Reverse Logistics Strategy for Electronic Waste Infrastructure in Indonesia

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Abstract

Electronic waste is a type of organic waste whose growth is very fast, about three times faster than other waste. The volume of e-waste generated worldwide in 2019 was around 54 million metric tons and is expected to continue to increase until by 2030, annual worldwide e-waste production will increase by around 30 percent or around 75 million metric tons. Specific regulations in e-waste management are important factors in preventing and reducing e-waste. Indonesia is an example of a country that does not yet have specific regulations for electronic waste management. Currently, Indonesia is the largest e-waste producing country in Asia with an e-waste value of 1.3 million metric tons. This research is one of the efforts to provide recommendations for strategies to reduce the amount of electronic waste in Indonesia. Strategies are collected based on literature and validated by experts for the suitability of strategy implementation in Indonesia. A total of 20 recommendations for the reverse logistics strategy for e-waste processing infrastructure were successfully validated and then arranged based on a structural hierarchical strategy. This study uses the help of the Interpretive Structural Modeling (ISM) method to develop a strategy in the form of a hierarchical structure. Matrice d'Impacts Croises Multiplication Appliquee aun Classement (MICMAC) analysis to determine the classification of strategies based on driving forces and dependencies between strategies. The resulting structural model is used as a strategic map for implementing a strategy to reduce the amount of e-waste in Indonesia.

Keywords
E-Waste, Reverse Logistics Strategy, Interpretive Structural Modeling (ISM), MICMAC.

1. Introduction
Over the course of many years, it has become widely recognized on a global scale that human lifestyles have caused irreversible harm to the environment. Consequently, it has become imperative to adopt a systematic and sustainable approach towards our consumption habits. The desire for a higher standard of living among the world's population has led to the introduction of numerous aids and equipment that greatly simplify our busy lives. As a result, Electrical and Electronic Equipment (EEE) has gained immense popularity and is now considered an essential component of everyday life. In fact, the production of such equipment has become one of the fastest growing manufacturing activities worldwide. The growing dependence on these diverse EEEs, catering to a wide range of needs and available in various sizes, has resulted in the development of innovative products with desired features. However, these products often have limited lifespans, leading to the rapid disposal of outdated and obsolete items. Unfortunately, the production, consumption, and disposal of EEEs generally lack consideration for eco-friendly practices, creating sustainability challenges. This situation has worsened the generation of a new environmental threat known as "E-Waste," which poses additional difficulties due to inadequate management. While the generation of E-Waste is inevitable, it could be less problematic if recycling avenues were widely accessible across the globe.

Electronic waste has become a global issue, especially in developing countries where the majority do not yet have specific regulations for e-waste management. Indonesia is an example of a developing country that does not yet have specific regulations for electronic waste management. In fact, Indonesia is one of the 10 countries that produce e-waste in the world with an e-waste value of 1.3 million metric tons according to 2017 Global E-waste Monitor data (Forti et al., 2020).

Currently, Indonesia lacks specific regulations pertaining to the management of electronic waste (e-waste). The primary source of e-waste in the country stems from domestic consumption, specifically the widespread utilization of electronic devices within households. With the advancement of technology and the availability of affordable options, Indonesians tend to excessively employ electronic devices and frequently replace them to keep up with technological advancements. According to the United Nations, Indonesia produced around 1.6 million tons of electronic waste in 2019. Furthermore, according to the Directorate General of Waste, Waste and Hazardous Toxic Material Management (Ditjen PSLB3), Ministry of Environment and Forestry (KLHK), it is estimated that electronic waste will be generated in 2021 has reached 2 million tons (Forti et al., 2020).

Moreover, electronic devices are also sourced from imports and the black market, with each accounting for an equal proportion of 50% of the total. Apart from households, electronic waste in Indonesia is acquired through ports situated across the country, serving as points of entry for ships transporting used electronic equipment from overseas. The informal sector plays a role in managing electronic waste by collecting damaged devices. Scavengers gather these damaged items and deliver them to waste agencies. Subsequently, the electronic devices within these waste agencies undergo a process of repair, disassembly, and recycling. This handling process transforms electronic waste, initially devoid of any monetary value, into marketable goods. The waste agents then sell the refurbished electronic waste to consumers, while those items that no longer hold any resale value are disposed of in landfills. However, the presence of electronic waste within landfill sites has not been significantly observed (Ciptaningayu, 2017).

