A Causal Loop Analysis for Proposed E-waste Funding Scheme in Indonesia

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Abstract

The dilemmatic condition between economic benefits, environmental drawbacks, and social dependency aspects of electronic waste (e-waste) rapid growth requires immediate attention and right policy structurization from the Indonesian government. Currently, regulations in Indonesia regarding the management of e-waste have only covered the collection procedures for the Municipal Environmental Service (DLH) and the recycling procedure for the third-party recycler. Meanwhile, the regulation regarding the various financial and material responsibilities between actors is still in the form of advisory. This paper provides a conceptual model that structures the current e-waste management system and the proposed funding scheme policy. Later, the model understanding of the current actors' relationship, factors dynamics, and the feasible policy is validated and evaluated by three stakeholders in the system. From these findings, policymakers could use such alternative schemes to improve the nation's waste management.

Keywords
E-waste, Funding Scheme, Causal Loop Diagram, Conceptual Model, Indonesia.

1. Introduction
Electronic waste (e-waste) has become a complex issue in many developing countries since it contains valuable yet hazardous materials that could affect the countries positively and negatively. As the fourth largest e-waste producer in Asia, Indonesia could obtain an economic benefit of US$ 1,8 million in 2020 from the precious metal recycled (Forti et al. 2020; Mairizal et al. 2021). From an environmental perspective, every ton of e-waste recycled equals 1400 tons of carbon emission reduction (Gu et al. 2017). However, the unregulated recycling activity domination in a developing country might cause environmental pollution via illegal waste dumping or process leakage (Ahirwar and Tripathi 2021). Recycling enterprises in that developing system might also have to raise their buying price since users still consider e-waste as precious goods (Zhang et al. 2020).

The Indonesian government has issued several hazardous waste policies to regulate the e-waste collection center facility and recycler's waste treatment procedure (Government of Indonesia 2020; Government of Indonesia 2021). To support these policies' implementation, the government also advises producers to take back their obsolete products from the customers to be recycled with their third-party recycler or with the municipal recycler. However, this extended producer responsibility (EPR) advisory put a new burden on producers' cost management, so the producers demand users to take responsibility for their waste and the government to provide robust infrastructures (DITJEN PSLB3 KLHK 2021). Therefore, a study on e-waste management and the proposed funding scheme to support this policy advisory design becomes relevant.

Several e-waste funding schemes studies in Indonesia have already focused on a linear relationship between several systems' variables (Ambarwati and Ardi 2019; Yunita et al. 2019). However, e-waste management exists in a complex and dynamic system (Hutami et al. 2020). That means studies have to acknowledge the nonlinearity of the stakeholder's dynamic and behavior over time before adopting the appropriate funding scheme policy. Researchers and policymakers must also have a complete understanding of several funding policy alternatives from mature countries. Otherwise, an unfit funding system that fails to internalize the system's externalities can burden the government financially (Chen et al. 2020; Gu et al. 2017). For this gap, this paper provides a conceptual model to

evaluate Indonesia's current e-waste management and the proposed funding scheme with policy exploration and the system's causality behaviors.

2. Literature Review

OECD (2016) defined EPR as an environmental policy approach to shifting the burden of specific municipality's waste management to producers and ultimately costumers by taking financial, operational, or organizational responsibilities. The early formulation of an EPR policy rests on the matters of funding, institutional competencies, and policy efficiencies (OECD 2016). United Nations (1997) defines economic instruments policy for funding as "fiscal and other economic incentives and disincentives to incorporate environmental costs and benefits into the budgets of households and enterprises.". It aims to internalize the polluter's negative externalities through full-cost pricing (OECD 2016; United Nations 1997). OECD (2014, 2016) mentions several types of economic instruments to support the funding policy, including deposit-refund, taxes, disposal fees, and advance fees. Several institutional structural involvement types are also mentioned, including governmental-based or designated-organization-based (OECD 2016). The proposed funding scheme in this study will describe how these economic instruments and structural types integrate.

Previous studies regarding economic instruments have been done in India with deposit-refund (Joshi et al. 2021), Japan with disposal fee (Lee and Na 2010), China with tax or levy (Yu et al. 2014), and several other countries with advance fees (Ivert et al. 2015; Khetriwal et al. 2009; Sander et al. 2007). In a developing country like Indonesia, UNEP (2012) and Damanhuri et al. (2019) suggested the implementation of the deposit-refund instrument in municipal buy-back centers whose activities are to be funded through fees levied on new products. These fees and fund mechanisms are managed by an authorized funding institution (Damanhuri et al. 2019).

