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Implementation of lean process to solid waste management in Bandung, Indonesia

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Abstract. *Indonesia, as a developing country, faces various challenges in processing its waste to benefit society socially, economically, and environmentally. The capacity of the Sarimukti Final Disposal Site (TPA) is only able to accommodate 1 200 tons per day, but the garbage collected every day reaches 1 500 tons. This research was conducted to improve current waste management by converting landfills into sustainable waste management sites. In addition, people's behavior needs to be changed by using the 5S concept, namely Seiri (Concise), Seiton (Neat), Seiso (Clean), Seiketsu (Treat), Shitsuke (Diligent) to gradually achieve zero waste conditions. Babakan Village in Cirebon Regency was used as a sample because it is a pilot project for the application of zero waste technology with a system dynamics approach and cost-benefit analysis. The results of the study show that by changing the function, waste generation in the TPA can be reduced by 49% per year. Based on the optimistic scenario in the fourth year, it has reached zero waste conditions, with the Benefit-Cost Ratio value of 1.268. The research output is the preparation of the Lean Business Model Canvas so that the resulting performance is more optimal than before and can be sustainable.*

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INTRODUCTION

Waste management has shifted from conventional landfills to sustainable waste management strategies (Silva *et al*., 2017). Conventional waste management can be done by two methods, namely sanitary landfills and open dumping by Collect–Transport–Disposal (Dhokhikah and Trihadiningrum, 2012). These two methods still depend on the final disposal site, which causes waste to accumulate in the landfill, so a sustainable waste management strategy is needed (Hui *et al*., 2006). This strategy applies the concept of Reuse and Recycle, where the discarded waste will be identified based on its type to be reprocessed so that it can be of economic value to the community (Silva *et al*., 2017). From traditional methods (Collect–Transport–Disposal) to sustainable waste management (Collect–Transport– Recovery), the definition of recovery is fundamental for countries with limited resources for sustainable development. With the recovery concept, every 1 kg of waste can be worth Rp 800 000 and can also increase income in the agriculture, fisheries, and livestock sectors (Abidin *et al*., 2021a, 2021b).

This sustainable waste management is expected to achieve the target of zero waste and 100% diversion from traditional landfills (Silva *et al*., 2017). The current zero waste concept based on ZWIA is a visionary and pragmatic goal that guides society to implement a sustainable natural cycle, where all discarded materials are resources that others can use. Zero waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserving and recovering all resources rather than burning or burying them (ZWIA, 2018). Zero waste practices will eliminate all waste dumped into the ground, water, or air that can threaten the earth's health, humans, animals, or plants. (ZWIA, 2018; Silva *et al*., 2017). The Zero Waste movement is revolutionizing the relationship between waste and society, aiming to keep everyone healthy and improve people's quality of life (Iqbal *et al*., 2020; Rahim, 2020).

The concept of zero waste is expected to support circular economic programs that can benefit the community (Silva *et al*., 2017). The idea of a circular economy was coined by Cesari and Jarrett (1967), namely as a circular system seen as a prerequisite for the maintenance of the sustainability of human life on earth (a closed system with practically no exchange of matter with the external environment) (Cesari and Jarrett, 1967). The circular economy is seen as a new business model that is expected to lead to more sustainable development and harmonious society (Ghisellini *et al*., 2016). In 2018, around 2 169 million tonnes of waste were treated in the EU. Total waste does not include exported waste but includes waste treatment imported to the European Union. This includes EU steps to achieve zero waste conditions to create a circular economy in European countries (Eurostat, 2018).

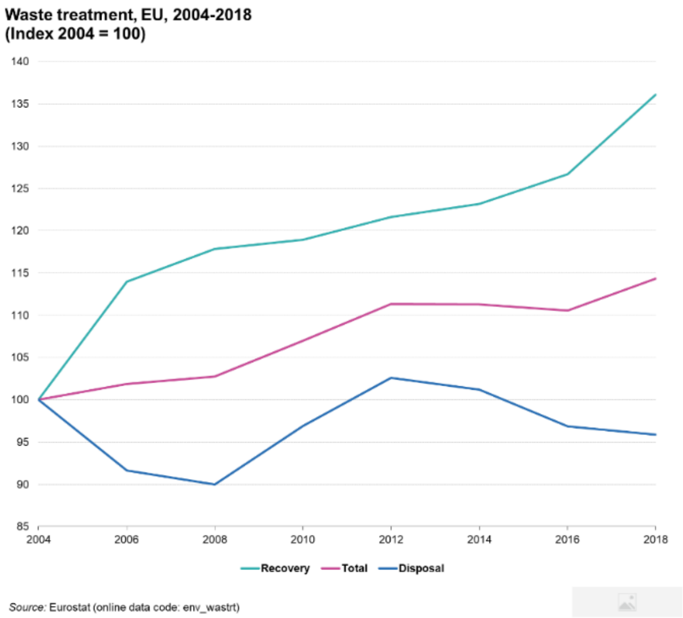

Figure 1 Waste treatment In the European Union (Source (Eurostat, 2018)

Figure 1 shows the increase in total sewage treatment in the European Union for the two classes of recovery and disposal from 2004 to 2018. The amount of waste recycled, and used for landfill or incineration with energy recovery increased by 33.9%, from 870 million tonnes in 2004 to 1 184 million tonnes in 2018; As a result, the recovery category in total waste treatment increased from 45.9% in 2004 to 54.6% in 2018. The amount of waste disposed of decreased by 4.2%, from 1 027 million tonnes in 2004 to 984 million tonnes in 2018. The disposal category in total waste management decreased from 54.1% in 2004 to 45.4% in 2018 (Eurostat, 2018).

Figure 2 shows that in 2018, the greater part (54.6%) of EU waste was processed in the recovery process: recycling (37.9% of total waste treated), backfilling (10.7%), or waste to energy (6%). The remaining 45.4% are landfills (38.4%), incinerated without energy recovery (0.7%), or disposed of otherwise (6.3%). There are significant differences in waste handling between the European Union member states. For example, some member countries have very high recycling rates (Italy and Belgium), and others prefer landfills (Greece, Bulgaria, Romania, Finland, Sweden) (Eurostat, 2018).