The significant challenges posed by e-waste are exemplified by the slow processes of collection and recycling, as well as external factors including resource consumption, greenhouse gas emissions, and the release of toxic substances during informal recycling practices. Improper management of electronic waste leads to detrimental impacts across various sectors, particularly the environment. E-waste contains hazardous substances and toxic additives such as mercury, brominated flame retardants (BFR), and chlorofluorocarbons (CFCs), or hydrochlorofluorocarbons (HCFCs). Each year, approximately 50 tonnes of mercury and 71 kt of BFR plastics are present within e-waste streams, predominantly released into the environment and adversely affecting the health of workers exposed to them. Furthermore, inadequate e-waste management contributes to the issue of global warming (Perkins et al., 2014). To address the escalating issue of annually increasing e-waste, the implementation of reverse logistics emerges as a viable solution within the e-waste processing systems in Indonesia. Reverse logistics encompasses a comprehensive range of logistical operations, starting from the collection of used products that are no longer required by consumers to the reintegration of reusable products into the market. Consequently, reverse logistics proves to be well-suited for recycling challenges where the flow direction moves from consumers to producers. One crucial advantage of reverse logistics in electronic waste processing lies in its capacity to enhance production speed while concurrently reducing costs associated with transportation, administration, maintenance, repairs, and replacements (Muhammad et al., 2020).
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1.1 Objectives
Therefore, this research is the same as the following research objectives to determine the right strategy to be able to reduce electronic waste in Indonesia.

2. Literature Review
2.1 Electronic Waste in Indonesia
The issue of electronic waste (e-waste) in Indonesia has evolved into a multifaceted problem, given the escalating consumption patterns and rapid advancements in technology. Indonesia faces various challenges in addressing this problem. Firstly, the country experiences a surge in electronic consumption, which corresponds to its economic growth and increased technological accessibility. Consequently, this surge contributes to a substantial rise in the volume of e-waste generated. One significant hurdle is the limited awareness and understanding among the population regarding electronic waste management. Many individuals remain uninformed about the detrimental impact of e-waste on both the environment and human health. Furthermore, Indonesia's infrastructure and management systems for e-waste are inadequate. The development of effective infrastructure and systems for managing e-waste presents persistent

challenges. Insufficient recycling and processing facilities exacerbate the situation, leading to a significant portion of e-waste ending up in landfills. Consequently, illegal trading of e-waste persists as a pressing concern in Indonesia. Illegally imported e-waste enters the country through smuggling routes, resulting in unregulated waste handling practices and adverse effects on the environment and public health. (Nindyapuspa, 2018)

To address the issue of e-waste in Indonesia, a comprehensive approach is necessary. It entails raising public awareness through educational campaigns, fostering an understanding of the negative consequences associated with improper e-waste disposal. Additionally, substantial efforts should be directed towards the development of adequate infrastructure and recycling facilities to ensure efficient e-waste management. Furthermore, stricter law enforcement measures need to be implemented to combat the illegal trade of e-waste. By imposing and enforcing stringent regulations, Indonesia can mitigate the flow of illicit e-waste, thereby minimizing uncontrolled waste handling and its detrimental impacts.

In conclusion, the complex nature of e-waste in Indonesia requires a mixed response. Nations should focus on increasing public awareness, developing strong infrastructure and recycling facilities, and enforcing stringent legal measures to combat the illegal e-waste trade. With the strategy of reverse logistics on e-waste infrastructure can effectively solve the problem of e-waste and protect the environment and public health (Ibom et al., 2021).

2.2 Reverse Logistic

The concept of Reverse Supply Chain has the following definition "The series of activities necessary to retrieve a product from a customer and either dispose of it or recover value." It can be said that the meaning of the sentence states that the reverse supply chain is a series of activities based on the process of returning products from consumers as end users or product improvement processes (Kocabasoglu et al., 2021). Another analysis was put forward by Miao (2009) which stated that the important activities of a reverse supply chain contain several concepts, namely "Product recalling, material replacement, the reverse flow of products and materials for returns, repair, remanufacture, and recycling". The above concept indicates that the reverse supply chain process includes issues such as defective products, material replacement, and the process flow can be in the form of products or materials to be returned to the company, repair processes, remanufacturing and recycling (Senthil, 2014)

2.3 Content Validy

To ensure the relevance of the reverse logistic strategy in the context of infastructure e-waste in Indonesia, content validity was conducted. A validation procedure was carried out by distributing a questionnaire to experts in waste treatment industry or in the field of electronics. The selection of expert panel members was based on specific criteria: 1) Having a minimum of 5 years of experience in the waste treatment service industry; 2) Experts from industry electronic companies, non-governmental agencies (NGOs), or academic fields; 3) Holding managerial positions in private or non-private waste treatment companies or having research experience in reverse logistic/e-waste management for academics/NGOs (Fernández-Gómez et al., 2020).

