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Bridging the Gaps in E-Waste Governance: E-Waste Management in Southeast Asia

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Abstract
Southeast Asia has emerged as both a major producer and recipient of discarded electronic products. Despite facing similar pressures from increasing electronic consumption, growing volumes of e-waste, and associated environmental risks, Southeast Asian countries exhibit considerable variation in their approaches to e-waste governance. This study comparatively examines e-waste governance arrangements in five Southeast Asian countries—Indonesia, Thailand, Malaysia, Vietnam, and Singapore—focusing on regulatory frameworks, institutional coordination, collection and recycling systems, and the involvement of informal actors. The findings reveal substantial differences in the organization and implementation of e-waste governance across the five countries. Singapore demonstrates a comparatively integrated regulatory and collection system, while Indonesia, Thailand, Malaysia, and Vietnam face varying challenges related to regulatory implementation, institutional coordination, and informal recycling practices. The comparison highlights the importance of examining not only formal regulatory arrangements but also the practical challenges associated with their implementation. The study concludes that strengthening e-waste governance in Southeast Asia requires context-sensitive regulatory improvements, institutional coordination, and greater stakeholder engagement, alongside opportunities for regional cooperation.

Key Words: E-waste governance; waste management; Southeast Asia; Environmental policy; institutional capacity

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INTRODUCTION

Electronic waste (e-waste) is one of the fastest-growing waste streams worldwide, with an estimated 50 million metric tons generated in 2019 and projected to reach 74 million tons by 2030 and 111 million tons by 2050 (Forti et al., 2020; Herat, 2021). Asia is the largest contributor, accounting for more than 24.9 million tons in 2019 alone (Andeobu et al., 2021). Within Southeast Asia, rapid economic development, rising consumption of electronic goods, and the transboundary movement of used electronics have made countries such as Indonesia, Malaysia, Vietnam, and the Philippines both major producers and recipients of e-waste (Herat, 2021; Terazono et al., 2006). Vietnam's per capita e-waste generation, for example, nearly doubled from 1.9 kg in 2014 to 3.7 kg in 2020 (Hoang et al., 2023). The largest generator in the region, Indonesia, produced about 1.9 million tonnes in 2022, followed by Thailand, which accounted for 750,000 tonnes (Baldé et al., 2024).

Much of this growing volume of waste ends up being processed through unsafe informal recycling practices, posing serious environmental and public health risks due to the presence of toxic substances like plastics and heavy metals, such as lead, nickel, cadmium, arsenic and mercury (Herat & Agamuthu, 2012). Despite growing scale of the problem, the management of e-waste in Southeast Asia faces varied challenges. In many countries, the infrastructure for collection and recycling is insufficient, and the informal sector dominates waste handling (Hoang et al., 2023; Kurniawan et al., 2022). Moreover, regulatory enforcement is weak, and public awareness remains low (Pandebesie et al., 2019). Insufficient coordination among stakeholders also further hinders progress (Sengupta et al., 2022).

With the exception of Timor-Leste, which recently joined ASEAN, all ASEAN members are parties to the Basel Convention, which regulates the cross-border movement of hazardous waste, including e-waste. Under its prior informed consent (PIC) procedure, covered waste shipments require prior notification and written consent from importing and relevant transit countries. However, e-waste governance does not develop uniformly across the region. Some countries have established more structured practices that are showing promising solutions. Singapore, for instance, has developed a strong regulatory framework that includes structured collection mechanisms (Shad et al., 2020a). Malaysia has also advanced in regulating the informal sector and promoting environmentally sound management (Shad et al., 2020a). In contrast, Indonesia, Vietnam, and the Philippines still lack comprehensive laws and rely heavily on informal recycling operations (Hoang et al., 2023; Kurniawan et al., 2022). Comparative studies highlight that stronger legal mechanisms, standardized recycling procedures, and state-private sector collaboration significantly contribute to improved e-waste outcomes (Yoshida et al., 2016).

Effective e-waste management also involves participation of diverse stakeholders, including governments, producers, consumers, and the informal sector. Governments play a crucial role in policymaking and enforcement. Producers often

evade responsibility for post-consumer waste, especially where the regulation is not enforced (Pandebesie et al., 2019). In Vietnam and the Philippines, informal recyclers handle most e-waste but work under unsafe and unregulated conditions (Hoang et al., 2023; Yoshida et al., 2016). The successful integration of informal collectors into formal systems, as attempted in India, would be an alternative strategy. Multi-stakeholder engagement is thus critical to building sustainable e-waste systems in the region (Sengupta et al., 2022).

Given the diversity of policy frameworks, institutional arrangements, and implementation challenges across Southeast Asia, a comparative approach can help explain variations in e-waste governance across national contexts. Although previous studies have examined e-waste management in selected countries and the challenges of regional policy coordination (Shad et al., 2020a; Yoshida et al., 2016), further research could synthesize existing evidence from different national contexts. Policy capacity, institutional capacity, and state capacity provide complementary analytical perspectives for examining the resources, coordination arrangements, and enforcement challenges associated with implementing e-waste policies. These perspectives help organize the analysis without assuming in advance that differences in capacity directly determine governance outcomes.

