Development of Integrated Electronic Waste Management System Strategies in Indonesia

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Abstract

Electronic waste in Indonesia continues to grow at an alarming rate. It is estimated that by 2040, the amount of e-waste generated will reach almost double the current amount. If not addressed, this condition will directly or indirectly negatively impact life aspects such as the environment, health, society, and economy. Currently, Indonesia's e-waste management efforts still rely on general rules that do not specifically regulate e-waste, such as the Law on Hazardous and Toxic Waste. In addition, research needs to discuss e-waste management strategies in Indonesia from a multi-actor perspective. To fill this gap, this article aims to develop relevant e-waste management strategies to be implemented in Indonesia from a multi-actor perspective. The initial stage of this research is to collect e-waste management strategies that have been implemented or proposed from various works of literature. Furthermore, the list of strategies that have been collected is assessed for their relevance on a four-level integer scale by experts from the government, non-government organizations, electronics manufacturers, recyclers, and academia which represent the stakeholders involved in the decision-making of e-waste management. Then, the validation process is carried out using the content validity index (CVI) method, where the results of this method will show consensus and valid strategies that are important for policymakers and researchers in the future.

Keywords
E-waste, Electric and Electronic Equipment, Content Validity Index, Indonesia.

1. Introduction
The use of electrical and electronic devices is essential in people's lives. Electronic equipment is one of the main aspects supporting productivity and improving human living standards. Besides these benefits, the extensive use of electronic equipment has a fairly worrying impact because electronic waste is currently a global problem. Forti et al. (2020) show that in 2019, the world generated 53.6 million metric tons of e-waste, and only 17.4% of this amount was recorded as properly collected and recycled. Indonesia's condition is no better than the condition of global e-waste management. This is proven by the fact that in 2019 only 10% of e-waste in Indonesia was processed by the formal sector (Yunita et al. 2019). Even though Indonesia itself in 2019 produced quite a large amount of electronic waste, as much as 1.6 million metric tons, which placed Indonesia as the fourth largest producer of electronic waste in Asia.

Various factors cause the rapid growth of e-waste globally, such as technological developments, increased purchasing power of new products, population growth, market penetration, and high obsolescence rates (Arora, 2008). In addition, factors like the ineffective supply chain mechanism for electronic products and product waste between formal stakeholders and the involvement of the informal sector significantly affect the high level of waste produced at the end of the cycle (Li et al. 2010). In fact, if managed seriously, electronic waste generates not only economic benefits but also gives social and environmental benefits. From an economic point of view, e-waste recycling will prevent the wastage of resources such as metals, plastics, and chemicals used as well as the energy and costs required to produce and mine them. From a social perspective, many people will be employed to fulfill the recycling resources of electronic waste, including the potential for utilization/conversion of the informal sector to become formal. In addition, the community's financial stability will improve due to more jobs. From an environmental perspective, implementing effective e-waste management will save landfills' availability and prevent environmental pollution caused by hazardous substances from electronic waste (Keith 2020).

Therefore, to manage e-waste problems in their countries, various countries have established various policy programs. For example, European Union countries and most OECD countries have adopted Extended producer responsibility (EPR) programs and policies. Other countries in Asia, Africa, and South America are also implementing similar programs at the scoping stage, in which the specific features and the results of their application vary significantly by region (OECD and Ministry of the Environment 2014). In Indonesia, various policies regulate waste management, such as UU No. 32 Tahun 2009 regarding environmental protection and management, Permendagri No. 7 Tahun 2021 regarding procedures for calculating retribution rates in managing waste management, UU No. 18 Tahun 2008 regarding Waste Management, and PP No. 101 Tahun 2014 regarding Management of Hazardous and Toxic Waste. However, no policies or regulations discuss the management of e-waste specifically, let alone regulate the management mechanism in detail. From a research perspective, currently, there have been several studies in Indonesia that discuss e-waste management. Such as Panambunan-ferse and Breiter (2013), who reviewed the conditions and results of e-waste management and government participation from the point of view of mobile phone waste. Then, Mairizal et al. (2021) discuss the estimation of e-waste generated, the potential for materials to be recovered, and the proposed framework for an e-waste recycling system in Indonesia; Yoshida et al. (2020) tried to evaluate recycling conditions in Indonesia, Vietnam, and the Philippines; Yunita et al. (2019) developed a funding scheme for a model of an electronic waste management system in developing countries, especially in Indonesia. These studies have not yet focused on designing or selecting a comprehensive e-waste management strategy. The research that comes closest is research conducted by Mariano (2019) and Dewi (2019) model of Extended Producer Responsibility (EPR) that is suitable for application in Indonesia. However, these studies are still limited from the point of view of producers and regulators, even though the involvement of every main actor, such as the recyclers, academics, and consumers, in e-waste management activities is crucial to ensure the sustainability of the management system. Therefore, these stakeholders need to be included in research regarding this issue.