The experts utilized a four-point item-rating scale, where 1 represented "not relevant," 2 represented "somewhat relevant," 3 represented "quite relevant," and 4 represented "highly relevant." They evaluated a set of items derived from an extensive literature review on the concept of supply chain resilience. To assess content validity, both the I-CVI (Item-Content Validity Index) and multi-rater kappa statistics were employed. The I-CVI value of each item was determined based on the proportion of experts who judged the content as valid (rating it as 3 or 4) or invalid (rating it as 1 or 2). The multi-rater kappa coefficient of agreement was analyzed and compared. According to Fleiss (1981), a kappa value greater than 0.74 was considered "excellent," between 0.60 and 0.74 was deemed "good," between 0.40 and 0.59 was classified as "fair," and below 0.40 was categorized as "poor." Items classified as fair or poor were removed from the questionnaire, while items classified as excellent or good were retained for future research considerations (Fleiss et al.,2003).

3. Methods

In this study, a review of the existing literature reviews regarding the strategy for implementing the reverse logistics system in electronic waste management was carried out. The main objective of this research is to identify the sequence of strategic relevance to reduce electronic waste in Indonesia. The research methodology used in this study combines several steps. The preliminary stage is the first step, and involves conducting a study related to the problem discussed in this study, outlining the context of the problem, formulating the problem, setting research objectives, and conducting a preliminary literature review to draw research (Waltz et al., 2016).

Furthermore, some literature is reviewed to develop a reverse logistics strategy in the context of the e-waste industry. From the literature study, 23 strategies were identified. Consisting of 8 strategies from the front-end dimension (see Table 1), the front end is a strategic step that focuses on the initial processing process, namely collection and prevention. Furthermore, there are 10 strategies from the dimensions of the machine (see Tabel 2), the machine is the first step that focuses on the processing of electronic liquid waste. Finally, there are 5 strategies from the Back-end (see Tabel 2), which are the initial steps that focus on returning products back to consumers. (Shrotryia & Dhanda, 2019).

In order to evaluate the relevance of factors related to the implementation of reverse logistic in the Indonesian, a questionnaire was developed using the Content Validity Index (CVI) method (Fleisset al.,2003). The experts were requested to rate each factor's relevance on a 4-point scale ranging from 1 to 4. This is how proportion is determined: I-CVI is the proportion of experts who concur that the question is relevant to the field devided by the total number of experts. The value of k* was obtained using formula 3.3, and a kappa value above 0.60 was considered good/substantial, indicating that the strategies is relevant. If the kappa value is below 0.60, the factor is considered irrelevant (Almanasreh et al., 2019).

$$Pc = \left[\frac{N!}{A!\,(N-A)!}\right] 0.5^{N}$$ .... formula 3.1

In this formula 3.1,
Pc = “probability of chance agreement”
N = “number of experts in a panel”
A = “number of panellists who agree that the item is relevant”

$$I-CVI = \frac{number\ of\ experts\ who\ rated\ the\ item\ as\ 3\ or\ 4}{number\ of\ total\ experts}$$ … formula 3.2

$$k* = \frac{I-CVI - Pc}{1 - Pc}$$ … formula 3.3

Table 1. Evaluation of Modified Kappa Values

Values	Strenght of Agreement
1	Poor
< 0.40	Fair
0.60 – 0.74	Good
0.74 – 1.00	Excellence

Source : (Barbosa & Cansino, 2022)

4. Data Collection

The Strategies were obtained based on the literature review related to reverse logistic implementation. There are total of 23 strategies divided into 3 sections. The framework is developed in three sections: front-end, engine and back-end (Alshammari, 2017). The first section is front-End, this dimension is related to the collection of product returns. The level of each indicator is then developed and increased to reach a condition where unbalanced supply and demand in the RL system can be reduced. The second is engine, this dimension refers to all activities of product returns recovery, where the used product is recovered into a product that can function as good as new. Several recovery strategies can be done, such as reusing, reconditioning, remanufacturing, and recycling (Anityasari & Kaebernick, 2008). The last is back-End, this dimension deals with remarketing products in the secondary market from planning remarketing strategies, pricing to assessing the availability and demand of the secondary market also prevent and anticipate the dangers of electronic waste. The list is shown in Table 2.