Against this backdrop, this study comparatively examines e-waste governance in Indonesia, Thailand, Malaysia, Vietnam, and Singapore. These countries provide a basis for examining variation in regulatory frameworks, institutional arrangements, and implementation practices within a shared regional context. The study asks: What similarities and differences characterize e-waste governance in these five countries, particularly in terms of regulatory frameworks, institutional arrangements, and implementation practices? And what capacity-related challenges shape the implementation of e-waste policies in these countries? By comparing their approaches, this study seeks to explain variation in governance outcomes and identify the capacity-related challenges are evident in the implementation of their respective policies. The study contributes a comparative account of national e-waste governance in Southeast Asia and identifies institutional and capacity-related issues that warrant further empirical investigation and regional cooperation on transboundary e-waste.

Literature Review and statement of art

Examining variations in e-waste management across Southeast Asia requires not only considering differences in the policies adopted but also assessing how these policies function and perform across different national contexts. We argue that variations in policy capacity, institutional capacity and state capacity may help explain differences in how Southeast Asian countries implement e-waste policies and translate formal regulatory commitments into practice.

Citing Gleeson et al., Capano et al. (2020) define policy capacity as the set of skills and resources, or competences and capabilities, necessary to perform policy functions across different sectors (Capano et al., 2020). A government's ability to respond promptly and decisively to a policy issue depends substantially on its capacity to mobilize administrative institutions and societal actors and to translate policy decisions into effective action. Although such capacity does not necessarily guarantee successful implementation or prevent policy errors, it remains a fundamental condition for an effective and decisive policy response (Wu et al., 2015). Wu et al. (2015) argue that policy capacity consists of three core competencies: analytical, operational, and political. Each competency operates across three distinct levels of capacity: individual, organizational, and systemic (Wu et al., 2015).

Differences in institutional capacity also explain the variations in the patterns and effectiveness of e-waste governance across countries. Countries with stronger institutional capacities are better able to mobilize relevant knowledge and resources, coordinate interactions among government agencies and non-state actors, and organize collective action to address the complex challenges associated with e-waste. Conversely, limited institutional capacity may lead to fragmented coordination, insufficient knowledge sharing, and difficulties in mobilizing stakeholders and resources for effective policy implementation. These variations in institutional capacity can therefore contribute to different patterns and levels of effectiveness in e-waste governance across Southeast Asian countries (Healey, 1998).

Variations in state capacity can further justify differences in e-waste governance across Southeast Asian countries. Although countries in the region face relatively similar pressures arising from growing electronic consumption, increasing volumes of e-waste, and environmental concerns, their response to these pressures varies considerably. States with stronger capacities are generally better positioned to formulate appropriate regulatory frameworks, coordinate relevant institutions and stakeholders, enforce regulations, and effectively implement e-waste policies. Conversely, limited state capacity may constrain these functions and create gaps between formal policy commitments and actual implementation. Consequently, variations in state capacity contribute to different patterns of e-waste governance and different levels of policy effectiveness across Southeast Asian countries (Hanson & Sigman, 2021).

METHOD

Following a qualitative methodology (Creswell, 2014), this study relies primarily on secondary data sources. To ensure validity and credibility, and to minimize bias, findings are triangulated by cross-verifying information across official academic texts, peer-reviewed journals, and non-state organization reports. The research examines e-waste management and governance across five Southeast Asian nations: Indonesia, Thailand, Vietnam, Malaysia, and Singapore, as significant e-waste-generating countries in the region. The unit of analysis is national e-waste governance. Regional and international instruments, such as ASEAN cooperation

and the Basel Convention, are treated as contextual factors rather than objects of analysis. Understanding these differences requires examining how governance is organized and implemented within individual countries, rather than focusing primarily on regional coordination or the harmonization of regulations across ASEAN member states. Data collection is structured around three core dimensions: regulatory frameworks, infrastructure capacity, and key stakeholder ecosystems (encompassing both state and non-state actors).

We use thematic analysis to identify, analyze, and report recurring patterns and their underlying contextual meanings (Braun & Clarke, 2006). This approach examines how e-waste management is regulated and operationalized across the selected cases. A cross-national comparative analysis is employed to identify points of convergence and divergence in enforcement and stakeholder involvement. The findings are synthesized to demonstrate broader institutional capacities and stakeholder relationships.

This research has two primary objectives: (1) to nationally examine the regulatory frameworks related to e-waste in Southeast Asia, and (2) to identify and analyze the key stakeholders involved in e-waste management and challenges associated with the policy implementation across these countries.

RESULT AND DISCUSSION

Indonesia

Indonesia, with its growing consumption of electronics, faces significant challenges in managing e-waste. The improper disposal of electronic waste can pose risks to the environment and public health. In response, the government has established a regulatory framework for managing waste containing hazardous and toxic materials (B3), including discarded electronic equipment. This framework comprises Law No. 18/2008 on Waste Management, Government Regulation No. 27/2020 on the Management of Specific Waste, Government Regulation No. 22/2021 on the Implementation of Environmental Protection and Management, and Minister of Environment and Forestry Regulation No. 9/2024 on the Management of Waste Containing Hazardous and Toxic Materials and Hazardous and Toxic Waste.

