research project with Multimedia University, Selangor-Malaysia, and the airline industry in Kingdom of Saudi Arabia. She is proficient in several data processing applications, including Smart PLS, AMOS, NVivo, and System Dynamic. She also worked as an assessor of Lamemba education quality assurance. For correspondence, connect via LinkedIn: Hesti Maheswari or email hesti.maheswari@prasetiyamulya.ac.id

Christiana Tercia is an associate professor (with special responsibilities) at Universitas Prasetiya Mulya, Indonesia. Her research covers the area of communication in tourism, word of mouth, experience economy in tourism, and experimental study in the family business. She has several publications in international journals, such as *Journal of Marketing Management*, *Consumer Behavior in Tourism and Hospitality*, *Journal of Destination Marketing and Management*, *Asia Pacific Journal of Marketing & Logistics*, and *Australasian Marketing Journal*. For correspondence, connect via via LinkedIn: Christiana Yosevina or email: yosevina.tercia@prasetiyamulya.ac.id

Fati Ramadhanti is a lecturer, researcher, and head of the Business Economics Undergraduate Program at Prasetiya Mulya University. She specializes in business economics and sustainability, with a focus on the circular economy concept and implementation. Fati teaches courses including microeconomics, environmental economics, and introduction to circular economy. Her work has been published in accredited national and international journals as well as popular media like *The Jakarta Post*. Certified in circular economy by institutions such as Wageningen University, the Ellen MacArthur Foundation, and the Circular Economy Institute, Fati also cofounded the Daur Project, a youth-driven plastic recycling initiative. She holds a master of business economics from Monash University, where she earned the Dean's Commendation Award. For correspondence, connect via LinkedIn: Fati Ramadhanti or email fati.ramadhanti@prasetiyamulya.ac.id

Agung Sigit Santoso holds and graduated in psychology and master of science in social psychology from University of Indonesia. Now as a lecturer at Faculty of Psychology at Mercu Buana University, Jakarta-Indonesia, he has been recognized as a professional psychologist at psychological consultant with more over 30 years' experience in working with several manners in the psychological field, especially in industrial and organizational psychology and social psychology. He has taught courses in entrepreneurship and social cognition and developing corporate culture in several organizational business (Eq. PT. Vale-Indonesia, Sorowako-South Sulawesi and PT. Semen Baturaja, Palembang-South Sumatra). He is a member of Indonesian Psychology Association (HIMPSI) and several human resources consultant as practician psychologist (PPSDM-Consultant, ARA Indonesia) and a member of Sport Psychology Association as a counsellor and advisor for sport organization (E-Sport Garuda Academy, Jakarta and Papua Football Academy, Timika-West Papua). For correspondence, connect via email agungsigits@gmail.com

Prameshwara Anggahegari is currently a young Research Expert at the Research Center for Cooperatives, Corporations, and the People's Economy. She received her doctoral degree in entrepreneurship under the research field of social entrepreneurship from Institut Teknologi Bandung, Indonesia. Her research interests include work cultural, sustainability communication, sharia empowerment, green product brand community, corporate social responsibility, and more focus on halal tourism studies. She also worked as a lecturer at School of Business and Management, Institut Teknologi Bandung, researcher for International Save The Children Indonesia, and Instructure of International Education Center. For correspondence, connect via prameshwara.anggahegari@brin.go.id