Previous researches also discuss the structural type of this institution which is mainly divided into two, either it is governmental based in Asian countries like China, Japan, and Taiwan (Lee and Na 2010; Yu et al. 2014) or designated organizational based called PRO (Producer Responsibility Organization) in European countries (Ivert et al. 2015; Sander et al. 2007; Sinha-Khetriwal et al. 2005). This structural difference determines the institution's responsibility and autonomy in the system (OECD 2016).

To model such funding scheme effect in a developing country, previous studies use several methods, including system dynamics (Joshi et al. 2021; Li et al. 2020), game theory (Chang et al. 2019), financial modeling (Shih 2017; Yunita et al. 2019), and serious simulation gaming (Ambarwati and Ardi 2019). These studies help the contextualization process of current policy research in Indonesian e-waste management yet still need to be validated by the system's stakeholders.

Currently, an economic instrument in Indonesia has been established formally only in the crude palm oil industries. Under the ministry of finance, a designated BLU (public service agency) called BPDPKS (The Public Agency for Palm Oil Fund Management) imposed an export levy and disbursed these funds across palm oil business locus (Mafira et al. 2020). In that case, a BLU can manage special (non-traditional) funds with a certain degree of autonomy to improve a particular sector's productivity. Under the same ministry, BPDLH (Public Agency for Environment Fund Management) can propose a funding scheme to support the e-waste management system. There is no research found regarding this potential institution utilization in the system. Also, a specific study about conceptualizing a valid funding scheme with several economic instrument policies in the e-waste management system is rare, only several studies discussing one instrument at a time with limited linearity (Ambarwati and Ardi 2019; Yunita et al. 2019). Therefore this study aims to propose a funding scheme with BPDLH involvement, various economic instruments, and valid causality interactions.

3. Methods

In understanding the Indonesian e-waste system's complexity and dynamic, a nonlinearity tool needs to conceptualize the stakeholder's system reality. A causal loop diagram (CLD) is a conceptualization tool derived from the system dynamic method to picture systems' feedback structure and predict the system's behavior (Sterman 2000). It consists of interconnected variables denoted by arrows with positive (+) or negative (-) causal linkages. Some linkages might form a loop with reinforcing (R) or balancing (B) feedback. These linkages and loops were references from previous studies and validated by stakeholders in the ministry of environment and forestry (KLHK), municipal environmental services (DLH), and third-party recyclers. Furthermore, a system diagram can elaborate

the conceptual model with the systems' problem owner, goals, stakeholders, and policy intervention (including several economic instruments).

4. Results and Discussion

Figure 1 shows the existing conceptual model as a system diagram. Indonesia's hazardous waste management has become one of KLHK's performance targets. This ministry has mandated DLH across Indonesia province to facilitate e-waste collection from users in TPSSS-B3 (municipal collection center for hazardous waste). After these collection facilities nearly reach their total capacity, third-party (formal) recyclers will come and proceed with the waste in their recycling facilities. In reality, this entire cycle only happens in big cities and is considered small in scale. More significant e-waste streams start predominantly from door-to-door scavengers groups as the informal collectors. These informal collectors are willing to sell their valuable waste to the formal or informal recycler in the pretension of higher payment.