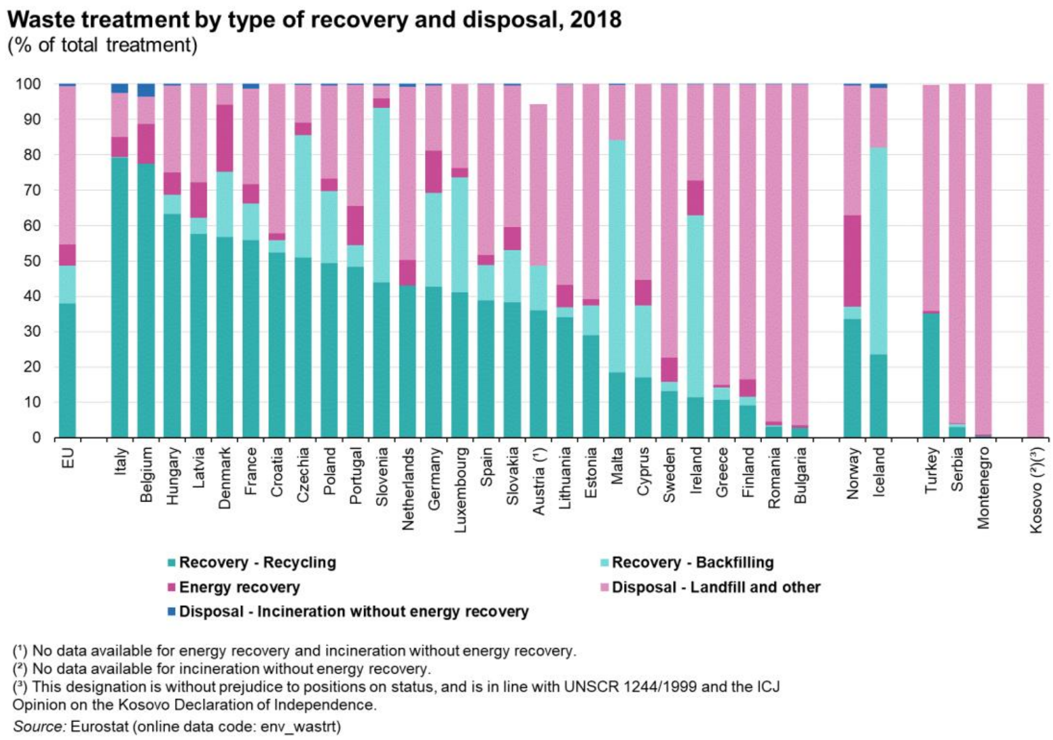

Figure 2 Waste treatment by type of recovery and disposal source (Eurostat, 2018)

Several countries in the European Union have started not using the landfill method and are maximizing recycling and converting waste into energy to achieve zero waste conditions and a circular economy (Rahim, 2020). In Asia, Japan has invested in waste management recycling systems. Governance and social systems for behavior change to achieve sustainable waste management divides the processing process into three main stages, namely firstly, identifying the type of waste, secondly, classifying waste based on its type, and thirdly processing waste at the landfill (Silva *et al*., 2017; Rahim, 2020).

The Japanese government has successfully implemented waste recycling with strict regulations through a recycling system for each product; Manufacturers and distributors require recycling, and consumers must pay recycling fees, including the cost of disposing of used household appliances and cars (Amemiya, 2018; Rahim, 2020). Singapore succeeded in reducing waste production in 2019 by 6% from the previous year by minimizing the use of packaging and influencing consumers to buy environmentally friendly products to encourage the use of environmentally friendly materials in every product consumed by the public (Rahim, 2020; The National Environment Agency, 2020).

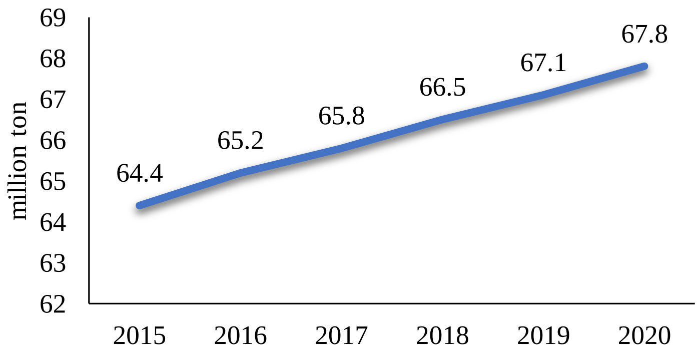

Figure 3 Total waste generation (Sources: Ministry of Environment and Forestry, 2020)

In Indonesia, the increase in population every year is directly proportional to the increase in waste during 2015-2020, an average of 5.9%, from 64.4 million tons to 67.8 million tons (Figure 3) (Ministry of Environment and Forestry, 2020). As much as 66% of the total waste comes from households (Damanhuri and Kojima, 2020). Indonesia, a member of the BRIICS group (Brazil, Russia, India, Indonesia, China, South Africa) is an emerging economy (Harsanto *et al*., 2018). An emerging economy is a developing country whose economic growth is essential compared to other developing countries (Nasution, 2016; Hutabarat, 2018). The main challenge in solid waste processing in the emerging economy is to provide social, economic, and environmentally friendly benefits to the community. This is difficult in emerging economies because waste processing uses open dumping or sanitary landfill. (Zohoori and Ghani, 2017; Fuss *et al*., 2018).

The increase in the amount of waste generated is due to processing waste in most major cities in Indonesia that still use the sanitary landfill process. The high waste generation causes the sanitary landfill method to change to open dumping due to limited land indirectly. For example, the Leuwigajah TPA, located in Bandung City, was closed in February 2005 due to a landslide. The waste could not transport to the TPA, which resulted in the accumulation of waste at the temporary disposal site. However, due to the limited capacity, the waste is finally dumped into the river, and piled up on the side of the road, causing damage and environmental pollution. (Hasibuan, 2016). Currently, the city of Bandung does not have adequate landfills (Noviandri, 2021). TPA Sarimukti is the only final disposal site located around the city of Bandung. Still, due to the increase in waste generation every year causing the TPA Sarimukti to be overloaded, TPA Sarimukti is designed to accommodate 1200 tons of waste per day. Still, in reality, the amount of waste disposed of TPA Sarimukti reaches 1 500 tons per day in three areas, namely Bandung City, Bandung Regency, Cimahi (Waste4Change, 2019).