2. Literature Review

In this section, the literature reviewed electronic waste (e-waste), integrated electronic waste management system, and content validity index (CVI).

2.1 Electronic Waste (E-Waste)

According to WEEE Directives No. 2012/19/EU, e-waste is waste from equipment that relies on electric currents or electromagnetic fields to function properly, as well as equipment for the generation, transfer, and measurement of such currents and fields and designed for use with a voltage rating of not more than 1000 volts for alternating current and 1500 volts for direct current. Based on WEEE Directives No. 2012/19/EU, there are 54 types of EEE products which are categorized into six broad categories based on their waste management features. These categories are temperature equipment, screens and monitors, lamps, large equipment, small equipment, and small technology and communication equipment. This categorization is intended for statistical purposes where the determination is based on function similarity, material composition, average weight, and end of life (Forti et al. 2020).

Electronic waste needs to be managed properly because it contains various valuable metals that can provide economic benefits. The electronic waste consists of 50% iron and steel, 21% plastic, and 13% non-ferrous metals such as copper (Cu), Aluminum (Al), Silver (Ag), Gold (Au), Platinum, Palladium, and other elements (Widmer et al. 2005). In addition, e-waste also contains dangerous heavy metals such as Lead, Mercury, Cadmium, Arsenic, Selenium, Hexavalent Chromium, and Flame Retardant (Agrawal et al., 2003), which, if not handled properly, can have harmful effects on health.

In general, the ideal e-waste supply chain flow consists of 8 stages (1) Production of raw materials, (2) production or import of electronic products, (3) distribution/retailer, (4) consumption, (5) collection, (6) transportation, (7) recycling, and (8) disposal. These flows are circular, where the waste material generated by the recycling stage is reused in the first stage as much as possible (Khetriwal et al. 2009).

2.2 Integrated Electronic Waste Management System

In this study, we proposed integrated e-waste management strategies in Indonesia that involved the perspectives of four main actors in e-waste management decision-making: the Government, Society, Academics, and Companies.

Adapted from Lau and Wang (2009) and following this research theme, the conceptual model developed in this study is as follows.

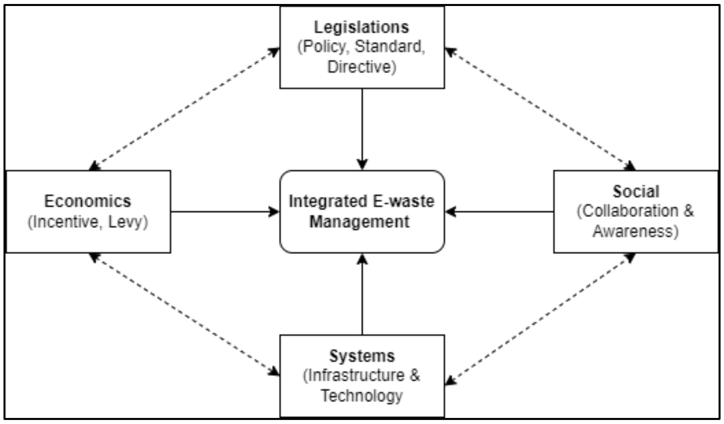

Figure 1. Conceptual model of the integrated electronic waste management system

- Economics: The strategic dimension related to the overall flow of funds used in e-waste management activities.
- Legislations: Dimensions of strategy related to policies, regulations, directives, and standardization in e-waste management.
- Systems: Strategic dimensions related to infrastructure systems, logistics networks, and technologies used in e-waste management
- Socials: Dimensions of strategy related to relationships between stakeholders such as community relations, producers, EPR, collaboration partners (donors), and supply chain partners.

2.3 Content Validity Index (CVI)

Content validity is a crucial thing to do in determining the strategy to be implemented, including in the field of e-waste management. One method that is useful in determining the instrument's validity is the content validity index (CVI) method. In quantitative evaluation, the CVI method is one of the most widely used index (Shi et al. 2012).