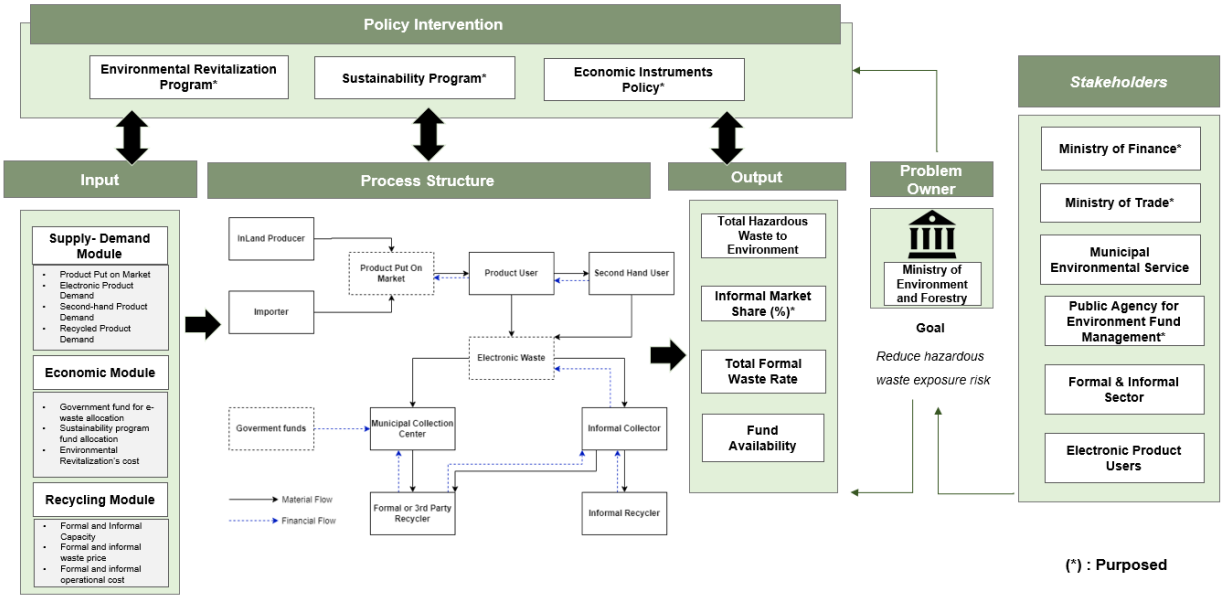

Figure 1. System Diagram

Dealing with this reality, the Indonesian government provides an annual budget for KLHK via state funds (APBN) to manage general hazardous waste. These funds are allocated to several programs and policies to keep the hazardous waste exposure at the minimum level. However, a specific waste requires a specific funding scheme that cannot solely rely on traditional state funds because of its limited budget ceiling and dependency on state accounts (Mafira et al. 2020). Likewise, e-waste requires a specific funding scheme policy where BPDLH can manage e-waste retribution funds flexibly under the ministry of finance and the ministry of trade supervision. Together, they can monitor the supply-demand, economic, market share, and recycling conditions to justify the fund's effectiveness.

Figure 2 presents the causal links and loops between variables in the existing e-waste management system. This causal loop diagram consists of three main sub-models: product lifetime, waste management, and funding sub-model. In these existing models, there are four balancing and two reinforcing loops. Later these sub-models are modified in Figures 3, 4, and 5 by adding two extra loops to facilitate the proposed funding scheme policy.

4.1 Product Lifetime Sub-Model

This study adopted the Rochman et al. (2017) product flow model in Figure 2. It covered the Indonesian import and production electronic product flow until its end-of-life cycle (becoming e-waste). There is also a chance that the users sold or donated their half-used product to a second-hand user. This sub-model points out how the demand module, which most likely has a similar structure to the Bass Diffusion Model by Frank Bass (Sterman 2000),

affects the overall product and waste flow. The Bass Diffusion Model forecasts the rate of e-waste generated based on the sales of new products from the potential adopter behavior.

4.2 Waste Management Sub-Model

The waste management sub-model adopted the Joshi et al. (2021) model in the middle of Figure 2. This sub-model covers B1, B2, B3, R1, and R2 loops that control the formal and informal waste treatment process. Both treatment process's rates contribute drawbacks to the environment but are significantly different in amount since they have different codes of conduct, efficiency, and capacity. Loop B1 represents the informal collector (IC) system where most e-waste flow goes. This dominant flow happens (and was validated by KLHK and DLH) because the municipal collection center (MCC) could not incentivize the product users. Therefore MCC loses most of the e-waste collection market share. Currently, KLHK and DLH are trying to keep the bare minimum level of market share by expanding the MCC capacity all across Indonesia province and conducting awareness programs.