Among these regulations, Minister of Environment and Forestry Regulation No. 9/2024 provides specific provisions relevant to discarded electronic goods, including their sorting at source, collection, collection facilities, operational procedures, record-keeping, and reporting. These provisions establish requirements for managing discarded electronic goods within Indonesia's broader waste management framework.

Indonesia's e-waste management framework distributes responsibilities across multiple actors rather than assigning overall responsibility to a single dedicated authority. The central, provincial, and regency/municipal governments share responsibility for managing e-waste according to their respective authorities. Local

governments at the regency or municipal level are responsible for collecting sorted waste from residential areas, while the Minister, governors, and regents/mayors each provide specific waste facilities according to their authority. Area managers are required to provide temporary collection facilities for waste containing hazardous and toxic waste. Licensed businesses may also cooperate in the provision of collection and treatment facilities. Coordination is facilitated through these arrangements, as well as through waste recording and reporting requirements (Minister of Environment and Forestry, 2024).

However, the regulation does not explicitly establish a dedicated national coordination mechanism for the entire e-waste management chain, leaving the extent to which responsibilities are coordinated in practice an empirical question. Furthermore, despite these regulatory provisions, Indonesia's e-waste governance remains embedded in broader waste management and hazardous waste regulations rather than in a dedicated framework covering the entire e-waste management chain. In this respect, the country differs from Singapore, whose e-waste management system incorporates extended producer responsibility (EPR) under the Resource Sustainability Act 2019. This difference raises questions about the extent to which Indonesia's existing regulations provide an integrated approach to e-waste management, particularly regarding the allocation of responsibilities and the implementation of collection, treatment, and recycling processes (Puluhulawa & Harun, 2024).

These gaps are compounded by implementation challenges on the ground. One key problem is the continued allowance of used electronics imports, which complicates e-waste management. Some ports enforce stricter controls than others, and the more lenient or poorly enforced ones enable the illegal import of hazardous e-waste, which highlights the need for uniform regulations and better enforcement. Meanwhile, the informal sector dominates e-waste collection and recycling, particularly in regions such as Batam and East Java. Informal recyclers extract valuable materials from discarded electronics using unregulated and unsafe methods, and without formal infrastructure or incentives for proper recycling, a significant portion of e-waste remains untracked or mismanaged (Rimantho, 2022).

Other challenges include low public awareness, inadequate recycling infrastructure, insufficient enforcement of existing regulations, and limited financial resources. The consequences are serious: workers and communities are exposed to hazardous substances such as lead, mercury, cadmium, and brominated flame retardants, and in areas like Pesarean Village, improper disposal has caused extensive soil and water pollution, while incineration degrades air quality (Shad, 2020a).

Compounding these problems, the country lacks accurate data on the volume of e-waste generated annually. One estimate suggests that Indonesia could generate approximately 487,416 tons of e-waste by 2028, driven by rapid technological advancement and economic growth. Without specialized policies and facilities for e-waste processing, Indonesia may struggle to handle this influx (Mairizal et al., 2021).

The private sector can help fill some of these gaps. Companies can drive public awareness campaigns, conduct eco-friendly refurbishment, and engage in recycling, and they have the capacity to implement circular economy concepts in e-waste management. In several respects, private sector initiatives have outperformed government efforts due to their greater efficiency and independence, whereas government awareness campaigns and educational workshops have lacked sufficient follow-through (Puluhulawa & Harun, 2024). Yet many provinces still lack dedicated e-waste programs, with regional efforts such as those in Jakarta remaining the exception (Mairizal et al., 2021). Collaboration between government and private entities could therefore standardize procedures, ensure regulatory compliance, modernize outdated practices, and encourage sustainable practices through waste reduction and innovative recycling technologies.

Research points to several priorities for improvement. Waste reduction strategies and optimization of the 3R (Reduce, Reuse, Recycle) program are essential. Public participation initiatives, such as the waste banks in Yogyakarta, Sleman, and Bantul Regency, have shown promising outcomes, whereas conventional pickup programs, though widely used across the country, are often inefficient, environmentally unfriendly, and hazardous to workers. Public education campaigns on the dangers of improper disposal and the benefits of recycling are also crucial, as is multi-stakeholder collaboration among NGOs, academic institutions, industry players, and international organizations (Yenita & Widodo, 2020). Given rising e-waste volumes driven by urbanization, consumerism, and the adoption of digital technologies, aligning national policies with international best practices could transform Indonesia's approach to e-waste. Ultimately, overcoming these challenges requires a coordinated national strategy, increased investment in infrastructure, and stricter enforcement of e-waste regulations.

Thailand

Thailand, along with three other ASEAN countries (Indonesia, Malaysia, and Vietnam), is recognized as one of the e-waste top contributors in the region. As of 2019, they account for 80% of ASEAN's total waste (UNODC, 2022). Thailand's National Statistical Office (NSO) reported that communities generated 442,251 tonnes of waste electrical and electronic equipment (WEEE) in 2023 (NSO, 2024). This figure is an estimate, as the government calculates WEEE as a fixed 65% share of community hazardous waste, and it excludes e-waste from industrial and commercial sources (see Table 1). The same publication also classify batteries and other hazardous household waste separately from WEEE, highlighting the importance of distinguishing between internationally comparable e-waste estimates and nationally defined waste categories.