The city of Bandung should start considering other processing methods, such as Mass Biological Technology (MBT) which can convert waste into energy (energy waste) (Indirawaty, 2020). Alternatively, a zero-waste method can turn waste into valuable products for society to create a circular economy instead of relying solely on open dumping or sanitary landfill methods (Abidin *et al*., 2020). Open dumping and sanitary landfill processes require a massive land area with a land-use rate of up to 57%. It is considered wasteful because it will take up a large land area. In addition, the shelf life of the idea of open dumping and sanitary landfill is only three years (Indirawaty, 2020). Using this method will only make waste continue to accumulate, environmental pollution that has an impact on health without any economic benefits generated (Hui *et al*., 2006; Ferronato *et al*., 2017; Mian *et al*., 2017; Wang *et al*., 2017; Yukalang *et al*., 2017; Vaccari *et al*., 2018; Ferronato and Torretta, 2019).

Meanwhile, MBT innovation can increase the age of the soil to 25 years. It is possible to produce alternative fuels from 1 kg of waste produced to 0.38 kg of alternative fuels (Indirawaty, 2020). Unlike the method that uses zero-waste technology, which is a patent (Abidin, 2021) from the Bandung Institute of Technology (ITB) (Abidin *et al*., 2020, 2021a, 2021b), for further the technology is called "*Manajemen Sampah Zero*" (Masaro), the age of the soil can be sustainable. The processed waste can use fuel oil, planting media, wood preservatives, organic pesticides, special liquid fertilizers, liquid organic concentrations, and compost (Abidin *et al*., 2021a, 2021b). Indonesia currently, through Presidential Regulation of the Republic of Indonesia Number 97 of 2017 concerning national policies and strategies for the management of household waste and types of household waste, sets the waste management target to be achieved, which is 100% waste that is appropriately managed and correctly by 2025 (Indonesia *Bersih Sampah*). This target is measured by reducing waste by 30% and handling waste by 70% (Ministry of Environment and Forestry, 2020).

With the targets, challenges, and opportunities for waste management that Indonesia wants to achieve, it is hoped that the Masaro Technology method can achieve these targets. In this study, a simulation with a dynamic system approach and cost benefits analysis will be carried out to assess how much benefit will be felt by the community if using the Masaro Technology method. The main novelty of this research is the first to examine the application of the zero-waste method in the city of Bandung to achieve lean waste processing.

Changes in people's behavior in dealing with waste are simulated with a dynamic system and cost-benefit analysis to illustrate the feasibility of the zero-waste method.

Research using the rotting and non-decomposing waste from the community. It can be processed into products that can be utilized by the agricultural sector (liquid fertilizer, compost, planting media, organic pesticides), livestock (organic nutrition), fisheries (organic nutrition), and fuel oil to run inorganic waste treatment plants (Abidin *et al*., 2021a, 2021b). Further research on the application of sanitary landfill waste processing methods is carried out using dynamic system simulations and cost-benefit analysis (Yuan *et al*., 2011). Meanwhile, research on waste processing using the recycling method complete with a cost-benefit Analysis (Chaerul and Rahayu, 2019). Research that applies lean concepts to improve the sustainability of waste management (Minh *et al*., 2019)

The research objectives are as follows, first, to find out the current waste processing method in the city of Bandung. Second, identify various types of waste in solid waste processing in the city of Bandung. Third, perform simulations with a system dynamics of several solid waste scenarios in the city of Bandung. Fourth, calculate the total costs and total benefits required from solid waste processing in Bandung City from several scenarios. Fifth, create a business canvas model as a solid waste management strategy in Bandung City, a new lean canvas business model for household zero waste management.

METHOD

Research Location and Time

In this study, primary data was obtained from observations made in Cileunyi Kulon Village, Bandung Regency, Pesawahan Village, Bandung Regency, Pasanggarahan, Bandung City, Babakan Village, Cirebon Regency. Historical data on waste processing was obtained from the Central Statistics Agency for the City of Bandung 2016-2020, and the results of interviews with respondents or related parties through focus group discussions. Secondary data were obtained from the relevant literature to support this research.

Method of Collecting Data

This research uses a mix of methods, qualitative and quantitative, with exploratory analysis. Mix methods use because quantitative methods cannot capture all phenomena, including social phenomena, so a qualitative approach is used. For example, identifying lean processes using flow process charts, identifying behavior changes using 5S Analysis (Seiri, Seiton, Seiso, Seiketsu, Shitsuke), and developing dynamic systems. Quantitative data is used to calculate the cost-benefit analysis model.

Data Analysis Method

System Dynamics

A causal loop diagram can be developed based on zero waste technology (Abidin *et al*., 2020) proposed in this study. Figure 4 is a causal loop diagram (Sarasi *et al.*, 2021), a conceptual model describing the interaction between variables based on systems thinking. Systems thinking in the causal loop diagram is broadly described as follows: 1) Public awareness as a qualitative variable affects managing household waste. Awareness to be able to reprocess waste into a valuable product; 2) Behavior change is an activity for the community to make habits in disposing of waste so that the collected waste can be processed based on its type (socialization and training); 3) Waste sorting is the first activity in waste management that positively influences the amount of waste that is sorted and the generation of waste; 4) The utilization of waste into products with value is an activity that can minimize or even eliminate waste disposed of in landfills; 5) The total cost of waste management includes direct and indirect costs in implementing the zero-waste technology method.