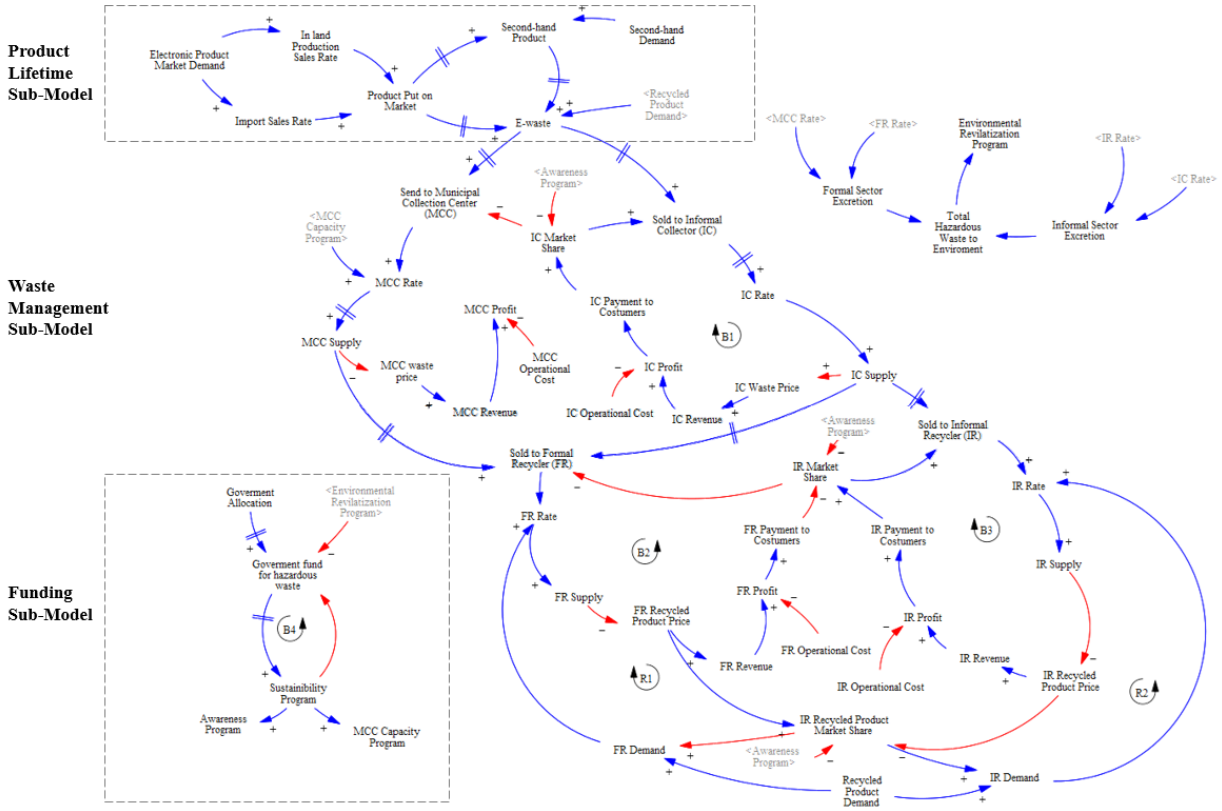

Figure 2. Current Causal Loop Diagram

Loops B2, B3, R1, and R2 represent the formal recycler (FR) and informal recycler (IR) systems where they are competitively fighting for the recycling market share. The difference with the previous collections systems is that there are two types of market share competing. First is the IC supply market share, which involves B2 and B3 loops. Besides having a formal supply from MCC, FR can gain more supply from this IC market via the B2 loop, while IR has to sustain its informal market from FR via the B3 loop. These two loops (and the B1 loop) point out the connection between supply-price relationships, payment to costumers positioning, and market to supply effect. The last R1 and R2 loop represent the second competing market where price affects the demand asked for the sector. This market dictates one's recycled product demand to keep their price as low as possible. In this regard, these two types of market share balanced each product price at the appropriate level, not too high nor too low. Based on the interview and validation with DLH Jakarta, DLH is not directly involved in this recycling system besides conducting several awareness programs and procedural monitoring because of authority limitations.

4.3 Funding Sub-Model

Figure 2 also represents that the government has indirectly supported the system financially. Though there are no specific state funds allocated for e-waste, the general hazardous waste programs by KLHK and DLH also contribute to the e-waste system (DLH Jakarta 2022; KLHK 2020). This sub-model is located in the bottom of Figure 2 and consists of Loop B4. This loop points out the government (state and local) funds allocated to several "sustainability" programs, i.e., MCC capacity and awareness. Another program outside the loop is the "revitalization" program that focuses on restoring hazardous soil, mainly caused by the informal sector. Based on the interview and validation with DLH, the implementation of these programs varies across Indonesian provinces. It depends on the province's waste condition, DLH priorities, and availability of funds. One of the most developed examples is DLH in Jakarta (the capital city), which accommodates free e-waste take-back policy from households to its MCC with a minimum of 5 kilograms.