Tabel 2. List of E-Waste Reduction Strategies based on Literature Study

Code	Sub Strategies	Description	Refrences
B1	Placing a special electronic waste bin in the city point	Collection points must be licensed or comply with national/international standards to receive, manage, sort, and store e-waste, and all recyclers must be licensed or certified to receive, unload, sort, process, and store e-waste and output material for final recycling.	(owakowski et al., 2021)
B2	Product design mechanism (eco design)	Manufacturers should adopt more eco-friendly designs for their products to reduce the use of hazardous materials and make recycling easier.	(Govindan et al., 2015)
B3	The government makes laws related to electronic waste	Make special laws that regulate the overall management of e-waste in Indonesia, especially regarding the definition of products and producers involved, producer responsibilities, roles of other actors, accreditation and monitoring of EPR schemes, and steps to mitigate illegal e-waste imports	(Ikhlayel, 2018)
B4	Return policy that benefits parties (collectors and users)	Improving human resources in the field of e-waste processing	(Yuliati, 2012)
B5	Collaborate with home developers for the e-waste collection process	Collaborate with home developers such as Sinarmas Land, Jaya, or Ciputra to facilitate collection on a small scale	(Gyawu et al., 2018)
B6	Collaborate with resellers for e-waste collection	Collaborate with online or offline resellers to facilitate collection when there are unused electronic devices	(Gyawu et al., 2018)
B7	Collaborate with electronic repair services for electronic waste collection	Collaborate with electronic device repair services to collect electronic waste	(Gyawu et al., 2018)
B8	Build and manage logistics network, e-waste channel & collection system (Collecting)	Building logistics networks such as e-waste transportation, temporary shelters, collection points, etc	(Salhofer et al., 2015); (Ardi, 2021)
B9	Human resource training in the field of waste management	Training in the field of environmentally friendly practices for electronics & recycler industry workers in accordance with established standards.	(Shrotryia & Dhanda, 2019)
B10	Invest in ewaste recycling technology	Latest technology investment for e-waste management	(Vishwakarma et al., 2022)
B11	Collaborating with outsourcing (private) parties for e-waste recycling	Collaborate with the private sector to manage electronic waste	(Gyawu et al., 2018)
B12	Building a reverse logistics information system so that it can run well	Building an information system network in reverse logistics management	(Ikhlayel, 2018)
B13	Integrated facilities and infrastructure support for value recovery from returns	Facility support such as infrastructure and technology to recover value from returns to make it more valuable	(Salhofer et al., 2015)

Code	Sub Strategies	Description	Refrences
B14	Exporting electronic waste for recycling	Exports to countries that have credibility are shown to simplify and speed up the recycling process	(Kahhat & Williams, 2012)
B15	Improving e-waste management	E-waste management is an important thing in the recycling process therefore it needs to be improved in all aspects so that the process is successful.	(Yuliati, 2012)
B16	Environmental certification and accreditation for companies	Providing certification for electronics manufacturers who are able to implement principles, policies, and protocols related to e-waste management systems	(Dwiningtyastuti, 2009), (Garg, 2021)
B17	Standardization of e-waste recycling practices	Standards are needed to regulate the collection, sorting, handling, storage, transportation, treatment and disposal of electronic waste	(Hotta et al., 2016)
B18	Transparency and monitoring in the e-waste management process	Transparency of information to the public such as fees charged to manufacturers, costs incurred, revenue from resale, etc. Monitoring should include the detection of 'free riders' (producers who do not pay a fee but still benefit from the existing scheme).	(WWF, 2020)
B19	Counseling for the public about the dangers of electronic waste	Outreach program for the community regarding the impact of e-waste on health, the importance of recycling e-waste, and how to participate in the recycling process	(Ikhlayel, 2018)
B20	Remarketing strategy for recycled products	Marketing strategy that focuses on recycled products	(Rodhiah et al., 2022), (Rusham et al., 2018)
B21	Recovery product pricing strategy	Competitive prices for products that have been recovered	(Wibowo, 2022)
B22	Recycling subsidies/incentives and e-waste collection	Subsidies are aimed at authorized recyclers or electronics companies to reduce cost deficits and increase profitability in the collection and recycling of e-waste.	(Govindan et al., 2015)
B23	Provide information about the dangers of electronic waste using social media	Provide information about the dangers of electronic waste using all media (social media and banners)	(Garg, 2021)