To conclude the validity of an instrument, it is necessary to calculate two forms of CVI, I-CVI, which functions to determine the validity of each item, and S-CVI, which functions to measure the validity of the entire instrument. In calculating the I-CVI, the expert assesses the relevance of each item on the instrument based on a four-point Likert scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant). If an item gets a rating of 1 or 2, then the item is given a value of 0, meaning the expert does not approve it. However, if it gets a rating of 3 or 4, the item is given a value of 1 which means it is relevant according to the expert. After the assessment, the overall value of an item is added up and divided by the total number of experts who evaluate it, as in Equation 1. In calculating the S-CVI, the overall I-CVI value for each item is summed up and then divided by the number of items in the instrument, as in Equation 2.

$$I - CVI = \frac{Expert\ Agreed}{Number\ of\ Expert} \quad (1)$$

$$S - CVI = \frac{\sum I - CVI}{Number\ of\ Item} \quad (2)$$

According to Polit et al. (2007), the CVI method is divided into two approaches. The first and most frequently used approach is the average approach or commonly referred to as CVI/Ave. CVI/Ave is an approach that is not too strict, where the relevance value of an item is generally considered valid if it has an I-CVI score above 0.80. The second approach is the Universal Agreement or CVI/UA. This approach requires all experts' approval to declare an item valid. The S-CVI value needed to determine whether an instrument is valid varies based on previous studies. This depends on the number of experts and the type of approach used, the details can be seen in Table 1. In addition, the selection of the two approaches is optional, where their use is very dependent on the stakeholder's agreement and the characteristics of the problem, which is the reason for making the instrument.

Table 1. The number of experts and acceptable CVI scores

Sources	Total Experts	I-CVI	S-CVI/Ave	S-CVI/UA
Lynn (1986)	2-5	1	1	-
	6	0.83	0.83	-
	7	0.86	0.86	-
	8	0.88	0.88	-
	9	0.78	0.78	-
	10	0.8	0.78	-
Davis (1992)	2	-	0.8	-
Polit et al. (2007)	3	1	0.8	0.8
	4	0.75	0.8	0.8
	5	0.8	0.8	0.8
	6	0.83	0.8	0.8
	7	0.71	0.8	0.8
	8	0.75	0.8	0.8
	9	0.78	0.8	0.8

3. Methods

The methodology used in this study is in line with Lynn (1986), where the step of determining content validity in this study is divided into two stages. The first stage is the development stage. At this stage, the dimensions and items of the strategy are developed to form a questionnaire that can be filled in for expert judgment. Then the second stage is the judgment-quantification stage. At this stage, an assessment is carried out by the expert based on the questionnaire form that has been made.

Development stage: this stage consists of 3 steps. The first step is identifying the dimensions used as a categorization list of validated strategies. As for this study, we used four strategic dimensions: economics, legislations, systems, and socials, as depicted in Figure 1. These four dimensions are used because these factors influence the development of reverse logistics at the macro level (Lau and Wang 2009) and also because it takes into account the background expertise of stakeholders that influence decisions in e-waste management. Then the second step is to identify the strategy items to be validated. The list of strategies was selected by conducting a literature study of previous research related to e-waste management in both developed and developing countries. From the literature study conducted, it was found that there were 29 lists of strategies grouped based on predetermined dimensions, as shown in Table 2. Then the third step is to assimilate the strategy items and dimensions into a ready-to-use questionnaire. This step involves making questionnaire filling instructions, creating a Likert scale, identifying expert experience, and sorting a list of validated strategies (Table 2).

Table 2. List of e-waste management strategies

Dimensions	**No**	**Strategy**	**Definition**	**Sources**
Economics	S1	Recycling & collection subsidies	Subsidies are aimed at authorized recyclers or electronics companies to reduce the cost deficit and increase profitability in collecting and recycling electronic waste.	Lau and Wang (2009)
	S2	Pollution tax for non-participants	Electronic companies not involved in collecting or recycling are taxed according to the amount of waste they produce.	Lau and Wang (2009)

