DOCTORAL (PhD) DISSERTATION

EDZA ARIA WIKURENDRA

DOCTORAL SCHOOL OF ECONOMIC AND REGIONAL SCIENCES

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCE

2024

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCE

DOCTORAL SCHOOL OF ECONOMIC AND REGIONAL SCIENCES

Head of the Doctoral School

PROF. Dr. ZOLTÁN BUJDOSÓ, PhD

full professor

Supervisor

PROF. Dr. IMRE NAGY, CSC

full professor

Integration Solid Waste Management with Circular Economy Model in Surabaya, Indonesia

DOI: 10.54598/004530

Author

EDZA ARIA WIKURENDRA

Kaposvár

2024

LETTER OF APPROVAL

The PhD School

Name:	Doctoral School of Economics and Regional Sciences
Discipline:	Environmental Management
Head:	Prof. Dr. ZOLTÁN BUJDOSÓ, PhD Professor, PhD MATE University, Faculty of Economic Science
Supervisor:	Prof. Dr. IMRE NAGY Professor, CSc MATE University, Faculty of Economic Science

……..... ……

Approval of the Head of Doctoral School Approval of the Supervisor

ABSTRACT

Waste management in developing countries is a considerable challenge because it is still practiced linear economy model. Circular economy provides a solution by offering a comprehensive and sustainable framework to address waste management challenges by transforming the linear economy model into a regenerative and resource-efficient system. This dissertation analyzes the integration of solid waste management with the circular economy model. Purpose of this dissertation is to find out how solid waste management with a circular economy model can be developed in Surabaya City. A mixed method will be used in this research, which is based on qualitative and quantitative research methods selected to answer four research questions. The research involved 6 informants, 100 respondents and 182 households to support the analysis of the results of this research. Study findings show that waste management in Surabaya City is still found problems in almost all aspects of waste management, including waste generation, containerization, collection, transportation, and disposal. Challenges in integrating waste management with circular economy model in Surabaya City include limited economies of scale in waste recycling, limited access to capital for informal actors, low technology adoption, high transaction costs, ambiguous regulations, and lack of community participation. A framework is suggested to integrate waste management with circular economy model in Surabaya City considering an effective approach to enhance regeneration efforts by including informal recycling participants into solid waste management methods. The results show that the potential environmental benefits and economic value of implementing a circular economy model in Surabaya City.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

€	Euro
3R	Reduce, Reuse, Recycle
APBN	Revenue Expenditure State Budget
APSRG	All-Party Parliamentary Sustainable Resource Group
CD	Compact Disk
CE	Circular Economy
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
GWP	Global Warming Potential
Ha	Hectare
ICEF	Indonesia Circular Economy Forum
IDR	Indonesian Rupiah
IPCC	Intergovernmental Panel on Climate Change
KUR	Kredit Usaha Rakyat
MSE's	Micro or Small Enterprises
NAP	National Action Plan
PDCA	Plan-Do-Check-Act
PLTSa	Waste Power Plant
PPP	Public Private Partnership
RPJMN	Medium Term National Development Plan
RQ	Research Question
RT	Neighborhood
RW	Hamlet
SDGs	Sustainable Development Goals
SNI	Indonesian National Standard
TPST	Integrated Waste Disposal Sites
WAF	Waste Absorption Footprint

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Waste is one of the complex problems faced by developing and developed countries in the world (Mmereki, Baldwin and Li, 2016). This waste issue is actually in line with economic and population growth. According to a World Bank report, people generated 2.24 billion tons of waste globally in 2020, amounting to a footprint of 0.79 kilograms per person per day (World Bank Group, 2022). The number is predicted to increase to 2.59 billion tons by 2030 and 3.4 billion tons by 2050 (World Bank Group, 2018). At the per capita level, the largest growth in waste came from low-income and developing countries. This will contribute to a 5% of global greenhouse gasses, reduction of the global food supplies as one-third of the food ended in landfills and hamper human quality of life because it can increase health risk of people especially to those who live near disposal sites (World Bank Group, 2018). Major environmental issues such as climate change, resource depletion and ecosystem damage are related to solid waste problems (Behrooznia, Sharifi and Hosseinzadeh-Bandbafha, 2020).

More than half of the expected increase of solid waste generation will take place in developing countries as the result of economic booming and the population growth (Nguyen *et al.*, 2020; Kabir and Kabir, 2022). Indonesia is one of those countries, becoming a huge producer of solid waste. Even though Indonesia generates less solid waste per capita compared with the developed countries, as the home of 230 million Indonesians, the country represents one of the major solid waste generators in the world (Sharma and Jain, 2020). Every year, Indonesia produces 64 million tonnes of waste, most of household waste, which accounts for 44.5% of the total waste that is transported without being processed in landfills (Wikurendra, Abdeljawad and Nagy, 2023). Waste production per day in Java Island was relatively high in 2019 compared to other islands, with Jakarta City being the highest by producing 8291.81 m^3/day followed by Semarang City producing 5080.51 m^3/day and Surabaya City producing 2223.9 m^3/day (Edza Aria Wikurendra *et al.*, 2022). As a city with the third largest amount of waste per day in Indonesia, Surabaya City still has problems regarding waste management. Waste generated in Surabaya City is dominated by household waste and comes from public activities, where 43.5% or 1,212 tonnes/day of household waste is generated (Muhamad *et al.*, 2020). If not managed properly, it is estimated that in the next 4-5 years the landfill will no longer be able to accommodate the waste of the population in Surabaya City. The government as a key player in waste management in Indonesia must ensure good and sustainable waste management according to Law No. 18/2008 (Purba and Erliyana, 2020).

Achieving sustainable waste management in Surabaya, several methods have been proposed in previous studies. Involvement of the private sector as part of stakeholder management of

sustainable waste management is one suitable approach. A viable option for sustainable waste management in Indonesia should emphasis on reducing, reusing and recycling (Fatimah *et al.*, 2020). However, the implementation of reduce, reuse and recycle requires a paradigm shift for sustainable waste management in Surabaya, from the current end of pipe approach to a cradle to cradle approach. Cradle to cradle means that a product is designed in such a way that its materials and components can be reused or recycled indefinitely (Sherratt, 2013). This makes the product "circular" and reduces environmental impact. The circular economy approach has received attention recently as a step towards a more sustainable economic model. In the European Union, the circular economy has been applied to address not only the manufacturing sector which is highly correlated with the economy but also to their waste management issues as part of a systematic economic cycle (Pires and Martinho, 2019).

Circular economy theory suggests that improved resource efficiency and reduced waste during the life cycle of manufactured goods are actually unexplored economic opportunities with potential for economic growth (Yang *et al.*, 2022). Solid waste management with the integration of circular economy is believed to not only address the economic problem of the high cost of solid waste management but can also bring environmental and social benefits (Mandpe *et al.*, 2022). To trigger a change towards sustainable solid waste management, the measurement of predicted environmental and economic opportunities of circular economy integration in solid waste management is also conducted in this study. This can improve the local government's cognition regarding the choice of solid waste management strategy in Surabaya City. Therefore, motivation enhancement and strategic allocation of resources such as funds, policies and organisational changes can be improved. This research will also calculate the waste absorption footprint of the current solid waste management and predict the environmental and economic opportunities of integrating solid waste management with circular economy model from the perspective of waste absorption footprint.

2 OBJECTIVES TO ACHIEVED

Waste generation in Indonesia continues to increase every year in line with population growth and urbanization (Kerstens *et al.*, 2016). In metro and big cities, the average waste generation is estimated to be >500 tons/day, while in medium cities with population <500 people/ha, the average waste generation is 100-300 tons/day. The waste management paradigm used is collection, transportation and disposal. In contrast, a city's mainstay in solving waste problems is landfilling. The circular economy approach has recently gained attention as a step towards a more sustainable economic model (Pieroni, McAloone and Pigosso, 2019). Circular economy theory suggests that increasing resource efficiency and reducing waste during the life cycle of manufactured goods are actually unexplored economic opportunities that have the potential for economic growth (E.A. Wikurendra *et al.*, 2022). The reduce principle implies the use of minimal inputs of energy, raw materials, and waste, for example by applying better technologies, simplifying packaging, and using energy-efficient equipment (Kirchherr *et al.*, 2023). The idea has also been put into practice with the argument that it reduces negative environmental impacts and stimulates new business opportunities (Korhonen, Honkasalo and Seppälä, 2018). According to the circular economy, energy combustion should be the penultimate option, while landfill disposal should be the very last option. In this way, the product value chain and life cycle can maintain the highest value and quality for as long as possible and also be as efficient as possible. Under these conditions, this dissertation analyzes the possibility of integrating solid waste management with circular economy models and evaluates its environmental and economic impacts. Thus, this dissertation aims to provide appropriate recommendations to improve the sustainability of solid waste management in Surabaya, Indonesia. As well as assessing the current solid waste management practices and their environmental impacts from a Waste Absorption Footprint (WAF) and economic perspective to provide strategies to maximize the benefits of solid waste management by applying circular economy principles. With this objective, the following research question (RQ) is addressed:

RQ1: What are the current solid waste management practices in Surabaya, Indonesia?

RQ2: What are the challenges for integrating solid waste management with circular economy model in Surabaya, Indonesia ?

RQ3: What are the feasible circular solid waste management frameworks to Surabaya, Indonesia ? How to enable it?

RQ4: What is the impact of current solid waste management practice from the perspective of waste absorption footprint and economics aspects? Is there any opportunity by integrating the circular economy principles in solid waste management from the perspective of waste absorption footprint and economics ?

3 LITERATURE OVERVIEW

3.1 Waste Management

3.1.1 Definition of waste management

Waste management is all activities carried out in handling waste generated up to final disposal, outlining the activities carried out in waste management including waste generation control, waste collection, transfer and transport, management and final disposal (Lissah *et al.*, 2021). According to Indonesian Law No.18 of 2008, waste management aims to improve public health and environmental quality and make waste a resource. Waste management efforts consist of reduction and handling (Skinner, 2004). Waste reduction activities include limiting waste generation, recycling waste; and/or, reusing waste known as 3R (Reduce, Reuse, Recycle) (Shukla and Khan, 2022). While waste handling activities include sorting, collection, transportation, processing and final processing (Fatimah *et al.*, 2020).

Waste management has several fundamental objectives such as improving environmental and public health, protecting natural resources, protecting social and economic facilities and supporting strategic sector development (Zorpas, 2020). The success of waste management does not only depend on technical aspects, but also includes non-technical aspects. Waste management is about setting up a system to function, a good management institution or organization, financing the system and involving the waste-producing community in waste management activities (Zhang *et al.*, 2019).

In the current reform era, the social acceptance of a waste disposal facility is very important, especially if it is operated in the middle of a residential area (Achillas *et al.*, 2011). To improve waste management downstream, waste managers should also look for new ideas for management from the source or upstream. A new approach or paradigm must be understood and followed so that waste can be reduced, reused and/or recycled, namely 3R (Kirchherr *et al.*, 2023). This new paradigm is not something new because it has been widely practiced in several countries and has succeeded in significantly increasing the efficiency of waste management. By implementing this approach, the burden of waste management will be reduced, and the budget and facilities that can be utilized will be more efficient. The burden of pollution can be reduced and furthermore can help preserve the environment so as to create sustainable waste management.

New paradigm turns waste, which has been mostly disposed of in landfills, into a valuable material for recycling, organic fertilizer or compost, and can even be used as an energy source for power generation. An example is the country of Denmark, where most of the waste is recycled and used for electricity generation and space heating, as well as managed for composting and the rest is disposed of in landfill (Roy and Tarafdar, 2022). Through this new

paradigm, waste management is no longer a series that only ends at the landfill (one-way street), but rather a cycle that is in line with the concept of ecology. New energy generated from the decomposition of waste and other recycling processes is not lost.

New paradigm of waste management is also in line with the thoughts of other researchers, namely the development of a hierarchy of waste management at the disposal level (Yakubu and Zhou, 2019; Menyuka, Sibanda and Bob, 2020; Mushtaq, Dar and Ahsan, 2020). In Figure 1. it is explained that the higher level of final disposal is energy recovery, where waste is seen as a resource that can generate energy. Its application is prevalent in landfills that are facilitated with a system for collecting and converting energy from methane gas formed during landfilling. The anaerobic process that naturally takes place in the waste heap is able to convert biodegradable organic waste into methane gas. If not managed and utilized, methane gas from landfills will be emitted into the atmosphere, and become one of the causes of global warming. The next hierarchy is the recycling of waste to produce new products, followed by a higher level of hierarchy, which is the reuse of waste. The next higher hierarchy is minimization, which means reducing waste generation as much as possible. While the highest hierarchy in handling municipal waste is to prevent the formation of waste as much as possible (prevention).

Figure 1. Waste management hierarchy

Source: Menyuka, Sibanda and Bob, 2020

3.1.2 Waste management concept

Waste that is the residue of human activities must be managed so as not to cause environmental pollution and health problems. Waste management is a systematic, comprehensive, and sustainable activity that includes waste reduction and handling (Purba and Erliyana, 2020). Waste reduction referred to in the law includes activities to limit waste generation, recycle

waste, and reuse waste. To be able to realize these activities, the community and business actors in carrying out their activities are expected to use materials that generate as little waste as possible, can be reused, can be recycled, and are easily decomposed by natural processes. Waste handling referred to in the law is an activity that begins with sorting in the form of grouping and separating waste according to the type, amount, and nature of the waste.

Next step is the collection and transfer of waste from waste sources to temporary shelters, and transportation of waste from temporary landfills to final processing sites. Then the waste that has been collected at the final processing site is managed by changing the characteristics, composition, and amount of waste and/or processed to safely return the results of previous processing to the environmental media. In general, waste management in urban areas is carried out through 3 stages of activity, namely collection, transportation and final disposal. Campitelli, Kannengießer and Schebek (2022) simply describes the stages of the activity process in waste management as follows. Collection, defined as the management of waste from its place of origin to temporary disposal sites before going to the next stage. At this stage, facilities such as trash cans, waste bins, waste containers, wheelbarrows, or temporary disposal sites are used. Collection generally involves a number of workers who collect waste every certain period of time. Transportation, which is transporting waste by using means of assistance in the form of certain transportation equipment to the final disposal/ processing site. This stage also involves personnel who, at certain periods of time, transport waste from temporary disposal sites to final disposal sites. Final disposal, where waste will undergo physical, chemical and biological processing until the completion of the entire process.

Samiha (2013) explains that the 3R principle can be described in three principles. The first principle is reduce or waste reduction, which is an effort to reduce waste generation at the source environment and can even be done before waste is generated. Each source can make efforts to reduce waste by changing consumptive lifestyles, namely changing habits from being wasteful and producing a lot of waste to being economical/efficient and producing little waste. Second principle is reuse, which means reusing materials so that they do not become waste (without going through processing), such as using paper back and forth, reusing used beverage bottles for water containers, and others. Thus reuse can extend the life of goods through maintenance and direct reuse of goods. Third principle is recycle, which means recycling a material that is no longer useful into another material or a new item after going through a processing process. Some waste can be recycled directly by the community using simple technology and tools, such as processing patchwork scraps into blankets, rags, foot mats and so on, or kitchen waste in the form of food scraps to be composted.

From some of the definitions described above, it can be concluded that waste management is a

gradual activity that is basically carried out to process waste so that it can be processed into other forms that provide benefits and are not harmful to the environment. Waste management referred to in this study is waste management activities carried out at the household level, in the form of reducing the use of materials that are difficult to decompose, sorting waste, transferring waste from waste sources to temporary shelters, reusing waste, and cleaning activities such as mutual cooperation for community service in the residential environment.

3.1.3 Waste classification

A waste generator is any person and/or natural process that generates waste while a waste source is the origin of waste. Waste sources come from households including dormitories, hospitals, hotels and offices; agriculture including fisheries plantations, livestock, which is often also called agricultural waste; the results of trade activities, such as markets and shops; the results of industrial and factory activities; the results of development activities; and road waste. Composition of waste can be divided into two types, namely uniform waste, sourced from industry and offices and non-uniform/ mixed waste sourced from market/ public places, agricultural households and others. Based on its form, there are three types of waste, namely solid waste, such as leaves, paper, cardboard, building waste, plastic, used tires; liquid waste; and gaseous waste (Wikurendra *et al.*, 2024). While organic waste includes semi-wet waste in the form of organic materials that generally come from the agricultural and food sectors such as kitchen scraps, vegetable waste and fruit peels, all of which are easily decomposed. Inorganic waste includes waste that cannot decompose, which comes from industrial products such as plastic, rubber, glass and the like. There are 2 types of waste based on the occurrence of natural waste and non-natural waste (Vis, 2017).

Waste can be distinguished on the basis of its biological and chemical properties, including waste that can decompose (organic waste) such as leftover food leaves, garden waste, agriculture, and others (Varshney, Singh and Yadav, 2022). Decay of this waste produces methane gas H_2S gas (toxic to the body and very smelly so that it disturbs aesthetics). Waste that cannot decompose/ difficult to decompose (inorganic waste), which can be recycled and or burned and waste in the form of dust/ ash from combustion. Size of dust/ ash from combustion is relatively small < 10 microns, can enter the respiratory tract so that it can cause Pneumoconiosis. Waste that is hazardous to health, such as industrial waste (hazardous toxic material). Because of its amount, concentration, chemical, physical and microbiological properties, it can increase mortality and morbidity, causing reversible and irreversible diseases and potentially causing present and long-term hazards. In its management, it cannot be united with municipal waste (Xu and Yang, 2022).

3.1.4 Quality and quantity of waste

Quantity and quality of waste is greatly influenced by various activities and the standard of living of the community (Phan *et al.*, 2021). Some important factors that affect waste production include population, the more the population, the more the waste production, this is in line with the rate of population growth. Socio-economic conditions, the higher the socio-economic condition of the community, the more waste is produced which is usually non-decomposable waste and this depends on the available materials, applicable regulations and public awareness. Technological progress, technological progress will increase the amount and quality of waste due to the use of increasingly diverse raw materials, packing methods and increasingly diverse manufactured products (Kibria *et al.*, 2023). The quality of municipal waste in terms of its composition consists of crude fiber (41-61%), fat (3-9%), ash (4-20%), water (30-60%), ammonia (0.5-1.4 mg/g waste) organic nitrogen compounds (4.8-14 mg/g waste) total nitrogen (7-17 mg/g waste) protein (3.1-9.3%) and pH (5-8).

3.1.5 Factors influencing waste generation

Factors that affect waste generation are population size or density, waste management system, geography, season and time, population habits, technology and socioeconomic level (Soukiazis and Proença, 2020). Accelerating population growth rate and population activities in an area bring major changes to aspects of human life and the environment. Population growth results in the expansion of residential areas which affects the increase in community business activities so that it will result in an increase in waste generated by each resident or household and business entity/ business activity. Therefore, waste becomes an important problem for densely populated urban areas. The population of a large city with a high density will produce a larger volume of waste as well. This waste volume will continue to increase along with the rate of population growth and socio-economic activities that occur in urban communities (Hoornweg, Bhada-Tata and Kennedy, 2013).

Problems in urban waste management do not only occur in big cities, but also in small cities and districts that have a high density and high economic activity. Increasing population is a factor in the increasing amount of waste. Currently, the amount of waste generated by humans is increasing and is not proportional to the population, the type of activity and the level of consumption of the population for a particular item. Greater the population, the greater the volume of waste generated (Wikurendra *et al.*, 2024). Another factor is the quality of life of the community or human and accompanied by advances in science and technology which also results in a shift in the lifestyle of people who tend to be consumptive. The use of packaged goods dominates daily needs so that it ultimately affects the production of waste, which is both

quality and quantity, including its increasingly diverse types and characteristics (Williams *et al.*, 2020). To deal with the waste problem as a whole, management alternatives need to be carried out. Landfill is not a suitable alternative, because landfills are not sustainable and cause environmental problems. These alternatives must be able to deal with all waste disposal problems by recycling all disposed waste back into the community economy or into nature, so as to reduce pressure on natural resources.

To achieve this, three assumptions in waste management must be replaced with three new principles (Djuric Ilic *et al.*, 2018). Instead of assuming that society will generate an ever-increasing amount of waste, waste minimization should be the top priority. Waste should be segregated, so that each part can be optimally composted or recycled, rather than being dumped into the current mixed waste disposal system. And industries should redesign their products to facilitate recycling. This principle applies to all waste types and streams. Mixed waste disposal damages and reduces the value of materials that might otherwise be reused. Organic materials can contaminate materials that may be recyclable and toxins can destroy the usefulness of both. In addition, an increasing portion of the waste stream coming from synthetic products and products that are not designed to be easily recyclable will need to be redesigned to suit recycling systems or phase-out.

Municipal solid waste programs must be tailored to local conditions in order to be successful, and cannot be made the same as other cities (Abdel-Shafy and Mansour, 2018). Especially programs in developing countries should not simply follow the pattern of successful programs in developed countries, given the different physical, economic, legal and cultural conditions. In particular, the informal sector (waste collectors or waste pickers) is an important component of the current waste management system, and improving their performance should be a major component of the waste management system in developing countries. One successful example example is Zabbaleen in Cairo, which has managed to create a waste collection and recycling system that is capable of waste collection and recycling system that is capable of converting 85 percent of the waste collected and 85 percent of the waste collected and employs 40,000 people. 40,000 people (Fahmi and Sutton, 2010). In general, whether in the North or in the South, systems for handling organic systems for handling organic waste are the most important components of a municipal waste management system.

Organic waste should be composted, vermi-composted (composting with worms) or fed to livestock to return nutrients to the soil. This ensures that recyclable materials are not contaminated, which is also key to the economics of alternative waste utilization. Waste recycling creates more jobs per ton of waste than any other activity, and generates a stream of materials that can supply industry (Purchase *et al.*, 2022). Through decomposition there is a

natural recycling of nutrients. Nutrients contained in dead organic materials or objects, with the help of microbes (microorganisms), such as bacteria and fungi, will break down into simpler nutrients with the help of humans, the final product is compost. Every organic material, biological materials that have died, will undergo a process of decomposition or weathering. Leaves that fall to the ground, broken stems or twigs, animal carcasses, animal waste, food scraps, and so on, will all undergo a decomposition process and then disintegrate into brown-black soil. So that its original form is no longer recognized. Through the decomposition process, there is a natural recycling process of nutrients.

Nutrients contained in dead organic materials or objects, with the help of microbes (microorganisms), such as bacteria and fungi, will decompose into simpler nutrients with the help of humans, the final product is compost (compost). Composting is defined as a biochemical process involving microorganisms as agents (intermediaries) that break down organic matter into materials similar to humus (Rynk *et al.*, 2022). Compost is usually used as fertilizer and soil conditioner. Compost and composting have been known for centuries. Development of industrial technology has created agricultural dependence on factory-made chemical fertilizers, making people forget about compost. Whereas compost has other advantages that cannot be replaced by chemical fertilizers, namely compost is able to reduce soil density and density, thus facilitating root development and its ability to absorb nutrients (Gondek *et al.*, 2020).

Geographical location affects the vegetation and habits of the community, in the highlands there are generally many vegetables, fruits and other types of plants which will ultimately affect the type and amount of waste (Davies, 2012). During the rainy season, waste gets stuck in gutters, sluices, and sewage filters. Also, in the morning, the amount of waste is less than in the afternoon. If a person likes to consume one particular type of food that uses packaging, it will increase the amount of waste. Technological advancement affects industry, which in turn uses better equipment, so that less food is wasted and the waste can be reused. In a good economy, people's purchasing power will be high and the waste generated will be high as well (Velis *et al.*, 2023).

3.1.6 Key aspects of waste management

Waste management in an area is often defined as the control of waste generation, starting from containerization, collection, transfer, transportation, processing, and final disposal of waste, with the best principles for health, economics, engineering, conservation, aesthetics, environment, and also public attitudes (Wikurendra *et al.*, 2024). Successful management does not only depend on technical aspects, but also includes non-technical aspects, such as how to set up the system so that it can function, what institutions or organizations should manage it, how to

finance the system and last but not least, how to involve the waste-producing community in waste management activities. To run the system, it must involve various disciplines, such as urban planning, geography, economics, public health, sociology, demography, communication, conservation, and materials science. Urban waste management policy according to the Ministry of Public Works positions that urban waste management is a system consisting of 5 (five) sub-system components (Amheka *et al.*, 2015), namely:

(a) Regulation/ law

Regulatory aspect is based on the fact that Indonesia is a state of law, where the joints of life rest on the applicable law. Municipal solid waste management in Indonesia requires the power and basis of law, such as in the formation of organizations, retribution collection, public order, and so on (Wikurendra *et al.*, 2024). Regulations needed in the implementation of urban waste management systems include those governing public order related to waste handling, city waste management master plans, forms of management institutions and organizations, management procedures, the amount of service tariffs or retribution and cooperation with various related parties, including inter-regional cooperation, or cooperation with the private sector.

(b) Institution and organization

Aspect of organization and management is a multi-disciplinary activity that relies on engineering and management principles concerning economic, social, cultural, and physical aspects of the city area, as well as paying attention to the parties served, namely the city community. Design and selection of the form of waste organization must be adjusted to the government regulations that guide it, the pattern of the operational system applied, the system's working capacity, the scope of work and the tasks to be handled.

Policy implemented in Indonesia in managing municipal solid waste formally is as directed by the Ministry of Public Works as the technical department that fosters urban solid waste management in Indonesia (Waluyo and Kharisma, 2023). Institutional form of municipal solid waste management adopted in Indonesia consists of a Cleanliness section under a department, such as the Public Works Department, especially if the problem of municipal cleanliness can still be handled by a section under the department (Damanhuri, Handoko and Padmi, 2014). Technical Implementation Unit under a department, such as the Public Works Department, especially if the organizational structure does not yet have a special section under the department that manages cleaning so that it puts more emphasis on operational issues, and has more autonomy than the section. Cleaning service will provide acceleration and service to the community and is non-profit. This office needs to be formed because of the increased activity and volume of work. A regional cleaning company is a management

organization that is formed when the problems in the city are already quite extensive and complex. In principle, this regional company is no longer subsidized by the local government, so that the effectiveness of collecting user fees will be more decisive for the development of the company and this form is suitable for metropolitan cities.

Recommended institutional forms for various categories of cities in Indonesia according to the SK-SNI T-13-1990-F Standard on technical management of urban waste are shown in Table 1.

Table 1. Institutional form of waste management

Category of city	Total population (people)	Institutional form
Greater city (metropolitan)	>1.000.000	Regional company
Big city	500.000 - 1.000.000	Agency
Medium city I	250.000 - 500.000	Agency
Medium city II	100.000-250.000	Agency
Small town	20.000-100.000	Regional Technical Implementation Unit Section

Source: Departemen Pekerjaan Umum, 1990

(c) Operational techniques

Operational techniques for municipal solid waste management include the basics of planning for various activities such as containerization, collection, transfer, transportation, treatment and final processing. In urban solid management, operational techniques are determined by several things, including the operational pattern used, namely the method of sweeping, collection, transportation and final disposal, the volume of waste transported and the capacity of the equipment. Sorting and recycling activities are carried out as much as possible from waste collection to final disposal of waste. Operational technique of urban waste management, which consists of waste collection to final disposal, must be integrated by sorting from the source (Abdel-Shafy and Mansour, 2018). Household hazardous and toxic waste management is managed specifically in accordance with applicable regulations. Sorting activities can also be carried out in transfer collection activities. Sorting and recycling activities are prioritized at the source.