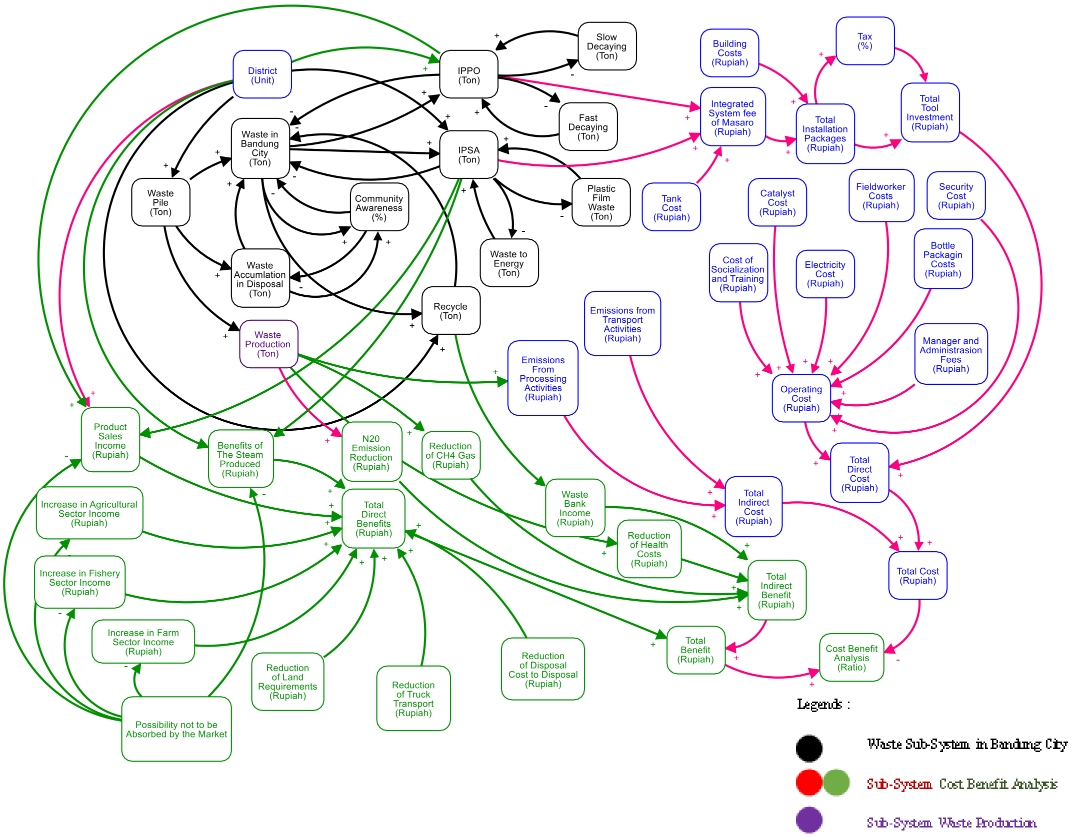

Figure 4 Masaro causal loop diagram model (Source: Primary data processed, 2021)

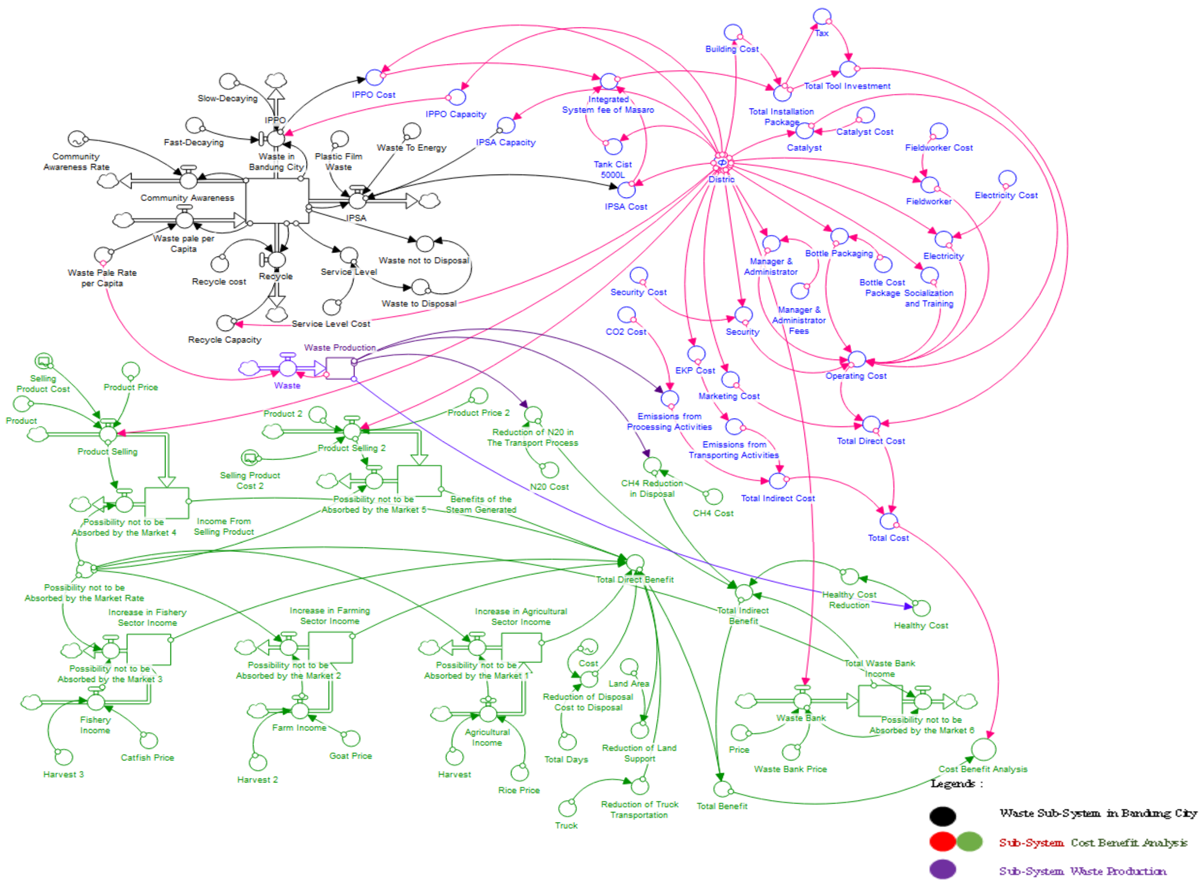

Figure 5 Stock and flow diagrams (Source: Primary data processed)

The total benefits of waste management include direct and indirect benefits that the community can feel due to the application of the Masaro waste management method. After the critical factors in the proposed waste management model are illustrated in the causal loop diagram, the next step is to compile a stock and flow diagram (Figure 5). The data source of the waste production variable comes from statistical reports issued by the Bandung City Government. As for the other variables, the data source comes from the author's survey as an example of the income variable from product sales. Therefore, stock and flow diagrams were compiled with the help of Isee Stella Architect version 1.5.2 software to be formulated further based on causal-loop diagrams.

Cost-Benefit Analysis

The Cost-benefit Analysis method is used to determine the value of the cost-benefit ratio of the Masaro waste management method. Cost-Benefit analysis is divided into two parts, namely costs and benefits. There are direct and indirect costs in the cost section, while in the benefits section, there are indirect and indirect benefits (Artika and Chaerul, 2020). Table 1 can be seen as direct costs and indirect costs.