Thailand's Pollution Control Department (PCD), the agency under the Ministry of Natural Resources and Environment responsible for e-waste, published a draft WEEE Integrated Management Action Plan for 2022–2026, which identifies growing dependence on electrical appliances and computer systems as a key driver of waste generation (EnviX, n.d.). The plan estimates WEEE generation across eight

product categories: televisions, air conditioners, refrigerators, washing machines, computers, CD/DVD players, telephones, and digital cameras.

Table 1. *Estimated Amount of E-Waste in Thailand, 2019–2023*

Year	E-waste (tons)	Total community hazardous waste (tons)
2019	421,335	648,208
2020	428,113	658,651
2021	435,187	669,518
2022	439,495	676,146
2023	442,251	680,386

Note. From National Statistical Office of Thailand (2024)

Notably, Thailand has yet to enact comprehensive legislation that specifically targets e-waste management (Mangmeechai, 2022). Although the government approved a national WEEE management strategy in 2007 called the Strategic Plan on Waste from Electrical and Electronic Equipment (Manomaivibool & Vassanadumrongdee, 2011), efforts to establish a dedicated WEEE Management Act based on the EPR principle have progressed slowly. The draft legislation has undergone repeated revisions and consultations, reflecting challenges in reaching agreement on implementation and the allocation of responsibilities among stakeholders. As of January 2026, PCD reported that it was still working to push forward a draft act that would require producers to share responsibility for taking back end-of-life products for recycling (The Nation Thailand, 2026).

In the absence of such a law, Thailand's e-waste management has relied on general legislation and a range of policy initiatives. The legal framework includes the Public Health Act B.E. 2535 (1992), which provides a basis for municipal waste management, and the Factory Act B.E. 2535 (1992), which regulates industrial activities and factory waste management (Pharino, 2017). Alongside these laws, Thailand adopted administrative policy instruments addressing waste management more broadly, including the National Master Plan on Cleaner Production and Cleaner Technology (2002) and the National Integrated Waste Management Plan (2003), as well as the Strategic Plan on Waste from Electrical and Electronic Equipment (2007) (Chotichanathawewong & Thongplew, 2009). These plans, however, are not legally binding. This regulatory disarray has hindered the country's ability to effectively address e-waste problems, largely due to the absence of a unified legal framework that could condition more collaborative and cohesive management mechanisms.

One significant issue in Thailand's e-waste management is the disparity in participation between the formal and informal sectors. Formal actors in Thailand's e-waste system include government bodies such as the PCD, which oversees policy, and local administrative organizations, which carry out collection, together with factories and facilities licensed under the Factory Act B.E. 2535 and the Public Health Act B.E. 2535 and inspected by officials. One report from Thailand's Office of Industrial Economics (OIE) approximately 90% of domestic e-waste was handled

by the informal sector, while only 10% reached formal recycling facilities (OIE, 2020).

Households typically dispose of e-waste through four main channels. These include the informal sector, such as peddlers who sell obsolete products to dealers, and nonprofit organizations or associations, including religious institutions like temples (Panyagometh, 2024). Additionally, e-waste is disposed of through the formal sector, such as government-led collection initiatives, and through routine household waste disposal, where it is discarded along with regular trash (Manomaivibool & Vassanadumrongdee, 2012).

Despite the variety, however, these channels are not well-coordinated. The Thai government's e-waste management strategy exhibits a pronounced centralization of authority, with responsibilities predominantly delegated to government agencies such as the Electricity Generating Authority and public universities. Additionally, private sector involvement included notable contributions from a few companies. General Motors, for instance, has pioneered the recycling of automotive parts and components. Similarly, Philips Electronic has spearheaded a campaign for the collection and recycling of used fluorescent light bulbs, while DTAC has initiated a program to collect used mobile phone batteries from consumers (Hotta et al., 2009).

Despite their substantial contribution, there is no clear direction for integrating informal sectors into the e-waste management agenda. These informal sectors account for the largest share of household e-waste handling, approximately 51,27% (Phoochinda & Kriyapak, 2021). Yet, the government efforts have predominantly concentrated on regulating and consolidating the formal sectors' role. Under the current situation, the informal sectors continue to operate within highly inefficient and fragmented systems, particularly in the northeastern region where they remain widely dispersed and uncoordinated (Mangmeechai, 2022). The Thai government current approach reflects a deficit in policy design capabilities, largely stemming from the absence of integrated, up-to-date information on e-waste distribution flows. As a result, e-waste management faces challenges in increasing its economic efficiency, environmental impacts, social awareness, and technological developments (Fetanat et al., 2021).

Thailand shows considerable promise in realizing economic value from e-waste management. A study suggests that given the huge volume of e-waste generated in the country, it could serve as a valuable source of secondary raw materials to boost up the "urban mining" concept and potentially convert it into profit that could reach over THB 9 billion (Phoochinda & Kriyapak, 2021). Since the informal, community-based sectors are actively involved in sorting and disassembling e-waste, there are open wide opportunities for the economic and social upliftment of impoverished communities. On top of all that, private sector companies in Thailand have demonstrated a keen interest in advancing e-waste management technologies. This indicates that the government could further enhance its strategy by better integrating and supporting the informal sector.