5. Results and Discussion

In this section, the result of (k*) value of the strategies are discussed in the perspective of the literature and research objectives from the experts (Table 3).

Table 1. List of Valid Strategies by Expert

Dimension	Strategy Code	Number of Agree	I-CVI	K	Interpretation of K
Front-end	F1	4	1	1	Excellent
	F2	4	1	1	Excellent
	F3	4	1	1	Excellent
	F4	4	1	1	Excellent
	F5	3	0,75	0.816	Good
	F6	2	0.667	0.565	Fair
	F7	1	0,5	0.273	Poor
	F8	4	1	1	Excellent
Engine	E1	4	1	1	Excellent
	E1	4	1	1	Excellent

	E2	4	1	1	Excellent
	E3	4	1	1	Excellent
	E4	4	1	1	Excellent
	E5	4	1	1	Excellent
	E6	1	0,5	0.273	Poor
	E7	4	1	1	Excellent
	E8	3	0,75	0.816	Good
	E9	4	1	1	Excellent
Back-end	B10	4	1	1	Excellent
	B2	4	1	1	Excellent
	B3	4	1	1	Excellent
	B4	4	1	1	Excellent
	B5	4	1	1	Excellent

5.1 Front-End

Front-End has 6 strategies that are valid: placing e-waste bins at city points has been implemented by various countries such as Japan, Germany and the Netherlands, and has proven to be quite helpful in the process of collecting electronic devices, especially for electronic devices that are easy to carry (Nowakowski et al., 2021). The next strategy is the eco product design mechanism, here this strategy aims to make electronic devices better for the environment in the future and easier to decompose and not harmful to human health (Govindan et al., 2015). The government makes laws related to electronic waste so that Indonesia can trigger and have regulations and policies on electronic waste in Indonesia. A return policy that benefits both parties (collectors and users) is implemented so that both parties benefit and can increase awareness (Ikhlayel, 2018). Working with a home developer for the e-waste collection process will ease the collection process as it is small in scope and easy to organize. and finally Build and manage logistics network, e-waste distribution & collection system (Collection) will be easier to monitor if there is a network that combines several sectors in the collection system (Gyawu et al., 2018).

5.2 Engine

Engine has 9 strategies that are valid: Human resource training in the field of waste management will improve the quality of human resources in managing electronic waste management. Investment in waste recycling technology is good for long-term investment because good technology will also increase the quality and quantity of electronic waste management results (Vishwakarma et al., 2022). Collaborating with outsourcing (private) parties to recycle waste will facilitate the management process because there will be more and more parties involved in the management and other processes (Gyawu et al., 2018). Building a reverse logistics information system is a strategy that makes it easy for all parties to find out about real time management processes (Ikhlayel, 2018). Support for integrated facilities and infrastructure for the recovery of value from returns will help produce electronic waste in terms of value after being processed by the manager. Improving e-waste management will improve the quality of management in a management and more structured manner (Salhofer et al., 2015). Environmental certification and accreditation for companies as a preventive measure so that something unwanted is not occur in the work environment (Dwiningtyastuti, 2009). Standardization of electronic waste recycling practices can improve the overall management process because it has a standard that must be owned (Hotta et al., 2016). Transparency and monitoring in the electronic waste management process in order to increase trust in consumers or all parties in the management of electronic waste (WWF, 2020).