(d) Financing

Financing aspect is the driving force for the waste management system in a city to move smoothly (Schneider *et al.*, 2017). It is expected that the waste management system in Indonesia will lead to self-financing, including the establishment of regional companies that manage waste. Waste management costs are calculated based on operational and maintenance costs and equipment replacement. Comparison of management costs from the total cost of waste management is as shown in Table 2. Funds for waste management in a city are required to be at least 10% of the local budget. It is attempted that the cost of waste management can be obtained from the community by 80% and the Local Government provides 20% for public services such as street sweeping, channel cleaning and public places (Wilson *et al.*, 2017). Amount of waste retribution is based on the amount of operational cost of waste management. In Indonesia, the amount of retribution that can be collected from each household is 0.5% and a maximum of 1% of household income per month (Ministry of Environment and Forestry, 2018). This can be said to be able to achieve self-financing if the calculation of the amount of retribution is done by classification and the principle of cross-subsidization.

Tabel 2. Percentage of waste management financing

Category	Percentage
Collection cost	20 – 40 %
Transportation cost	40 – 60 %
Final processing cost	10 – 30 %

Source: Wilson *et al.*, 2017

Regional Government is obliged to determine the amount of waste management service fees collected from the community and business actors by considering the economic capacity of the community. Amount of waste management service fees from the community and business actors to be determined by the Local Government must consider the available infrastructure and equipment. To improve the waste management system, it is also possible to develop incentive and disincentive mechanisms. Financing in waste management includes the source of funds used by the local government in the management of municipal solid waste, the amount of budget received and the amount of costs that must be incurred for waste management (operational and maintenance costs). Source of funds for municipal solid waste management comes from the State Budget, Regional Budget, payment of retribution for cleaning services, recycling and composting businesses (Abubakar *et al.*, 2022). Common

problems faced in waste financing are that the collected retribution is generally not proportional to the operational and maintenance costs as well as the investment invested in this sector, the waste budget is less prioritized in the regional development budget. This is due to the lack of understanding of solid waste issues in relation to environmental health and cleanliness. Another problem is that the preparation of retribution rates is not based on the correct method and the method of collecting waste retribution is not appropriate.

3.2 Circular Economy

Circular economy (CE) approach refers to an economic system designed to be restorative and generative (Charonis, 2021). More specifically, it maintains the value of products, materials and resources in the economy for as long as possible and minimizes the production of waste (European Commision, 2015). As such, the CE approach has received recent attention as a step towards a more sustainable economic model (Ranta *et al.*, 2018). CE theory suggests that increased resource efficiency and reduced waste during the life cycle of manufactured goods are actually unexplored economic opportunities that have the potential for economic growth (Ghisellini, Cialani and Ulgiati, 2016).

Circular economy is often discussed through the 3R principles of reduce, reuse and recycle (Zhijun and Nailing, 2007). Reduce principle implies the use of minimal inputs of energy, raw materials, and waste by, for example, applying better technologies, simplifying packaging, and using power-efficient equipment (Su *et al.*, 2013). The principle of reuse refers to the use of fewer resources, less energy, and less labor than would be required to produce a new product from new materials or even to recycle and dispose of the product (Castellani, Sala and Mirabella, 2015). Principle of recycling or recycle refers to recovery operations where waste materials are reprocessed into products, materials or ingredients, either for their original or other purposes. It includes reprocessing of organic materials but excludes energy recovery and reprocessing into materials to be used as fuel or for landfilling operations. Recycling is often discussed almost in the same breath as CE, and waste policy includes a strong focus on increasing recycling rates.

Circular economy is a system designed to be restorative and regenerative, where restoration replaces the concept of "end-of-life" for products, energy systems are shifted to renewable technologies, toxic chemicals that interfere with reuse are eliminated and waste is eliminated as much as possible through improved materials, products and system design (Ellen MacArthur Foundation, 2015). Circular economy provides an economic system with an alternative flow model that is cyclical in nature (Ellen MacArthur Foundation, 2012). The idea of material cycles dates back to the early days of industrialization (Korhonen, Honkasalo and Seppälä, 2018). The idea has also been put into practice with the argument that it reduces negative environmental

impacts and stimulates new business opportunities (Desrochers, 2004). Unlike traditional recycling, practical policies and business-oriented circular economy approaches emphasize the reuse of components and materials, remanufacturing, refurbishing, repairing, developing and upgrading as well as energy utilization and product waste (Braungart, McDonough and Bollinger, 2007).

Circular economy concept is depicted in Figure 2. The point of the figure is that the circle depicts product reuse, remanufacture and repair, demanding less resources and energy and more economical than conventional recycling of materials that make low-quality goods (Mihelcic *et al.*, 2003). The time the resource spends/life cycle inside the circle should be maximized. Materials should first be recovered for reuse, renewal and repair, then for remanufacturing, and only then for raw material utilization, which has been the main focus in traditional recycling. According to CE, energy combustion should be the second to last option while disposal to landfill is the very last option. In this way, the product value chain and life cycle can maintain the highest value and quality for as long as possible and also be as efficient as possible.

Figure 2. Circular economy concept

Source: Ellen MacArthur Foundation, 2012

3.3 Implementation of Circular Economy

One example of a circular economy that could include food waste, natural yarns, wood products and biopolymers would create 'biological nutrients' (compost) while another could include non-

organic materials such as polymers (plastics) and electronic materials that become 'technical nutrients' for next generation products (Liu *et al.*, 2022). The concept was originally introduced in the 1970s by Swiss architect and economist, Walter Stahel, who proposed that materials be processed in a 'closed loop' and 'waste' become resources. Stahel defined this as a 'Cradle-to-Cradle' system and the Linear model was defined as Cradle-to-Grave (Giarini and Stahel, 1993). It also identifies the need to extend product life through repair and remanufacturing, which is also now seen as an integral part of the circular economy (Stahel, 2016). Cradle-to-Cradle is also a design method used by William McDonough (architect) and Michael Braungart (environmental chemist) who stated that it would facilitate 'design for abundance' and as a consequence they developed the C_2C benchmark to support and promote products that meet this standard (McDonough and Braungart, 2002). Dematerialization (reducing material inputs while maintaining performance) and alternative business models such as leasing and service provision (which includes maintenance for example) are also integral parts of the circular economy (Vegter, van Hillegersberg and Olthaar, 2020).

The product life cycle consists of four main stages: 1. Extraction of raw materials and processing, 2. Manufacture; 3. Use and 4. End of use. It has been explained that, in a linear economy, at end-of-use, materials are treated as waste and either sent to landfill or incinerated. Besides using land that could be used for housing or agriculture, the decomposition process in landfills or incineration can produce emissions, toxins and other pollutants. In contrast, the circular economy reduces supply risks by keeping materials in circulation and although energy and resources will still be required for decomposition and recycling, eliminating the initial lifecycle stage (extracting and processing large quantities of materials) also reduces the amount of damage, up to 75% of the energy and water involved, associated emissions, environmental and other impacts (Yang *et al.*, 2022).

Extending the life of products, purchasing services (such as replacing physical CDs with MP3 format and online music services, e-books and digital format reader apps) and leasing also contribute to the circular economy and are profitable as the manufacturer has control over products that can be easily maintained, repaired and upgraded throughout their life. Furthermore, at end-of-life, suppliers have control over reprocessing and recycling and can manage the outcome in open or closed material cycles (where materials are remade into different products or the same products). In addition to reducing resource supply risks, the circular economy also has the potential to reduce corrupt and unethical practices, which will promote sustainable development as it will be much easier to conduct accurate supply chain audits and select ethical suppliers and/or encourage unethical suppliers to change their practices (Rizos *et al.*, 2016).

Some large manufacturers (e.g. Rolls Royce, Philips and Caterpillar) and some smaller ones (e.g. Closed Loop which recycles and re-assembles plastic bottles and The Bond Group which manufactures commercial refrigeration equipment) are developing alternative businesses on their way to a circular economy. However, the majority of businesses are not doing so due to a lack of knowledge and understanding of circular economy concepts. Some concerns and barriers are practical (e.g. availability of networks and/or supply chains for dismantled products and components and materials for recycling have not been established) while other barriers are perceptual (there is a general belief that remanufactured/reengineered components and recycled materials are inferior to virgin materials). Furthermore, currently most products in circulation are not designed for disassembly or recycling and as a result the process can damage components and materials while the cost and complexity of disassembly is relatively high. These and other constraints are being addressed by several UK government and non-government bodies including APSRG (the All-Party Parliamentary Sustainable Resource Group), Innovate UK, the Ellen MacArthur Foundation and the Royal Society of Arts' Great Recovery project which all promote and support research into the benefits and business opportunities associated with aspects of the circular economy.

3.4 Waste Absorption Footprint

Waste Absorption Footprint (WAF) refers to the amount of waste generated by an individual, community, or entity that can be effectively absorbed or managed by the environment without causing negative impacts (Jiao *et al.*, 2013). It represents the capacity of the environment to assimilate, decompose, or handle the waste produced within its natural cycles without causing harm to ecosystems, human health, or the environment's equilibrium. Calculating the waste absorption footprint involves assessing various types of waste produced, such as organic, non-biodegradable, recyclable, etc., and understanding the capacity of the environment to process and manage these waste streams sustainably (Gupta and Gaur, 2019). It's an important metric in understanding the ecological impact of human activities and helps in designing strategies for waste management, resource conservation, and environmental sustainability.

Waste absorption footprint accounting employs the methodology of ecological footprint accounting. Process that used the land and water area's ability to generate resources or absorb waste. However, waste absorption footprint accounting solely concentrates on the waste absorption services offered by nature and evolved independently from resource production. Therefore, it has the ability to replicate the process of waste absorption not only in forested areas but also in various other types of land (Jiao *et al.*, 2013). The distinction between Waste absorption footprint and ecological footprint accounting is based on the utilization of the land

type for waste absorption service. Within the framework of ecological footprint accounting, the sole waste category taken into consideration is carbon dioxide (CO_2), and the only region deemed capable of providing waste absorption services is forest land. All other areas are excluded from the waste assimilation accounting. This is because the fundamental premise of ecological footprint is to avoid double-counting ecosystem services. This measure is implemented to prevent the overestimation of the space needed to meet human demand (Jiao *et al.*, 2013; Mancini *et al.*, 2018).

Waste absorption footprint accounting allows for the calculation of various ecosystem services delivered by a certain location. Waste absorption footprint accounting categorizes land into four types: farmland, grazing land, fishing grounds, and forest land. The accounting did not include the built-up land as it was deemed to lack the capacity to provide waste absorption services (Jiao *et al.*, 2013). The waste absorption footprint idea encompasses ecosystem services related to waste absorption, which can be further classified into two major types of ecosystem services. The first type is determined by the bio-productive capability of the land or water region, referred to as the waste bio-productive provision footprint or waste absorption capacity (WAC). The second type is the waste absorption footprint, which is further divided into two categories. The two categories are carbon sequestration footprint and nutrient removal footprint. Waste absorption capacity refers to the amount of bio-productive area that is capable of providing waste absorption services and can effectively mitigate the negative effects caused by waste. To calculate the waste absorption capacity of carbon dioxide or a specific nutrient (WAC_i), the equation can be expressed as follows:

$$WAC_i = A_i \times rSF_i \quad (1)$$

Equation 1 Waste absorption capacity

Where A_i is the area available to absorb i substance load while rSF_i is regional supply factor for i substance absorptivity. Sustainability is accomplished when the overall waste absorption capacity is more than or equal to the entire waste absorption footprint (Jiao *et al.*, 2013). The carbon sequestration footprint is synonymous with the carbon footprint notion in ecological footprint accounting, as both are derived from the capacity to sequester CO_2. However, the carbon footprint notion employed by various organisations pertains to the amount of CO_2 or comparable emissions necessary for the production of a product, execution of a process, or undertaking of an activity. The equation for calculating the carbon sequestration footprint (WAF_{CO2}) is provided as follows:

$$WAF_{CO2} = \frac{W_{CO2}}{LA_{CO2}} \mathrm{rSF}_{CO2} \quad (2)$$

Equation 2 Carbon sequestration footprint

Variables in question are as follows: W_{CO2} represents the quantity of carbon dioxide or its counterparts released into the ecosystem, measured in kilograms (kg); LA_{CO2} denotes the local capacity of carbon dioxide or its equivalents to be absorbed, measured in kilograms per hectare (kg/Ha); and rSF_{CO2} represents the regional factor that determines the capacity of the ecosystem to absorb carbon dioxide or its equivalents. Nutrient removal footprint refers to the amount of land needed to absorb nutrients such as chemical oxygen demand (COD), excess nitrogen (N), or phosphorus (P). Ecological footprint accounting does not include the measurement of nutrient absorption footprint, in contrast to carbon footprint. However, it bears some resemblance to the water footprint idea, which is another member of the footprint family. The water footprint concept quantifies the volumetric quantity of water needed to manufacture a product, carry out a process, or engage in an activity.

$$WAF_{NR} = \frac{W_{NR}}{LA_{NR}} \times rSF_{NR} \quad (3)$$

Equation 3 Nutrient removal footprint

Equation represents the discharge of a specific nutrient, denoted as W_{NR}, into the ecosystem measured in kilograms. LA_{NR} represents the local absorptivity of that nutrient, measured in kilograms per hectare. Lastly, LA_{NR} represents the regional supply factor for the absorptivity of that nutrient.

3.4.1 Waste absorption foodprint for solid waste management

Waste absorption foodprint was created with the same objective as the ecological footprint. Primary objective of waste absorption foodprint is not to quantify the precise influence of waste, but rather to convey a comprehensible ecological message regarding the potential consequences of corrective measures pertaining to waste management (Jiao *et al.*, 2013). This article aims to evaluate the existing solid waste management methods in Surabaya City by employing the waste absorption foodprint framework. In addition, the potential environmental benefits of implementing circular economy in solid waste management were examined using the waste absorption foodprint approach. This phase was undertaken to determine whether the integration of the circular economy into solid waste management results in a reduced or larger waste absorption footprint. The operational components of solid waste management are the waste sources identified in this research. Consequently, an investigation was conducted on the waste

produced by these activities.

3.4.2 Vehicles emission

Emissions from vehicle activities will be quantified using the tier 1 methodology of the Intergovernmental Panel on Climate Change (IPCC). In this approach, the emission is determined by multiplying the total fuel use by a specified emission factor (IPCC, 2019). The formula for calculating the emissions of CO_2 and CH_4 will be presented:

$$Emission_{CO2/CH4/N2O} = \sum_a [Fuel_a \times FA_a] \quad (4)$$

Equation 4 Emission of CO_2/CH_4/N_2O using IPCC tier 1 method

Where, emissions of CO_2/CH_4 (kg); a is the type of fuel; $Fuel_a$ is fuel consumed for a type of fuel (TJ); EF_a is the emission factor for fuel a.

3.4.3 Landfill gas emission

Lack of data on solid waste characteristics and landfill performance restricts the use of the first order decay method, which accounts for temporal considerations. Consequently, the calculation method is confined to relying on the default method provided by the Inter-Governmental Panel on Climate Change (IPCC). The default methodology assumes that all potential methane is released at the moment of solid waste disposal (IPCC, 2019). Equation 5 is utilised to compute the quantity of methane produced.

$$Y_{methane} = \left(MSW_T . MSW_F . MCF . DOC . DOC_F . F . {}^{16}/_{12} - R\right) . (1 - OX) \quad (5)$$

Equation 5 Amount of methane generated using IPCC default method

Where $Y_{methane}$ is the amount of methane emission (Gg/year); MSW_T is the total generated MSW (Gg/year); MSW_F is the fraction of the generated MSW that ended up in landfill; MCF is methane correction factor; DOC is degradable organic carbon (kg C/ kg SW); DOC_F is fraction DOC dissimilated (IPCC default is 0.77); F is the fraction of CH_4 in landfill gas (IPCC default is 0.5); R is recovered CH_4 if it is available (Gg/year); OX is oxidation factor (IPCC default is 0). On the equation above DOC is calculated by

$$DOC = (0{,}4 \, . A + 0{,}17 \, . B + 0{,}15 \, . C + 0{,}3 \, . D) \quad (6)$$

Equation 6 Degradable organic carbon

Where, A represents the percentage of paper and textiles in the solid waste; B represents the

percentage of garden-park and non-food organic putrescible waste; C represents the percentage of food waste; D represents the percentage of wood and straw waste. Meanwhile, the equation provided by the United States Environmental Protection Agency (EPA) is utilized to compute CO_2 emissions from un-recovered FPS. The computation relies on the methane gas production from landfill (Toha and Rahman, 2023).

$$Y_{CO2} = Y_{methane} \cdot \left(\frac{1-F}{F} + OX\right) \cdot \frac{44}{16} \quad (7)$$

Equation 7 Amount of CO_2 generated on un-recovered landfill gas site

$Y_{methane}$ represents the quantity of methane produced annually, measured in gigagrams (Gg/year). F denotes the proportion of methane in landfill gas, with the default value set by the IPCC at 0.5. OX represents the oxidation factor, also with a default value of 0 according to the IPCC.

3.4.4 Landfill gas sequestration

The composition of landfill gas mostly comprises carbon dioxide (CO_2) and methane (CH_4), with the presence of other gases being insignificant (IPCC, 2019). Ecological footprint accounting has already been considered in CO_2 sequestration. Therefore, its inclusion in the waste absorption foodprint technique will be more robust compared to the capture of greenhouse gases like methane. Methane, classified as a greenhouse gas (GHG), has a global warming potential (GWP) of 25. This means that 1 tonne of methane has the same capacity as 25 tonnes of CO_2 to enhance the net radiation in the atmosphere over a span of 100 years (IPCC, 2019). Therefore, it is crucial to determine the necessary biosorption area for methane. The conversion of methane to carbon equivalent is determined by the fact that approximately 90% of methane elimination occurs by the oxidation of methane by hydroxyl radicals, resulting in the formation of carbon dioxide (Walsh, O'Regan and Moles, 2009). Equation 8 illustrates the process of methane conversion into carbon dioxide. The biosorption area required for methane can be determined by taking into account the molecular weight of methane and carbon dioxide.

$$CH_4 + 5O_2 + NO + 2OH \quad \overrightarrow{UV-A} \quad CO_2 + H_2O + NO_2 + 4HOO \quad (8)$$

Equation 8 Conversion of methane into carbon dioxide in atmosphere

However, alternative method of converting methane into carbon dioxide by utilizing the Global Warming Potential (GWP) equivalent, prior to determining the necessary biosorption area (Walsh, O'Regan and Moles, 2009). This step is taken to illustrate the detrimental effects of methane on the ecosystem. In addition, numerous scientists employ the concept of Global

Warming Potential (GWP) equivalence to translate methane emissions into their equivalent carbon dioxide emissions (Lauder *et al.*, 2013; Lynch *et al.*, 2020; Sand *et al.*, 2023). Therefore, this study will opt to utilize the Global Warming Potential (GWP) equivalent in order to determine the required biosorption area for methane.

3.4.5 Carbon dioxide uptake rate

Biomass has the ability to absorb carbon dioxide through the process of photosynthesis, which occurs in the chlorophyll-containing leaves. Through a series of metabolic processes, carbon dioxide and water are transformed into sugar, oxygen, and water with the aid of sunshine. Hence, the rate at which carbon dioxide is absorbed is contingent upon the velocity of the photosynthetic process. The rate of the photosynthetic process is influenced by both internal and external elements, including the intensity of sunlight, the concentration of carbon dioxide in the atmosphere, and the availability of water and nutrients (Yahia *et al.*, 2019). The carbon dioxide absorption rate for different types of land cover is displayed in Table 3. According to this table, trees are the largest carbon dioxide sink. Although paddy fields provide a relatively smaller amount to the intake of carbon dioxide.

Table 3. Carbon dioxide uptake rate from various types of land cover

Land Cover type	CO_2 uptake rate (ton/Ha.year)
Trees	569.07
Bushes	55
Pasture Land	12
Paddy field	12

Source: Arneth *et al.*, 2017

3.5 Economic Potential of Waste Management

From an economic point of view, the utilization of municipal waste has economic value if the waste is processed into useful goods. An effort to utilize waste for the community is said to be successful if the products it produces can be useful for the community and have economic value so that they sell well (Yana *et al.*, 2022). Similarly, the various products resulting from waste processing will benefit if they can be felt by many people and have high economic value, so that they can help the economy of people whose livelihoods depend on scavenging waste in existing landfills. To achieve this, it is necessary to have a business to manage the utilization of waste and market the production of waste utilization so that it is sold. In addition, the feasibility of the business needs to be known with a financial analysis so that the objectives to be achieved can be met and make a profit for those who manage it. The kinds of things that can be produced by

waste management include: Waste to compost, waste to electricity, waste to recycled materials, etc.

Waste has different economic values according to the composition of each waste and the treatment before sale. Types of organic waste that can be recycled include waste from household activities, namely vegetables and fruits that are discarded in the cooking process. Meanwhile, inorganic types of waste include plastic, paper, aluminum, wood and others. Plastic waste cannot be disposed of directly into the ground because plastic takes a long time to decompose. Therefore, it is necessary to process plastic waste so that it can be reused and can reduce its amount. According to Sala, Ciuffo and Nijkamp (2015), assessment in the economic concept is defined as an assessment activity related to community change. In this case, community participation in waste management development is needed. Community participation in waste management can be direct or indirect. Direct participation is the participation, involvement and togetherness of the community, starting from ideas, policy formulation to the operational implementation of the program. While indirect participation is in the form of involvement in financial matters, thoughts and materials.

According to Yukalang *et al.* (2017), waste management will fail when too much waste is in the wrong place, is not close enough to sell, or is not recycled enough. The solution lies in redesigning products, packaging, and processes suitable for input into the value chain. Initiatives and tools can also support successful sustainable waste management strategies. One example of a developing waste management strategy is the circular economy approach (Viva *et al.*, 2020). The circular economy aims to generate economic growth by maintaining the value of products, materials, and resources in the economy for as long as possible, thereby minimizing the social and environmental damage caused by the old linear economic approach (Velenturf and Purnell, 2021). Not just better waste management with more recycling, a circular economy encompasses a broad range of interventions across all sectors of the economy (Kirchherr, Reike and Hekkert, 2017). Circular economy activities are focused on the 5Rs: Reduce, Reuse, Recycle, Refurbish, and Renew (Table 4).

Table 4. A circular approach consisting of 5R

Reduce	• Eliminating waste in production and supply chains (such as 3D printing) • Virtualization of products and services (such as e-books) • Reducing energy use (such as improving energy efficiency) • Redesign the product to use fewer inputs (such as the use of solid steel in construction)
Reuse	• Sharing existing assets (such as houses, cars, and other equipment) • Use of second-hand goods • Improve asset use by offering products as services
Recycle	• Reusing existing materials • Anaerobic digestion and biochemical extraction for organic waste
Refurbish	• Remanufacture products or components • Longer life cycle with product maintenance
Renew	• Prioritizing renewable energy and materials (such as replacing plastic packaging with paper-based ones)

Source: Ellen MacArthur Foundation, 2012

There are conditions needed for the community to participate in the development of waste sorting that can make economic value in the community, namely the opportunity to build opportunities in development, the ability to take advantage of these opportunities and the willingness to participate. The willingness of the community to participate in waste management is very necessary. This can be done, for example, by providing their own waste bins such as trash cans that match the type of waste, placing the waste they produce regularly in locations that are easily accessible to waste collectors, keeping waste from scattering. Community participation is the participation of the community in carrying out every activity or program established by the government to empower the community, so that the community wants to take an active role in the planning, implementation and maintenance process (Ford and Daviso, 2010). Community participation in waste management programs can reduce the amount of waste generation, problems in the environment and get economic benefits.

A form of community participation in a waste management organization is participation in waste bank socialization. This is useful for the community to be involved in discussions held during socialization by the waste bank. Willingness of the community to contribute to the efforts of collecting, sorting and saving waste to achieve group goals, for example for the construction of mosques and improving the community's economy. Willingness of the community to start learning to manage waste into items that have economic value. Management of the waste bank derives economic benefits in the form of income, which means that implementation is profitable. Cleaning staff is in charge of transporting waste from households to the waste bank. After sorting between organic and inorganic waste, the organic waste is then transported to temporary landfills. Estimated economic benefits for cleaning staff in participating in the transportation of organic waste at the waste bank. Transportation of waste from the waste bank to collectors or marketed products makes economic value. Level of community participation and increase knowledge creativity in the utilization of used waste to be used as selling value. Economic

benefits of waste management are obtained from the sum of the economic benefits for waste bank managers, waste bank members, cleaning staff and labor. This shows that the existence of a waste bank can provide economic benefits by striving to form community independence and self-reliance through the formation of awareness, knowledge and abilities that encourage participation in managing the environment in their community.

3.5.1 Relationship between economy and environment

Environment is an input factor in economic activities. However, the definition of the environment is not limited as an input factor because the production process will also produce outputs such as waste which then becomes an input factor for environmental sustainability. The relationship between the environment and economic activity can be seen in Figure 9.

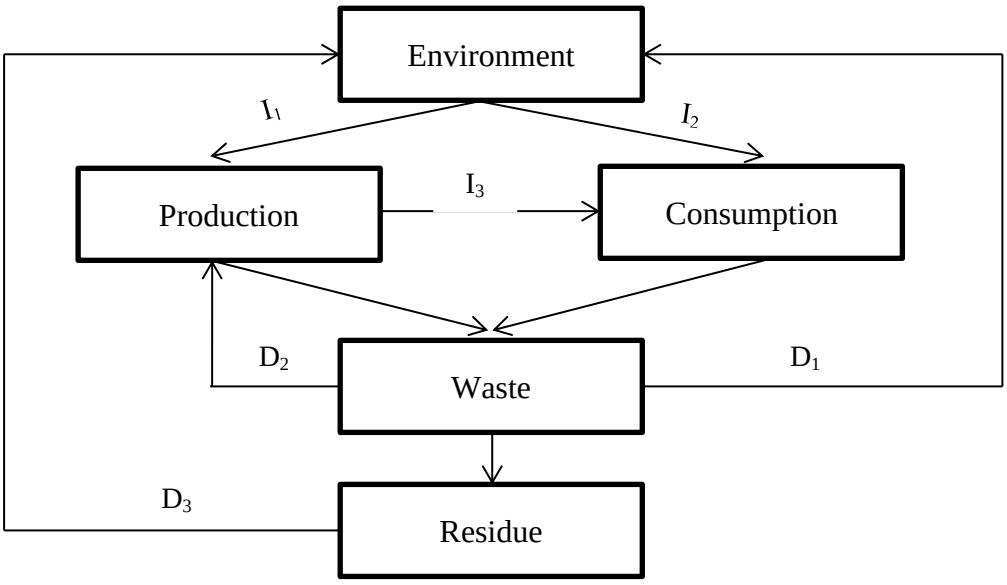

Figure 3. Relationship between environment and economic activity

Source: Mally, 2007

In Figure 3, it can be seen that natural resources (I) produce goods and services for industrial processes based on natural resources (I_1) and those directly consumed by households (I_2). From the industrial process, goods and services are produced which can then be used by households for consumption (I_3). Production activities by industries and consumption by households produce waste (D) that can then be recycled (D_1 and D_2). This recycling procedure is either directly back to nature and the environment, or back to the industry (D_2). From this waste, some components can be recycled and become residual (D_3) which will return to the environment. Economic activities have positive and negative effects on humans and other living things.

Economic activities are usually carried out through increased production processes or industrialization processes. Industrialization process has a positive effect on humans for their needs. But on the other hand, the increase in economic activities causes an increase in waste and other environmental pollution, such as other waste, as shown in Figure 10.