Despite the promising opportunities, Thailand must remain vigilant addressing potential challenges. The government's decision to halt the issuance of new import permits for all types of waste, including the e-waste, has resulted in a loss of business for recycling companies that hold existing legal import permits (Sasaki, 2021). Additionally, many of Thailand's e-waste issues stem from the lack of a unified regulatory framework. These gaps have exacerbated problems, particularly affecting informal workers. Without adequate legal mandates, the government lacks the obligation to invest in enhancing the knowledge and tools available to these workers. Consequently, this neglect poses substantial health risks, as workers are exposed to hazardous components such as copper and arsenic (Vassanadumrongdee et al., 2015).

Malaysia

The advancement of technological innovation and increasingly sophisticated marketing techniques has led to a global increase in the use of electronic goods, resulting in a volume rise in electronic waste. Malaysia, like many other countries, is encountering notable challenges in managing this growing e-waste. According to the Global E-Waste Monitor 2017, electronic waste production per capita in Malaysia reached 8,8 kg or 280,000 tons per year (Shad et al., 2020a, 67). In response to this, the Department of Environment has formulated regulations regarding electronic waste in Malaysia under SW 110, First Schedule, Environmental Quality (Scheduled Wastes) Regulations 2005. To mitigate environmental impact, this regulation prohibits the direct disposal of e-waste into landfills, mandating instead that it be recycled and managed by licensed facilities. SW 110 waste includes e-waste from electronic goods assembly containing components such as accumulators, mercury switches, cathode ray tube glass, polychlorinated biphenyl (PCB) capacitors, or is contaminated with hazardous substances like cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or PCBs.

The Department of Environment Malaysia provides specific guidelines for classifying electronic goods and components as e-waste. According to these guidelines, six types of electronic waste include televisions, washing machines, refrigerators, mobile phones, personal computers (both laptops and desktops), and air conditioners. In addition, the guidelines detail various other goods that are also classified as e-waste, such as metal waste, waste from partial production facilities, printers and accessories, radios and loudspeakers, circuits, microwaves, ovens, ink cartridges, facsimile machines, printed circuit boards and video recorders, photocopiers, hard disks, motherboards, electrical cables, air conditioners, and cathode ray tubes (CRT). The guidelines also specify requirements for categorizing electronic equipment as waste, including items that cannot be turned on, have non-functional motherboard, fail self-checks, cannot connect, or are unable to print, copy, scan, or record documents.

Electronic waste management in Malaysia is primarily regulated by the Department of Environment (El-Gawhari et al., 2024, 164). Electronic waste in Malaysia is

treated by two different sectors: informal and formal sector (See Figure 2). The formal sector is the treatment of e-waste that includes official facilities and external actors such as NGOs. This sector also covers the area of e-waste produced by industry. Meanwhile, the informal sector is a sector that uses traditional/illegal ways to collect electronic waste. Due to the high gaps in management guidelines, high operational costs, and the lack of household e-waste regulations, informal sectors are still dominating the e-waste treatment produced by household (Shad et al., 2020b; Yong et al., 2019). There are some possibilities of household electronic waste. If it is collected by social organizations, municipalities or the manufacturers, it will end up in the appropriate landfill after treated by partial and full recovery facility. Meanwhile, if it is mixed with household waste, sold to street buyers, or discarded to random landfills, it will never be treated in an ideal way and will end up in the inappropriate landfill (Shumon et al., 2014). The dominant informal method involves collectors who store the waste in traditional ways. The prevalence of informal management is attributed to gaps in regulatory guidelines, high operational costs, and ineffective implementation of e-waste management laws.

There are two schemes of electronic waste recovery operations; partial recovery facilitation and full recovery facilitation which accept industrial and household waste. Partial recovery facilities focus on segregating reusable components. Workers manually or physically extract parts that retain residual value—such as functioning electronic components—which are then redirected to secondhand electrical and electronic equipment (EEE) markets. Sorted e-waste, such as LCD screens or batteries, is dismantled into its constituent materials. Metallic components are sent to licensed full recovery facilities, while non-metallic parts are processed by dedicated recycling plants.

Full recovery facilities, in contrast, tend to purchase dismantled e-waste from the partial recovery facilities or collect the waste by themselves (Yong et al., 2019). Under the formal system, e-waste is collected and sent to materials recovery facilities (MRF) located in each state in Malaysia. As of 2016, there were 129 e-waste management facilities in the country, including 97 partial recovery facilities (which separate e-waste physically or manually) and 32 recovery facilities that process metal materials for reuse (Shad et al., 2020b). After recovery, the waste is forwarded to integrated management facilities for final disposal.

In addition, Malaysia employs an alternative formal electronic waste management scheme, knows as direct incineration with energy recovery. Under this scheme, collected electronic waste is transported to a materials management facility where it is incinerated. This combustion process generates two types of output: reusable materials for the production of new goods and residual waste. The residual is then sent directly to the final disposal site. This incineration process reduces the need for transportation to landfills and maximizes the recycling of electronic waste for reuse. When compared to conventional methods, the incineration mechanism proves to be more effective (Ismail & Hanafiah, 2021, 8).