5.3 Back-End

Back-end has 5 startegies that are valid: Counseling for the public about the dangers of electronic waste as an educational step for the whole community to be aware of the dangers of electronic waste (Ikhlayel, 2018). A remarketing strategy for products resulting from recycled processes is needed to return electronic waste products that have been processed back to the market using remarketing methods (Rusham et al., 2018). Pricing strategies for recovery products must be considered so that consumers are attracted back to electronic waste products (Wibowo, 2022). Recycling subsidies/incentives and e-waste collection help authorized recyclers to reduce cost deficits and increase profitability so that their products can be resold (Govindan et al., 2015). Providing information about the dangers of electronic waste using social media is a long-term step and can provide extensive information about the dangers of electronic waste (Garg, 2021).

6. Conclusion

Research on reverse logistics has been increasing over the years, especially in the case of electronic waste, with many practitioners being interested in the reverse logistics concept which has many benefits for environmental balance as well as effective waste management, cost, carbon impact and health or safety. The implementation of reverse logistics for e-waste processing infrastructure in Indonesia is a long-term step that will change the entire infrastructure from the process of collection, recycling to redistribution and the main goal is to be able to reduce e-waste in Indonesia. Therefore, a strategy of various is needed to reach that goal. In this study there are 3 sections consisting of 20 validated strategies which can be seen in the Figure 1. This research requires the help of all stakeholders so that it can run well and in a structured manner.

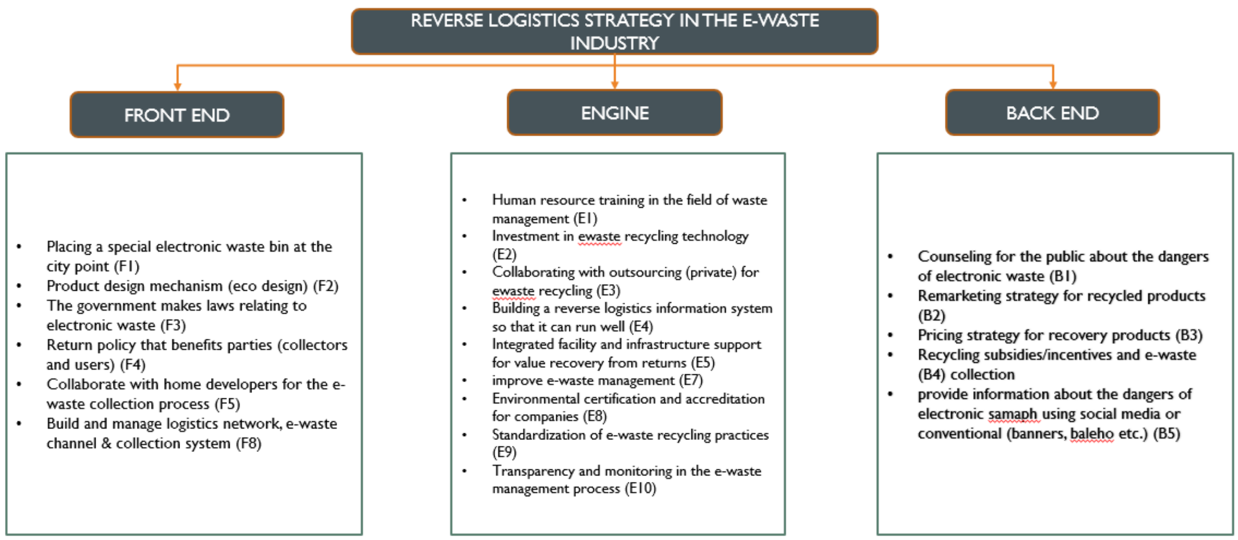

Figure 1. Validated Strategies

Admittedly, this research has some limitations. There is still little research on electronic waste in Indonesia and the implementation of reverse logistics has not been widely used in various industries. This of course can make the results of this study not fully related. In fact, we have presented experts from small companies to multinational companies, non-governmental organizations and academics. Subsequently. These limitations represent viable avenues for future research on this topic. Future work might try to expand the expertise. Also, this study suggests using ISM and MICMAC to be able to prove the relationship between existing elements. This method can be developed to formulate policy strategies, especially for waste management. This will determine the level of hierarchy between strategies based on analysis using the level of driving power and dependency power of each variable.