From Figure 4, it can be seen that the relationship between economic activity and environmental pollution has a positive relationship. Vertical axis shows the level of pollution, while the horizontal axis shows the level of economic activity. If economic activity increases, for example from Y_1 to Y_2, it will be followed by an increase in the level of environmental pollution from P_1 to P_2. Economic activities in addition to producing goods and services also produce negative effects, namely pollution and waste.

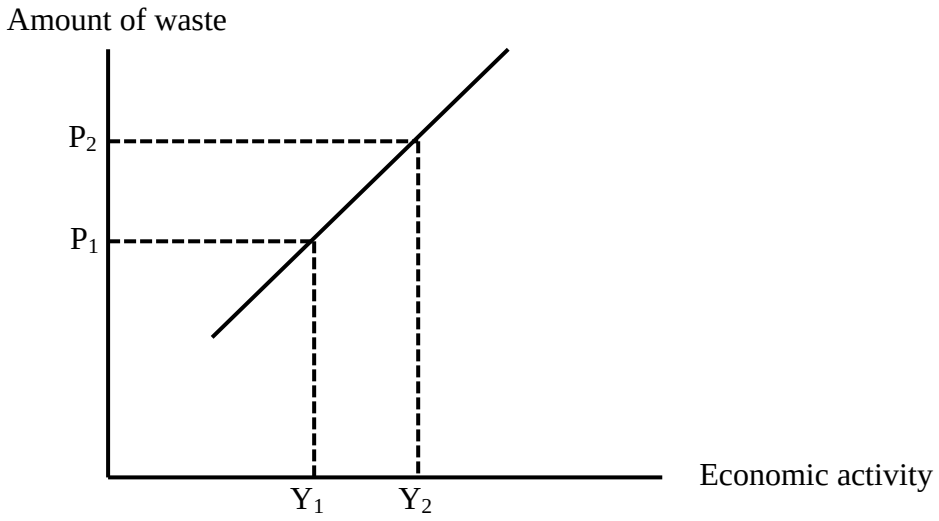

Figure 4. Relationship between environmental pollution and economic activity

Source: Yu *et al.*, 2022; Kılıç, Soyyiğit and Bayrakdar, 2023

3.6 Solid Waste Status in Indonesia

Waste generation in Indonesia continues to increase from year to year in line with population growth and urbanization. In metro and big cities, waste generation is estimated to reach >500 tons/ day on average, while in medium cities with a population of <500 people/ ha, the middle waste generation is 100-300 tons/ day (Central Bureau of Statistics, 2020). The composition of Indonesia's waste is organic waste (food waste, wood branches and leaves) at 57%, plastic waste at 16%, paper waste at 10%, and others (metal, textiles, leather rubber, glass) at 17% (Syafrudin, Masjhoer and Maryono, 2022). The average percentage of waste processed by composting for cities in Indonesia by means of 16.2%, about 11 million tons/ year (Ministry of Environment and Forestry, 2018). Improvements do not match this increasing waste generation in waste management infrastructure and efforts to reduce waste at the source (application of the 3R

concept: reduce, reuse, recycle). The quality of service is still limited (regarding costs, human resources, facilities, infrastructure, and community participation). From an institutional perspective, the roles of operators and regulators are unclear. Landfill as a place for the final waste processing often gets public protest and rejection. As a result, environmental quality is decreased, especially in urban areas.

Volume of waste increases from year to year due to population growth, technological improvement, and socio-economic activities of the community, as illustrated in Table 5. regarding the projected increase in waste based on population (Abdel-Shafy and Mansour, 2018). Same opinion was expressed by Liu et al. (2019); the growth of the volume of waste is closely related to the rapid increase in population from rural to urban areas. In addition, landfill is still the primary choice in waste management in Indonesia. Most waste is directly transported and disposed of in landfills without pre-treatment; only about 10% of the waste is used (Ministry of Environment and Forestry, 2018).

Table 5. Projected increase in waste volume based on total population

Year	Projected Total Population in Million	Waste generation projection (liter/day)	Waste generation projection (m^3/day)	Waste generation projection (m^3/year)
2010	238,5	150.255.000	150.255	54.832.125
2015	255,4	160.902.000	160.902	58.729.230
2020	271	170.730.000	170.730	62.316.450
2025	284	178.920.000	178.920	65.305.800
2030	296,4	186.732.000	186.732	68.157.180
2035	305,6	192.528.000	192.528	70.272.720

Source: Central Bureau of Statistics, 2020

Rapid population growth in urban areas has increased the amount of waste generation. From studies and evaluations that have been carried out in cities in Indonesia, it can be identified the main problems in the management of municipal solid waste, including (Damanhuri, Handoko and Padmi, 2014):

(a) Urban population growth provides a logical consequence of the increasing complexity of the solid waste problem.
(b) Increasing population density demands better methods/ patterns of waste management.
(c) Heterogeneity of the urban population's socio-cultural level adds to the problem's complexity.
(d) The situation of funds and the relatively low priority of handling from local governments is a common problem on a national scale.
(e) Shifting food handling techniques, such as non-biodegradable packaging such as plastic.
(f) Limited appropriate human resources are available to deal with the waste problem.
(g) Prolonged moving waste equipment design development

(h) Community participation, in general, is still not well-directed and well-organized.

(i) Waste management concept is sometimes unsuitable to be applied, and the possibility of modifying the idea is not open in the field.

Until now, the paradigm of waste management used is collect-transport and throw away. In contrast, the main mainstay of a city in solving waste problems is landfilling. The government tends to pay less serious attention to landfills, so there are cases of landfill failure. The government seems to think that its landfills can solve all waste problems without paying proportional attention to these facilities; landfills can be a time bomb for the government. Landfill operations in Indonesia are mostly still in an open dumping system. Clause 44 of Law Number 18 of 2008 concerning Waste Management mandates that no later than 2013, every regional/ city government will have a representative landfill that meets technical and environmental principles (sanitary landfill).

In the early 1990s, the Indonesian Ministry of Public Works introduced the transition method using a controlled landfill system, especially for small and medium-sized cities, by delaying the closing time to 5 to 7 days. However, most waste managers in districts/ cities still consider this method expensive. A landfill that has been designed and prepared as a sanitary landfill will quickly turn into open dumping if the landfill manager does not consistently apply the applicable regulations. In addition, another challenge faced in developing a solid waste management system in Indonesia is the low level of access to dependable waste services. There is still a gap in waste services between the SDGs targets in 2015, 70%, with the existing achievement of 56.2%.

Urban waste management in Indonesia still uses a pattern of transporting and disposing of waste (Kinantan, Rahim Matondang and Hidayati, 2018). Waste from houses or commercial areas is collected at temporary storage sites coordinated by the neighborhood association or local managers. After the waste reaches the temporary storage, it is put into a container which is then transported using a truck to the landfill (Kubota, Horita and Tasaki, 2020). Some of the problems that often arise include the increasing community resistance to waste disposal facilities over the past eight years (Agamuthu and Babel, 2023). This can happen because the promised sanitary landfill system is not implemented properly, the reason is the limited land so that the open dumping system is implemented (Munawar *et al.*, 2018).

According to data Ministry of Environment and Forestry (2018), access to solid waste services in Indonesia at the national level reaches 86.73% (this value includes total waste management: fulfilling and not fulfilling). Table 6. shows the achievement of access to waste management in Indonesia, consisting of rural, urban, and national accomplishments. In addition to the low coverage of waste services in several cities, the Government of Indonesia is also still facing challenges, including the lack of facilities and infrastructure, the absence of a management

agency that handles explicitly waste, the lack of budget allocations provided by the local government as a result of this sector not being become a priority in regional development, the behavior of people who have not implemented clean and hygienic living behavior, and weak law enforcement. Law Number 18 of 2008 concerning Waste Management mandates reducing and handling waste. It was reinforced by the Regulation of the Minister of Public Works Number 3 of 2013 concerning the Implementation of Facilities and Infrastructure for Handling Household Waste and Types of Household Waste which mandates sorting and storage from the source of the waste.

Table 6. Achievements of access to waste handling in Indonesia

Access to Waste Handling Achievements	2010	2013	2018
Rural	73,70 %	72,60 %	82,00 %
Urban	87,40 %	87,00 %	91,43 %
National	80,50 %	79,80 %	86,73 %

Source: Ministry of Health of the Republic of Indonesia, 2018

Based on the Medium-Term National Development Plan (RPJMN) 2015-2019, the Government of Indonesia has set a universal access target in the sanitation sector, namely increasing population access to proper sanitation (domestic wastewater, solid waste, and environmental drainage) to 100% at the level of basic needs. In solid waste, the targets are reducing waste by 20-35% and transportation and final waste processing by 65-80%. In achieving the target of universal access, appropriate policies and strategies are needed by involving the active role of the community and development partners, including the private sector and donors from abroad, to obtain alternative sources of financing, in addition to those available from the Revenue Expenditure State Budget (APBN) funds.

3.6.1 Old paradigm of waste management (Collect - Transport - Dispose)

This system is implemented based on Indonesian National Standards. Specifications used are Indonesian National Standard (SNI) Number T-12-1991-03 concerning Waste Management Procedures in Settlements, Indonesian National Standard (SNI) Number T-13-1990 concerning Technical Management Procedures for Urban Waste and Indonesian National Standard (SNI) Number S-04-1993-03 concerning Waste Generation Specifications for Small and Medium Cities in Indonesia. Operational techniques of urban waste management consisting of containerization activities up to final disposal must be integrated as shown in Figure 5.

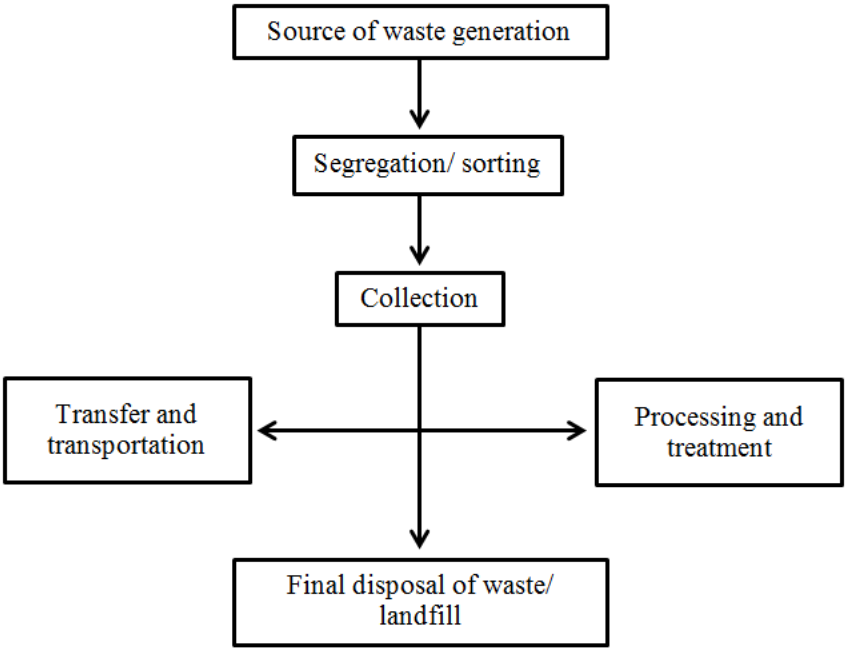

Figure 5. Schematic of waste management operational engineering system with old paradigm
Source: Departemen Pekerjaan Umum, 1990

In order to support the success of waste collection operations, it is necessary to have a container that should be made by the homeowner. Containers should be placed in such a way that it is easy for the workers to collect them regularly and hygienically. Time of waste disposal can be done in the morning, afternoon, evening or at night and is adjusted to the time of collection by officers so that the waste does not settle for too long. Waste collection is the way or process of taking waste from the waste storage container to the temporary disposal site. Temporary disposal sites used are usually containers with a capacity of 10 m^3, 6 m^3, 1 m^3, transfer depots, masonry tubs, used 200 liter drums, and others. Placement of these temporary disposal sites is adjusted to the existing field conditions.

Waste transportation is the stage of carrying waste from the transfer location or directly from the waste source to the final disposal site. Transportation pattern is based on a waste collection system that is carried out based on a transfer system (transfer depot). Transport vehicles leave the pool directly to the transfer location to transport waste to the landfill. From the landfill, the vehicle returns to the transfer depot for the next collection.

Container system waste collection is carried out for temporary non-fixed or movable disposal, with its transportation pattern (Gustiabani and Lingga, 2023):

(a) Container emptying pattern method I

Vehicles from the pool carry the empty containers to the containers to replace them and pick them up directly and take them to the landfill. Vehicles carry the empty containers from the landfill to the next container location, and so on until the last rhythm.

(b) Container emptying pattern method II

Vehicle from the pool goes to the first filled container to transport the waste to the landfill, the empty container is returned to its original place and goes to the next filled container to be transported to the landfill.

(c) Container emptying pattern method II

Vehicle from the pool goes to the first container, pours the waste into the compactor truck and places it back in its original location empty. Vehicles go to the next container location until the truck is full and then taken to the landfill, and so on until the end of the rhythm.

Principle of final disposal of waste is to destroy domestic waste at a final disposal site in such a way that it does not cause disturbance to the surrounding environment after processing. Waste treatment method that has been applied to most landfill sites in Indonesia is the landfill system (Sudibyo *et al.*, 2017). Final disposal of waste with an open dumping system is a simple method of disposal where waste is only spread on a location, left open without security and abandoned after the location is full. This method is no longer recommended considering the many potential environmental pollution it causes such as the development of disease vectors such as flies, rats and so on, air pollution by the odors and gases produced, water pollution due to the amount of leachate (waste liquid) that arises, the potential for fire hazards that are difficult to extinguish and poor environmental aesthetics due to dirty scenery (Vaverková, 2019).

Controlled landfill method is an improved or enhanced open dumping system. In this method, after the landfill is full of waste, it is covered with soil. As long as the landfill is not covered with soil, the conditions are similar to the open dumping system. Sanitary landfill method is a standard method used internationally where the closure of waste with a layer of soil is carried out every day at the end of the operation so that after the operation ends there will be no visible waste piles (Ambat, 2020). Combustion is a chemical waste treatment method with an oxidation process (combustion) with the intention of stabilizing and reducing the volume and weight of waste (Faaij, 2004).

3.6.2 New paradigm of waste management

New paradigm waste management is a modern concept because it applies efforts to prevent, reuse and recycle waste. If waste generation has been collected, the waste will be sorted between organic and non-organic waste and then recycled which allows it to be used as a new product so that only small-scale residues are disposed of in the final disposal site (Abdel-Shafy and Mansour, 2018).

One of the goals of modern waste management is to minimize and prevent waste generation from its main source, namely waste generated from household activities, this can be done by not using

plastic. Household waste must be managed properly so as not to cause the potential for large amounts of waste generation. This waste management technique if the waste has been mixed then it must be sorted. Waste generated from every daily household activity is sorted and separated based on the waste category (organic and non-organic) in their respective homes (Fadhullah *et al.*, 2022). Community is encouraged to reuse household waste before it is collected in temporary disposal sites as residual waste to be disposed of in landfills. As explained in Figure 6.

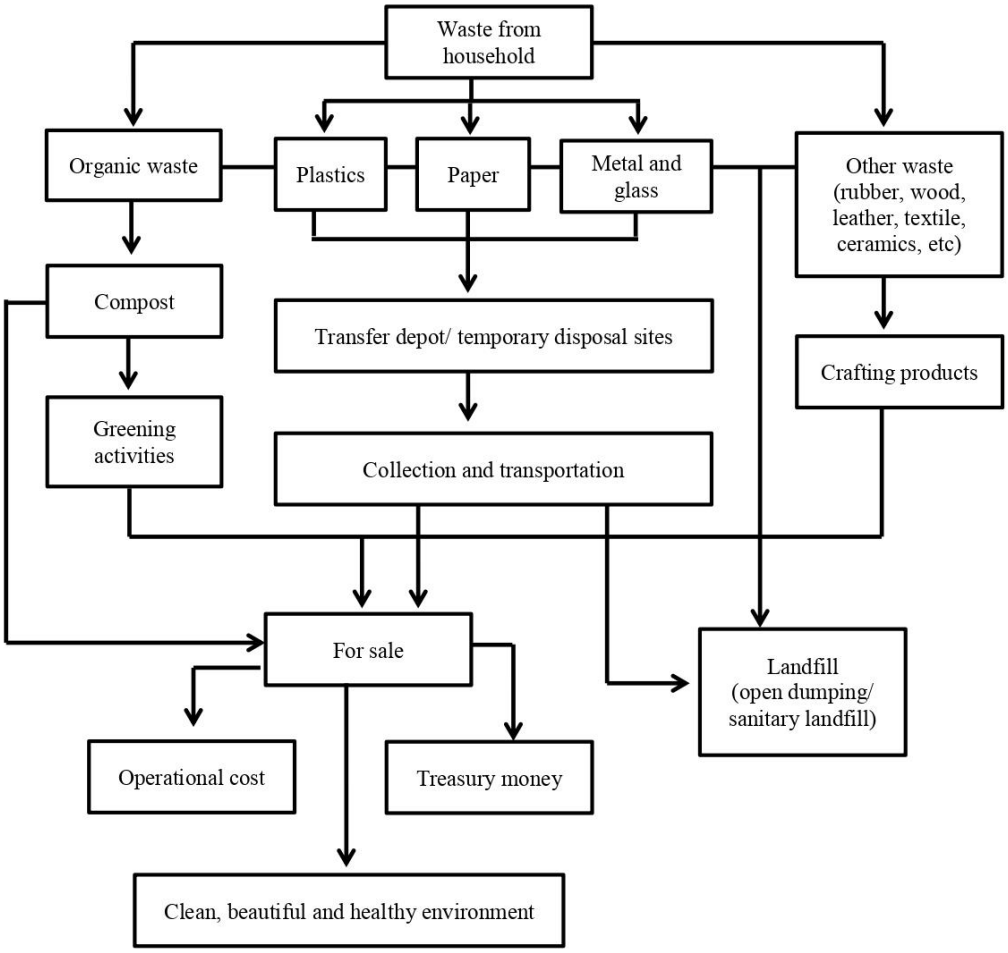

Figure 6. Technical management of household waste

Source: Ministry of Environment and Forestry, 2018

Waste must be managed properly as a form of community responsibility for the waste generated from household activities, namely by sorting waste categories before being reused or becoming residues that will be disposed of in temporary disposal sites (Qomariyah and Hamid, 2023). Residue produced is usually transported using a wheelbarrow and cator by the waste management officer. Waste management officers come from the community itself with a total of 3-5 officers. Although there are waste management officers, the community remains the most

important part of this waste management because the source of waste comes from the household activities of the community itself which must be managed in collaboration with the government. Law No. 18/2008 on waste management emphasizes that the main priority that must be done by all parties is how to reduce waste as much as possible. Part of the waste or residue from waste reduction activities that still remain is then processed (treatment) or landfilling. However, long before the waste that inevitably produces residue, efforts must be made to sort waste according to its type and characteristics. According to Law No. 18/2008 on waste management, there are 2 main groups of waste management. First is waste reduction which consists of limiting waste generation (R1), reuse (R2) and recycling (R3). The second is related to waste handling, which consists of sorting in the form of grouping and separating waste according to the type, amount, and/or nature of the waste. Collection in the form of taking and transferring waste from waste sources to temporary shelters or waste processing sites. Transportation by carrying waste from the source and/or from temporary landfills or from integrated waste processing sites to the final processing site. Processing by changing the characteristics, composition, and amount of waste. Final processing of waste by safely returning waste and/or residues from previous processing to environmental media (organic pesticides).

3.7 Government Policies to Encourage Circular Economy Implementation in Indonesia

The Indonesian government has established a policy to encourage the implementation of a circular economy in the context of sustainable economic development and environmental quality improvement. This is contained in the narrative of the 2020-2024 National Medium-Term Development Plan (RPJMN), which contains plans for the preparation of an integrated waste management system from upstream to downstream, and the development of green industries (Pemerintah Republik Indonesia, 2020). Based on a report by the Ministry of National Development Planning, there are several industrial sectors in Indonesia that will be the focus in implementing the circular economy, namely food and beverages (packaging); clothing or textiles/garments; construction services; plastics; and electronics (Kementerian PPN, Embassy of Denmark and UNDP, 2021). The purpose of this policy is also to achieve target 12 (sustainable consumption and production) which overlaps with targets 6, 7, 8 and 15 of the Sustainable Development Goals (Kementerian PPN, Embassy of Denmark and UNDP, 2021).

In addition to the RPJMN, based on information from the Indonesia Circular Economy Forum (ICEF), there are government policies that encourage the implementation of the circular economy, namely Presidential Regulation Number 97 of 2017 concerning National Policy and Strategy for the Management of Household Waste and Waste Similar to Household Waste

(Perpres Jaktranas) (Pemerintah Republik Indonesia, 2017). Broadly speaking, the Perpres Jaktranas contains two things, namely the policy direction for reducing and handling household waste and similar household waste; and strategies, programs, and targets for reducing and handling household waste and similar household waste (Pemerintah Republik Indonesia, 2017). The policy target based on the Perpres Jaktranas is the reduction of household waste and similar household waste by 30 percent or 20.9 million tons; and the handling of household waste and similar household waste by 70 percent or 49.9 million tons in 2025, compared to the projected waste generation of 70.8 million tons (Pemerintah Republik Indonesia, 2017). To realize this, the appendix of the Presidential Regulation on Jaktranas contains several policy scopes, strategies, and programs that involve multi-stakeholders, namely ministries and institutions at the central level, and regions (provinces, cities/districts) in a synergistic manner.

Waste management policies are also regulated in Presidential Regulation No. 83/2018 on Marine Debris Handling. In this Presidential Regulation, there is an Action Plan for Handling Marine Debris 2018-2025 which is embodied through strategies, including a national movement to increase awareness of stakeholders; management of land-based waste; coastal and marine waste management; financing mechanisms, institutional strengthening, supervision, and law enforcement; and research and development. The existence of this policy is a follow-up to the government's commitment to tackle marine plastic waste by 70 percent by 2025 (Pemerintah Republik Indonesia, 2018).

In its development, the National Action Plan (NAP) on circular economy is currently being developed. This development is urgently needed because the implementation of circular economy is not solely a business matter but also requires a framework that is supported by policy makers, namely the government (UNDP, 2019). In the formulation of circular economy policies, there are three main scopes of regulation formulated, first, product manufacturing which includes managing the process of reuse, repair, recycling, providing added value within the framework of the manufacturing business; second, support for research and innovation of environmentally friendly technology; and third, the provision of an environmentally friendly product market ecosystem (Milios, 2018). In addition, due to its relationship with environmental conservation efforts and social aspects, the formulation of policies requires the application of risk mitigation (Johansson, Velis and Corvellec, 2020).

Circular economy implementation policy is multi-sectoral and requires synergistic involvement of relevant stakeholders as it requires an upstream to downstream regulatory scheme (Klein, Ramos and Deutz, 2020). Stakeholders in policy making consist of government, business/industry, academia, and civil society within the framework of the quadruple helix model (Hysa *et al.*, 2020). The government functions as a regulator in providing support for legal

frameworks, financing mechanisms, and governance. Academia functions in research activities and innovation of environmentally friendly technologies, and scientific recommendations. The business sector, industry functions in the development of business models, products, and the application of sustainable production. Civil society functions in information literacy to the public, liaison of cooperation networks, and monitoring and evaluation of policies. The model is illustrated in Figure 7. (Cordova, 2020).

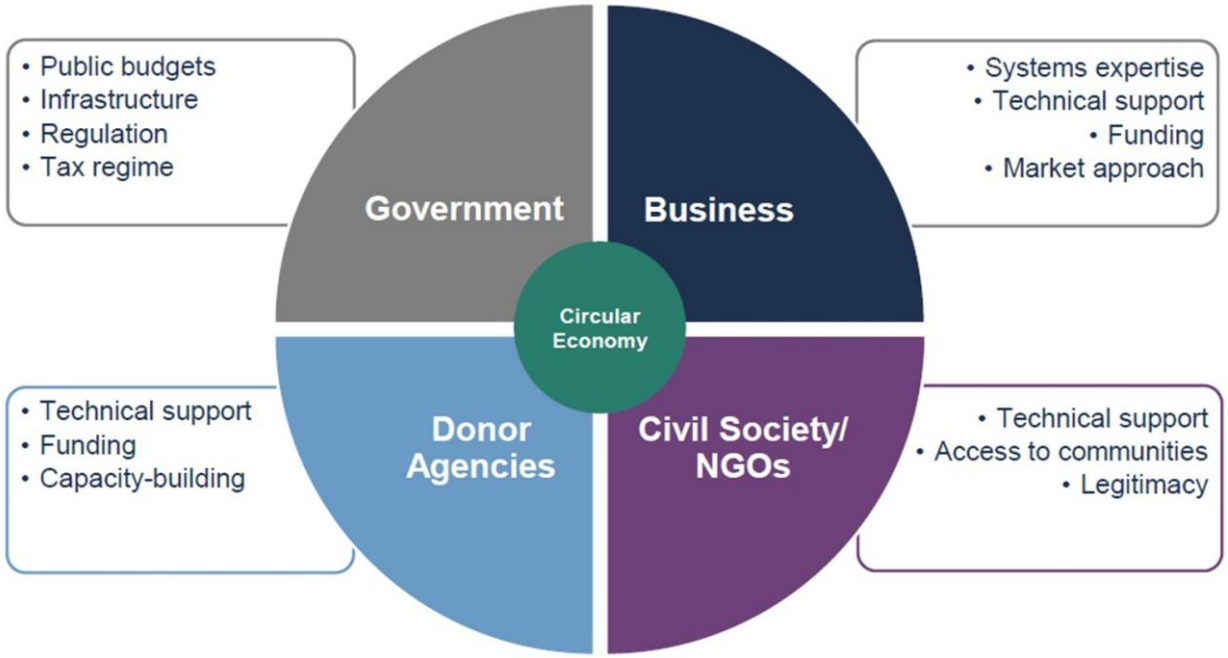

Figure 7. Quadruple helix model in circular economy implementation

Source: Cordova, 2020

3.8 Benefit of Integration Circular Economy Into Waste Management in Indonesia

Increased production has created a problem that requires landfills. Waste is generated when extracting raw materials and during the production process. The most effective way to reduce the waste problem is to reduce the amount and toxicity of the waste. But with the increasing desire for a better standard of living, humans are becoming more and more consuming and generating more waste. Consequently, the community must look for effective waste management methods and ways to reduce the amount of waste that needs to be disposed of in landfills. Following Law No. 18 of 2008, waste management aims to improve public health and environmental quality and make waste a resource.

Increase in waste resulted in increasingly complex problems for managing waste. Solid waste management is complex because it includes many technologies and disciplines. Includes

technology associated with control over the generation, storage, collection, transfer and transportation, processing, and disposal of waste, which is acceptable and by the principles of public health, economics, engineering, aesthetics, and other environmental considerations, including responsiveness to the general public (Thyberg and Tonjes, 2015).

According to Yukalang et al. (2017), waste management will fail when too much waste is in the wrong place, is not close enough to sell, or is not recycled enough. The solution lies in redesigning products, packaging, and processes suitable for input into the value chain. Initiatives and tools can also support successful sustainable waste management strategies. One example of a developing waste management strategy is the circular economy approach (Viva *et al.*, 2020). The circular economy aims to generate economic growth by maintaining the value of products, materials, and resources in the economy for as long as possible, thereby minimizing the social and environmental damage caused by the old linear economic approach (Velenturf and Purnell, 2021). Not just better waste management with more recycling, a circular economy encompasses a broad range of interventions across all sectors of the economy (Kirchherr, Reike and Hekkert, 2017).