Table 1 Cost components and benefit components

Type	Component
Direct cost	Investment Cost: • Integrated masaro systems and tools • Building cost Operating costs : • Field worker fee • Security fee • Manager & administrator fee • Catalyst cost • Boto packaging fee • Socialization and training costs • Electricity cost • Marketing fee
Indirect cost	• Emissions from transport activities • Emissions from processing activities
Immediate benefits	• Income from product sales • Benefits of the steam generated • Reduction of truck transportation • Reduction of land requirements in landfill • Reducing disposal costs to landfill • Increase in agricultural sector income • Increase in livestock sector income • Increasing fishery sector income
Indirect benefits	• Waste bank income • Reducing N2O emissions from waste transport • Reduction of CH4 gas in landfill • Health impact cost reduction

Source: (Chaerul and Rahayu, 2019) reprocessed, 2021

Analysis Stage

At this stage, the waste processing process identification is carried out using a flow process chart that aims to describe the lean process of waste processing. Analysis of 5S culture is carried out to change people's behavior in processing waste. The results of the analysis of lean process and 5S culture are input in developing a dynamic system that aims to describe the process flow of Masaro's household solid waste management method. The CBA method describes how much economic benefit is generated when using the Masaro household solid waste management method. The Analysis results will be presented in a lean canvas business model.

RESULTS AND DISCUSSION

Zero Waste Management

This waste processing uses zero waste by adopting Masaro Technology (Zero Waste Management) to answer challenges and opportunities in implementation reuse and recycling. However, in addition to using the concept of reuse, recycling, there is also an addition that recovery, so that people can use waste into valuable products and create a circular economy. Innovations made based on this technology in waste management are: 1) Organic Fertilizer and Animal Food Industry (IPPO). It processes organic waste into valuable products by installing organic feed and fertilizers. Garbage that decomposes quickly is processed into organic fertilizer and organic feed concentrate. Garbage that is slow to decompose is processed into compost and planting media (Abidin *et al*., 2021a);

2) Inorganic Waste Treatment Industry (IPSA). Inorganic waste processing installations solve problems by processing non-recycled inorganic waste through a plastic refinery unit. The MASARO plastic refinery (Abidin, 2021) divides non-recyclable inorganic waste into two groups, namely low-value plastic waste (plastic film, thermosetting plastic, biodegradable plastic, and other plastics of poor quality) and waste into energy. The Inorganic Waste Treatment Plant products are fuel, planting media, organic pesticides, and wood preservatives (Abidin *et al.*, 2021b);

3) Clean, Green, and Productive Environment Program. This program is used to process and manage organic waste on a community scale. The program itself was held to increase awareness of waste management while at the same time creating a space for social interaction in the community. The program collects slowly decomposing organic waste from local sources and processes it into compost and polybag farming (Abidin *et al*., 2021a). This activity is carried out to facilitate the waste processing process, which will be shown in Figure 6.

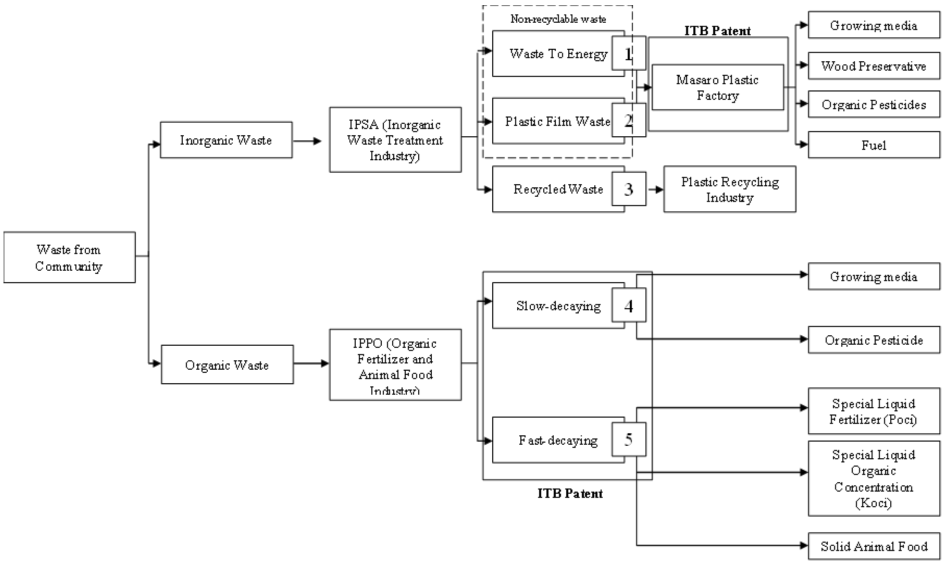

Figure 6 Flow chart of massaro's waste management process (Source: Abidin *et al*., 2021a)

Based on Figure 6, Masaro's technological waste management process begins with the waste produced by the community, which is separated into non-decomposing and decomposing waste. The sorted waste will be put into the inorganic waste treatment plant for non-decomposing waste and the organic fertilizer and feed installation. The inorganic waste treatment plant is further divided into three parts, and the first and second parts are non-recyclable waste. The third part is recycled waste distributed to the recycling industry. Non-recycled waste, namely burning waste and plastic film waste, will be processed through a plastic refinery to produce planting media, wood preservatives, organic pesticides, and fuel. Meanwhile, the recycled waste will be distributed to the recycling agency. Furthermore, the Organic Fertilizer and Feed Installation are divided into two parts, the first part is difficult to decompose, and the second part is easy to decompose.

Waste that is difficult to decompose is processed into planting media and masaro compost. The easily decomposed waste will be processed into special liquid organic fertilizer and special liquid organic concentrate. By processing using the Masaro Technology method, the waste generated from the community will not be disposed of to the TPS and TPA. However, it will be processed into valuable products that have value for the community to create zero waste conditions. In Table 2 below, the authors classify the types of waste processed by reuse and recycling based on Masaro Technology.

Table 2 Garbage identification

Garbage Type	Garbage Identification	Reuse	Recycle	Waste Processing Results
Inorganic waste	Waste to energy	✓	-	Growing media Wood preservative Organic pesticides BBM
	Plastic film waste	✓	-	Growing media Wood preservative Organic pesticides fuel
	Recycled waste	-	✓	
Organic waste	Slow-decaying	✓	-	Growing media compost
	Fast-decaying	✓	-	Special liquid fertilizer (Poci) Special liquid organic (Koci) concentration Solid animal food

Source: Research results, 2021

Lean Operations

The flow process chart method is used to identify waste in solid waste processing in Bandung in 2020. Figure 7 is a flowchart of waste processing at the current condition, while Figure 8 is a flowchart of waste processing proposed using the Masaro Technology method. Based on Figure 7A, the current method starts with household waste transported by scavengers to be recycled and returned to households. Garbage that scavengers cannot recycle will be transported to a temporary disposal site. The collected waste will be transported by garbage trucks to the final disposal site and stacked using the open dumping or sanitary landfill method.