4.4 Proposed Funding Scheme

The effort to support funding scheme policy in Figure 1 requires several sub-model modifications. This study improved each sub-model with structural change and variable addition. The proposed funding policies are deposit-refund in Figure 3, BPDLH involvement in Figure 4, also tax and advance fees in Figure 5.

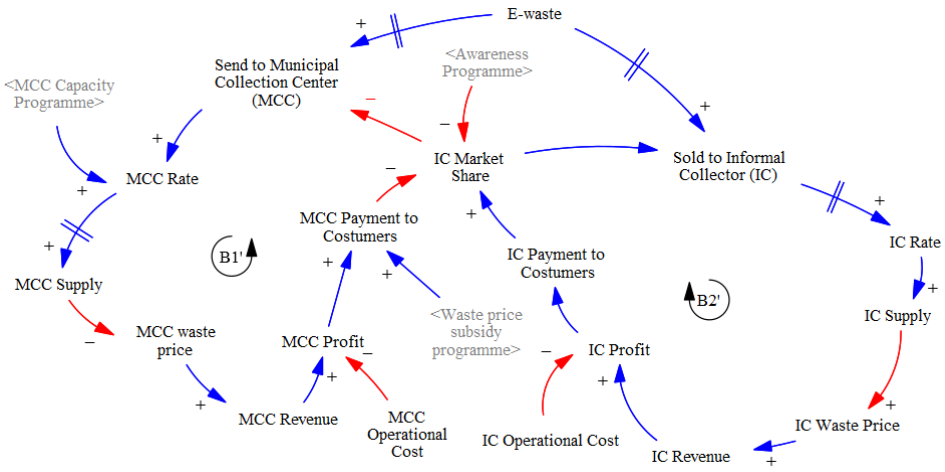

Figure 3. Proposed Waste Management Model with Deposit-Refund in MCC

Figure 3 shows the proposed MCC deposit-refund scheme's effect on the market share competition with IC. The B1' Loop activates the MCC payment abilities to the product user. This scheme is inspired by UNEP (2012) in Thailand; based on the interview and validation with KLHK and DLH, this scheme fits the user's perception in Indonesia, where e-waste is considered valuable. The incentive will encourage users not to hold waste in their home and trade it formally with competitive buy-back prices. This policy also plays a significant role in the overall hazardous waste reduction since MCC dominance will dictate IR and FR supply availability. One must notice that domination will create unintended social tension from the informal sector, so the government must provide an alternative strategy, i.e., formalization of the informal workers to accommodate the potential job loss. A country needs to have an excellent environmental policy and significant market bargaining power to support such an alternative strategy (Ghisolfi et al. 2017).