3.8.1 Five priority sectors offer great potential for a circular economy approach in Indonesia

Applying a circular economy in Indonesia has potential in five sectors: food and beverage, textiles, construction, wholesale and retail trade (focusing on plastic packaging), and electrical and electronic equipment (Kementerian PPN, Embassy of Denmark and UNDP, 2021). These sectors play an essential role in the Indonesian economy. Based on data published by the Central Bureau of Statistics 2020b, these five sectors contributed more than 30 percent of Indonesia's GDP and employed more than 43 million people or a third of Indonesia's workforce in 2019 (Table 7).

Table 7. Five focused sectors contribute ~33% of GDP and employ over 43 million people

Sectors	GDP in 2019 (Indonesian trillion)	Percentage of total (%)	Workforce in 2019 (Million)	Percentage of total (%)
Food and Drink	1014	9,3 %	13,1	10,1 %
Textile	146	1,3 %	1,2	0,9 %
Construction	1108	10,1 %	7,6	5,9 %
Wholesale and retail	1168	10,7 %	19,8	15,3 %
Electrical and electronic equipment	204	1,9 %	1,6	1,3 %
Total	3640	33,2 %	43,3	33,5 %

Source: Central Bureau of Statistics, 2020

These five sectors generated a significant amount of waste in 2019. Food wastage and waste, excluding food waste during production, amounts to nearly 57.4 million tonnes. Waste volume is

expected to increase to 82 percent by 2030 in several sectors (Figure 8) (Kementerian PPN, Embassy of Denmark and UNDP, 2021). The increase in a waste generation comes from physical waste, such as food scraps or textile waste, and structural destruction, such as empty office space or inefficient energy use. Two key factors will likely drive waste generation growth in the next decade. First, by 2030 there will be an additional 90 million Indonesians who will join the class of consumptive society, which will drive demand for basic consumer needs (e.g., packaged food) and discretionary consumer products (e.g., electronics and clothing) (Oberman *et al.*, 2012). Second, by 2019 and 2030, more than 35 million people will live in urban areas (Wang *et al.*, 2019).

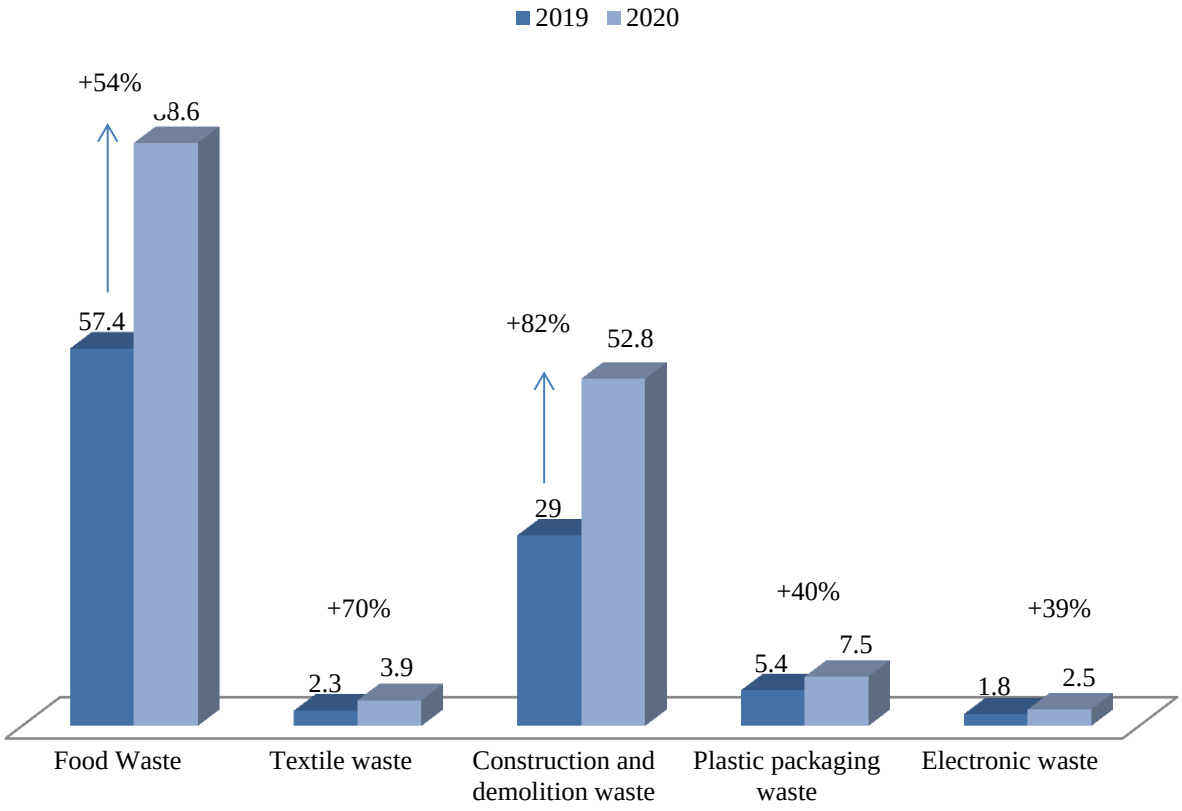

Figure 8. A predicted increase in waste generated by five key sectors

Source: Kementerian PPN, Embassy of Denmark and UNDP, 2021

According to government estimates, by 2045, around 67 percent of Indonesia's population will live in urban areas (Minister of National Development Planning, 2021). To minimize this, the Indonesian government has made various efforts. One of them is moving the national capital from Java Island to Kalimantan Island which aims to equalize development. In addition, there are several policies that are currently prioritized by the Indonesian government. First, efforts to improve the education aspect in villages can be done by promoting vocational secondary education. Vocational secondary education will certainly be very helpful in developing the

talents of students who are practical in accordance with the desired specialization. In addition, this aspect can also be used to encourage the emergence of an entrepreneurial spirit so that it can provide jobs in the village. Of course, the presence of jobs in the village will reduce the rate of urbanization that occurs. Secondly, the accessibility aspect (in terms of transportation) in the village is an important factor to support economic activities, despite the fact that many villages in our country still have poor accessibility. This accessibility serves as a connecting route for the flow of goods and services (economic activity). Through the improvement of accessibility in villages, such as the construction of roads and bridges as well as telecommunication facilities, the empowerment of potential resources in the village can be optimally developed. The ease of access can also be a pull factor for the government and the private sector to partner and develop the superior aspects of the village concerned. Third, empowering the main potential of the village can be done to reduce urbanization. One way to develop the potential of the village can be done in accordance with existing resources such as agribusiness potential and tourism aspects. The agribusiness potential in the village can be developed and marketed in a more "selling" way so that the potential can be empowered. Urbanization drives demand for consumer products and the construction of houses and other public infrastructure, generating waste.

3.8.2 A waste track in five sectors is an opportunity for a circular economy

Based on the potential and opportunities of 5R circularity in each sector, prioritization can be done in each sector (see Table 8). These opportunities are identified based on available evidence that they can make the most impact in the sector and then revised in consultation with stakeholders. For example, "Reduce" and "Recycle" have the most significant opportunity for the food and beverage sector. As a result, four opportunities are prioritized, namely as follows: (1) reducing food wastage after harvest; (2) reducing wastage and waste in the food supply chain; (3) reducing food waste generated by consumers; and (4) reducing food waste and waste in the production process. Impact of each prioritized opportunity, an estimate of the current adoption rate in Indonesia is used. For example, the recycling rate of e-waste in Indonesia is estimated at 5 percent (Mairizal *et al.*, 2021).

Table 8. Potential and opportunities for 5R circularity in every sector

5R	Food and Drink	Textile	Construction	Wholesale and retail trade	Electrical and electronic equipment
REDUCE	Reduce food wastage at the postharvest stage	Reduction of waste at the production stage	Reduce waste with existing processes	Reduce the use of plastic packaging	Virtualization and dematerialization of physical goods
	Reducing food wastage in the food supply chain		Reduce waste with new processes		
	Reduce consumer		Optimization of		

	food waste		building use		
REUSE		Product reuse	Reusing materials	Reusing plastic packaging	Product reuse
RECYCLE	Process materials from food waste during the processing stage	Recycle materials	Recycle materials	Redesigning plastic packaging so that it can be recycled Increase the recycling rate of plastic packaging	Recycle materials
REFURBISH					Increase product life and reduce product obsolescence Product repair
RENEW		Using materials that are more environmentally friendly	Using materials that are more environmentally friendly Design and build buildings that are more resource-efficient	Using materials that are more environmentally friendly	

Source: Kementerian PPN et al., 2021

High potential
Medium potential
Low potential

Estimates of the potential for each circular economy opportunity are made based on national and international references that can be applied to Indonesia in 2030. Indonesia can increase its e-waste recycling rate and match India's e-waste recycling rate of 21 percent by 2030 (Sari, Masruroh and Asih, 2021). Case studies elsewhere are also used to understand this potential further. Pilot projects in Benin, Cape Verde, India, and Rwanda have documented a reduction in food wastage of more than 50 percent during field trials with various storage techniques and low-cost handling practices (Kitinoja and AlHassan, 2012). Thus, it can be assumed that if Indonesia invests in improving infrastructure and food handling (e.g., temperature control during storage), it can reduce postharvest food wastage by as much as 50 percent by 2030.

A successful transition to a circular economy can help Indonesia reduce waste production at the source and increase recycling rates. A circular economy can also reduce waste by up to 50 percent by 2030 (compared to a "business as usual" scenario). Depending on each sector type, recycling rates can also increase by 4-17 percent compared to the business as usual scenario. The analysis shows that the circular economy can contribute significantly to government efforts to reduce waste in five sectors (Figure 9) (Kementerian PPN, Embassy of Denmark and UNDP, 2021). Indonesia can reduce food waste and waste by 50 percent and recycle as much as 4 percent of its remaining food waste and waste compared to the business as usual scenario. Indonesia can reduce textile waste by 14 percent and recycle 8 percent of the remaining textile waste. Indonesia can reduce construction and demolition waste by 5 percent and recycle the

remaining 15 percent of construction and demolition waste. Indonesia can reduce plastic packaging waste by 21 percent and recycle 17 percent of the remaining plastic packaging waste. Indonesia can reduce e-waste by 13 percent and recycle 16 percent of the remaining e-waste.

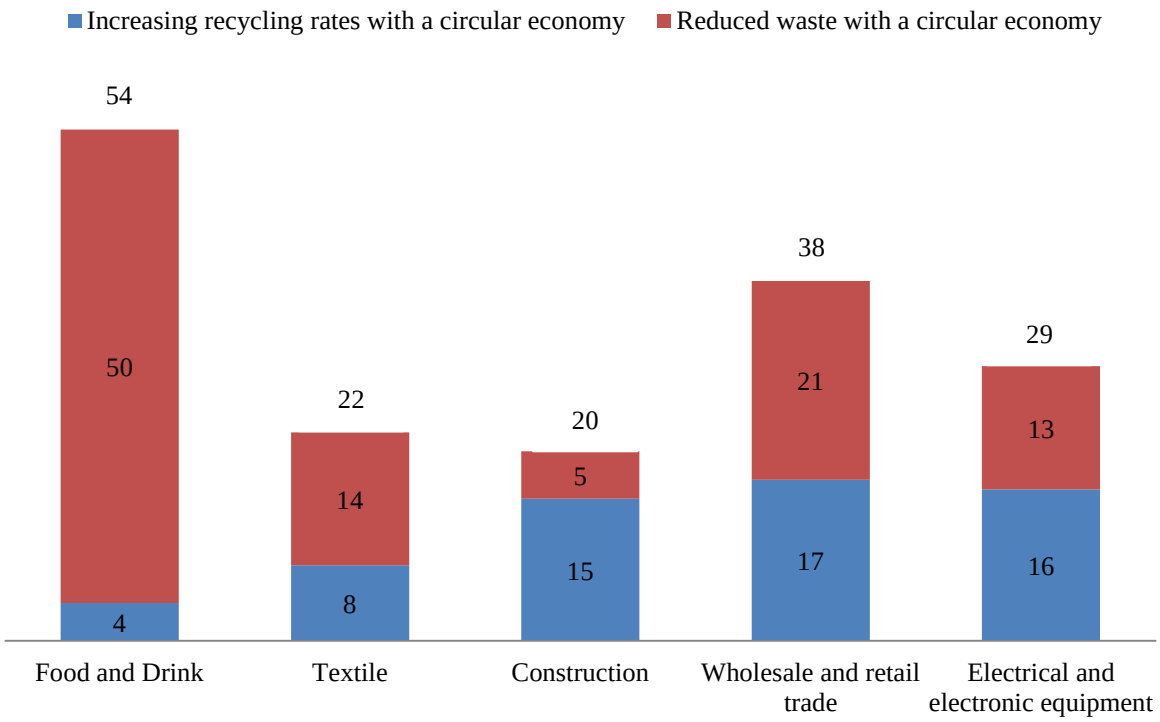

Figure 9. Prediction of the circular economy's contribution to waste reduction in Indonesia

Source: Kementerian PPN, Embassy of Denmark and UNDP, 2021

3.8.3 Potential significant economic impacts from the implementation of a circular economy

Generating less and recycling more waste can significantly impact the Indonesian economy (Figure 10). Based on two methodologies (model based on the IO table and the Incremental Input-Output Ratio), the transition to a circular economy could increase Indonesia's gross domestic product (GDP) by IDR 593 – 638 trillion (equivalent to USD 42 – 45 billion) in 2030 (equal to 2.3 to 2.5 percent of projected GDP in 2030) (Central Bureau of Statistics, 2023). Economic value can be more significant than the "business as usual" scenario in which Indonesia does not actively implement a circular economy.

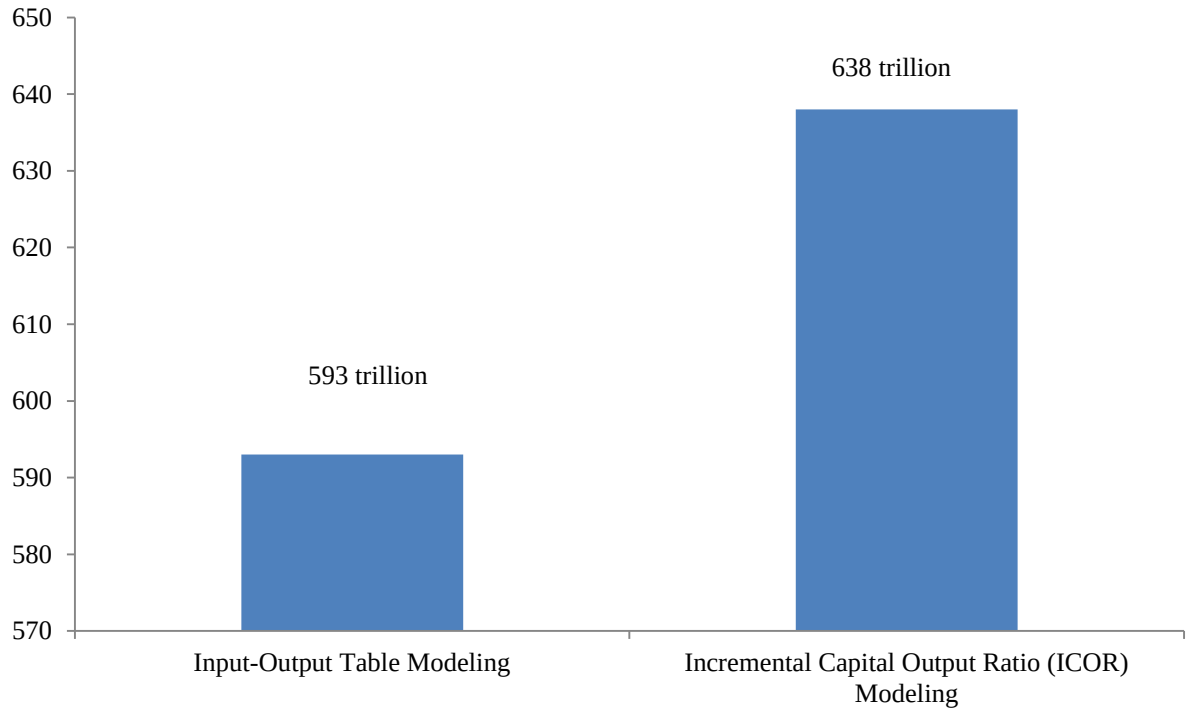

Figure 10. The impact of the circular economy on Indonesia's GDP in 2030

Source: Kementerian PPN, Embassy of Denmark and UNDP, 2021

There are two essential aspects of the analysis. The latest government estimates show Indonesia's GDP will decrease by 1.6 and 2.2 percent in 2020 (Muhyiddin and Nugroho, 2021). The International Monetary Fund (IMF) projects Indonesia's GDP to grow as high as 6.1 percent in 2021 (International Monetary Fund, 2020). However, the relationship between GDP growth and waste volume in the five priority sectors cannot be directly assessed, and COVID-19 may have a more significant impact on waste and circular opportunities (which is difficult to quantify) than the current linear economy. For example, declining household income could decrease the demand for electronic goods, reducing e-waste. There is an increase in the percentage of formal workers working from home, and digitalization can potentially increase the volume of electronic waste (Dutta *et al.*, 2021). Other results are also uncertain whether reducing the volume of e-waste caused by a decrease in income can outweigh the increase in the volume of e-waste caused by digitalization. It is essential to update this analysis once the impact of COVID-19 on the Indonesian economy and the volume of waste is known. It aims to determine the potential of the circular economy after COVID-19.

Five sectors derive broad economic benefits from adopting circular economic opportunities. These economic benefits are derived from reducing waste in critical sectors, where savings can be utilized in other sectors (health, education, recreational services, etc.). It is important to note that although the economy will benefit significantly from the adoption of a circular economy, it does not mean that the economic output of these five sectors will be higher. Understanding the

exact financial impact in each sector is problematic because it depends on how businesses and consumers take advantage of the savings resulting from adopting a circular economy. For example, if consumers reduce their food waste (which causes their food spending to also decrease due to the food savings they make) and decide to use the excess spending money to buy food of higher quality and price, then the impact on the food sector and drink to be positive.

However, if the savings are used in other sectors, the effect on the food sector can be damaging. Adopting business efficiency opportunities linked to a circular economy can generate significant returns to GDP and employment growth in the industry. However, if adopting a circular economy causes a decrease in consumer demand, this will drive economic growth to slow down compared to business-as-usual conditions. The results of this study need to be studied further, especially the impact on the broader economy, especially on spending caused by savings from the circular economy. However, these findings reinforce the importance of understanding the existence of winners and losers in the transition process to a circular economy. Businesses and policymakers must prepare themselves to ensure that the transition that is carried out prioritizes the principles of justice and does not harm several things in the Indonesian economy and society.

Indonesia's micro, small and medium enterprises (MSMEs) can also be essential in supporting the economic transition. In 2018, there were 64 million MSMEs in Indonesia, employing around 61 million people (equivalent to almost 90 percent of the total workforce) (Handayani, Dewi and Satriawan, 2020). MSMEs also contributed nearly 60 percent of Indonesia's GDP in 2017 (Tambunan, 2019). A circular economy can reduce MSME production costs with greater production efficiencies and waste reduction and result in new business models, such as a focus on recycling and recovery, which can provide significant opportunities for MSMEs (Plant Chicago, 2020). In addition, MSMEs can play a better role than large companies in adopting a circular economy. MSMEs are also better positioned to adopt a circular business model that requires a decentralized production system, such as a business model that focuses on reusing, recycling, and repurposing resources locally. MSMEs have great opportunities to be close to ending consumers than large companies (Bark *et al.*, 2017). However, most MSME companies are still micro or small in Indonesia. According to the Central Bureau of Statistics, micro and small enterprises contributed 98% of all MSMEs in 2016 (Central Bureau of Statistics, 2023). Small and medium enterprises have limited knowledge regarding adopting a circular economy, so the government will need a policy concept that is adaptive to business variations in MSMEs. To support micro and small enterprises, the government could consider these enterprises part of supply chain partnerships that have proven effective in Europe.

3.8.4 A circular economy can reduce carbon emissions and clean water use significantly

There is great potential for reducing carbon dioxide emissions, other greenhouse gases (CO_2e), and consumption of clean water, which can help Indonesia achieve its low-carbon and sustainable development targets. For example, based on a document submitted by the Government of Indonesia to the United Nations Framework Convention on Climate Change (UNFCCC), Indonesia is committed to reducing CO_2e emissions by 29 percent from the "business as usual" scenario with its resources up to 41 percent with international assistance by 2030 (Ministry of Environment and Forestry Directorate General of Climate Change, 2021). Based on this analysis, a circular economy can help Indonesia achieve around 15 percent of its lowest target to reduce CO_2e emissions and approximately 11 percent of its highest target of reducing CO_2e emissions by 2030 relative to a "business as usual" scenario.

The reduction in CO_2e emissions is driven by several factors, including lower waste generation, alternative feedstocks that are more energy-efficient, and increased resource lifetime. Emissions released during various products related to the five focus sectors (e.g., food, textiles, plastics) are expected to account for the emissions that could be avoided if Indonesia adopted circular opportunities. A circular economy can offer several other environmental benefits besides preventing carbon emissions. For example, increasing the reuse of textile products can reduce the production of textile materials and reduce the negative impact of wastewater pollution from textile factories. Increased food waste recycling through composting can help avoid land degradation and reduce the need to clear new land in pursuit of fertile agricultural land elsewhere (Ayilara *et al.*, 2020).

3.8.5 A circular economy can create 4.4 million green jobs cumulatively and significant savings on household expenditure

Opportunities in a circular economy across five sectors could generate 4.4 million net jobs between 2021 and 2030 in Indonesia. The additional jobs generated from the circular economy could contribute to Indonesia's target of generating three million jobs annually as stated in Law no. 11 of 2020 concerning Job Creation (Omnibus Law) (Kementerian PPN, Embassy of Denmark and UNDP, 2021). It is important to note that there will be winners and losers in this job transition. For example, some jobs upstream (such as mining or manufacturing) are likely lost. However, new jobs were created in the downstream sector (e.g., in other manufacturing or service sectors). The direct impact on employment in the five sectors could vary from -14 to 2.5 million jobs under different scenarios. Policies are needed to support job transition by retraining sector-shifting workers to create new jobs. The action plan preparation will review this required policy response in detail. Despite its direct impact on employment, a circular economy limiting

carbon emissions and reducing environmental pollution is an investment in human capital, health, and productivity. A report from Pollution and Health Metrics by the Global Alliance on Health and Pollution revealed 232,974 pollution-related deaths in Indonesia (Global Alliance on Health and Pollution, 2019). By reducing the demand for raw materials directly from nature, a circular economy can reduce deaths related to this pollution.

In addition, the circular economy can also contribute to reducing gender disparities in Indonesia. According to the Organization for Economic Co-operation and Development (OECD), the poor labour conditions faced by the female workforce and situations that force them to be exposed to more hazardous products and chemicals are examples of why women are disadvantaged in a linear economy (OECD, 2020). Even plastic pollution has a disproportionate impact on women. Women are more likely to be exposed to the adverse effects of plastic pollution than men, such as direct exposure to emissions from incineration or waste disposal because they are more likely to be responsible for household tasks that expose them to waste pollution. Furthermore, women workers in the informal waste treatment sector often face health and safety risks and violence and discrimination in the workplace (WIEGO, 2018).

Circular economy can also create significant economic opportunities for Indonesian women. According to the International Labor Organization (ILO), the emergence of "green jobs" can offer opportunities for women's empowerment (International Labour Organization, 2015). Particularly relevant for the textile sector in Indonesia, where women account for 58 percent of employment (Horne and Andrade, 2017). Underscores the importance of a circular economy to create benefits for gender equality in Indonesia and the need for a women-centered, proactive approach to policy development. Based on this analysis, 75 percent of the total net employment created by the circular economy in Indonesia in 2030 can empower women. Potential for job transfer from sectors that are generally male-dominated (e.g., construction, where women only occupy two percent of total employment) to jobs that will be created in sectors that women dominate typically (e.g., education, human resources, health and social work, which allows households to have a more significant allocation of storage that can be reinvested).

3.9 Research Framework and Definition of Concept

Research conceptual framework is a method used to explain the relationship or relationship between the variables to be studied (Moleong, 2018). In this study, researchers will examine the integration of solid waste management with circular economy model in Surabaya, Indonesia.

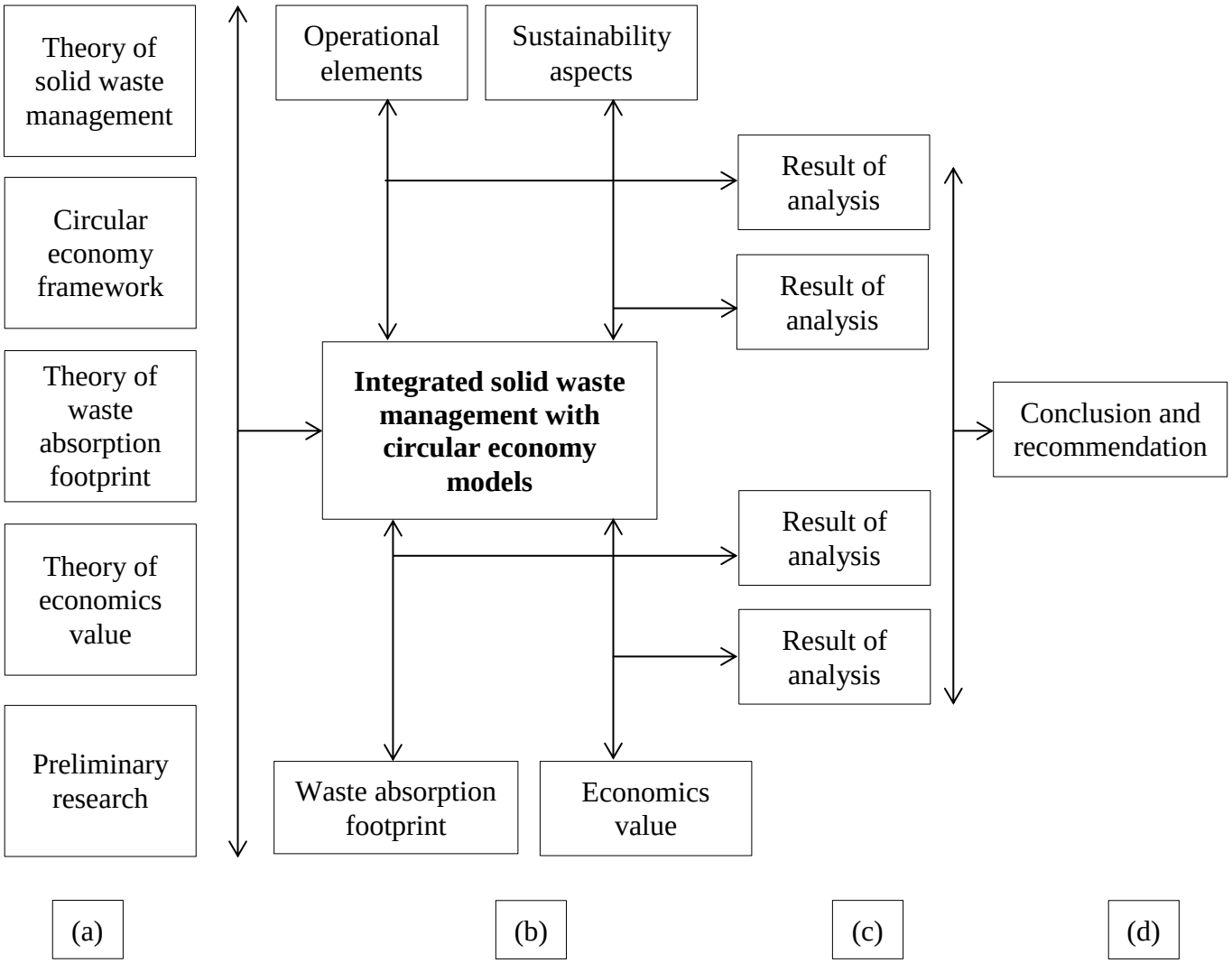

Figure 11. Research framework

Source: Primary Analysis, 2024

For the purpose of the study, the following is a definition of the concept of the study:

Sustainable Solid Waste Management describes basic principles and recent advances for handling solid waste in an environmentally sustainable way (Shekdar, 2009). Solid waste poses problems of quantity the sheer amount is increasing around the world but also of environmental impact, especially with the introduction of materials harmful to ecosystems. A more sustainable waste management approach prioritizes practices such as reduced production, waste classifications, reuse, recycling, and energy recovery over the common practices of landfilling, open dumps, and open incineration (Abubakar *et al.*, 2022).