Based on Figure 7B, it can be seen that the process flow starts from household waste, where those that are suitable for recycling will be transported by scavengers who will later return to households. Waste that cannot be recycled will be transported by a tricycle (triseda) to the waste processing plant (IPPO, IPSA) to be processed into products that value the community. Processed results from waste which can be in the form of POCI, KOCI, planting media, biopesticides, and wood preservatives, will be returned to households to feel the benefits. Furthermore, 5S activities can be arranged that can help change people's habits from disposing of waste to processing waste (reuse and recycle). Table 3 is a recommendation for 5S activities. With the 5S practice, it is hoped that people's behavior can change from their initial habit of throwing garbage in its place and processing waste to the maximum so that it has economic value.

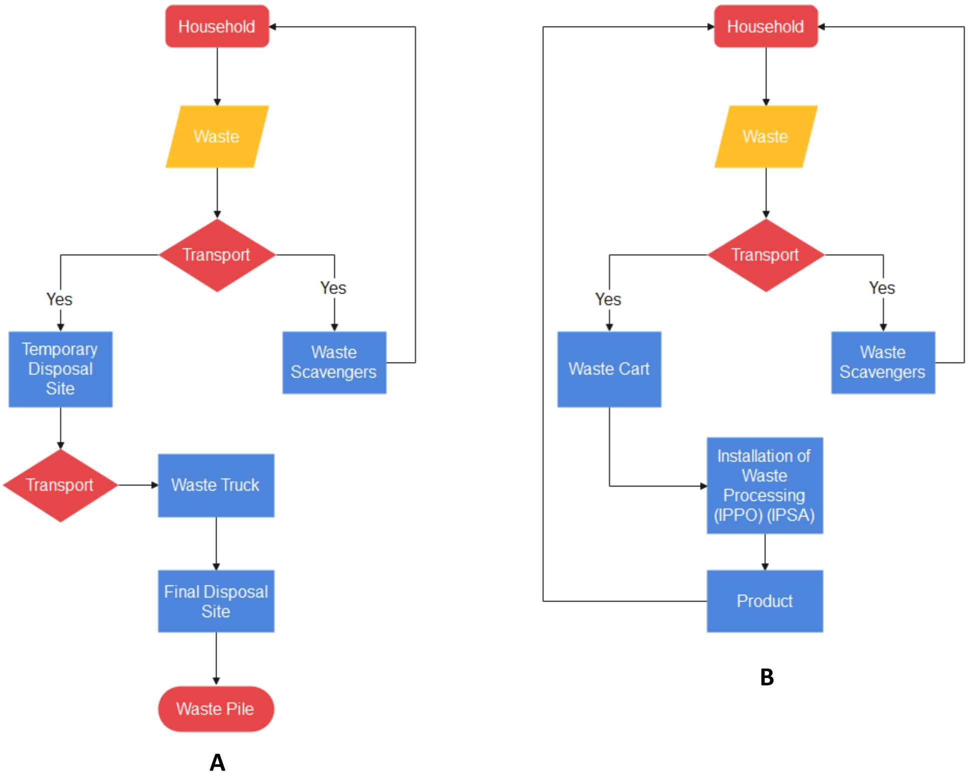

Figure 7 Flowchart of waste processing current condition (A), Flowchart of waste processing proposed using Masaro Technology method (B) (Source: Processed primary data, 2021)

Table 3 Recommendations for 5S Activities

Theme	Activity
(Seiri): Stratification management and dealing with causes	1. Sorting waste by type (waste to energy, plastic film waste, recycled waste, and rotting waste) 2. Provide particular trash bins for easily decomposed waste, plastic waste, and waste to energy and recycled waste 3. Perishable waste can be spent directly at the source to be used as planting media or transported to a waste processing plant to be used as POCI and KOCI 4. Plastic waste and waste to energy are transported to waste processing plants to be used as wood preservatives or biopesticides 5. Recycled waste is taken to the recycling industry or given to scavengers
(Seiton): Functional storage and waste time searching for items	1. Each waste is provided with a special place to facilitate processing 2. Temporary garbage dumps can be converted into Waste Treatment Plants 3. Garbage is transported every day to the Waste Treatment Plant 4. A bulletin board contains the waste processing process flow into valuable products at the waste treatment plant

Theme	Activity
	5. Available placement for organic fertilizer processing installation (IPPO) and Inorganic waste installation (IPSA) 6. Waste treatment standards 7. Regional division and IPPO and IPSA placement marks
(Seiso): Functional storage and waste of time looking for items	1. Clean the trash can by spraying POCI 2. Creating a sparkling clean campaign in each RW 3. Cultivate a sense of responsibility for cleaning 4. Perform hygiene checks and correct minor problems on IPPO and IPSA 5. Cleaning places that people overlook
(Seiketsu): Visual management and 5S enhancement	1. Trash cans are given special marks or labels to facilitate the sorting and transportation process 2. Dangerous areas are marked on the meter 3. Provide temperature label 4. Warning color 5. Fire extinguisher sign 6. Instructions for the flow of the waste processing process 7. Security 8. Responsibility label 9. IPPO and IPSA precision maintenance labels 10. Labeling of production capacity limits 11. Prevents noise and vibrations generated during the processing
(Shitsuke): The formation of habits and a disciplined workplace	1. Joint cleaning 2. Clean, Green, and Productive Environment Program includes polybag farming activities to dispose of easily decomposing waste directly at the source into planting media 3. Practice and assistance with polybag farming activities 4. Emergency handling practice

System Dynamics and Cost-Benefit Analysis

Scenarios for processing household solid waste are made based on several conditions, namely, most likely, and optimistic (Planellas and Muni, 2019). The system dynamics make it possible to run scenarios based on these conditions to provide an overview of stakeholders' decision-making. The policy scenario can be seen in Table 4.