References

Almanasreh, E., Moles, R., & Chen, T. F., Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *15*(2), 214–221, 2019. https://doi.org/10.1016/j.sapharm.2018.03.066

Alshammari, S., *Developing Reverse Logistics Maturity Model to Transition to Circular Economy Scottish Institute of Remanufacturing 2 • Circular economy-CE-business motivation. • CE challenges. • Role And Requirements Of Logistics For A CE. • Reverse Logistic Maturity Mo*. 1, 2017. www.cranfield.ac.uk

Anityasari, M., & Kaebernick, H., A concept of reliability evaluation for reuse and remanufacturing. *International Journal of Sustainable Manufacturing*, *1*(1–2), 3–17, 2008. https://doi.org/10.1504/IJSM.2008.019224

Barbosa, M. W., & Cansino, J. M. , A Water Footprint Management Construct in Agri-Food Supply Chains: A Content Validity Analysis. *Sustainability (Switzerland)*, *14*(9), 1–17, 2022. https://doi.org/10.3390/su14094928

Ciptaningayu, T., *PENGELOLAAN LIMBAH BAHAN BERBAHAYA, 2017*.

Dwiningtyastuti, I., Penerapan Sistem Manajemen Lingkungan Iso 14001 Di Pt Sari Husada Unit I Yogyakarta. *Laporan Khusus*, 1–70, 2009.

Fernández-Gómez, E., Martín-Salvador, A., Luque-Vara, T., Sánchez-Ojeda, M. A., Navarro-Prado, S., & Enrique-Mirón, C., Content validation through expert judgement of an instrument on the nutritional knowledge, beliefs, and habits of pregnant women. *Nutrients*, *12*(4), 2020. https://doi.org/10.3390/nu12041136

Forti, V., Baldé, C. P., Kuehr, R., Bel, G., Jinhui, L., Khetriwal, D. S., Linnell, J., Magalini, F., Nnororm, I. C., Onianwa, P., Ott, D., Ramola, A., Silva, U., Stillhart, R., Tillekeratne, D., Van Straalen, V., Wagner, M., & Yamamoto. *The Global E-waste Monitor 2020: Quantities, Flows, and Resources, 2020*. https://ewastemonitor.info/gem-2020/

Garg, C. P., Modeling the e-waste mitigation strategies using grey-theory and DEMATEL framework. *Journal of Cleaner Production*, *281*(xxxx), 124035, 2021. https://doi.org/10.1016/j.jclepro.2020.124035

Govindan, K., Soleimani, H., & Kannan, D., Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *European Journal of Operational Research*, *240*(3), 603–626, 2015. https://doi.org/10.1016/j.ejor.2014.07.012

Gyawu, M. A.-, Larbi, B. O., & Addai, S.-P., *E- Waste Management ; A Collaborative Approach Towards Sustainability*. 26–35, 2018. https://doi.org/10.15680/IJIRSET.2018.0701009

Hotta, Y., Visvanathan, C., & Kojima, M., Recycling rate and target setting: challenges for standardized measurement. *Journal of Material Cycles and Waste Management*, *18*(1), 14–21, 2016. https://doi.org/10.1007/s10163-015-0361-3

Ibom, A., Polytechnic, S., Choube, P. R., George, E. E., Ibom, A., Polytechnic, S., Osurua, I., & State, A. I. , *Challenges of Electronic Waste in Nigeria : 8*(7), 280–288, 2021.

Ikhlayel, M., An integrated approach to establish e-waste management systems for developing countries. *Journal of Cleaner Production*, *170*, 119–130, 2018. https://doi.org/10.1016/j.jclepro.2017.09.137

Joseph L. Fleiss, Bruce Levin, and M. C. P. (2003). The Measurement of Interrater Agreement. *Fleis*, 598–626, 2003. https://doi.org/10.1002/0471445428.ch18

Kahhat, R., & Williams, E., Materials flow analysis of e-waste: Domestic flows and exports of used computers from the United States. *Resources, Conservation and Recycling*, *67*, 67–74, 2012. https://doi.org/10.1016/j.resconrec.2012.07.008

Kocabasoglu, C., Prahinski, C., & Klassen, R., *Linking Forward and Reverse Supply Chain Investments : The Role of Business Uncertainty Forward Supply Chains (FSCs), 2022*.

Muhammad, A., Muhammad Hussein, M. Z. S., Zulfakar, M. H., & Sundram, V. P. K., Reverse logistics activities for household e-waste management: A review. *International Journal of Supply Chain Management*, *9*(1), 312–318, 2020.

Nindyapuspa, A., *KAJIAN TENTANG PENGELOLAAN LIMBAH ELEKTRONIK DI NEGARA. 20, 2018*.