Sustainability is a condition where the fulfilment of present need can meet the balance of environmental preservation, social responsibility and economic practice with concern to intergeneration justice (Luna-Nemecio, Tobón and Juárez-Hernández, 2020).

Solid waste has been defined variably by institutions or individuals for management or academic

research purposes. It can be regarded as the domestic and industrial refuse, waste, or any disregarded materials produced in pursue of daily lives and industrial activities; it can be hazardous or nonhazardous (Trivedi *et al.*, 2020). In this study solid waste term is used interchangeable with waste.

Circular economy solid waste management is waste management by making structural changes by integrating circular economy concepts to create long-term stability, maximising the use and circulation of commodities, resources, and nutrients while providing economic, environmental, and social benefits that help the public and private sectors to meet the short-term and long-term goals of the SDGs (Ellen MacArthur Foundation, 2012).

Waste absorption footprint is a methodological approach to calculate the land and water uptake of waste generated by human activities with results in average hectares by scaling different land use types proportionally (Jiao *et al.*, 2013).

Economic value is the potential for economic added value from solid waste management with a circular economy approach and is one way to assess the impact of implementing a new concept from an economic perspective (Mandpe *et al.*, 2022).

4 MATERIAL AND METHODS

The purpose of a research design is to provide a study plan that allows an accurate assessment of the cause and effect relationship between independent and dependent variables as well as a strategy to answer the research question or to test the research hypothesis. This chapter will explain the materials and methods used to obtain answers to the research questions. The results of the research conducted will provide recommendations related to improving municipal waste management in Surabaya City using a circular economy approach.

4.1 Research Frameworks

A research framework is used to implement the steps taken during the research. The research framework is used as a guide to make the research more focused on the scope of the research. The research framework includes step-by-step activities to achieve the research objectives. The research framework consists of seven steps as seen as follows:

Step 1: Briefly describe the objectives of the research project

The objective of this research is to provide recommendations for the implementation of integrated solid waste management with a circular economy model towards viable and sustainable management.

Step 2: Determining the research object

The research object in this study is the implementation of current solid waste management practices in Surabaya City.

Step 3: Establish the nature of the research perspective

This research proposes by analyzing a solid waste management framework with a circular approach as a feasible and sustainable solution to address the less than optimal performance of solid waste management in Surabaya City. The implementation opportunity of solid waste management with circular approach will be analyzed from the perspective of waste absorption footprint and economic potential as a communication tool for the local government to consider the suggestions generated from this research. Therefore, this research is categorized as a type of change research (Verschuren & Doorewaard, 2010).

Step 4: Determining sources of research perspectives

This research uses various scientific literature references in developing its conceptual model in order to obtain new scientific findings. The theories that will be used in this research are shown in Table 9:

Table 9. Source of research perspective

Key concept	Theories and documentation
Solid waste management with circular economy approach	Theory of solid waste management Circular economy framework Theory of waste absorption footprint Theory of economics value

Source: Primary Analysis, 2024

Step 5: Create a schematic presentation of the research framework

The research framework is described in Figure 11.

Step 6: Formulate the research framework

The research framework was formulated as follows:

(a) Analyze the theories of solid waste management, waste absorption print, economics value, circular economy framework, preliminary research and produce an integration of solid waste management with circular economy model.

(b) This model is used as a criterion to assess solid waste management practices in Surabaya City.

(c) The results of the analysis based on the specified criteria are used as the basis for drawing conclusions and potential recommendations.

(d) Research conclusions that resulted in recommendations were used to improve the sustainability of solid waste management practices in Surabaya City.

Step 7: Checking whether the model requires any change

There is no indication that any change is required.

4.2 Research Strategy

A research strategy is an overall approach relating to the ideation, planning, and execution of a study over a period of time to obtain answers to research questions (Johannesson and Perjons, 2014). This type of research is a case study with a single case study design. Single case study is a study whose research direction is centred on one case or one phenomenon only. In single case studies, the purpose or focus of the research generally leads directly to the context or core of the problem. Another approach used is a literature study to identify data sources that will be used to measure the environmental impact of solid waste management.

4.2.1 Research unit

The research unit for this study is solid waste management and the unit of observation is solid waste management practices. Surabaya City will serve as the locus of the case study in this research.

4.2.2 Selection of research unit

Informants and respondents in this research were selected based on their influence and impact on solid waste management in Surabaya City and represent interests or projects related to this research, among others:

- Surabaya City Environment Agency
- Surabaya City Cleanliness and Green Open Space Agency
- Other actors related to solid waste management in Surabaya City
- Respondents, which are divided into two types of data obtained include:

(a) In this study, author narrowed down the population, which is the total number of residents in Surabaya City of 2,880,284 respondents by calculating the sample size using the slovin formula. Slovin's formula is usually used to calculate and determine the exact sample when conducting research in any field. The existence of this sample does not mean the entire subject or target in the research, but only a representative that provides an overview of the population to be observed. This formula is very suitable for sampling in Surabaya City with a large population so that it can represent the entire existing population. With these considerations, the results of the study in this research can be accounted for according to scientific principles. The sampling technique in the study used cluster random sampling. Area-based random sampling or cluster random sampling is one of the sampling methods used where the population does not consist of individuals, but consists of groups of individuals or clusters. So that the unit selected as a sample is not an individual, but an organized group of individuals. This technique was chosen considering the complexity of Surabaya City so it is necessary to do clusterization by considering 5 regions in Surabaya City namely North Surabaya, West Surabaya, South Surabaya, East Surabaya and Central Surabaya. Respondents were asked about routine solid waste activities by sending questionnaires. The slovin formula to determine the sample is as follows:

$$n = \frac{\mathrm{N}}{1 + \mathrm{N}\,(e)^2} \qquad (9)$$

Equation 9 Slovin formula

Where:

n = Sample size/ number of respondents

N = Population size

e = Percentage of allowance for the accuracy of sampling errors that can still be tolerated

e = 0,1

In the Slovin formula there are the following provisions:

The value of e = 0.1 (10%) for large populations

The value of e = 0.2 (20%) for small populations

Population in this study includes a large population, so the percentage of allowance used is 10% and the calculation results can be rounded to achieve suitability. To find out the research sample, with the following calculations:

$$n = \frac{2.880.284}{1+2.880.284\ (0.1)^2}$$

$$n = 99{,}99 \approx 100 \text{ respondent}$$

Based on the calculations, the sample of respondents in this study was adjusted to 100 respondents, this was done to facilitate data processing using SPSS and for better test results.

(b) Household samples were also used in this study to estimate the waste generation and composition of each household. The basis for determining the number of household samples required is Indonesian National Standard (SNI) 19-3964-1994. Stratified random sampling is used to fulfill the requirement of the methodology. The formula to determine the household sample is as follows:

$$S = C_d \sqrt{P_s} \quad (10)$$

Equation 10 Household samples formula

$$S = 0{,}5 \sqrt{2.880.284}$$

$$S = 848,56 \approx 849$$

Where:

S = Number of required sample (people)

C_d = Housing coefficient (for Surabaya=0.5)

P_s = Population (people)

From the statistical bureau also the number of people in each household known = 4,66 people/house. This is means total of sample is:

$$\frac{849}{4{,}66} = 182{,}18 \approx 182 \text{ household}$$

4.2.3 Research boundary

Research boundaries are based on the researcher's decision regarding the variables to be included and excluded. The limitations of this study limit the research to be more

controllable and relevant for researchers so that the research objectives can be answered. The following boundary is set for this research:

- Administrative boundary of Surabaya City was used to localise the discussion (only actors that live in the city were interviewed, the absorptive capacity is provided globally however only land with absorptive capacity used to calculate the environmental impact)
- Environmental opportunity was discussed from the perspective of waste absorption footprint
- Economic impact calculation results based on secondary data
- This research does not cover other issues that are not relevant to the research objectives.

4.3 Research Material

Research data were collected from interviews, questionnaires and field measurements. Several informants were interviewed with semi-structured interviews regarding waste management in Surabaya City. Respondents involved in this in-person interview are:

- 1 informants from Surabaya City Environment Agency
- 1 informant from Surabaya City Cleanliness and Green Open Space Agency
- 1 informants from Surabaya main waste banks
- 1 informants from compost businesses
- 1 informant from waste collection sector
- 1 informant from local creative industry

To collect data on the understanding of community awareness and participation in waste management, it is necessary to use a questionnaire. Slovin formula in section 4.3.2 is used to determine the number of respondents in this study. Estimated waste generation is calculated using the Indonesian Standard Method number 19-3964-1994 as a baseline for calculating the waste absorption footprint. The data required and the method of accessing it identified through a series of research sub-questions are presented in Table 10.

Table 10. Research methodology

Research question	Required information	Sources of information	Method to access data	Data analysis
		Primary Data		
Whatarethose current solid waste management practices?	Factors that influence the elements of solid waste management	Interviews: The head of environmental department, cleanliness division, waste subdivision, landfill operation unit and the citizen of Surabaya, Indonesia	Questionnaire and Semi-structured interviews	Descriptive statistics
What are the challenges for circular solid waste management implementation in Surabaya, Indonesia?	Circular economic implementation barriers	**Primary and Secondary Data** Document: Report of waste management in Surabaya, Indonesia Interviews: The head of environmental department, people from waste banks, waste collection, composting sector and creative industry	Content analysis, Semi-structured interviews, and questionnaire	Descriptive statistics
What are those feasible circular solid waste management frameworks to Surabaya, Indonesia ? And how to enable it?	Factors that influence the aspects of solid waste management	**Primary Data** Interviews: The head of environmental department, agriculture department officer, youth, sport and tourism department, people from waste banks, waste collection, composting sector and creative industry	Questionnaire and Semi-structured interviews	Descriptive statistics
What is the impact of current solid waste management practice from the perspective of waste absorption footprint and economics aspects? Is there any opportunity by integrating the circular economy principles in solid waste management from the perspective of waste absorption footprint and economics ?	The characteristic and amount of waste generation	**Primary Data** Data collection	Survey and Calculate using Standard Method of Indonesia number 19-3964-1994	Descriptive statistics
	The amount of manageable solid waste	**Secondary Data** Document: Environmental Management Performance Information Document of Surabaya City	Content analysis	Descriptive statistics
	The fuel consumption for waste handling	**Secondary Data** Document: Environmental Management Performance Information Document of Surabaya City	Content analysis	Descriptive statistics
	The method of waste collection, treatment, and disposal	**Primary Data** Interviews: The head of cleanliness division waste sub-division and the landfill operation unit	Questionnaire and Semi-structured interviews	Descriptive statistics
	The environmental condition	**Secondary Data** Document: Environmental Management Performance Information Document of Surabaya City	Content analysis	Descriptive statistics

	The environmental impact of solid waste and operation	**Secondary Data** Literature: Journal or book related with that topics	Content analysis	Descriptive statistics
	The economics impact of implementation of circular solid waste management	**Secondary Data** Document: Environmental Management Performance Information Document of Surabaya City	Content analysis	Descriptive statistics

Source: Primary Analysis, 2024

4.4 Data Analysis

This section presents the evaluation process of the data obtained in the field based on the analytical framework. The data analysis method and framework are described in this section.

4.4.1 Method of data analysis

This research uses a mixed method research approach by combining the advantages of quantitative and qualitative methods with the aim of producing a more complete and in-depth picture of the problem under study. This research uses quantitative methods to collect numerical data about the problem under study, and then uses qualitative methods to understand more deeply why these problems occur and how these problems occur. Thus, this research method can provide a more complete and in-depth picture of the problem under study see Table 11.

Table 11. Data and method of data analysis

Sub research questions	Required information	Sources of information	Research method
Whatarethose current solid waste management practices?	Current implementation of solid waste management practice in Surabaya City	Head of Surabaya City Environment Agency, cleanliness division, waste sub-division, landfill operation unit and citizen of Surabaya City	Semi-structure interviews, document analysis
What are the challenges for circular solid waste management implementation in Surabaya, Indonesia?	Barriers to achieving high performance solid waste management	Surabaya main waste banks, compost businesses, waste collection sector, local creative industry, Head of Surabaya City Environment Agency, cleanliness division, waste sub-division, landfill operation unit and citizen of Surabaya City	Semi-structure interviews, observation, content analysis, and questionnaire
What are those feasible circular solid	Suitable solution to overcome the barriers	Surabaya main waste banks, compost businesses, waste	Document analysis, semi-structured interviews

waste management frameworks to Surabaya, Indonesia ? And how to enable it?		collection sector, local creative industry, Head of Surabaya City Environment Agency, cleanliness division, waste sub-division, landfill operation unit and citizen of Surabaya City	
What is the impact of current solid waste management practice from the perspective of waste absorption footprint and economics aspects? Is there any opportunity by integrating the circular economy principles in solid waste management from the perspective of waste absorption footprint and economics ?	Parameters for waste absorption footprint measurement and economics benefit for implementation of waste management with circular economy approach	Data collection from household in Surabaya City and document literature	Measurement, semi-structure interviews, document analysis and content analysis

Source: Primary Analysis, 2024

4.4.2 Analytical framework

Analitycal framework conceptualizes the research problem and its objectives and incorporates them into relevant theoretical knowledge and related outcomes of the research. A schematic presentation of the analytical framework is presented in Figure 12.

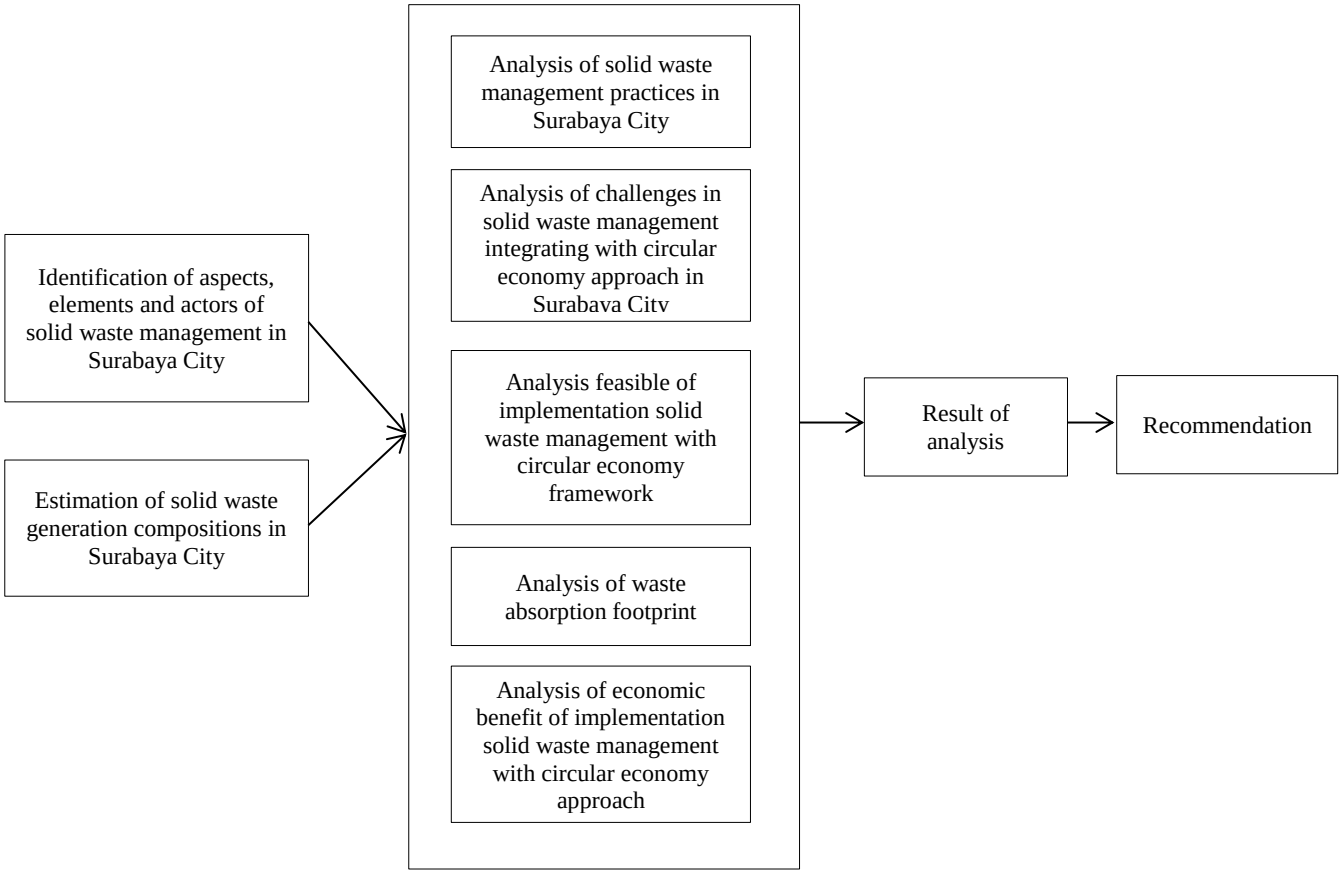

Figure 12. Analytical framework scheme

Source: Primary Analysis, 2024

The data analysis steps were as follows:

(a) The first stage is to understand the current waste management practices in Surabaya City by analyzing each element that affects waste management performance. Survey information collected from informants was also used as supporting data.

(b) Identifying sector challenges from non-governmental organizations in integrating waste management with circular economy approach in Surabaya City.

(c) Identifying the necessary policies in integrating solid waste management with circular economy approach in Surabaya City based on research results and in-depth study results by researchers. The recommendation script is the main output shown to the Mayor of Surabaya City.

(d) Last stage is to analyze the waste absorption footprint and economic benefits of implementing integrated solid waste management with circular economy approach. Indonesian National Standard (SNI) number 19-3964-1994 was used as the basis for calculating the waste absorption footprint by calculating data on collection, transport,

treatment, disposal, and recycling practices gathered during the first stage. Then calculate the environmental consequences of implementing solid waste management with circular economy approach, the level of environmental pollution from current solid waste management practices, and calculate the amount of waste absorption footprint based on data collection conducted by researchers. For economic benefit data, researchers used document reviews from the Surabaya City Environment Agency regarding information on the performance of environmental management in Surabaya City in 2021.

Main research questions can be answered to some extent through the above-mentioned steps. Limitations of the study will be discussed in the conclusion and suggestions section.

5 RESULTS AND DISCUSSIONS

5.1 Overview of Study Area

Before discussing the condition of solid waste management in Surabaya City, here is an overview of Surabaya City. Surabaya City as the capital city of East Java Province is center of almost all activities, mainly commercial, financial, trade, information, social, health, and administration. This makes the surrounding satellite cities connected to the city of Surabaya. Surabaya also has a large and well-known airport and seaport in Indonesia, making it a connecting city between eastern Indonesia and western Indonesia. Seeing the many activities that are created in Surabaya City, makes the emergence of demands and expectations of Surabaya City. Surabaya City is located between 07°09' to 07°21' south latitude and 112°36' to 112°54' east longitude. The area is low-lying with an elevation of 3-6 meters above sea level, except, in the south with an elevation of 25-50 meters above sea level. In the national spatial plan, Surabaya City is designated as a specific area and is one of the national activity centers which has an important role as a driver of economic growth in the surrounding area. From a regional point of view, the regional structure of East Java Province establishes Surabaya City as the Provincial Capital with a dominant function as the center of commercial, financial, trade, information, administrative, social, and health activities.

Surabaya City has administrative boundaries on each side. Some are adjacent to the Regency / City and some are bordered by the strait. The administrative boundaries of Surabaya City are as follows:

North : Java Sea and Madura Strait

East : Madura Strait

South : Sidoarjo Regency

West Side : Gresik Regency

Details administrative boundaries if Surabaya City can also be seen in Figure 13. The total area of Surabaya City is 33,451 Ha which is divided into 31 sub-districts and 154 villages. The sub-district with the largest area is Sukolilo Subdistric located in East Surabaya with an area of 3,016.25 Ha, while the sub-district with the smallest area is Simokerto sub-district with an area of 270.04 Ha located in Central Surabaya (Central Bureau of Statistics Surabaya City, 2021).

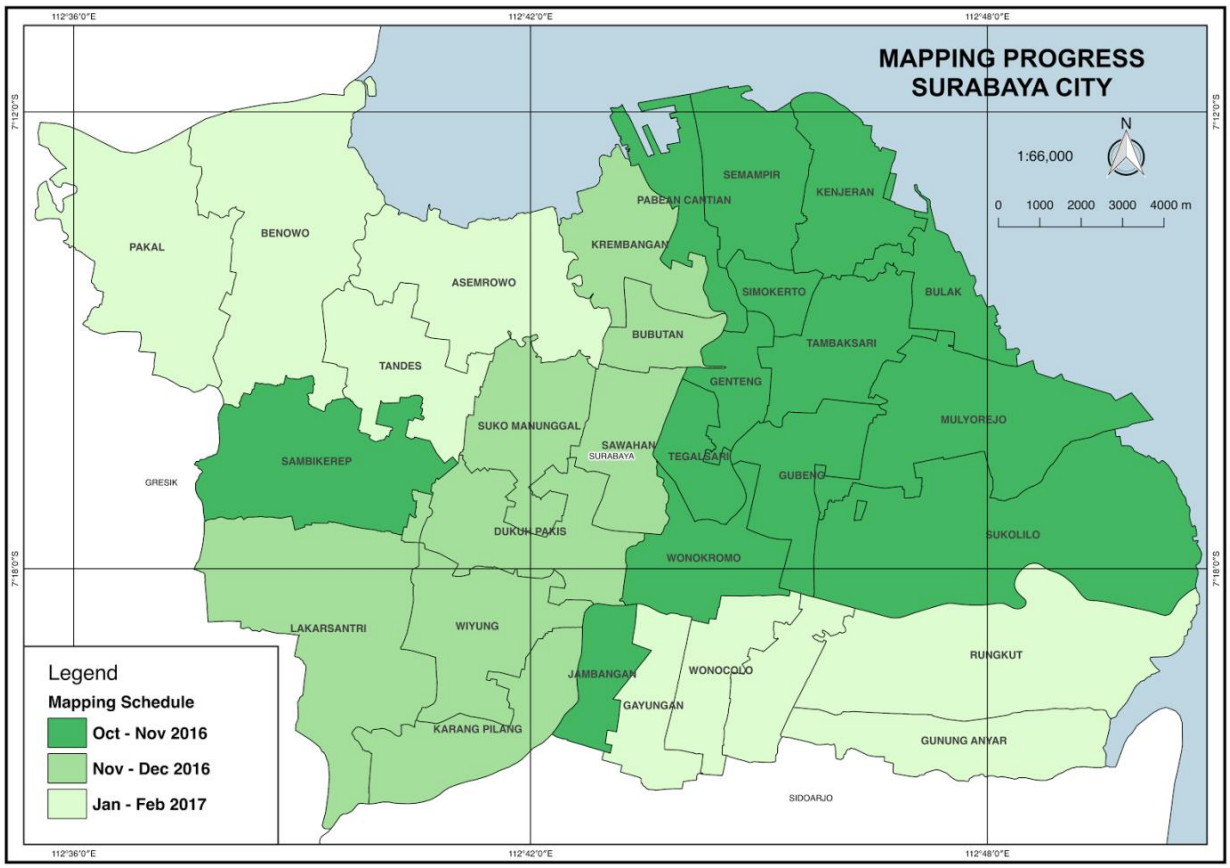

Figure 13. Administrative map of Surabaya City

Source: Central Bureau of Statistics Surabaya City, 2021

Currently, the population of Surabaya City is recorded at 2,970,730 people. This figure has increased by 20,500 people from the previous year. In practice, this fluctuating population certainly has an impact on the surrounding environment, this impact can be in the form of meeting daily needs, development to the need for fulfillment of health aspects. The activities carried out by the community certainly have an impact on the environment, both positive and negative. This requires the city government to take maximum care of the surrounding environment.

5.2 Current Pratice of Solid Waste Management in Surabaya City

Identification of stakeholders in solid waste management practices in Surabaya City starts from the community as a waste producer, government as a waste manager, private sector and education sector such as schools and universities. Practice of waste management in Surabaya City is officially and structurally the responsibility of Cleanliness and Green Open Space Agency. The establishment of the Surabaya City Cleanliness and Green Open Space Agency is in accordance with Regional Regulation Number 6 of 1997 with the title of the Cleanliness

Agency and Regional Regulation Number 8 of 1997 with the title of the Parks and Cemeteries Agency. Then in 2005 it was established as the Cleanliness and Parks Agency through Regional Regulation Number 14 of 2005. Furthermore, in 2006, Mayor Regulation Number 1 of 2006 concerning the Elaboration of Duties and Functions of the Cleanliness and Parks Agency was issued. Then continued in 2008, namely the issuance of Regional Regulation Number 14 of 2008 concerning Regional Apparatus Organizations, and finally the formation of the Cleanliness and Green Open Spaces Agency through Regional Regulation Number 16 of 2016. Technical waste management is carried out by the Cleanliness and Green Open Space Agency but in its implementation there are two divisions that are responsible. The cleaning division is responsible for the transportation of waste and waste sourced from road and pedestrian cleaning. The waste management division is responsible for waste utilization, liquid waste management and handling hazardous and toxic waste. Organizational structure of the Cleanliness and Green Open Space Agency can be seen in Figure 14.