Beside state actor, Malaysia also influenced a lot by non-state actors (PSAs and CSO) in e-waste governance. The involvement of non-state actors by playing complementary roles is trying to fill the gap left by state actors. They took their role on doing persuasion, self-governance, and co-governance (Tengku-Hamzah, 2011). One of the most impactful non-state actor movements was the strategic cooperation between the Department of Environment with the Japan International Cooperation Agency (JICA), has embarked on the "Project for Development of Mechanism for Household E-waste Management in Malaysia." where JICA played the role to co-governance and persuade the state actors to improve the e-waste management. The main objective of this project is to implement legal structures and organizational mechanisms capable of facilitating a sustainable and independent e-waste management system. The new mechanism is based on the principle of assigning clear obligations and shared responsibilities among various actors involved in e-waste management. These actors include waste producers, collectors, and recyclers (Sari, 2021).

Within this framework, waste producers bear the responsibility to ensure that their waste is exclusively collected by licensed collectors. The collectors, which include retailers, goods collection centers and goods pickup vehicles, are in turn responsible for delivering electronic waste to a centralized recycling facility that possesses the necessary licenses. Manufacturing companies are required to pay recycling and public education fees, as well as fees based on the volume of waste they generate (Sari, 2021). They also require to provide information on the location of hazardous materials to both collectors and recyclers. Initiated in 2013, this scheme was targeted for completion in 2018. However, to date, there have been no journal articles or news reports detailing the scheme's current status. The only available information pertains to the second phase of the project, which reached its conclusion in 2018. Despite the lack of recent updates, with the extensive preparatory work, including various stakeholders' trainings and a well-structured scheme, Malaysia has a promising opportunity to see this project through to full implementation.

One of the primary challenges with Malaysian electronic waste management is the persistently low collection rates by formal entities. Public awareness and waste management education are urgently needed to shift the mindset of people who continue to store electronic waste at home or sell it to informal collectors. This situation is further compounded by the absence of clear technical procedures and regulations governing e-waste management (Khan, 2023). Furthermore, Malaysia struggles with recyclers who prioritize only high-value materials. From an operational standpoint, the recycling and recovery process are costly, requiring large investments in equipment, machinery, and safety measures. Consequently, these methods often lack commercial viability.

Vietnam

E-waste is an increasingly urgent issue in Vietnam, primarily due to the rapid increase in waste volume and inadequate capabilities to recovering valuable

materials (Hai et al., 2017). Vietnam's population is expected to grow substantially, with the middle-income population projected to exceed 100 million by 2030. As a consequence, the EEE market will continue to expand, heightening the importance of future e-waste management across the country (Yoshida et al., 2015). On average, each person in Vietnam uses more than five pieces of EEE on their daily basis, indicating an exceptionally high level of consumption (Brindhadevi et al., 2023). However, despite these rising numbers, several major issues threaten to turn Vietnam into an e-waste dumping region should standardized e-waste management strategies are not promptly adopted. These issues encompass: the environmental harm caused by inadequate infrastructure and the predominance of the informal sector; the absence of specific e-waste legislation; and the lack of comprehensive monitoring data systems.

First, types of treatment and methods employed in the processing e-waste exert significant causal effects on the concentration of hazardous metals across various environmental settings (Brindhadevi et al., 2023). For example, most of the e-waste processing facilities in Vietnam are in proximity to agricultural areas, thereby posing a substantial risk of contaminating consumables, such as root vegetables and rice from the paddy fields. Moreover, workers in these facilities are exposed to over a thousand hazardous chemicals, which can result in severe health conditions including lung cancer, systemic blood disorders, neurological damage, and peripheral nerve impairment (Brindhadevi et al., 2023).

Second, environmental issues arise from the dominance of the informal private sector, which relies on inadequate infrastructure for dismantling processes—a situation closely linked to the absence of comprehensive legal frameworks and their ineffective implementation (Hai et al., 2017). Previous legislation did not specifically define e-waste, instead categorizing it under the broader term of hazardous waste. The first legal instrument specifically addressing e-waste management within the EPR framework is the Prime Minister's Decision No. 16/2015/QĈ-TTg 2015 on Prescribing Retrieval and Disposal of Discarded Products, which later replaced the Decision 50/2013/QĈ-TTg 2013 (Nguyen et al., 2017).

Lastly, a huge discrepancy exists between valid statistical data and the on-the-ground realities, leading to inconsistencies within monitoring data. Despite the issue being regulated under Circular No. 36/2015/TT-BTNMT on Hazardous Waste Management, the government, particularly the Department of Natural Resources and Environment, has not issued any official reports (Tran & Salhofer, 2018). Hence, the dominance of the informal sector as the primary handler of e-waste is closely associated with illegal importation and exportation activities, complicating the data collection processes for establishing a real-time monitoring system. Additionally, tendencies to evade taxes and the proliferation of remanufactured appliances undermine the feasibility of accurate data collection.

The cooperation and involvement of various stakeholders in managing e-waste in Vietnam are crucial, with scholars noting slight variations in the number of stakeholders involved in the disposal flow. The central stakeholders in the e-waste

disposal process are producers/sale agents and consumers (households or offices). Hazardous waste and final treatment facilities also play a significant role, although some stakeholders operate as private actors, which may include informal or illegal operations. These private actors include collectors, junk shops, dismantlers, recyclers, and exporters (Nguyen et al., 2017). Among these stakeholders, government intervention is predominantly focused on regulating producers within the confines of the existing legislation.