Table 2. Continue

Dimensions	No	Strategy	Definition	Sources
Economics	S3	Levy funds on manufacturers & importers	Imposing levies on electronics manufacturers and importers to finance an integrated e-waste management system. The mechanisms can be in the form of disposal fees, advanced recycling fees, take-back schemes, etc.	Watkins and Gionfra (2020), Gollakota et al. (2020), Ardi (2021)
	S4	Transparency & monitoring of the finance practices	Transparency of information to the public, such as costs charged to producers, costs incurred, revenue from sales, etc. Monitoring should include the detection of 'free riders' (manufacturers who pay no fees but gain benefits from the applied scheme).	Watkins and Gionfra, (2020)
	S5	Favorable investment conditions	Creating favorable investment conditions for experienced cyclers to bring the required technical expertise.	Step Initiative (2016)
	S6	Stimulate competition in recycling systems	Fair competition between logistics providers and recyclers must be established to ensure the long-term cost-effectiveness of the system.	Step Initiative (2016)
Legislations	S7	Eco-friendly product design rules	Manufacturers should adopt more environmentally friendly designs to reduce the use of hazardous materials and simplify the recycling process.	Lau and Wang (2009)
	S8	Certification & accreditation for companies	Certification for electronics manufacturers who can comply with policies and protocols related to e-waste management systems.	Garg and Sharma (2020)
	S9	Special laws for e-waste management	Create a special law that regulates 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 mitigation measures for illegal e-waste import.	Ikhlayel (2018), Watkins and Gionfra, (2020)
	S10	Collection point and recycler license	Recyclers and collection points must be licensed according to national/international standards for e-waste handling.	Salhofer et al. (2016), Step Initiative (2016)
	S11	Standardization of e-waste recycling practices	Standards are needed to regulate the collection, sorting, handling, storage, transportation, treatment, and disposal of electronic waste.	Salhofer et al. (2016)
	S12	Strengthen regulatory compliance	Strengthen monitoring & law enforcement to ensure that all stakeholders comply with regulatory requirements.	Step Initiative (2016)
	S13	Elimination of conflicting policies	Eliminate policies that conflict with e-waste management. For example, a subsidy program for the extraction of raw materials because it will reduce the interest of producers in using recycled raw materials.	OECD (2001)
	S14	Recycling targets for companies	Assign actual responsibilities to formal producers or recyclers, e.g., measurable targets for waste recovery, collection, and recycling	Watkins and Gionfra, (2020)

Table 2. Continue

Dimensions	No	Strategy	Definition	Sources
Legislations	S15	Rules equivalent to the Restriction of Hazardous Substances Directive	This rule forbids the use of lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (CrVI), polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), and phthalates in the manufacture of electronic products (DEHP, BBP, BBP, DIBP).	Ardi (2021)
Systems	S16	Build new e-waste management infrastructures	Build additional dismantling, treatment, and recycling facilities with qualified technology.	Lau and Wang (2009), Watkins and Gionfra, (2020), Ardi (2021)
	S17	Monitoring the flow of illegal e-waste	Monitoring of illegal e-waste imports at customs checkpoints.	Salhofer et al. (2016)
	S18	Develop logistics network and collection system	Building logistics networks such as e-waste transportation, temporary shelters, collection points, etc.	Salhofer et al. (2016), Ardi (2021)
	S19	Monitor recycler performance	Supervise the performance of recyclers/manufacturers/PROs regarding recycling targets, standards compliance, etc.	Salhofer et al. (2016)
	S20	Increase the capacity of existing recycling units	Increase the capacity of existing infrastructure (dismantling, treating, and recycling) with qualified technology.	Kumar et al. (2022), Ardi (2021)
	S21	Monitoring EEE POM, e-waste generation, collection rate, etc	Monitor EEE Placed on Market (POM), generated e-waste, the amount collected by the formal sector, and all data relating to circulating e-waste.	Forti et al. (2020)
Social	S22	Educational & awareness program about e-waste	Training programs for the public regarding the impact of e-waste on health, the importance of e-waste recycling, and how to participate in the recycling program.	Ikhlayel (2018), Step Initiative (2016)
	S23	Create Producers Responsibility Organizations (PRO)	PRO is a third-party institution with a mandate from producers to manage the process of collecting, processing, and handling e-waste.	Ardi (2021)
	S24	Integration of the informal sector	The informal sector is formalized through proper training. The training aims to prevent improper waste handling, increase waste management capacity, and facilitate waste collection.	Ikhlayel (2018), Kumar et al. (2022), Step Initiative (2016)
	S25	Facilitating a platform for collaboration	Create a collaboration platform that serves as a forum for dialogue between stakeholders (PRO, producers, government, local municipalities, waste companies, consumers, NGOs)	Watkins and Gionfra, (2020), Ardi (2021)
	S26	Training for workers	Training in the field of environmentally friendly practices for workers in the electronics & recycling industry in accordance with standards.	Kumar et al. (2022)
	S27	Research finance support	Support financing of e-waste research & recycling technology to encourage the acquisition of the latest technology/strategies that can increase e-waste management capacity	Ghost (2020)