Nowakowski, P., Kuśnierz, S., Płoszaj, J., & Sosna, P., Collecting small-waste electrical and electronic equipment in Poland—How can containers help in disposal of E-waste by individuals? *Sustainability (Switzerland)*, *13*(22), 2021. https://doi.org/10.3390/su132212422

Perkins, D. N., Brune Drisse, M. N., Nxele, T., & Sly, P. D., E-waste: A global hazard. *Annals of Global Health*, *80*(4), 286–295, 2014. https://doi.org/10.1016/j.aogh.2014.10.001

Rodhiah, Wijaya, Y. L. A., & Bakti, K. K., Pengenalan Strategi Pemasaran Pada Produk Daur Ulang Di Pamulang Tangerang Selatan. *Prima : Portal Riset Dan Inovasi Pengabdian Masyarakat*, *1*(4), 63–72, 2022. https://doi.org/10.55047/prima.v1i4.295

Rusham, Hendrayanti, E., Pramono, J., & Fajarwati, D., Pemasaran Produk Kerajinan Hasil Daur Ulang Sampah Rumah Tangga Berbasis Web Di Kelurahan Bahagia Kecamatan Babelan Kabupaten Bekasi. *Universitas Islam "45" Bekasi*, *4*(1), 31–40, 2018.

Senthil, S., Reverse Logistics: a Review of Literature. *International Journal of Research in Engineering and Technology*, *03*(23), 140–144, 2014. https://doi.org/10.15623/ijret.2014.0323031

Shrotryia, V. K., & Dhanda, U., Content Validity of Assessment Instrument for Employee Engagement. *SAGE Open*, *9*(1), 2019. https://doi.org/10.1177/2158244018821751

Vishwakarma, S., Kumar, V., Arya, S., Tembhare, M., Rahul, Dutta, D., & Kumar, S., E-waste in Information and Communication Technology Sector: Existing scenario, management schemes and initiatives. *Environmental Technology and Innovation*, *27*, 102797, 2022. https://doi.org/10.1016/j.eti.2022.102797

Waltz, C. F., Strickland, O. L., & Lenz, E. R., Measurement in Nursing and Health Research. In *Measurement in Nursing and Health Research, 2016*. https://doi.org/10.1891/9780826170620

Wibowo, T. S. . A. M. . A. M. A. . H. H. . & W. E., Efektifitas Strategi Penetapan Harga Produk Barang pada Daya Beli Konsumen: Studi Literature Authors. *Management Studies and Entrepreneurship Journal (MSEJ)*, *3*(5), 2987–2996, 2022. https://www.yrpipku.com/journal/index.php/msej/article/view/1108

Yuliati, E., *MEASURING THE REVERSE LOGISTICS PERFORMANCE OF CONSTRUCTION MACHINERY REMANUFACTURING COMPANY*. *55*(July), 1–4, 2012.

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Dr. rer.pol Romadhani Ardi S.T., M.T is an Assistant Professor at Universitas Indonesia, in Depok, Indonesia. He teaches at the graduate and undergraduate level, with almost 14 years of experience. He graduated as an Industrial Engineer from Universitas Indonesia in 2009 and continue his Master's Degree in the same field while becoming a Lecturer Assistant at 2009-2011 then became a Lecturer at 2011. He continued to study at University of Duisburg-Essen at 2013 and got the Doctor rerum politicarum degree in 2016. Currently he got promoted as Associate Dean for Student Affairs, Research and Community Engagement at Faculty of Engineering Universitas Indonesia. His expertise is in the fields of environmental engineering and sustainability, especially circular economy and e-waste management. He trained in systems analysis on e-waste management as well as in advanced statistical analysis. His research focuses in the development of sustainable waste management systems, the use of renewable energy sources, and the development of sustainable communities. He has published numerous papers on these topics and has presented his work at international conferences. He is also experienced in working on building community engagement projects of sustainability issues. He has a deep understanding of the complexities of sustainability issues and the importance of engaging communities in the process.

Sangdaffa Adetyantama is a graduate degree student in Industrial Engineering, Universitas Indonesia. He got his bachelor degree as Electrical Engineer in 2021 also in Universitas Indonesia. He works at E-Commerce in businness development that focused on getting products to customers that pushed he to have a deep understanding about supply chain and reverse logistic.