Table 4 Scenarios of waste processing

No	Scenario	Description
1	Most Likely	1. The installation was applied to 100 urban villages in the city of Bandung. 2. IPPO capacity is 10 tons per day, and IPSA capacity is 2 000 tons/day*. 3. Recycling capacity 0.6-0.8 ton/day 4. The level of public awareness in managing waste is 10%, with an annual increase of 10%. 5. The possibility of not being absorbed by the Market due to pandemic conditions is 50%

2	Optimistic	1. The installation was applied to 151 urban villages in the city of Bandung. 2. IPPO capacity 15.1 tons/day and IPSA capacity 3 020 tons/day* 3. Recycling capacity 0.6-0.8 ton/day 4. The level of public awareness in managing waste is 20%, with an annual increase of 10% 5. The possibility of not being absorbed by the Market due to pandemic conditions is 5%.

Source: Primary data processed, 2021. Notes: *IPPO and IPSA capacities are obtained from the calculation results (Capacity Per Day x Number of Village); IPPO capacity= 0.1 ton/day; IPSA capacity= 20 tons/day

These scenarios can be chosen according to the policy to be carried out, where each scenario has advantages and disadvantages. The Most Likely scenario is a scenario with a cost that is not too expensive and quite effective in minimizing waste accumulation. The optimistic scenario has a high cost and effectively minimizes waste accumulation. The Cost-Benefit Analysis results are based on the system dynamic approach at the end of the simulation year (Appendix). Meanwhile, Figure 8 is the simulation result of each proposed scenario.

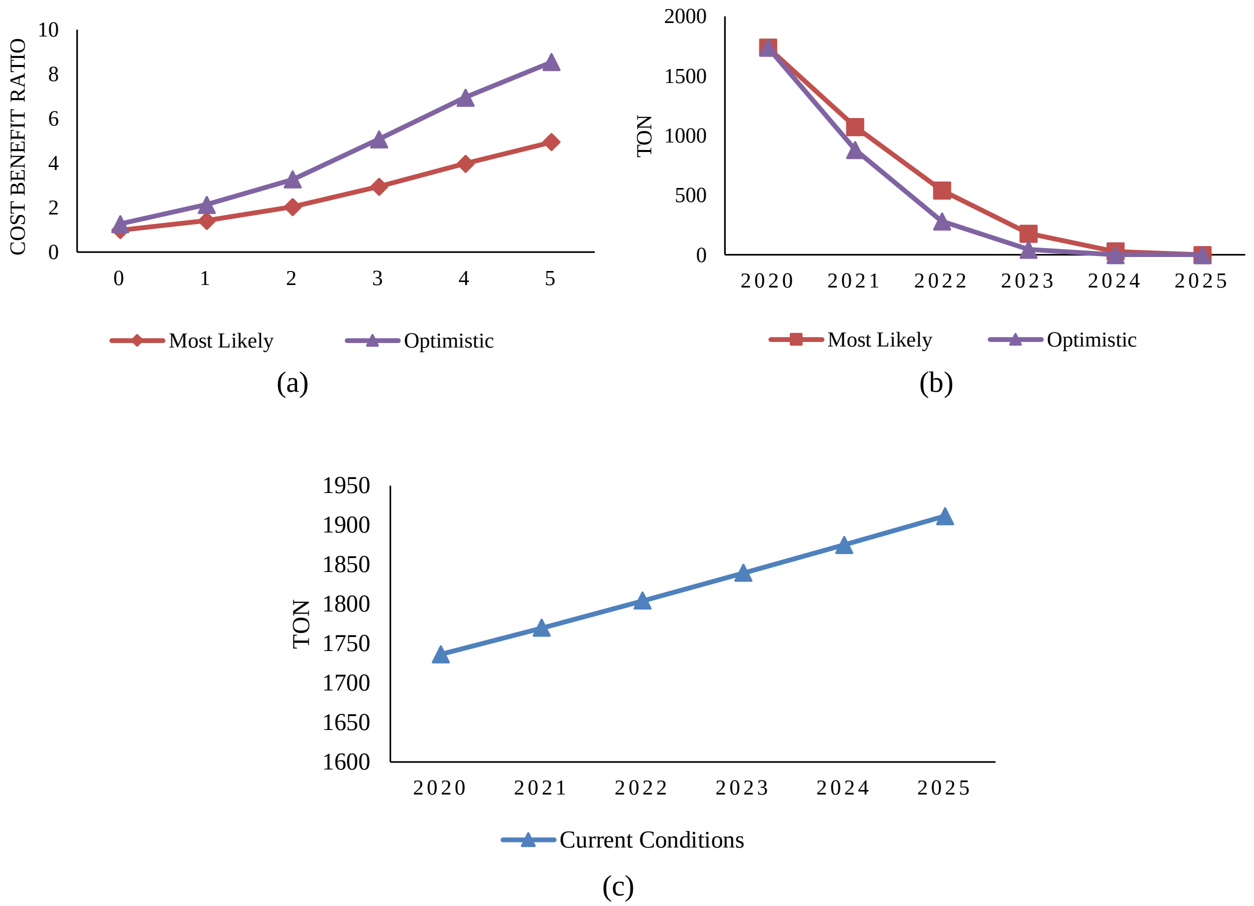

Figure 8 Scenario simulation (a), simulation of Bandung City waste (b), current conditions of waste Production in Bandung City (c) (Source: Primary data processed, 2021)

The CBR value is obtained from the calculation of total benefits/total costs. If the CBR value is >1, then the method can provide benefits. Based on Figure 8a, it can be seen that the optimistic scenario is better than the most likely, wherein in year 0, the CBR value >1 is 1.268. In the optimistic scenario, the variable Likely Not Absorbed by the Market is 5% for income from product sales, an increase in income from the agricultural sector, the fisheries sector, the livestock sector, and benefits from the steam produced (Tim Yanmas DPKM-UGM, 2020). In addition, Masaro Technology has a particular activity to increase public awareness to process waste at the source called the Clean, Green, and Productive Environment Program. One of the activities is polybag farming. Polybag farming activities allow the community to decompose waste from food scraps into organic fertilizer quickly. The garbage produced from leftover food is stored in polybags and then sprayed using POCI, after which it is stored for one week for the fermentation process. After one week, the food waste is ready to be mixed with husk charcoal, animal manure, and soil with the formula 4:3:2:1 (Abidin *et al*., 2021a, 2021b). If the process has been completed, the leftover food can be used as a planting medium.