The most common flow for end-of-life (EOL) appliances involve either selling them to the private sector, keeping them within households, or passing them on to others (Hai et al., 2017). Treatment methods employed are typically centered around dismantling or refurbishing through manual processes rather than recycling. These informal dismantling activities are concentrated in approximately 3,000 craft villages across the country, with around 30 of these villages actively engaged in e-waste recycling (Yoshida et al., 2016).

During the collection phase, thousands of peddlers gather appliances and distribute them to service shops and private collectors. The collection is then classified to determine whether it can be repaired and sold as a new product or whether it should be exported. In these villages, workers specialize in handling specific types of appliances. For instance, some junk shops focus solely on refrigerators and washing machines, while others just collect DVDs or plastic. On average, each village processes between 1 and 10 tons of e-waste per day, totaling 40 to 50 tons per month (Tran & Salhofer, 2018).

Formal e-waste management in Vietnam is conducted by enterprises that hold licenses issued by Vietnam Environment Administration. These companies operate under the framework established by Decision No. 155/1999/QD-TTg—Regulation of Hazardous Waste Management—and Decision No. 23/2006/QD-BTNMT on the list of hazardous waste (Tran & Salhofer, 2018). However, only 15 out of 150 certified enterprises are tasked with managing e-waste across Vietnam. Notable examples include the Urban Environment Company (URENCO), a state-owned company responsible for waste collection and treatment in various provinces and cities since 2009, as well as Hoa Binh Treatment and Recycling of Industrial Waste Joint Stock Company and Tan Thuan Phong Co., Ltd. The volume of e-waste processed by these formal enterprises is significantly disproportionate to the total amount generated nationwide.

Given the current structure and mechanism of e-waste management, several imminent challenges must be resolved. Foremost among these is the lack of specific e-waste legislation and the need for stringent enforcement to penalize non-compliant agencies. Another challenge lies in the maintenance of data collection for accurately calculating and forecasting e-waste generation. Reliable and precise data are indispensable for enhancing the effectiveness of government policies and refining stakeholder strategies related to e-waste management.

Despite the prevailing pessimistic narrative in the previous discussion, there are two recommendations that need to be advanced by legitimate authorities in Vietnam to develop a concrete action plan. First, Vietnam must fully transition to and strengthen its formal sector policies by adopting new environmental regulations that incorporate the EPR system, a framework already implemented in several developing countries. The Prime Minister's Decision No. 16/2015/QĈ-TTg 2015 marks the foundational step in this direction, mandating government oversight of material flows and the phasing out of the informal sector (Nguyen et al., 2017). The core principle of the EPR system is that producers and importers are responsible for their discarded products, with oversight provided by government authorities. This scheme requires them to establish collection points and networks to facilitate its effective implementation.

Second, the implementation of the EPR system has been hampered by several factors, including insufficient public awareness and limited stakeholder connectivity. Law and regulations stemming from grassroots initiatives need to be introduced to encourage residents to actively engage in e-waste management. Social pressure can be a strong instrument to promote recycling behaviors (Nguyen et al., 2019). There is, however, a paucity of research on public behavior and perceptions regarding e-waste management. Reluctance to pay disposal fees implies a critical issue: many EOE users are either unaware of or unwilling to participate in the recycling system. To address this, it is crucial to bridge the gap between the formal and informal sectors to foster a more integrated and cohesive approach among stakeholders, with a particular focus on incorporating e-waste management into daily practices.

Singapore

As a highly developed economic nation, Singapore faces a significant challenge in managing its substantial e-waste production. According to the studies conducted by the Ministry of Sustainability and the Environment (MSE) and the National Environment Agency (NEA), each individual generates roughly 11 kg of e-waste per year, amounting to approximately 60,000 metric tonnes in total (NEA, 2018a). This number is projected to rise with the increasing economic activity, especially in the acquisition of electrical and electronic equipment. Moreover, the study reveals the typical patterns in e-waste disposal among Singaporeans. As consumers, they are inclined to trade in or sell valuable e-waste while discarding fewer valuable items, primarily home appliances like washing machines, refrigerators, and televisions. Most of the time, this waste ends up in informal collectors who lack the capacity for proper recycling, leading to environmental contamination from hazardous pollutants. Despite these challenges, the recycling rate remains relatively low at 6% compared to 26% of e-waste collected as general waste (Bea & Low, 2019).

Since the 20th century, Singapore has addressed several problems regarding waste management. In the 1970s, the city-state faced an increase in household waste due to a drastic rise in Housing and Development Broad (HDB) apartments. In response, the National Recycling Programme was implemented, which introduced a recycling

bin for each HDB block. Despite these efforts, domestic recycling rates remain low, at only 22 percent (Ministry of the Environment and Water Resources and National Environment Agency, 2019). To improve upon existing recycling efforts, Singapore launched the "Year Toward Zero Waste" (YTZW) initiative in 2019, adopting a circular economy approach. This initiative, based on the concept of "turning trash into treasure," aims to build a sustainable economic system and maintain the value of the product by emphasizing the principle of 3R. Furthermore, involving various state and non-state stakeholders could help to control the e-waste stream.