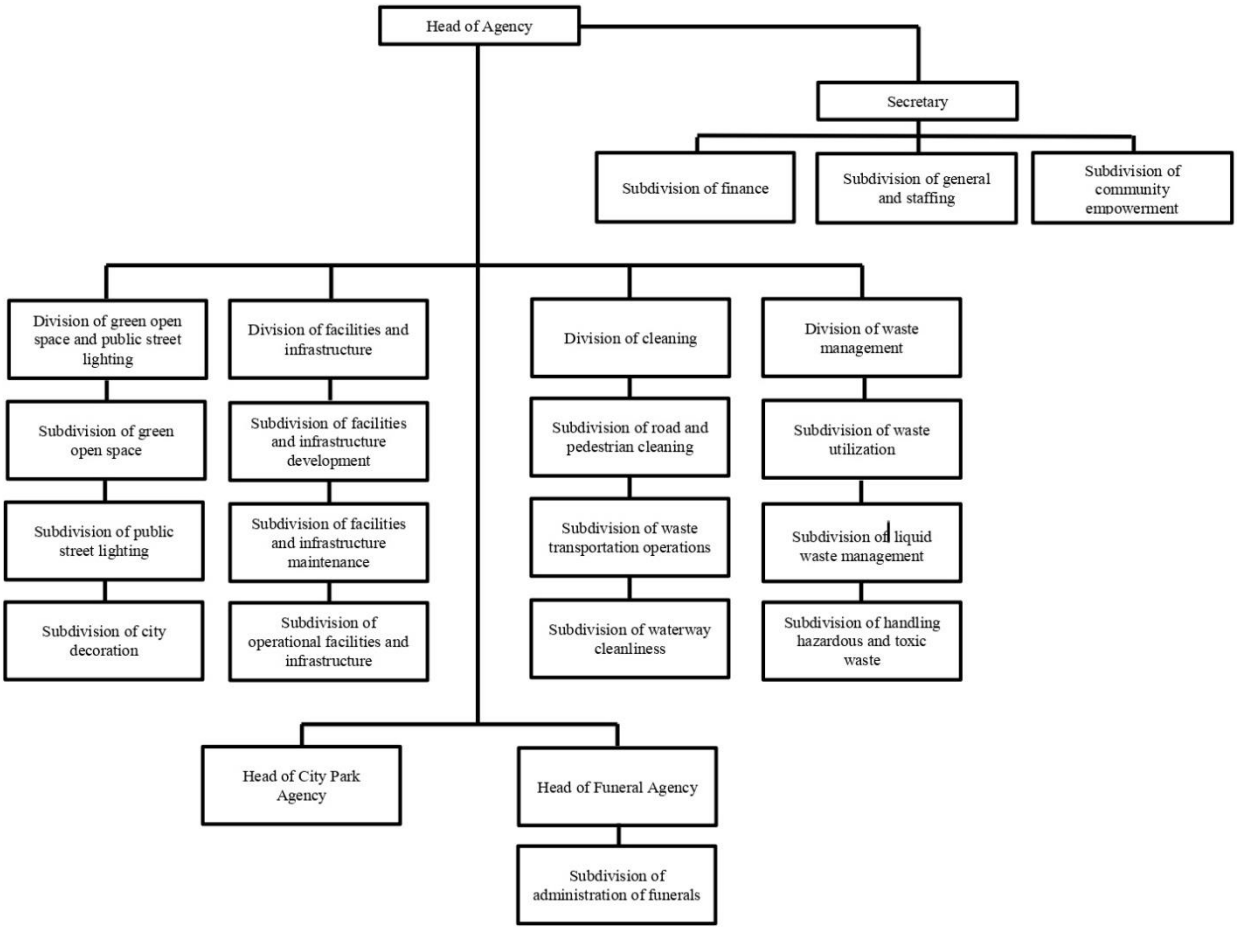

Figure 14. Organizational structure of cleanliness and green open space agency

Source: Primary Analysis, 2024

According to Mrs. Anna Fajriatin as Head of Surabaya City Cleanliness and Green Open Space Agency, the city has made various efforts and programs in reducing waste generation. Solid waste management practices in Surabaya City are among the best in Indonesia. The solid waste management involves several stakeholders with the aim of sustainability. The main stakeholders of solid waste management in Surabaya are summarized in the PLAN-DO-CHECK-ACT (PDCA) matrix presented in Table 12.

Table 12. Stakeholders of solid waste management in Surabaya City

PDCA	Stakeholder	Key unit	Level of operation	Main tasks
Plan	City Development Planning Agency	Department of urban planning, settlement and environment	City	Urban development planning includes: - defining goals - measuring action plans - analyzing results
Do	Cleanliness and Green Open Space Agency	- Cleaning division - Waste management division - Main waste bank	City	- Operation and transportation of solid waste from transfer station to landfill - Material recovery management and composting facilities - Collecting and managing waste from waste bank units
	Community organization	Neighbourhood/ hamlet (RT/ RW)	Village	Operation and transportation of household solid waste to the transfer station
	Private-formal sector	Recycling industry	City	- Managing waste in landfill - Recycling (mainly) plastic waste to produce raw materials
	Informal sector	Waste bank	Village	Management of recyclable household waste, e.g. paper and plastic waste
		Collectors (small scale)	Subdistrict	Recyclable waste collection business by receiving waste from waste bank units and households
		Collectors (big scale)	City	Recyclable waste collection business by accepting waste from main waste banks and small-scale waste vendors
Check	Surabaya City Environment Agency	Supervision and control division	City	Monitor, control, and evaluate the results and processes of municipal solid waste management
Action	Universities and non-governmental organizations	All university in Surabaya City and organization related with waste issues	City	Observe the process and contribute to research and development planning and actively engage in city planning and development deliberations.

Source: Primary Analysis, 2024

Stakeholder responsible for urban development planning in Surabaya City is the City Development Planning Agency. This agency is responsible for the development of policies, technical guidelines for urban development planning, including the urban waste masterplan, in accordance with the 2016-2021 Surabaya City Strategic Plan. This agency discusses all the technicalities of waste management in its strategic plan in detail.

Implementation of waste management in Surabaya City involves not only the Cleanliness and Green Open Space Agency but also community organizations as well as the formal and informal sectors. The formal sector of sustainable waste management in Surabaya City includes Neighborhood/ hamlet (RT/ RW) and recycling industry. Informal sector includes waste banks as well as small and large-scale recycling companies. Waste banks are a common type of community-based waste management in Indonesia. They are managed by community organizations at the sub-district level on a voluntary basis. Waste collected in the waste bank units will then be sold to the main waste bank or small-scale waste collectors. Small-scale waste collectors in Surabaya City are people or small business units that collect recyclable materials (e.g. plastic and paper waste) from waste banks or households and then sell them to large-scale waste collectors.

Agency responsible for checking the process is the Surabaya City Environment Agency. In terms of urban waste management, the agency has the responsibility to monitor, control and evaluate the results and processes of urban waste management. The agency has not addressed plastic waste management in its strategic plan specifically but contributes to environmental monitoring and control measures.

Universities, research institutions, and non-governmental organizations are stakeholders responsible for scrutinizing the implementation of urban waste management in Surabaya City. These organizations are actively involved in city planning through city planning and development deliberations.

5.2.1 Solid waste management elements in Surabaya City

A comprehensive solid waste management system consists of six basic functional elements, including solid waste generation, on-site handling and storage, collection, transfer and transportation, material and resource recovery, and disposal (Rajput, Prasad and Chopra, 2009; Kadafa *et al.*, 2014). In this section we will discuss in depth six important elements of solid waste management in Surabaya City.

5.2.1.1 Solid waste generation

Surabaya City has two categories of solid waste that are of importance in solid waste

management: residential generated solid waste and non-residential generated solid waste. As per Ministerial Regulation of Public Work Number 3/2013, residential solid waste refers to the daily solid waste generated by households, offices, commercial establishments, industrial facilities, and other public activities. This definition excludes fecal slurry and specific types of solid waste. Residential solid waste is gathered from residential areas across the city, whilst non-residential solid waste is collected from commercial districts, workplaces, schools, hospitals, marketplaces, and other public facilities.

According to Table 13, the solid waste production in Surabaya City is predicted to be 0.704 kg/ capita/ day, resulting in a daily generation of 2,032.61 tonnes/ day or 5,761.37 m^3/ day. These figures are based on calculations done by Cleanliness and Green Open Space Agency. More than half (54.31%) of the solid waste is decomposable organic waste, the other components are: paper/ paper materials (14.63%), plastic (19.44%), metal (0.48%), glass (1.12%), rubber (1.14%), wood/ wood products (1.61%), leather (1.19%), fabric/ textiles (1.47%), ceramics (0.17%), toxic hazardous materials (0.86%) and others (3.59%).

Table 13. Solid waste generation in Surabaya City

SOLID WASTE GENERATION OF SURABAYA CITY	Weight per cap	0.704 kg/ capita/ day
	Volume per cap.	2.39 litre/ capita/ day
	Weight generated	2,032.61 tonnes/ day
	Volume generated	5,761.37 m^3/ day
COMPOSITION	Organic	54.31%
	Paper/ paper materials	14.63%
	Plastic	19.44%
	Metal	0.48%
	Glass	1.12%
	Rubber	1.14%
	Wood/ wood products	1.61%
	Leather	1.19%
	Fabric/ textiles	1.47%
	Ceramics	0.17%
	Toxic hazardous materials	0.86%
	Other	3.58%

Source: Primary Analysis, 2024

Monthly cost levied by homes to the municipality is contingent upon the installed electricity capacity and the dimensions of the building. Households in categories 1 and 2 are charged the lowest waste cost, which amounts to IDR 500/ 0.03 €. Category 3 households pay IDR 750/ 0.04 €, category 4 households pay IDR 4,500/ 0.26 €, category 5 households pay IDR 11,500/ 0.68 €, and category 6 households pay IDR 19,000/ 1.12 €. Meanwhile, the cost for managing waste from non-residential areas fluctuates based on the specific location and classification. This cost encompasses all services provided, ranging from waste collection to transportation and disposal. The fees paid are specified in Surabaya City Regional Regulation No. 10/2012 on the retribution

for solid waste/ hygiene services.

Based on the interviews, it has been determined that the waste collected is not processed at the location where it is generated. Instead, the sorting process is carried out by the Cleanliness and Green Open Space Agency. Survey results depicted in Figure 15 corroborate this assertion, revealing that a mere 42.7% of individuals possess the ability to categorise their refuse. Waste sorting is performed by several groups, such as scavengers, homes that sell sorted waste to itinerant waste buyers, students, and households that sell waste to waste banks. Additionally, waste officers serve as crew members for trucks responsible for collecting recyclable waste.

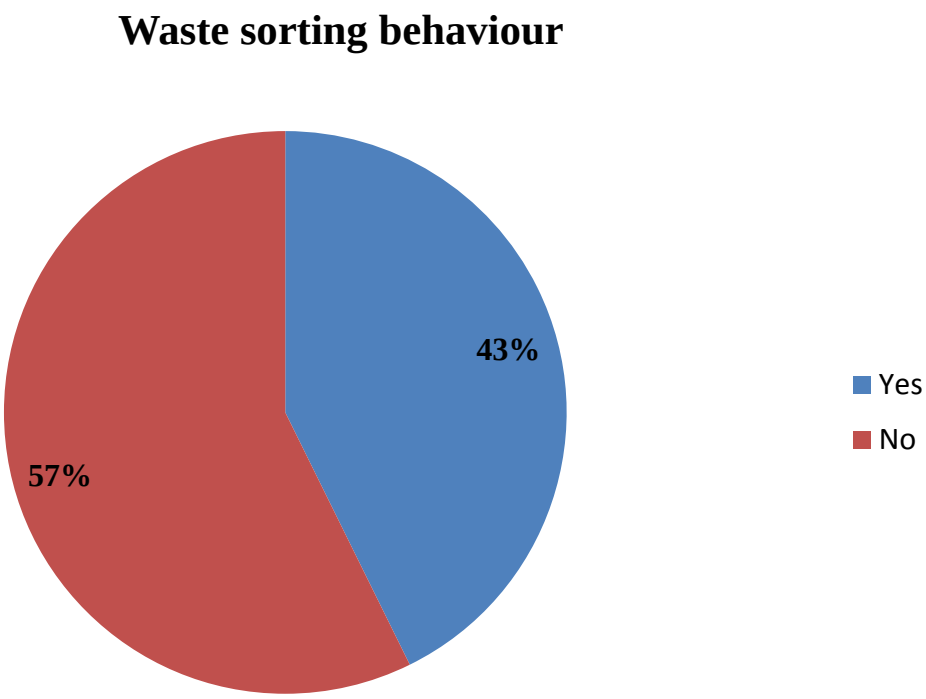

Figure 15. Waste sorting behavior of respondent in Surabaya City

Source: Primary Analysis, 2024

5.2.1.2 Solid waste collection and transportation

Waste transportation is a sub-system that aims to carry waste from the transfer location or from the waste source directly to the final processing site, or landfill. Waste transportation is one of the important components and requires careful calculation (Jayasinghe, Derrible and Kattan, 2023). Waste transportation in Surabaya City is 70% the responsibility of the Cleanliness and Green Open Space Agency and 30% by the private sector (supervised daily by independent Cleanliness and Green Open Space Agency supervisors). Besides being responsible for waste transportation, the Cleanliness and Green Open Space Agency is also responsible for street

sweeping around the city center, markets, and other public places. Currently, the Cleanliness and Green Open Space Agency of Surabaya City has a total of 628 vehicles and 190 temporary shelter location to support waste transportation including 468 wheelie bin, 53 compactors, 26 dump trucks and 81 armrolls.

Waste transportation activities are carried out in each house using wheelie bin, while in shopping areas and markets/ trades, strong and closed bin containers are provided which are then directed to temporary storage locations, compost houses, temporary disposal sites (reduce, reuse and recycle), and waste power plants for waste sorting. Usually, solid waste pickups take place in the morning and continue until mid-day. Waste from these various sources as well as residues from the previously mentioned waste processing facilities will be transported to the Benowo Landfill using compactor trucks for further processing. Surabaya City Government has also developed a policy for managers of residential areas, commercial areas, industrial areas, special areas, public facilities, social facilities and other facilities as well as those responsible for activities and / or businesses that produce more than 30 m^3 of waste every month, they are required to dispose of their own waste to integrated landfills or landfills as stated in Regional Regulation Number 1 of 2019 concerning Waste Management and Cleanliness in Surabaya City.

Currently the coverage area served by waste transportation is divided into 5 specific areas including West Surabaya, East Surabaya, Central Surabaya, North Surabaya and South Surabaya. Based on information from the Environmental Agency, the Surabaya City government is able to transport around 88.12% of the total waste generation in Surabaya City. In the analysis of the survey results, it is known that all research respondents receive waste transportation services.

5.2.1.3 Treatment and disposal

Treatment is a process of activities in handling waste that aims to reduce the amount of waste generation before entering the landfill (Ustohalova, 2011). So that waste processing or management can take place properly, waste management is carried out from the source first, because less waste is generated and the more waste that has been processed will facilitate waste management at the next stage. Activity starts from sorting or separating dry waste and wet waste, then wet waste will be made into compost.

Waste management is also carried out by hotels and hospitals that usually produce large amounts of waste. Even hospitals already have incinerators, which are places to burn waste, namely toxic and hazardous waste. Toxic and hazardous waste generated by hospitals should not be disposed of together with other waste, but must be processed by destroying the waste in the incinerator. In addition to supporting the success of waste management, the Cleanliness and Green Open Space Agency also has activities to reduce the volume of waste entering the Benowo Landfill, the

program includes the 3R concept (reduce, reuse, recycle) which is implemented in the Sutorejo Super Depot and community-based management that invites the community to manage waste.

Next program owned by Cleanliness and Green Open Space Agency is Surabaya Green and Clean with theme “Freedom from Waste”. Surabaya Green And Clean is one of the programs from newspaper company together with the Surabaya city government and manufacture companies to improve the environmental quality of Surabaya. Surabaya Green and Clean invites the community to make the environment clean and process waste. In this program, the community can be directly involved in activities to make the environment clean and create cleanliness innovations and environmental arrangements that have an element of beauty. It is necessary to instill in the community that participating in this program will bring benefits to the environment and the community itself. Existence of government programs, support from the community, and cooperation from the business world in efforts to provide facilities can create a healthy environment, and can support environmentally sound sustainable development.

Accordance with the research from Nguyen *et al.* (2023), waste management efforts need government intervention and support from residents, for example the Cleanliness and Green Open Space Agency socializes waste management activities for the community and the management is supported by community members, then from the private sector and the Cleanliness and Green Open Space Agency provide waste management facilities for residents. These efforts are made to create a clean environment. In addition, from a social perspective, the community finally has social activities that care about waste management. Results of these social activities are realizing a clean environment, making people care about waste, and providing benefits to the community in terms of the economy, because people can deposit the dry waste into the waste bank or recycle waste into goods that have economic value.

5.2.1.4 Recycling and material recovery

Waste recycling in Surabaya City is primarily conducted by both governmental and non-governmental entities. Typical recycling activities include the sorting and resale of recyclable material, the shredding of plastic, and the creation of handicrafts. Recycling process commences by gathering recyclable waste materials, including plastic, glass, and metal. Typically, scavengers are responsible for collecting this kind of waste, however homeowners and waste banks often participate in its collection. Based on the observations made during the data collecting period, there are multiple entities involved in recycling and material recovery in Surabaya City. These entities are listed in the Table 14 below:

Table 14. Actor of solid waste management in Surabaya City

Actors in technical material's loop	Actor in Biological material's loop
Scavengers	Compost house
Waste processing center	Waste processing center
Waste bank	Farmers
Waste power plant	

Source: Primary Analysis, 2024

In 2020, Surabaya City was able to process 322.83 m^3/ day of compost material from all waste processing facilities. The following waste processing facilities are owned by the Surabaya City Government:

(a) Compost house: A facility for processing organic waste in the form of leaves and tree branches into compost. Currently, there are 26 compost houses located in the Surabaya City area. The amount of organic waste that entered all compost houses during 2020 was 36,005 tons.

(b) Market waste processing: Similar to compost houses, in Surabaya City, several markets with large waste generation are also equipped with facilities for processing organic waste in the form of vegetables and food waste into compost. In 2020, market waste processing has reached 11,361.750 tons.

(c) 3R (reduce, reuse and recycle) waste processing centers: Sutorejo Super Depot is a waste sorting, recycling and composting facility. Waste sorting is divided into two categories: organic waste and inorganic waste. Organic waste is transported to the Wonorejo Compost Center and processed into compost, while inorganic waste is sold and recycled by third parties. In 2020, the processing of waste entering 3R waste processing centers reached 4,676.676 tons. Like the Sutorejo Super Depot, waste sorting is also carried out at the Jambangan Recycling Center. Organic waste is directly processed into compost, and inorganic waste is sold to third parties for recycling. Results of this sorting and utilization can reduce organic waste generation by 518.210 tons and inorganic waste by 187.835 tons during 2020. Bratang sorting facility is integrated with the Bratang Compost House and Bratang Waste Power Plant. Organic waste from the Bratang sorting facility will be processed into compost while inorganic waste will be sold to third parties. In addition, some inorganic waste that contains aluminum foil or has a high calorific value will be processed to become raw material for Bratang Waste Power Plant. Sorting and utilization results can reduce waste generation by 373.956 tons/ year.

(d) Composter for parks and greenways: The Surabaya City Government also carries out composting of organic waste in city parks, urban forests, and green lanes in Surabaya City. The results of this composting are used as fertilizer in the parks and greenways. The results

of this activity can reduce waste generation by 146.236 tons/ year.

(e) Waste power plant (PLTSa): Inorganic waste made from aluminum foil and plastic which has a high calorific value will be used as raw material in PLTSa with a gasification system. In Surabaya City there are 4 (three) PLTSa, namely PLTSa Bratang, PLTSa Wonorejo, PLTSa Jambangan and PLTSa Tambak Osowilangun. The mass of waste that can be reduced by this activity is 87.305 tons/ year.

Overall, in 2020 Surabaya City through waste handling activities is able to process 53,258.89 tons/ year. Waste management practices in Surabaya City can be illustrated as in Figure 16.

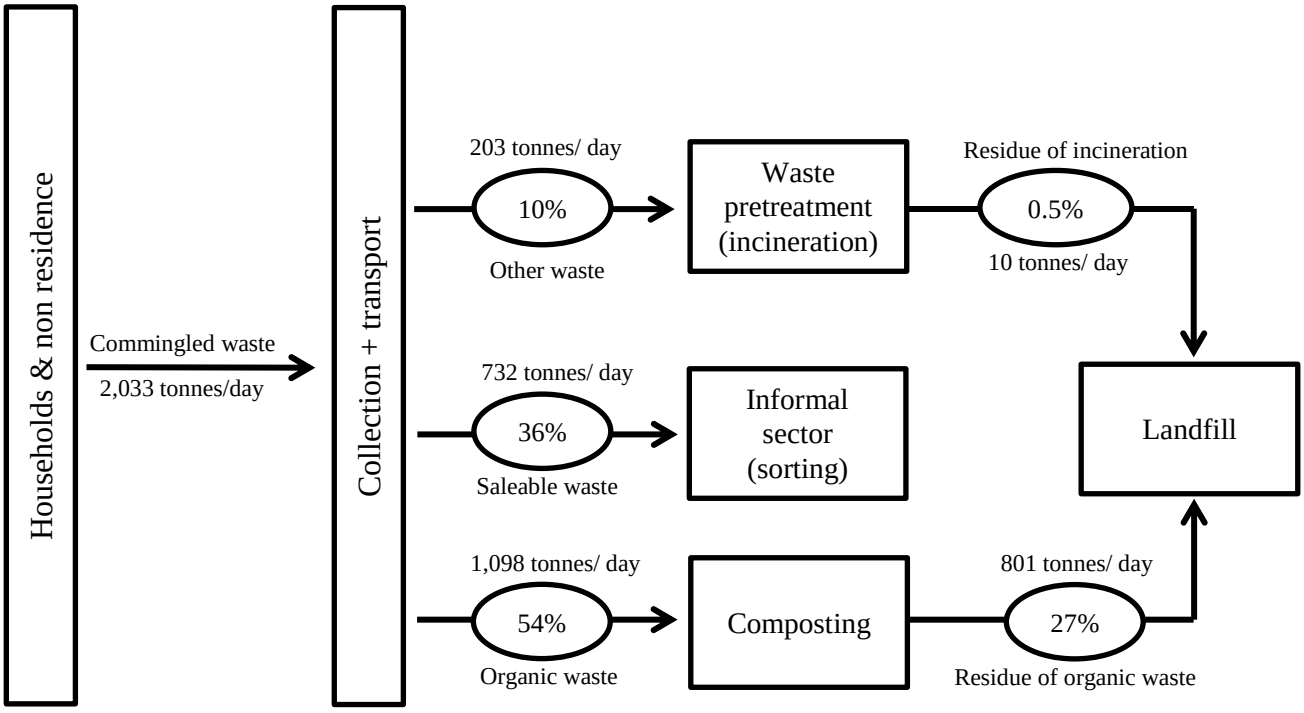

Figure 16. Material flow of generated solid waste in Surabaya City

Source: Brunner and Fellner, 2007

5.2.2 Aspects of current solid waste management practice in Surabaya City

Waste management in industrialized city is often defined as control over the generation of waste, starting from the storage, collection, transfer, transportation, processing, and final disposal of waste, with the best principles for health, economy, engineering, conservation, aesthetics, environment, and also to the attitude of society (Ferronato and Torretta, 2019). The success of management does not only depend on technical aspects but also includes non-technical aspects, such as how to regulate the system so that it can function, how the institution or organization should manage it, how to finance the system, and last but not least how to involve the waste-producing community in handling the waste. A waste management system must involve various disciplines, such as urban planning, geography, economics, public health, sociology,

demography, communication, conservation, and materials science (Hannon, 2020). Before Law Number 18 of 2008 was issued, urban waste management (issued by the Ministry of Public Works) in Indonesia positioned that urban waste management was a system consisting of 5 subsystem components (Figure 17), that is (Abdul and Syafrudin, 2018).

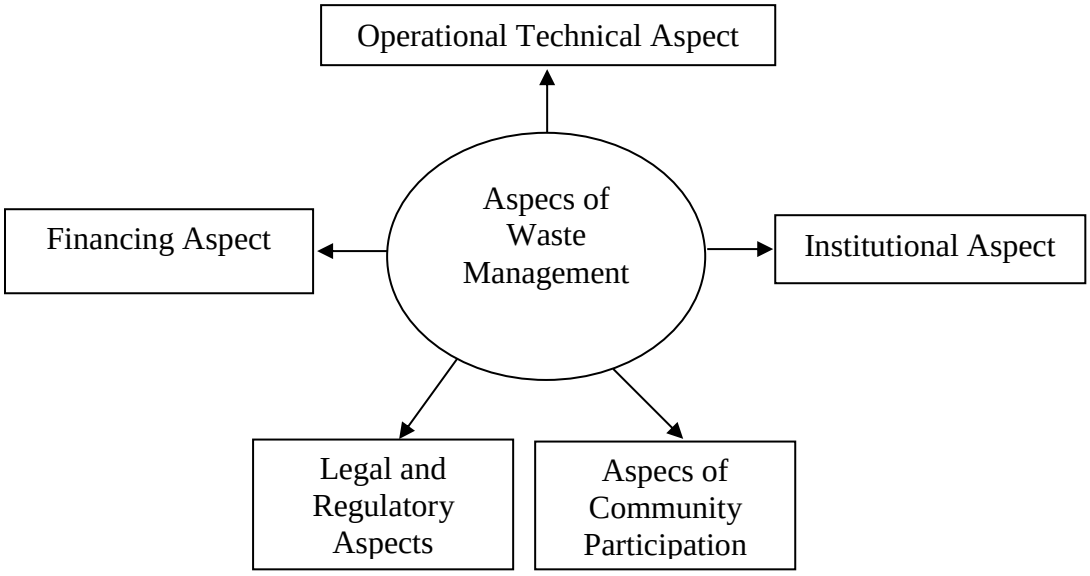

Figure 17. Aspects of urban waste management

Source: Abdul and Syafrudin, 2018

However, if you pay attention, this concept applies to the approach to solving the waste problem and to other sectors that are generally related to community services. Therefore, the five components are more accurately described as essential aspects that affect solid waste management.

5.2.2.1 Regulations/ laws

Regulatory aspect is based on the fact that Indonesia is a state of law where life joints rely on applicable laws. Solid waste management in Surabaya City requires strength and a legal basis, such as forming organizations, collecting levies, public order, and so on (Purba and Erliyana, 2020). Regulations needed in the implementation of the waste management system in urban areas are those that regulate public order related to waste handling, waste management master plan for cities, form of management institutions and organizations, procedures for implementing management, number of service fees or levies and cooperation with various related parties.

Legal umbrella related to waste management in Indonesia is Law Number 18 of 2008 concerning Waste Management. Furthermore, it is also elaborated in several Government Regulations and Ministerial Regulations such as the Minister of Public Works Regulation Number 3 of 2013 concerning the Implementation of Facilities and Infrastructure for Handling Household Waste

and Waste Similar to Household Waste which mandates sorting from the source. Regional Regulations on waste management are also already owned by Surabaya City. However, the socialization of these regulations has not been carried out, so the implementation of these regulations has not been optimal. For example, sanctions for violations and law enforcement that have been stipulated in the local regulations have not been fully implemented. Likewise, the things regulated by the Law on Waste Management have not all been implemented, such as the provisions on landfills with sanitary landfill systems or minimal control landfills and the implementation of consumer obligations to manage their waste or better known as Extended Producer Responsibility (EPR). Table 15 shows the list of municipal solid waste management regulations in Indonesia that do not include hazardous waste management.

Table 15. List of regulations on solid waste management

Title	Subject
The Law 18/2008	About solid waste management
The Law 32/2009	About environmental protection and management
Government Regulation 81/2012	About solid waste management
Ministry of Public Work Reg. 21/PRT/M/2006	About national policies and strategies for development of solid waste management system
Ministry of Home Affairs Regulation 33/2010	About solid waste management guidelines
Ministry of Environment Reg. 16/2011	About content guidelines of local regulation design about domestic solid waste
Ministry of Environment Reg. 13/2012	About implementation guidelines of reduce, reuse, recycle through waste banks
Ministry of Public Work Reg. 03/2013	About domestic solid waste management
Ministry of Environment & Forestry Reg. P.59/Menlhk/Setjen/Kum.1/7/2016	About leachate quality standards of solid waste final processing site for business and / or activities

Source: Primary Analysis, 2024

5.2.2.2 Institutions and organizations

Aspect of organization and management is a multi-disciplinary activity based on technical and management principles concerning the economic, social, cultural, and physical conditions of the city area and pays attention to the parties served, namely the city community (Taelman *et al.*, 2018). Design and selection of the organizational form are adjusted to government regulations that foster it, pattern of the operating system applied, working capacity system, scope of work and tasks to be handled.