This Clean, Green, and Productive Environment Program can increase public awareness of processing waste and change people's behavior from disposing of waste to processing waste. This activity has been carried out in Pasawahan Village, Bandung Regency, which produces 250 polybag units with a harvest period of 3 months and a selling price of Rp 15 000 per unit. Meanwhile, in Cileunyi Kulon Village, Bandung Regency, assistance is needed so that these activities can continue despite the COVID-19 pandemic. In Figure 8c, the condition of Bandung's waste is increasing every year, and proper handling is needed so that the government can manage the increase in waste. A simulation with a system dynamic is carried out to see how much waste reduction occurs with the application of Masaro Technology. The simulation was carried out in Babakan Village, Ciwaringin District. Masaro Technology has been carried out in Babakan Village, Ciwaringin District, Cirebon Regency to support the simulation results. Because the waste at the location has reached a zero-waste condition, the waste is imported from the surrounding market. The Bandung City waste simulation based on the scenario can be seen in Figure 8b.

Based on Figure 8b, the optimistic scenario is very effective in realizing the creation of zero-waste conditions in the city of Bandung because, in the optimistic scenario, the masaro installation has been installed in 151 urban villages. The amount of city waste in 2024 has been wholly processed into products that are beneficial to the community so that zero waste conditions in the city of Bandung will occur in 2024. With the application of this technology, the Indonesian government can realize a Clean Indonesia, which targets 100% of waste to be appropriately managed and correctly by 2025. This goal is stated in the Presidential Regulation of the Republic of Indonesia Number 97 of 2017 concerning National Policies and Strategies for Household Waste Management and Garbage Kind of Household Garbage.

Lean Canvas Business Model

The lean process can be achieved if 5S practices can be implemented correctly. However, it needs assistance until the community feels used to it, and changes in behavior in the community can occur. Communities that initially carried out the waste disposal process at two levels now have enough to do it at one level. The finished waste is processed at a temporary disposal site, and converted into a Waste Treatment Plant. From the discussion of the previous sub-chapter, a Lean Canvas Business Model can be compiled (Table 5).

Table 6 Lean canvas business model

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customers Segments
1. Increased waste generation	1. Processing waste with zero waste	1. One kg of garbage is equivalent to	Having IPPO and IPSA installations that can process waste into	Producer household Consumer household

2. Sarimukti landfill capacity reaches its limit 3. The increase in costs due to the transfer of transportation to the Legok Nangka TPA 4. No waste management technology	management method 2. Processing organic waste into planting media 3. Increase public awareness in processing waste at the source (5S Approach) 4. Lean Waste processing. 5. A partnership between stakeholders, community, and expert team following the Penta-helix concept 6. Applying the 5R concept and circular economy to achieve sustainable development goals	one gram of gold 2. Environmentally friendly 3. Provide a multiplier effect to the agriculture, fisheries, livestock sectors	products that have economic value. Produce liquid organic fertilizers and concentrates, planting media, biopesticides, masaro compost. It contains bacteria that can increase soil fertility. The benefits of steam combustion can be used as biopesticides and wood preservatives. Sustainable soil life. Making asphalt from waste.

Key Metrics	Channels
1. Reduction of waste generation in landfill by 49%/year 2. Reduction of waste generation per person per day by 49% 3. Increase in people's income 43%/year 4. The decrease in the amount of	1. Shorten the transportation channel for waste transportation 2. Waste management pilot project with zero waste management method 3. Involving NGOs in increasing the income of the agriculture, fisheries, livestock sectors

waste in the city of Bandung by 49%/year 5. Reduction of CH4 gas in landfill by 49%/year 6. N2O emission reduction by 49%/year 7. Reduction of disposal costs to landfill by 95%/year 8. Reduction of land requirements in landfills reaches 49%/year	
Cost Structure	**Revenue Structure**
1. Operational cost= IDR 181 407 989 160 2. Marketing fee= IDR 18 875 000 000 3. Equipment investment cost= IDR 264 929 500 000 BREAK-EVEN POINTS: Rp 14 391 376 or 1 497 Units	1. Producer household= IDR 3 932 271 230 280 2. Consumer household= IDR 442 306 540

CONCLUSIONS

The study's conclusions are, first, waste management in its current condition still causes piles of garbage at the final disposal site. With the waste generation rate increasing every year and the capacity of the Sarimukti TPA, which has reached its limit, the Bandung City Government immediately moves the waste disposal location to the Legok Nangka TPA. The current sanitary landfill process at the Sarimukti TPA is less effective and cannot solve the problem of piles of waste at the final disposal site. Second, the waste processing method with Masaro Technology can cut the flow of the waste disposal process that previously occurred at two levels to only one level. The waste transportation process is only completed at a temporary disposal site, converted into a Waste Treatment Plant. Implementing the 5S recommendations on waste management can increase public awareness to process waste directly at the source.

Third, the analysis of masaro's processing model using a dynamic system produce two scenarios that stakeholders can consider in decision making. In the Most Likely Scenario, the amount of waste in Bandung City can reach zero waste conditions in the fifth year. In contrast, the optimistic scenario in the fourth year can already reach zero waste conditions. Fourth, the result of the cost-benefit analysis of the most likely scenario in the first year is above one (feasible). The cost-benefit analysis of the optimistic scenario in year zero (early year) is above one (feasible). Fifth, the lean canvas business method can map essential points that will help turn a zero-waste management business idea into a more concrete one. Suggestions for various parties so this research can be sustainable are: First, for the government, zero waste management technology (Masaro) can be used in other waste processing centers with adjustments to the amount of waste generated in a city.

Second, for the community to carry out the Clean Green Productive Environment Program in a sustainable manner to reduce the generation of easily decomposed (organic) waste and get used to managing waste at the source rather than just transporting and throwing waste to the landfill. The government can take strict action by imposing sanctions on the community through local regulations so that new habits can occur in managing waste at the source. Third, for the community to implement the basic management principles with 5S. It must be implemented and bring in a team of experts to assist. Public awareness of processing waste at the source increases so that new habits occur, namely processing waste more optimally than before, which only disposes of waste in its place. Furthermore, the community can apply the 5R concept (Reduce, Reuse, Recycle, Recovery, Repair) and circular economy to achieve sustainable development goals.

Fourth, the government can apply the lean process principle in waste processing now and in the future. With the application of the lean process, waste that occurs during the processing of waste from households to the final disposal site can be eliminated. Waste processing activities become more effective and efficient. Fifth, for stakeholders to collaborate with local governments, experts, and the community following the Penta-helix concept, which involves five parties, city governments, universities, the private sector, non-profit associations, and enthusiastic citizens so that innovation can be sustainable.

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