Table 2. Continue

Dimensions	No	Strategy	Definition	Sources
Social	S28	Maintain effective communication	Communicate programs and achievements effectively to the public to increase public and company trust in supporting the implemented programs.	OECD (2001)
	S29	Cooperation with donor agencies	Partnerships with donor agencies such as the Japan International Cooperation Agency (JICA) are helpful for learning best practices from developed countries and receiving grant funds to implement pilot projects.	Ardi (2021)

Judgment-Quantification Stage: This stage consists of 2 steps. The first step is to fill in the validation questionnaire that has been made. The results of completing the questionnaire are then calculated for the I-CVI value as in Equation 1. The results of these calculations determine which strategies are valid enough to calculate the S-CVI value in the second stage. At this stage, the determination of experts was also carried out, as shown in Table 3. Then the second step is to calculate the validity value of the proposed strategy instrument. The level of instrument validity is illustrated by the resulting S-CVI/Ave or S-CVI/UA value.

4. Data Collection and Processing

The data collection begins with determining the experts who will be used as respondents. In selecting respondents, the researcher determined the same number of expert representatives to prevent interest bias due to overrepresented actors. There were five experts, each representing an academic, non-government organization, government, recycler, and electronics manufacturer, as shown in Table 3. This selection is based on actors usually involved in e-waste management mechanisms and research on e-waste. The background of the experts is as follows. Expert A is a Ph.D. Candidate in e-waste technology who has conducted several studies on e-waste in Indonesia. Expert B is a researcher, and a toxics & zero waste program officer at a non-government organization (NGO) engaged in protecting society against hazardous waste, including e-waste. Then expert C is a sub-directorate head in a government agency whose job is to process technical approval for hazardous waste from industry and process clarification and qualification of hazardous waste. Expert D is a Senior Engineer and Technical Support Manager from a company that provides collection, recycling, treatment, and disposal services for hazardous and non-hazardous waste. Finally, expert E is a manager in an electrical equipment manufacturing company whose job is to lead the sustainability impact program, which includes teacher mission programs, green programs, and give back to the community (Table 3).

Table 3. List of e-waste experts

Expert	background	Experience
A	Academic	5-10 years
B	Non-Government Organizations	5-10 years
C	Government	7 years
D	Recycler	14 years
E	Electronics Manufacturer	5-10 years

The next step is collecting data through the CVI questionnaire. The experts who have been selected assess the relevance rating of each strategy that has been developed. There are 29 strategies being considered. If the resulting I-CVI/Ave value is below 0.80, then the strategy is considered invalid and needs to be eliminated or revised. Table 4 contains the results of expert ratings on e-waste management strategies that may be applied in Indonesia and the results of CVI calculations.

Table 4. Results of e-waste management strategy validation by experts

Dimensions	No	Experts in Agreement	I-CVI Average	Avg Validity	I-CVI UA	UA Validity
Economics	S1	3	0.6	Invalid	0	Invalid

Dimensions	No	Experts in Agreement	I-CVI Average	Avg Validity	I-CVI UA	UA Validity
	S2	3	0.6	Invalid	0	Invalid
	S3	4	0.8	Valid	0	Invalid
	S4	2	0.4	Invalid	0	Invalid
	S5	5	1	Valid	1	Valid
	S6	5	1	Valid	1	Valid
Legislation	S7	5	1	Valid	1	Valid
	S8	4	0.8	Valid	0	Invalid
	S9	4	0.8	Valid	0	Invalid
	S10	4	0.8	Valid	0	Invalid
	S11	5	1	Valid	1	Valid
	S12	5	1	Valid	1	Valid
	S13	4	0.8	Valid	0	Invalid
	S14	4	0.8	Valid	0	Invalid
	S15	4	0.8	Valid	0	Invalid
Systems	S16	5	1	Valid	1	Valid
	S17	5	1	Valid	1	Valid
	S18	5	1	Valid	1	Valid
	S19	5	1	Valid	1	Valid
	S20	5	1	Valid	1	Valid
	S21	5	1	Valid	1	Valid
Social	S22	5	1	Valid	1	Valid
	S23	4	0.8	Valid	0	Invalid
	S24	5	1	Valid	1	Valid
	S25	5	1	Valid	1	Valid
	S26	5	1	Valid	1	Valid
	S27	4	0.8	Valid	0	Invalid
	S28	4	0.8	Valid	0	Invalid
	S29	5	1	Valid	1	Valid