Waste management process in each region is the responsibility of the local government and no institutional standardization related to waste management. Institutional form of waste management in the district/city can be in the form of agencies, tribal agencies, sections and even regional companies. There is a lack of functional division between waste management operators and regulators, resulting in a situation where the same entities responsible for carrying out waste management operations are also in charge of making rules and overseeing their execution.

Responsibility for waste management in Surabaya City is assigned to a specific position within the Cleanliness and Green Open Space Agency. Waste manager role is occupied by the head of the cleaning sector. Government employees of a specific rank can be appointed to the position, regardless of their lack of adequate knowledge in solid waste management. There are no specific standards or requirements in place to determine the eligibility of waste managers, such as demonstrated expertise in solid waste management or the completion of specialized technical training. As a result, solid waste managers frequently struggle to articulate effective solid waste management strategies in order to accomplish waste management goals. Surabaya city also lacks a systematic training program for its solid waste staff. Only consistent training available for solid waste management is conducted by the central government specifically for waste managers and at the administrative level. Implementers like as sweepers, operators, or drivers do not receive any training.

Existing organizational structure is also not supported by adequate human resource capacity and capability. Process of transferring and changing the structure of positions in the local government often causes the transfer of human resources who are capable and have good knowledge in waste management. As a result, waste management institution again loses qualified human resources. Likewise, unclear work procedures between administration and field implementers, and various authorities, be it waste transportation, retribution collection and budget allocation, make the implementation of waste management activities constrained. Lack of coordination and cooperation between waste sector agencies, as well as the inflexible form of the institution, also hampers the implementation of waste management in terms of budget allocation, budget utilization and accountability.

5.2.2.3 Operational technical

Based on the Indonesian National Standard (SNI) 19-2454-2002, the operational and technical procedures for urban waste management include the basics of planning for service area, service level and operational technical, starting from waste container, waste collection, waste removal, waste transport, waste processing and sorting and final disposal of waste

Sorting and recycling activities are carried out as much as possible from the collection to the final disposal of the waste. Waste generation in Surabaya City to increase from year to year and is not proportional to the quality of waste management (Wikurendra *et al.*, 2023). Currently, the reference for waste management specifications is Indonesian National Standard (SNI) No. 19-2454-2002 concerning Waste Management Procedures in Settlements. This waste management operational technique is integral, integrated in a chain and sequential manner, namely: storage/ containerization, collection, transfer, transportation to disposal / processing.

Landfill operations if referring to Law Number 18 of 2008 in sanitary landfill have been implemented, but in reality until now only control landfill systems have been carried out in several regions, and most landfills in Indonesia are still operating in open dumping. The financing factor is the main obstacle in implementing sanitary landfill. Another obstacle is the limited land for landfills, so in some places a regional landfill system is implemented.

5.2.2.4 Financing/ levies

As with other activities, the financing component of a municipal solid waste management system is ideally calculated based on investment costs, operation and maintenance costs, management fee, cost for development and cost of counseling and community development. Financing aspect is a driving resource so that the city's waste management system's wheels can move smoothly (Yao & Woerden, 2018). It is Surabaya City solid waste management system will lead to 'self-financing, including forming local companies. This financing sector involves several aspects, such as Revenue Expenditure Regional Budget (APBD) for waste management, retribution, and waste management costs, cost for salaries, transportation, maintenance, education and development, and administration, proportion between retribution and community income and applicable levy structure and withdrawal.

A waste levy is a concrete form of community participation in financing the waste management program. Structure of retribution is justified if the implementation is a formal body authorized by the government. A major obstacle to waste management in Surabaya City is limited funding, including sources of funding for investment, operations and maintenance of waste equipment and other facilities. Waste management has not been prioritized by the head of the region and the legislature so that the budget allocation for waste management is very minimal, which is mostly only < 5% of the Revenue Expenditure Regional Budget (APBD).

Cooperation with the private sector both in the form of investment and Corporate Social Responsibility (CSR) has been carried out in Surabaya City. For example, CSR from several companies in the form of infrastructure assistance (waste bins, transportation equipment, and waste management training to the community). However, cooperation in the form of investment is still constrained by several things, such as private investment in landfills and integrated waste disposal sites (TPST) cannot take place continuously due to resistance from residents. Then when viewed from the waste tariff/retribution, the current retribution has not been based on adequate calculation and data collection, both in terms of the amount of waste generated and the amount of potential payment. Tariff calculation has also not been optimized based on the type of waste generator, which can be in the form of waste from residential houses, commercial sector waste or industrial sector waste. Realization of retribution collection is also still low nationally,

still around 20%. This causes the government's burden in financing waste management to be very large.

5.2.2.5 Community participation

Without the participation of the waste-producing community, all planned waste management programs will be in vain. One approach to the community to assist Surabaya government programs in cleanliness is to familiarize the community with behavior following the program's objectives. Includes how to change public perception towards orderly and orderly waste management, local social, structural, and cultural factors and habits in waste management.

According to Damanhuri et al. (2014), problems that occur are related to community participation in waste management including unequal distribution of population, no desire in community to protect environment, no standard method for community development that can be used as a guideline for implementation, many cleaning managers who have not included counseling in their programs and managers are concerned that community initiatives will not be compatible with existing management concepts.

Communities that have been generating waste play an important role in waste management, especially when the waste is still at the source. Low public awareness in waste management is one of the obstacles in Surabaya City. Although in some places there are already community groups that care about waste, but in general, community participation in waste management is still relatively low. Disposal of waste out of place (even into rivers and waterways) is a common occurrence. Regulations and Standard Operating Procedures (SOPs) that have been made regarding waste management have not been fully informed to the community.

Surabaya government continues to encourage people to start managing waste from their homes in various ways. For example, 3R promotion, composting, and waste banks. Waste banks are a well-established activity that has been participated in by several community groups in various parts of Surabaya City. The business world and academia are part of the community. So far, the synergy of roles between the central government, provincial government, district/city government, private sector, community and universities has not been optimal. As a result, it has not been able to produce a reliable waste management system. Private investment is still low, CSR utilization is also not optimal. Waste-producing producers (in this case the business world) have not yet implemented Extended Producer Responsibility (EPR).

5.2.2.6 Technical waste management

Waste management operational system also includes a waste processing and processing subsystem, which needs to be developed in stages by considering processing that relies on reuse, either directly, as raw materials, or as energy sources (Beraud, Barroca and Hubert, 2012). The implementation of the waste management system currently carried out in Surabaya City.

(a) Open dumping

This method of processing waste is straightforward; it is often used in developing countries (Yoada, Chirawurah and Adongo, 2014). Usually used to cover indentations in the ground, swamps, or ravines, waste is dumped there without covering the ground. With this way of processing waste, there will be environmental pollution such as odor pollution, outbreaks of disease due to the breeding of fly or mosquito populations, and pollution of surface water and groundwater by leachate due to rinsing waste heaps rainwater.

(b) Composting

Composting is carried out to process waste and, simultaneously, get results from the compost (Ayilara *et al.*, 2020). Waste must be separated to be composted, for example, organic waste leaves, food scraps, and other waste that can rot. Waste as fuel has change the state of the soil to be like hummus, returning collected organic materials, enriching substances Natrium, Phosphorus, Potassium, and Calcium are essential for plants and fertilization process takes place slowly and lasts a long time.

(c) Burning (incineration)

Burning waste must be done very carefully because burning waste can cause air pollution (Bulto, 2020). This way, by-products are produced in scrap metal and steam, converted into electrical energy. Other advantages of using this tool include can reduce the volume of waste by 75%-80% from the source without a sorting (Lam *et al.*, 2010). The method of burning requires a high cost of about three times; therefore, the waste that is burned is waste that can no longer be used for other purposes. Ash or slag from combustion residues is dry enough and free from decay so that it can be taken directly to landfills in vacant land, swamps, or low-lying areas as backfill material. A large enough incinerator with a capacity of about 300 tons/day can be equipped with a power plant so that the electrical energy produced can be used to reduce process costs. Types of incinerators include high temperature (suppose the waste is not separated between combustible and non-combustible waste temperature between 800°C-1000°C), semi-high temperature (if the waste is not separated, more waste is burned) and low temperature (used for combustible waste with temperature is between 650°C-750°C).

(d) Sanitary landfill

A Sanitary landfill is a reasonably good way of processing waste; it is done by placing the waste in the ground and then covering it again with soil (Arockiam JeyaSundar *et al.*, 2020). This method will require extensive land if all waste is processed. Therefore, processed waste is waste that really cannot be used for any purpose. This method is widely used in developing

countries. The principle is waste dumped in the basin, waste is compacted and covered with soil.

5.3 Circular Economy Situation of Solid Waste Management in Surabaya City

Based on the results of interviews with respondents, most respondents in Surabaya City are still unfamiliar with the concept of circular economy and they have no awareness of its benefits. Consequently, it is unclear to them if they have the capability and desire to adopt the principles of a circular economy. Identification of circular economy techniques in Surabaya City was hindered by this condition. In addition, in a linear economic society like Indonesia or Surabaya City specifically, where the take-make-dispose approach is seen as a more affordable and convenient solution for daily activities, concepts such as circular economy or related terms (such as closing the loop or cradle to cradle) have never been familiar.

In order to examine the present implementation of circular economy concepts in solid waste management in Surabaya City, a number of activities pertaining to solid waste management were identified. Based on the observations made during the data collection period, it can be concluded that the waste bank business is the predominant type of business in Surabaya City. While the city does have a few waste regeneration enterprises, the extent of their application is restricted. Ellen Macarthur Foundation stated that the adoption of a circular economy is intimately linked to the regeneration efforts in the solid waste management sector (Ellen MacArthur Foundation, 2012).

Associated enterprises in the field of solid waste management include scavenging operations, itinerant waste buyers, waste trading organizations, waste banks, and creative industries. While numerous players have been identified, the range of activities remains indistinguishable from one another. Majority of businesses depend on the lower to medium levels of the solid waste recycling industry. Furthermore, the majority of these individuals, particularly independent scavengers, rely on their daily income derived from engaging in solid waste-related tasks. Figure 18 provides a concise presentation of the hierarchical overview.

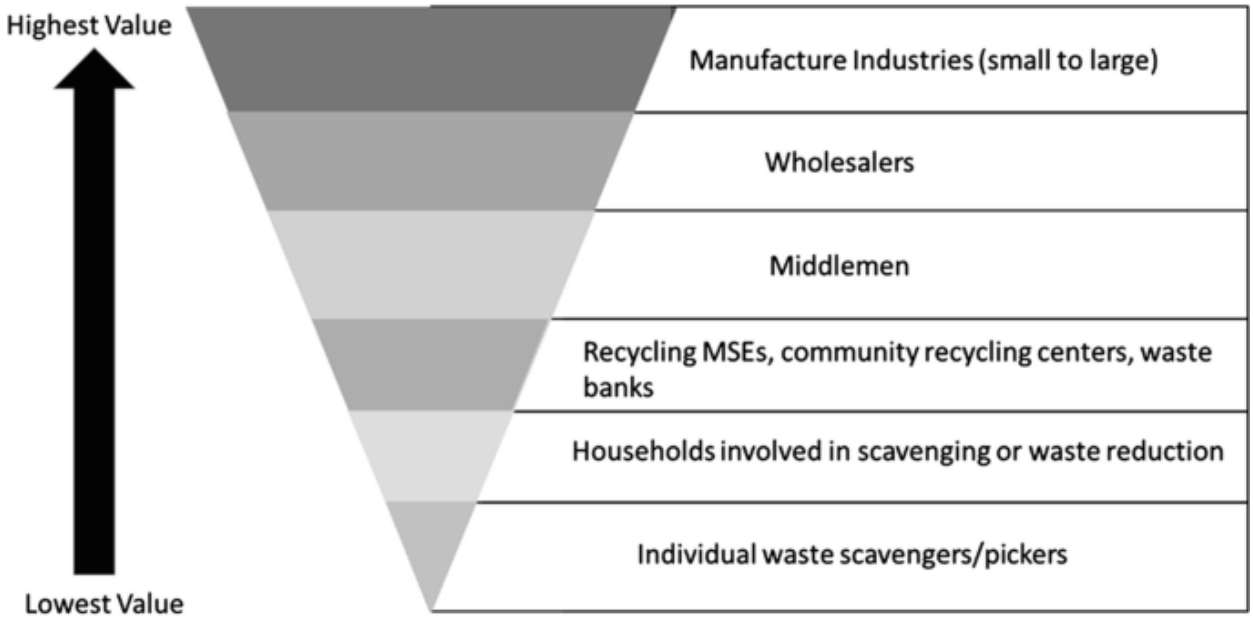

Figure 18. Hierarchy of informal sector recycling

Source: Meidiana, Tomoo and Subagiyo, 2020

Recycling hierarchy suggests that the players at the top of the hierarchy will get the greatest added value (Wilson, Velis and Cheeseman, 2006). Solid waste management enterprises in Surabaya City are positioned towards the lower to middle levels of the hierarchy. This indicates that the economic component of these businesses does not have a big impact on the recycling industry, unlike the actors at the top of the hierarchy.

Primary impetus for the founding of Surabaya City's central waste bank was a social concern regarding the subpar execution of solid waste management in the city. Waste bank programme was selected as a method to raise awareness among the residents of Surabaya City regarding the concealed worth of waste. Enterprises involved in the management of solid waste in Surabaya City are structured as foundations or operate separately without a formal union. Consequently, regular communication between these enterprises is not facilitated. Chance for them to meet occurs when they receive an invitation to the annual government agenda meeting. Position of these enterprises, particularly those at the lower end of the recycling hierarchy, is comparatively less strong than that of the purchasers. Sole opportunity to obtain a more favourable price is by juxtaposing the price proposed by one prominent waste broker with that of another.

Furthermore, based on interviews and conversations with multiple officers at the Cleanliness and Green Open Space Agency, it has been determined that these enterprises had sufficient expertise to provide higher levels of value for the recycled materials. Nevertheless, they need sufficient assistance in terms of financial, technological, and managerial factors. Successful implementation of a circular economy in Surabaya City necessitates more than conventional collaboration across sectors. Successful implementation of circular economy necessitates

collaboration across sectors, including access to capital investment, strategic marketing, and other factors that enhance the capabilities of circular economy actors (Hina *et al.*, 2022). Relying solely on the support of the local government is insufficient.

5.4 Challenges of Integration Solid Waste Management with Circular Economy Model in Surabaya City

This section examines the challenges of integrating solid waste management into the circular economy model in Surabaya City by identifying the current barriers. This section provides further elaboration on key challenges to integrating solid waste management with the circular economy model, including net profitability, capital, and transaction costs.

5.4.1 Net profitability

According to data from Table 12, the proportion of waste that can be sold amounts to 36.67% of the total waste produced, which is equivalent to 725 tons per day. Daily quantities of plastic waste, paper, glass, and metal are 395 tons, 297 tons, 22.77 tons, and 9.76 tons, respectively. Economic value of plastic is IDR 790,000,000/ 46,500 € per day, paper is IDR 297,000,000/ 17,450 € per day, glass is IDR 91,080,000/ 5,350 € per day, and metal is IDR 9,760,000/ 575 € per day (these prices were obtained from the interview with waste bank owner). This demonstrates that the economies of scale associated with non-biodegradable recycling are substantial, indicating great prospects for recycling various types of plastic. Composting is a prevalent practice employed to reclaim biodegradable substances. Quantity of organic matter derived from Surabaya City waste is around 1,104 tons per day, which is nearly double the amount of waste that may be sold. Compost yield amounts to merely half the weight of biodegradable materials, resulting in a production of 552 tons of compost (Ayilara *et al.*, 2020). Current market value of compost is IDR 1,500 per kilogram (Sitanggang and Siahaan, 2021), indicating that the economic potential of the compost might amount to IDR 828,000,000/ 48,650 € per day. Nevertheless, attaining this outcome necessitates a substantial amount of exertion, since it demands a composting process lasting 21-40 days to obtain the compost.

Economies of scale in solid waste management businesses in Surabaya City are rather low in relation to the population size. This is further corroborated by the fact that only the informal sector is engaged in the business. The majority of enterprises fall under the classification of Micro or Small Enterprises (MSEs), which typically have a workforce of fewer than 20 individuals. Furthermore, the enterprises engaged in solid waste recycling in Surabaya City have the lowest position in the waste recycling hierarchy. Extent to which the formal sector participates in waste management in the region will be contingent upon subsidies (Phonchi-

Tshekiso, Mmopelwa and Chanda, 2020). Potential for informal business engagement in enterprises associated to solid waste management is relatively significant. This situation can arise if the informal sector is able to effectively handle all the waste produced in Surabaya City.

5.4.2 Capital

Waste regeneration enterprises are characterized as informal businesses (Katusiimeh, Burger and Mol, 2013). While a few firms claim to be self-sufficient, the majority acknowledge that lack of financial resources is the primary obstacle preventing them from effectively managing waste in Surabaya City. Nevertheless, certain enterprises, such as waste banks, exhibit comparatively more resilience in terms of capital. This is because of their distinctive procurement system, wherein they may acquire and store the gathered waste without the need for physical currency, as is typically expected of traditional waste collectors.

5.4.3 Technology

Participation of the informal sector is distinguished by limited technical adaptation, which is substituted by the utilization of inexpensive human resources (Hettiarachchi *et al.*, 2018). Hence, the informal sector requires technological adaptation to enhance its efficiency. Recycling methods in Surabaya City are now restricted to the sorting and selling of materials to external waste collectors, with little emphasis on the internal circulation of materials within the city. Lack of major industrial sectors inside the city restricts the possibility of self-sufficiency and self-sustaining economic activities. It is imperative to investigate the participation of creative industries as final consumers of reclaimed materials. Based on the interview with Mr. Anjar in the creative industry, it can be inferred that the main problems are the scarcity of proficient personnel and the limited access to technology inside the city.

Creative industry relies on technological innovations to effectively collaborate with recycling firms (Corral-Marfil *et al.*, 2021). An example of ownership can be seen in the domain of plastic recycling technologies. This technology will facilitate the advancement of solid waste management in the recycling hierarchy, consequently improving the integration of solid waste management with the circular economy model. Furthermore, the creative industry in Surabaya City has the potential to be advanced through technology innovations, making it a significant contributor to waste management.

5.4.4 Externalities

Purchase decisions of Surabaya City citizens are significantly influenced by price sensitivity. Conclusion is based on the survey findings presented in Table 16, indicating that 70% of the

participants concurred that affordability is a crucial factor when buying recyclable materials. Furthermore, the community highly values the item's distinctiveness and creative merit, making it a sought-after purchase.

Table 16. Criteria to purchase recycled goods

Reason for purchase	Criteria (Percentage %)				
	Very unimportant factor	**Unimportant factor**	**Fairly important factor**	**Important factor**	**Very important factor**
Can be used for daily activities	5%	10%	25%	20%	40%
Durable	2.5%	7.5%	20%	45%	25%
Affordable price	7.5%	2.5%	32.5%	20%	37.5%
Artistic value	7.5%	7.5%	20%	22.5%	42.5%
Uniqueness	10%	10%	40%	25%	15%
Fashionable/ trendy	15%	15%	25%	25%	20%
Branded	20%	25%	25%	15%	15%
Can be used as symbol (environmental conservation symbol)	17.5%	15%	22.5%	30%	15%

Source: Primary Analysis, 2024

5.4.5 Infrastructure

Lack of infrastructure poses a significant challenge for waste entrepreneurs in Surabaya City, particularly in attracting investors involved in composting and the separation of biodegradable waste. Implementing waste segregation practices will lower the expenses associated with waste management, therefore making it more appealing to potential investors. Survey findings indicate that the lack of waste segregation infrastructure is a significant issue contributing to people's hesitancy to separate waste. Implementation of measures such as the introduction of dedicated receptacles for homeowners will enhance the potential for private sector participation in waste management. Lack of transportation options hinders solid waste management enterprises from achieving maximum revenue. Accessibility of affordable transportation will decrease the operational expenses of solid waste management enterprises.

Presence of transportation options greatly facilitates the growth of waste bank operations. The presence of several transportation modes has been demonstrated to significantly enhance the extent and capability of waste collection, surpassing previous levels. This demonstrates the significance of infrastructure for waste businesses. Having waste segregation infrastructure in place can significantly contribute to the expansion of their waste management enterprise. According to the study, over 60% of the respondents believe that having waste segregation facilities is vital. This finding is further reinforced by the survey results, which indicate that 76% of the respondents agree to sell the waste they generate. Furthermore, the survey findings indicate that individuals have a preference for door-to-door waste pickup, even when presented with a lesser cost option.

5.4.6 Imperfect information

Implementing circular economy concepts necessitates innovative and non-traditional methods to recognize potential opportunities (Ellen MacArthur Foundation, 2012). A strong information role is inevitable in turning these opportunities into practical action. Majority of waste recycling enterprises struggle to develop innovative methods for waste regeneration prospects, as they continue to focus on traditional opportunities provided by waste regeneration businesses (Ezeudu and Ezeudu, 2019). Hence, the rapid increase in information poses a significant obstacle to the integration of solid waste management with the circular economy model in Surabaya City.

5.4.7 Transaction cost

Informal actors in the waste recycling industry in Surabaya City often occupy the lowest position in the recycling business hierarchy, as previously stated. This factor renders them significantly reliant on purchasers. Players are unable to ascertain the selling price of the recycled materials. Instead, the price is established by the buyer acting as an intermediary. Informal waste recyclers are compelled to either compare the buyer's maximum price or retain and sell the stockpiled raw materials when the price provided rises, due to this mechanism.

5.4.8 Inadequately defined legal

Interviews found that laws and regulations do not hinder the informal sector from operating solid waste management businesses in Surabaya City. The Cleanliness and Green Open Space Agency promotes the involvement of the informal sector in solid waste management and assists informal actors by providing equipment support for their operations. Nevertheless, certain sectors within the local government lack the ability to accurately establish legislation pertaining to solid waste.

5.4.9 Poorly defined target and objectives

Residents active engagement in solid waste management, particularly their willingness to separate their waste, might contribute to the availability of higher-quality recyclable materials for recycling initiatives. Consequently, sorting these resources at their origin will result in a higher commercial value (Ellen MacArthur Foundation, 2015). Discovering superior-grade recyclable resources in Surabaya City would enhance the potential for utilizing these materials in the production of economically valuable products. Nevertheless, the government has never taken into account the execution of regulations pertaining to solid waste separation.

5.4.10 Capabilities and skills

An important challenge in implementing the circular economy model is enhancing the capacities and expertise of informal enterprises in the field of solid waste management. Hence, the utilization of novel knowledge and/ or technology has the potential to unveil fresh perspectives in their commercial methodologies. Thus, waste management enterprises can be appealing ventures, even for established corporations to engage in. Integration of the informal sector provides benefits in the form of improved performance of waste management services, increased waste recycling, savings in waste management costs and increased availability of more credible waste management data. In the institutional context, the integration of informal sector workers in waste management can be formal cooperation between the government/private sector and the informal sector/informal sector associations, e.g. provision of recycling warehouses/facilities by the government/private sector for informal sector operations in waste recovery or establishing formal cooperation agreements between the government/private sector and informal sector organizations to manage waste in certain areas. Informal sector recruitment by the government/private sector, e.g. scavengers recruited as waste collection operators, or carters recruited as workers in recycling centers.

5.4.11 Custom and habit

Integration of solid waste management with the circular economy concept is greatly impacted by customs and habits. Survey results indicate that the community is in favor of the practice of waste reduction and reuse. Nevertheless, the community's adherence to waste sorting remains insufficient, posing a challenge to the successful integration of solid waste management with a circular economy model in Surabaya City.

5.5 Solution to the Challenges

In order to address the difficulties associated with integrating solid waste management into the circular economy model in Surabaya City, as outlined in section 5.4, a framework inspired by the Ellen MacArthur Foundation is employed. Proposed remedies for the obstacles in the integration are outlined in Table 17. Higher government policies and regulations may constrain the application of the circular economy model at the city level. Some recommendations in this framework are not open to discussion. Furthermore, it is not feasible to suggest remedies exclusively for specific sectors. Hence, some solutions are outlined as follows.

Utilizing the economic factors can expedite the integration of solid waste management with the circular economy model in Surabaya City. Primary driving force behind many recycling enterprises in Surabaya City is their economic incentive. Government financial support, such as

tipping fees, is the primary method used to engage the formal private sector in solid waste management, as mentioned earlier. This approach has been successfully applied in multiple developed countries (Damanhuri, Handoko and Padmi, 2014). Nevertheless, Surabaya City is unable to offer such financial assistance. Hence, this study will not address the involvement of the formal sector.

Based on the interviews, it is evident that the informal sector significantly contributes to solid waste management in Surabaya City, encompassing activities ranging from waste collection to recycling. A major obstacle faced by the informal sector is the limited access to finance, which hinders its ability to play a more significant role in solid waste management. One possible method to address this issue is to offer incentives to capital proprietors, specifically banks. Presently, the national government has implemented a scheme called Kredit Usaha Rakyat (KUR) that allows for borrowing funds from banks without the need for collateral. Kredit Usaha Rakyat is a microcredit program designed for unregistered enterprises or individual entrepreneurs, which offers a non-collateralized loan of up to IDR 50,000,000/ €2,950 (Leksono, 2016). Significant number of informal recycling enterprises are unaware of the Kredit Usaha Rakyat (KUR) program. Many enterprises exhibit a hesitancy to seek credit from financial institutions due to their presumption of ineligibility. Conversely, the plan of program will approve credit applications regardless of their bankability (Leksono, 2016). Hence, the municipal government should proactively facilitate by arranging consultations between the informal sector and financial institutions. By implementing this strategy, the informal sector will gain improved access to financing, leading to the expansion of their businesses and increased capacity to handle the waste generated in Surabaya City.

Existing waste recycling business model in Surabaya City lacks significant economic benefits for the participants. Present condition of waste management necessitates the involvement of additional participants in the management of solid waste. Inviting numerous economic-based business players to participate in waste recycling in Surabaya City is not suitable due to their relatively low economies of scale. Suggesting the implementation of a Public Private Partnership (PPP) is one of the potential strategies to resolve this predicament. By enhancing community engagement, the existing stakeholders can effectively manage a greater volume of waste.

To overcome technological limitations, it is crucial to offer organizations regular training on solid waste management (Aparcana, 2017). These trainings should encompass not just the technical components but also encompass financial solutions, legal needs, and managerial abilities. Trainings can also serve as regular gatherings for the informal sector to discover emerging prospects and obstacles to growth, while also enhancing collaborative endeavors such as joint sales of waste materials to wholesalers (Ferronato and Torretta, 2019). These monthly

meetings can also serve as opportunities to enhance one's knowledge and extend recycling networks, such as establishing commercial connections with end users.

Informal sector in the recycling industry can achieve efficient results when provided with sufficient support (Kala, Bolia and Sushil, 2022). Significance of community engagement in urban solid waste management cannot be disputed (Robert, 2021). Development of waste banks, which are community-based organizations, is crucial. Waste banks facilitate cooperative initiatives between citizens and the informal sector. Waste banks can facilitate awareness and education initiatives for community members regarding their responsibilities in managing solid waste (Wulandari, Utomo and Narmaditya, 2017). They can also spread information about the drawbacks of unlawful activities like waste incineration. Waste banks can employ social pressure mechanisms to ensure that members adhere to the agreed-upon practice of segregating waste. Waste banks can serve as a central institution for the informal sector to play a significant role in the management of solid waste inside the city (Kubota, Horita and Tasaki, 2020).