On August 5th, the Resource Sustainability Act (RSA) was introduced to the public by the Minister for Environment and Water. Drawing on successful e-waste management practices from other countries, Singapore established an EPR approach by 2021 (Kidangoor, 2023). One of the main goals is to channel e-waste under licensed recyclers for proper treatment and to reduce the amount of e-waste disposed of in landfills. This approach ensures that producers not just sell the product but also take responsibility for post-market waste management. Under the supervision of the NEA, manufacturers are required to provide access and resources to collect and then recycle the e-waste.

The RSA mandates the involvement of cross-field stakeholders in e-waste management, including producers/manufacturers, retailers, collectors, Producer Responsibility Scheme (PRS) operator, and consumers. The NEA appoints a PRS operator through an open tender mechanism, which was won by ALBA, a German company specializing in e-waste recycling. Under the RSA, producers and retailers are responsible for collecting Annex A, which includes regulated consumer products such as ICT equipment (printers, desktop computers, laptops, and mobile phones), large household appliances (refrigerators, air conditioners, washing machines, and TVs), lamps, and batteries (Ministry of Sustainability and the Environment, 2020). The goal is to collect at least 20% of total put-to-market (PTM) weight for these items, with a specific target of 60% for large appliances.

Producers and retailers can collect e-waste through several methods, e-waste bins located throughout the city, 1-for-1 take-back programs, or collection by local government services. Large producers and retailers with facilities of 300 square meters or above, are required to build on-site collection points and provide free collection services for consumers. Once collected, the e-waste is transferred to the ALBA's facility for the recycling process.

Singapore's comprehensive and well-established e-waste regulatory framework has contributed to the relatively effective implementation of its e-waste management policies. As one of the leading countries in ASEAN in this area, Singapore demonstrates how institutionalized e-waste management practices can foster broader public awareness and encourage community participation. A notable example is Repair Kopitiam, a volunteer-driven initiative that seeks to challenge the prevailing "throw-away" culture by extending the lifespan of electronic devices through repair and reuse. The initiative also organizes monthly activities to promote basic repair skills and raise public awareness of sustainable consumption

practices (Kidangoor, 2023). This example highlights the complementary role of community-based initiatives in supporting formal regulatory frameworks and collection systems, particularly in advancing circular economy principles and encouraging more sustainable patterns of consumption.

CONCLUSIONS

The comparative analysis of e-waste management in Indonesia, Thailand, Malaysia, Vietnam, and Singapore reveals substantial differences in institutional frameworks, regulatory mechanisms, and the balance between formal and informal sectors. Among the cases examined, Singapore has a more structured regulatory and collection system, while the other four countries face different challenges in organizing e-waste management and addressing informal recycling practices. These differences provide a basis for examining the diverse approaches to e-waste governance within Southeast Asia.

Indonesia and Thailand share a strong reliance on informal e-waste handling. In Indonesia, although a number of regulations address waste management, the absence of specific and well-coordinated mechanisms for e-waste management limits their effectiveness. High dependency on informal collectors tends to have negative effects including widespread pollution from unsanitary waste disposal and burning, health risks from hazardous materials and infections. Thailand also faces challenges associated with informal e-waste handling, highlighting the difficulties of extending formal collection and recycling arrangements to actors operating outside established regulatory mechanisms.

Malaysia's system, while comparatively more structured, nonetheless has problems with its institutions. The environmental Quality (Scheduled Wastes) Regulations 2005 set clear rules for how to handle e-waste. However, it still has high operating costs, legal ambiguities, and limited household collection allow informal actors to remain influential. Malaysia's collaboration with JICA illustrates how the involvement of foreign institutions can play in strengthening the institutionalization of e-waste management, although the extent of its contribution to long-term institutional development requires further assessment.

Vietnam faces more persistent challenges since the dismantling of e-waste in small artisan villages highlights the risks of leaving informal groups in charge without strong regulations. Although the government has introduced relevant regulations, enforcement remains inconsistent and monitoring data systems are unreliable. Only a small number of licensed enterprises formally manage e-waste. Most of it is processed by unlicensed workers operating under dangerous conditions. The persistence of illegal imports and remanufactured goods further undermines the effectiveness of existing policies. Vietnam's experience underscores the importance of robust regulations, improved data collection mechanisms, and clearer pathways for integrating informal actors into formal waste management processes.

Singapore, by contrast, possess most systematically structured strategy in the e-waste management. The unified system of the Resource Sustainability Act and Extended Producer Responsibility (EPR) program connect all stakeholders from the government, producers, stores, recyclers, and civic society. Initiatives such as Repair Kopitiam also illustrate how grassroots movements may make government policy better by getting people to think about and support ideas for a circular economy. Singapore therefore demonstrates that clear rules, cooperation among many groups, and public involvement together can make e-waste management more effective and sustainable.

Taken together, the five cases reveal recurring challenges involving regulatory implementation, institutional coordination, collection and recycling arrangements, and the relationship between formal institutions and informal practices. However, the nature and extent of these challenges differ across countries, and the available evidence does not establish a uniform relationship between institutional capacity and e-waste governance outcomes. Narrowing this difference will require stronger regulatory frameworks and institutions, alongside more effective collaboration among all stakeholders. Regional cooperation through ASEAN may also provide opportunities to improve information exchange and address the transboundary dimensions of e-waste. The measures required, however, should reflect differences in national regulatory frameworks and institutional contexts.

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