5. Results and Discussion

Based on the results of the evaluation using I-CVI, there are only three strategies that are considered invalid, which are S1, S2, and S4 (Table 5). These three strategies were eliminated because they did not meet the acceptable I-CVI/Ave value of 0.8. However, if we refer to the universal agreement approach, there are only 16 valid strategies. From the results of the elimination, a new set of items is then compiled (Polit et al. 2007). In this second round, the S-CVI value was calculated, and it was found that the S-CVI/Ave value is 0.92, which is considered acceptable by the experts and included in the category of excellent content validity, where the minimum value to be considered excellent is 0.90 (Polit et al. 2007). As for the S-CVI/UA value, 0.62 is considered moderate according to (Rodrigues et al. 2017), but it is still not acceptable because it is below 0.8, which is unacceptable if we use the universal agreement approach. However, the instruments that have been made can be considered valid because the low value of S-CVI/UA can be supported by the very high value of S-CVI/Ave and also considering that the universal agreement approach will be too stringent if there is any possibility of opinion bias and misunderstanding on several experts (Polit et al. 2007).

Table 5. CVI results after the elimination of invalid strategies

Dimensions	No	Experts in Agreement	I-CVI Average	I-CVI UA
Economics	S3	4	0.8	0
	S5	5	1	1
	S6	5	1	1
Legislations	S7	5	1	1
	S8	4	0.8	0
	S9	4	0.8	0

Dimensions	No	Experts in Agreement	I-CVI Average	I-CVI UA
	S10	4	0.8	0
	S11	5	1	1
	S12	5	1	1
	S13	4	0.8	0
	S14	4	0.8	0
	S15	4	0.8	0
Systems	S16	5	1	1
	S17	5	1	1
	S18	5	1	1
	S19	5	1	1
	S20	5	1	1
	S21	5	1	1
Social	S22	5	1	1
	S23	4	0.8	0
	S24	5	1	1
	S25	5	1	1
	S26	5	1	1
	S27	4	0.8	0
	S28	4	0.8	0
	S29	5	1	1

Finally, from this study, 26 strategies were considered valid. Overall, all strategy items are considered valid on legislations, systems, and social dimensions. As for the economics dimension, three strategies are considered invalid, which are "Recycling & collection of subsidies", "Pollution tax for non-participants", and "Transparency & monitoring of the finance practices". The strategy "Recycling & collection of subsidies" is considered invalid by recyclers and the government. This is because even though this strategy seems to benefit recyclers in the future, they argue that this strategy is not yet urgent to be implemented in Indonesia because, currently, the profit generated from e-waste management by the formal sector is still high. "Pollution tax for non-participants" is also considered invalid by the government and recyclers. They argue that the government has required producers to be responsible for the waste they produce. There are also sanctions that apply to violators, so the tax on non-participants is considered less relevant. The strategy “Transparency & monitoring of the finance practices” is considered invalid by NGOs, recyclers, and companies. They argue that recyclers set their costs individually, and they consider it to be a company secret, so it will be difficult to be transparent. Meanwhile, from the producer's point of view, this cost transparency will be burdensome, and it is feared that it will harm the brand image if they do not contribute but still benefit from the implemented e-waste management program. Even so, they think this strategy can be implemented, but not in the near future (5-10 years).

6. Conclusion

Research on e-waste management is crucial for Indonesia as a country still not well established in e-waste management. This research provides a new reference regarding the future strategies that might be applied in e-waste management in Indonesia. From the results of the literature review conducted, we identified 29 strategies. Experts then validated this list of strategies. From the validation process, it was determined that there were 26 strategies from four dimensions (3 economic strategies, 9 legislative strategies, 6 systems strategies, and 8 social strategies) that were valid because they obtained an I-CVI/Ave value above 0.80. As for S-CVI/Ave, a value of 0.92 was found, which an excellent validity value for content is. However, if we use the universal average approach, there are only 16 valid strategies with an S-CVI/UA value of 0.62. We recommend using the average approach considering the possibility of bias and misunderstanding by experts.

In future research, we recommend using the multi-criteria decision-making (MCDM) approach to analyze the driving and dependence power of the strategies in the implementation of electronic waste management. Besides that, an analysis of the interrelationships between strategies and strategy prioritization can also be carried out.

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