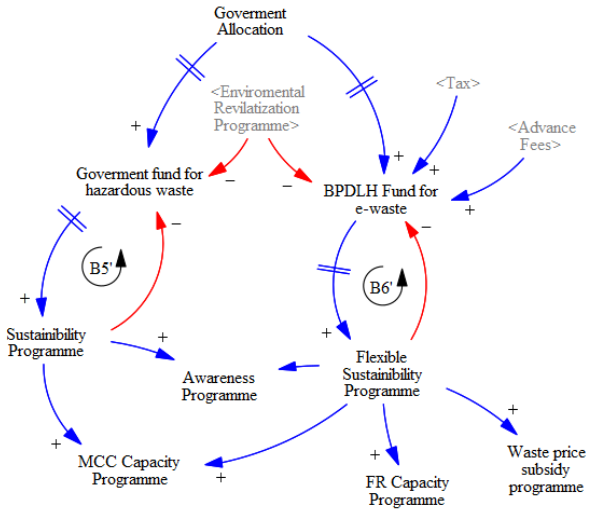

Figure 4. Proposed Funding Model with BPDLH

Figure 4 shows the proposed BPDLH's involvement in managing flexible funds. Tax and advance fees are collected from producers and importers (Figure 5) to support revitalization and sustainability programs. For the sustainability programs in Loop B6', these funds can expand beyond DLH authority to support the FR capacity improvement program and allocate waste price subsidy for the deposit-refund scheme. This policy also reinforces the availability of general funds to increase the MCC capacity and awareness. In the process, BPDLH is responsible for reporting its funding performance to stakeholders in the system, especially producers and importers. Based on the interview and validation with KLHK, DLH, and formal recycler, these stakeholders agree that a designated organization can manage this specific waste. Nevertheless, DLH and recycler suggest that MCC has to be involved in that organization to determine the standardized waste prices. Later, MCC needs to assess the user's "willingness to accept" waste price rate to support the subsidy program (UNEP 2012).

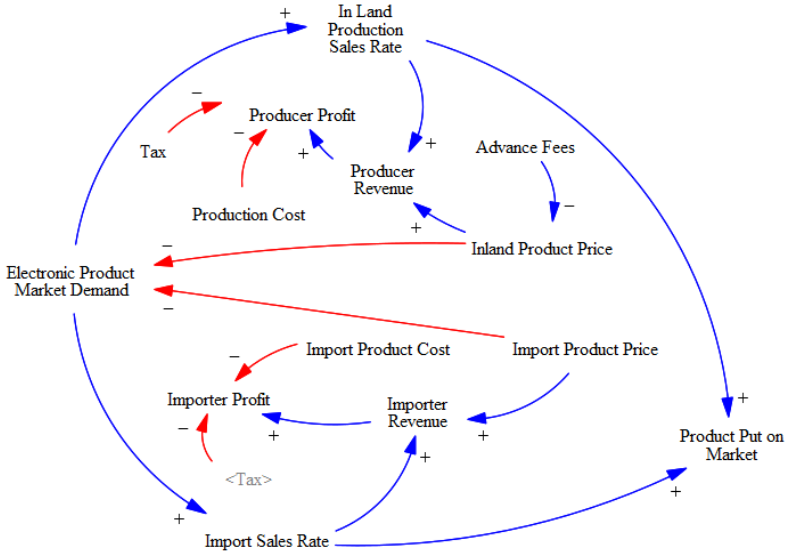

Figure 5. Proposed Product Lifetime Model with Tax and Advance Fees

Figure 5 shows the proposed version of the product lifetime sub-model. Focusing on the system before being put on the market, this model points out how fees are collected and how they affect product profitability and market

demand. Ardi and Leisten (2016) and Liu et al. (2021) inspired the causal model research in a developing country. Based on the interview and validation with DLH and recycler, only communal stakeholders' agreement can determine these funding tariffs amount and implementation. Because stakeholders in Figure 1 directly affect the product demand, regulation, infrastructure development, and the e-waste collection and recycling process (Ambarwati and Ardi 2019).

5. Conclusion

This study aims to conceptualize the Indonesian e-waste management system and the developed funding scheme for funding policy structurization. The model provides a qualitative causal analysis of loops and links between variables in the system. The model is discussed with three stakeholders and finely tuned to their approval. The proposed model shows that the deposit-refund scheme managed by BPDLH and funded by tax or advance fees can help KLHK goals reduce hazardous waste exposure. The deposit-refund scheme finding is consistent with Damanhuri et al. (2019) financial policy recommendation for Indonesia's e-waste management system. Nevertheless, the clear causality between BPDLH and several economic instruments provides a novel and valid logic for future e-waste policy.

However, the valid conceptual model is only the fundamental step in understanding the e-waste management system's complexity and its potential funding scheme. Further research can be done quantitatively via system dynamic simulation modeling to test different scenarios (i.e., funding scheme, tariff, and social tension) with more relevant data. Within that approach, policymakers can measure the system's behavior effect and determine the optimal funding scheme.

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Biography

Muhammad Irfan Kemal is a master's degree student in Industrial Engineering Department at Universitas Indonesia. He has an interest in the Supply Chain Management field, so he interned in several companies: aluminum manufacturers, mass rapid transportation providers, and fast-moving goods manufacturers. Kemal also researched supplier assessment and inventory modeling policy in his late company. Currently, he developed an interest in e-waste management in Indonesia after doing a research project for UNDP under Dr. Romadhani Ardi's supervision.

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