Table 17. Suggested solutions for barriers in circular economy

High relevance **Medium relevance** **Low relevance** **Barriers**		Information and awareness	Collaboration platforms			Business support scheme		Public procurement and infrastructure		Regulatory framework					Fiscal framework
		Public communication campaign	Public private partnerships	Industry collaboration platform	R&D and programmes	Financial support	Technical Support	Public procurement rules	Public investment in infrastructure	Government strategy and targets	Product regulations	Waste regulations	Industry, consumer, competition and trade	Accounting, reporting, financial, regulation	VAT and excise duty reductions
Economics	Net profitable														
	Capital														
	Technology														
Market failures	Externalities														
	Infrastructure														
	Insufficient competition														
	Imperfect information														
	Split incentives														
	Transaction cost														
Regulatory failures	Inadequately defined legal														
	Poorly defined legal														
	Implementation														
	Unintended consequences														
Social factor	Capabilities and skill														
	Custom and habit														

Source: Primary Analysis, 2024

5.6 Suitable Circular Solid Waste Management Framework in Surabaya City and How to Enable It

As previously stated, regeneration activities, such as recycling and material recovery, are strongly associated with the implementation of solid waste management principles within a circular economy model. This association is higher compared to other activities, such as sharing, optimizing, looping, virtualizing, and exchanging (Ellen MacArthur Foundation, 2012). Hence, in order to incorporate solid waste management principles into the circular economy model, it is crucial to optimize recycling and material recovery activities within the solid waste stream. Several nations, like Japan and Germany, have implemented effective systems to maximize recycling and material recovery in their solid waste management practices (Ogunmakinde, 2019). Nevertheless, it is important to note that certain solid waste management strategies may not be effectively implemented in different geographical areas. Assessing the capacity and competency is essential for prioritizing solid waste management (Doussoulin and Colther, 2022). Participation of the formal sector is widely regarded as enhancing the effectiveness of solid waste management in numerous developed nations. Insufficient funding for implementing comprehensive solid waste management is a significant obstacle to engaging the formal business sector in Surabaya City solid waste management efforts. While engaging the community in implementing effective solid waste management is the most cost-effective and optimal method to address the waste issue, depending only on community involvement will necessitate significant amounts of energy and time (Sinthumule and Mkumbuzi, 2019). Similarly, like in several urban areas in emerging nations, Surabaya City also has an informal sector engaged in the recycling and reclamation of waste products. Majority of individuals are motivated by economic factors, hence engaging them in the formal establishment of solid waste management will encounter minimal opposition (Brunner and Fellner, 2007; Salvia *et al.*, 2021). Regarding Surabaya City, the participants engaged in solid waste management operations include scavengers, itinerant waste buyers, waste collectors, and waste banks.

Despite being described as labor-intensive, lacking advanced technology, offering poor wages, and operating without registration or regulation, this sector has the potential to contribute substantial advantages to municipal solid waste management. It is crucial for the Surabaya City Council to explore potential collaborations with these informal sectors in order to enhance solid waste management (Muheirwe, Kombe and Kihila, 2023). Establishment of an optimal environment for the solid waste management industry in Surabaya City necessitates the active participation of both the local government and the community. It is suggested that a collaborative structure involving the government, informal companies, and the community be established to effectively integrate solid waste management with the circular economy model in

Surabaya City.

5.6.1 Initiative from the municipality

Informal enterprises are characterized by their independent, unstructured, and uneducated nature (Günther and Launov, 2012). It is difficult to build an organization to bring informal company owners together even for bigger economic rewards. Conducting regular meetings to promote the advantages of collaborative work can help raise awareness among informal business participants and encourage them to establish formal organizations. Supportive policies such as legalizing the business activities of informal organizations in solid waste management, providing incentives for waste collection and treatment services carried out by organizations can be used to increase the contribution of informal actors in solid waste management (Gutiérrez-Galicia *et al.*, 2021; Zisopoulos *et al.*, 2023).

5.6.2 Increase the capacity of informal actors

Wilson, Velis and Cheeseman (2006) propose numerous measures to augment the involvement of the informal sector in the management of solid waste. These measures are enabling them to streamline, enhance the structure of recycling enterprises, and maximize the capacity to generate and extract value from recycled waste. Establishing an organization is crucial for the majority of individuals operating in the informal sector of the recycling industry, particularly for independent waste collectors or itinerant waste buyers. Establishing an organization enhances their ability to withstand exploitation by collectors by providing them with a more advantageous position for negotiation in the market (Wilson, Velis and Cheeseman, 2006; Clauss *et al.*, 2021). Organizations can also be a platform to address issues or opportunities among members (Kretschmer *et al.*, 2022). Absence of standardized protocols for forming informal corporate entities complicates the process of determining the appropriate organizational structure for the informal sector.

Community-based organizations (CBOs) such as waste banks already have this system. In Indonesia, waste banks as a type of cooperative organization have defined requirements for founding an organization as indicated in the Minister of Environment Regulation No. 13/2012. Several waste banks in Indonesia had comparable challenges during their inception and expansion, making it more feasible to devise an effective framework for organizing and operating waste banks (Latanna, 2022; Eka *et al.*, 2023). Non-official participants in the waste recycling industry have the potential to become official members of waste banks. Consequently, they possess identical entitlements and responsibilities as other individuals inside the group. Administration of the organization is deliberated upon in periodic gatherings, such as yearly

meetings, and might be comprised of individuals chosen from the government, community, or informal sector. With this cooperative model, informal sector firms can be absorbed into an organization (Wilson, Velis and Cheeseman, 2006). This plan facilitates the implementation of organizational partnership activities, such as collaborating with the government to generate compost. The local administration can potentially implement a Public-Private Partnership (PPP) with a waste bank, as stated in Article 39 of Local Regulation 8/2015. Surabaya City has implemented several past Public-Private Partnership (PPP) projects specifically focused on solid waste management. Exploring collaborative ties with industries, such as the creative industry, is also an option. Local government has acknowledged waste banks as significant participants in the management of solid waste. Consequently, the local government has provided substantial support for the establishment and growth of waste banks.

After organizing the informal sector in waste management, the subsequent task is to enhance the efficiency of the informal sector in the waste recycling hierarchy. A possible approach is to avoid the involvement of middlemen in the waste recycling cycle (Suthar, Rayal and Ahada, 2016). Avoiding middlemen means that waste banks must interact directly with the final users of the recycled products. This can be achieved through the exploration and establishment of novel commercial partnerships with end-users. These users may belong to the agricultural sector or the creative industries.

Final stage in bolstering the capabilities of informal players is to augment their capability to both contribute to and derive value from the reclaimed waste. Middlemen have a vital function in collecting and consolidating a significant quantity of waste, which they subsequently transport to collectors or businesses at an increased price (Tong, Huynh and Khong, 2021). An individual actor from the informal sector is not capable of undertaking this activity due to the significant time investment needed to accumulate a big amount of waste, and they also lack the ability to get remuneration throughout the collection process. This condition is exacerbated by the economic status of the majority of individuals in the informal sector who belong to the low-income bracket (Korsunova *et al.*, 2022). These limitations hinder the ability of numerous informal sector participants to expand their firm. This can be accomplished by creating a unified corporation that effectively collects a significant amount of waste within a short period of time and then sells the reusable materials to manufacturers. This strategy enables the extraction of greater value from the accumulated waste.

5.6.3 Increase the participation of community

It is necessary to develop community engagement, enhance awareness, and improve the organizational and technical capabilities of the community. Important to promote and provide

assistance to waste banks, which are community-based organizations (CBOs), in order to educate the community about the significance of improving waste management. Community is more likely to readily accept knowledge shared by community-based organizations (CBOs) like waste banks, as opposed to information provided by the government (Bratianu, 2015; Aljuwaiber, 2016).

Figure 19 exemplifies the integration of solid waste management into a circular economy framework, which entails collaboration among waste banks, citizens, informal actors, local government, and creative industries. Waste bank serves as a waste collection facility exclusively for its members, offering segregated waste collection services. Waste is segregated into recyclable and non-recyclable categories. Funds generated from the sale of recyclable waste are transferred to the member's waste bank account, while the municipality collects biodegradable waste at a predetermined place. Members are required to remit a monthly charge to the municipal government for the provision of biodegradable waste collection services, with payments sent to the waste bank. Fee charged is contingent upon the frequency of waste collection and the agreement between the waste bank and the municipality. Waste bank may offer a subsidy program based on the deposit of separated waste. Waste banks can collaborate with creative industry to gather biodegradable waste. By implementing this approach, the local government can significantly decrease or potentially eliminate the necessity for waste collection services, so relieving citizens of the financial burden associated with paying for such services.

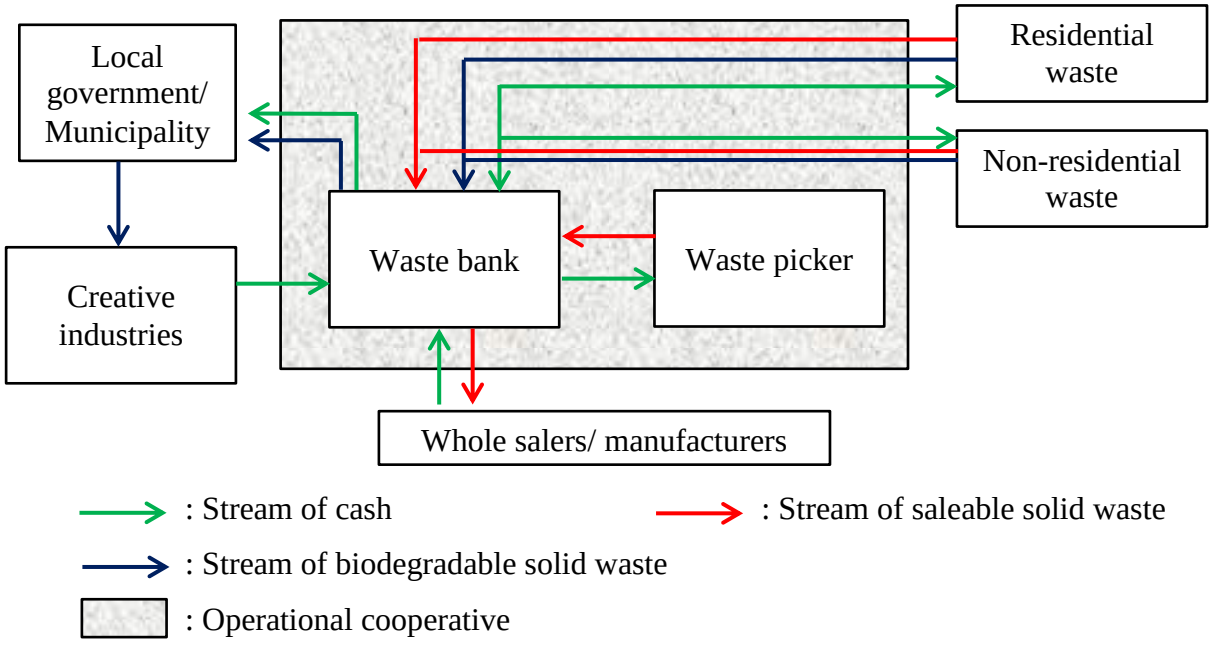

Figure 19. Proposed model for integration solid waste management with circular economy approach in Surabaya City

Source: Primary Analysis, 2024

Implementation of this strategy will also yield advantages for the creative industries. A study by Aye and Widjaya (2006) has demonstrated that centralized waste segregation offers significant advantages to creative industries. Creative industries are exempt from the obligation to do waste segregation, as it is inherently separated at the origin (Kala, Bolia and Sushil, 2022). Waste that is sorted at its origin is seen as superior in quality compared to waste that is only sorted after being transported (Ellen MacArthur Foundation, 2012).

5.7 Waste Absorption Footprint

This section provides an estimation of the environmental impact of the current waste management system, specifically focusing on the waste footprint. This study does not provide a comprehensive waste footprint calculation, which includes the nutrient footprint, although it is feasible to determine the waste footprint of solid waste management in Surabaya City. This is a result of the lack of access to the necessary data. This study focuses solely on quantifying gas emissions (CH_4, N_2O, and CO_2) when assessing the environmental impact of solid waste management. WAF_{CO2} analysis was performed by analyzing the activities of solid waste management.

5.7.1 Collection, transportation (emissions)

Emissions resulting from collecting and transportation activities were calculated using Equation 4, which employs the IPCC tier 1 methodology to estimate $CO_2/CH_4/N_2O$ emissions. Respondents reported that 739,768 liters of diesel fuel are used annually for collecting and transportation activities. According to Ministry of Environment (2012), the calorific value of diesel fuel is 36 x 10^{-6} TJ/liter. Emission factors for diesel engines, according to the IPCC, (2019) methodology for mobile sources are 74,100 kg CO_2/TJ; 3.9 kg CH_4/TJ and; 3.9 kg N_2O/TJ. Yearly emissions resulting from the collecting and transportation activities amount to 1,973,283 kg CO_2; 103.857 kg CH_4; and 103.857 kg N_2O.

Waste collection manages 88.12% of the waste produced in the city. In order to fully address the waste requirements of the city, it is necessary to enhance waste collection and transportation operations. Nevertheless, this will lead to increased fuel consumption and the generation of additional CO_2, CH_4, and N_2O emissions. This study does not consider the calculation of such plans because there is no available data on actions linked to collection and transportation.

5.7.2 Disposal activity emission

Similar methodology employed to calculate emissions from collection and transportation activities was also applied to disposal activities. According to interviews, it was ascertained that

the yearly fuel consumption totals 399,874 liters. Fuel used throughout the collection and transportation phase is the same as the one employed specifically diesel fuel. Assessment of emissions arising from disposal activities is conducted comprise of 1,066,704 kg CO_2; 56.14 kg CH_4; and 56.14 kg N_2O.

5.7.3 Landfill emission

Emissions of the landfill were calculated by gathering operating details through interviews. Informants stated that the site is transitioning from unregulated dumping to a regulated landfill. Site lacks a gas collection infrastructure and the height of the pile is approximately 4 meters. Based on the IPCC technique, Equation 5 and Equation 6 are more suited for describing these properties. Amount of methane produced can be determined using the following formula:

$$Y_{methane} = \left(MSW_T . MSW_F . MCF . DOC . DOC_F . F . {}^{16}/_{12} - R\right).(1 - OX) \qquad (11)$$

Equation 5 Amount of methane generated using IPCC default method

Table 13 presents data on solid waste production, indicating a daily generation of 2,032.61 ton/ day or 741.90 Gg/ year. It is noteworthy that 88.12% of this waste was really disposed of in landfills, as revealed in the interview with respondent. Moisture content factor (MCF) for shallow unmanaged landfill is 0.5. DOC was determined using IPCC Equation 6, yielding a value of 0.1759. Values for the DOC_F, F, and OX parameters were obtained by utilizing the default values provided by the IPCC, which are 0.5, 0.5, and 0.1, respectively. On-site gas recovery based on PT. Sumber Organik data resulted in an R-value of 0.0028. Based on this data, the annual methane generation in the landfill amounts to 20.793 Gg CH_4. Landfill produces a yearly total of 619.626185 Gg $CO_{2\text{-eq}} \approx$ 619,626.185 tonnes $CO_{2\text{-eq}}$/ year.

5.7.4 Waste absorption capacity of carbon sequestration in Surabaya City

Determine the quantity of CO_2 that may be stored by biomass, it is important to identify potential reservoirs for carbon dioxide. Capability for carbon sequestration in Surabaya City is facilitated by the presence of green open space and agricultural land, which have the ability to absorb waste. Green open space in Surabaya City comprises tombs, fields and stadiums, ponds/reservoirs/boezems, public facilities and residential social facilities, protected areas, botanical forest parks, and parks or greenways. Total green open space in Surabaya City is 7,358.87 hectares.

Table 3 provides an estimation of the quantity of CO_2 that is taken in by green open space. According to the data in Table 3, it is possible to determine that the green open space in

Surabaya City has the capacity to absorb 642,794.59 ton CO_2/ year. Local absorption capacity for CO_2 is calculated by dividing the overall CO_2 absorption capacity by the total area available for CO_2 absorption. In this case, it is equal to 642,794.59 tons CO_2/ year divided by 7,358.87 hectares, resulting in an absorption capacity of 87.35 tons CO_2/ hectare. Surabaya City has a carbon sequestration capability of 642,794.59 tons CO_2/ year. Due to the calculation being restricted to the city area, a regional supply factor of "1" is utilized. Equation 1 is used to evaluate the waste's absorption capacity for CO_2. Waste absorption capacity of $CO_{2\text{-eq}}$ in Surabaya City is 7,358.87 hectares.

5.7.5 WAF_{CO2} of solid waste management in Surabaya City

Emissions in the present solid waste management techniques are the cumulative result of emissions generated by each individual action in the solid waste management process. Solid waste management activities, which include collection, transportation, and disposal, result in annual emissions of 3,088.436 tonnes $CO_{2\text{-eq}}$. Landfilling is the primary source of pollution in solid waste disposal, releasing 619,626.185 tonnes $CO_{2\text{-eq}}$/ year. Total annual $CO_{2\text{-eq}}$ emissions generated from solid waste management techniques amount to 622,714.621 tons/ year. It is evident that landfilling procedures are the primary source of CO_2 emissions in the management chain. Equation 2 can be used to compute the WAF_{CO2} of solid waste management operations after determining the total emission resulting from these practices.

$$WAF_{CO2} = \frac{W_{CO2}}{LA_{CO2}} \times \mathrm{rSF}_{CO2} = \frac{622{,}714.621}{87.35} \times 1 = 7{,}128.9596\ Ha \qquad (12)$$

Equation 9 WAF_{CO2} of solid waste management in Surabaya City

WAF_{CO2} represents the entire quantity of CO_2 equivalent emissions, which is 622,714.621 tons. LA_{CO2} refers to the local absorptivity of CO_2, specifically 87.35 tons CO_2/ hectare. rSF_{CO2} represents the regional supply factor for CO_2 absorption, which is 1 in this particular situation. Analysis reveals that the WAF_{CO2} for solid waste management operations in Surabaya City is 7,128.9596 Ha. This indicates that an area of 7,128.9596 Ha is required to fully absorb the emissions generated by solid waste management practices in Surabaya City.

5.7.6 Current WAF_{CO2} status

Waste absorption footprint accounting of solid waste management techniques in Surabaya City reveals that the WAC_{CO2}, which measures 7,358.87 hectares, is still larger than the WAF_{CO2}, which measures 7,128.9596 hectares. Thus, the current solid waste management practices in Surabaya City are deemed sustainable as the city has the capacity to mitigate the negative effects

of CO_2 emissions resulting from these practices. Nevertheless, this study does not take into account the ecological consequences resulting from unregulated disposal of solid waste. Uncontrolled disposal of solid waste has a substantial environmental impact, as it accounts for 11.88% of the total solid waste created in Surabaya City and contributes considerably to the formation of emissions from waste management. Furthermore, the ability to capture carbon dioxide extends beyond just absorbing emissions from solid waste management to include other activities like transportation.

Hence, to ensure the sustainable management of carbon emissions in the solid waste practices of Surabaya City, a viable approach would be to acquire sufficient land areas capable of absorbing the generated carbon dioxide. Given the city's current carbon absorptive capacity of 87.35 ton $CO_{2\text{-eq}}$/ Ha, each individual in Surabaya must possess 0.303 m^2 of land capable of absorbing carbon.

5.7.7 Environmental opportunities of circular economy integration from the perspective of waste absorption footprint

As previously stated, the incorporation of solid waste management concepts into the circular economy model focuses on promoting actions that promote regeneration, such as fostering public-private partnerships in management. By promoting public-private partnership (PPP) initiatives in their operations, corporations have the opportunity to explore the utilization of reclaimed materials from solid waste, commonly known as "waste". Hence, the quantity of solid waste being sent to landfills can be diminished or potentially eradicated. An activity involves establishing a connection between waste banks and organic fertilizer companies in order to generate compost from solid waste. Economic worth of undesirable biological resources can be enhanced by generating compost from solid waste. Furthermore, it is possible to decrease the quantity of methane produced by landfills. An example that exemplifies the environmental opportunity is a waste bank located in Malang, East Java.

Malang waste bank manages a daily volume of 2.5 tons of recyclable waste, which is equivalent to 7.16 tons of waste management per day (Suryani, 2014). Thus, a single waste bank has the potential to decrease landfill waste by 0.35%. Equation 5 can be used to compute the annual emissions of waste that can be prevented from reaching the landfill in this situation. Calculation findings indicate that waste bank activities can prevent the annual emission of 66.262 tonnes $CO_{2\text{-eq}}$/ year. If the 603 waste banks in Surabaya City are equipped with this capacity, the integration of solid waste management in the circular economy model can result in a reduction of 39,955.986 tons $CO_{2\text{-eq}}$/ year or a decrease in WAF_{CO2} by 467.424 Ha, which is equivalent to 1.62 m^2/ capita. Estimation demonstrates that the incorporation of solid waste management with

a circular economy model can offer environmental prospects for Surabaya City. In addition, the integratuin of solid waste management with circular economy model that emphasizes cooperation between communities, private sector, and government is in line with the country's waste management plan contained in Minister of Public Works Regulation No. 21/PRT/M/2006 outlining the national policy and development strategy for waste management.

5.8 Economic Value

Increased production has created a problem that requires landfills. Material flow in society is schematically depicted in Figure 20. Waste is generated when extracting raw materials and during the production process. Most effective way to reduce the waste problem is to reduce the amount and toxicity of the waste. But with the increasing desire for a better standard of living, humans are becoming more and more consuming and generating more waste. Consequently, the community must look for effective waste management methods and ways to reduce the amount of waste that needs to be disposed of in landfills. Following Law No. 18 of 2008, waste management aims to improve public health and environmental quality and make waste a resource.

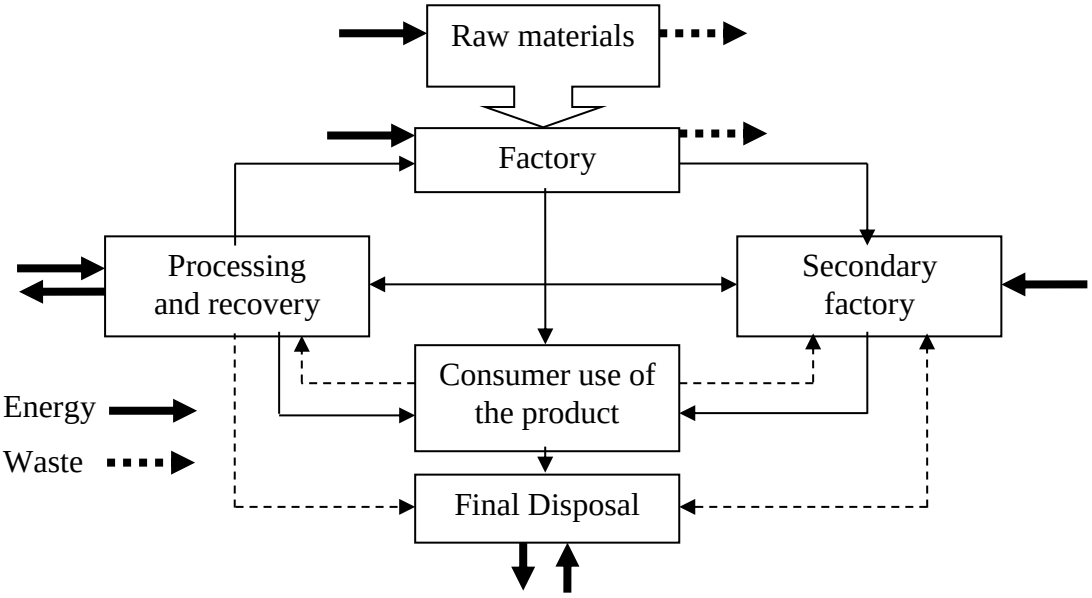

Figure 20. Flow of materials and waste in industrial society

Source: Wikurendra *et al.*, 2024

Increase in waste resulted in increasingly complex problems for managing waste. Solid waste management is complex because it includes many technologies and disciplines. Includes technology associated with control over the generation, storage, collection, transfer and transportation, processing, and disposal of waste, which is acceptable and by the principles of

public health, economics, engineering, aesthetics, and other environmental considerations, including responsiveness to the general public (Thyberg and Tonjes, 2015).

Implementing a circular economy with a focus on the 5Rs can generate economic benefits. The indicator in analyzing the economic value of waste management in Surabaya City is based on the amount of informal sector income from circular economy activities. Informal sector income from circular economy activities can be seen as a direct economic benefit received by the local government (Korsunova *et al.*, 2022). Analysis of the potential economic value of implementing waste management with a circular economy model is based on informal sector income related to waste management. According to Hemidat *et al.* (2022) waste has different economic values according to the composition of each waste and the treatment before sale. An interesting aspect in this analysis is the potential budget savings from implementing waste management with a circular economy model. Activities carried out in waste management, both through reduction and handling, the estimated amount of waste that was transported to the landfill in 2020 was 1,645,350 kg/day. This estimated amount of waste generation is calculated based on household waste entering the landfill, then divided by the total population. This is because waste in Surabaya City that is transported from temporary disposal sites can serve several regions. In addition, compactor trucks that transport waste from temporary disposal sites also transport from various regions based on predetermined routes so that transportation is expected to be fast and effective. Efforts in reducing and handling waste by the community and the Surabaya City Government are also followed by savings in waste transportation costs incurred by the Surabaya City Government. Estimated economic value of implementing the circular economy model in the informal sector, with an emphasis on the 5Rs, in Surabaya City is summarized in Table 18 and amounts to IDR 20,171,164,657.

Table 18. Economic value of implementation the circular economy model in informal sector focusing on 5Rs in Surabaya City

Solid waste management facilities	Amount of waste treated (tons/ year)	Economic value (IDR/ year)
Composting process in compost houses and markets	47,366.750	17,939,588,162
Super depot sutorejo	2,178.293	825,002,334
Jambangan recycling center	831.975	315,100,547
Bratang waste sorting	373.956	141,631,324
3R solid waste processing facility (TPS 3R) – Tambak Osowilangun	736.570	278,967,048
3R solid waste processing facility (TPS 3R) – Tenggilis	321.630	121,813,502
3R solid waste processing facility (TPS 3R) – Kedungcowek	207.325	78,521,855
3R solid waste processing facility (TPS 3R) – Gunung Anyar	192.335	104,734,312
3R solid waste processing facility (TPS 3R) – Karang Pilang	209.335	72,884,573
3R solid waste processing facility (TPS 3R) – Waru Gunung	146.236	79,283,119

Garden and greenway composter		55,385,130
Waste power plant (PLTSa) - Bratang	18.875	7,148,679
Waste power plant (PLTSa) - Wonorejo	19.020	7,203,596
Waste power plant (PLTSa) - Jambangan	25.430	9,631,307
Waste power plant (PLTSa) - Tambak Osowilangun	23.980	9,082,137
Organic waste sweeping	47.230	17,886,420
Plastic waste for surabaya bus	68.747	26,037,305
Other waste (old tires, used sandals, coconut shells and used ceramics)	214.669	81,303,307
TOTAL	53,258.891	20,171,164,657

Source: Primary Analysis, 2024

Benefit of this circular economy implementation is the new source of income obtained from the implementation of the circular economy model in informal sector focusing on 5Rs. Implementation of the circular economy model in informal sector focusing on 5Rs provides economic benefits in the form of revenue of 0.7% of the total environmental management budget of Surabaya City which reaches IDR 2,862,212,000,165. This means that the implementation of the circular economy model in Surabaya City has an economic impact but the amount is still far from the environmental management budget. Some strengthen the researcher's argument that the integration of solid waste management with a circular economy model has an economic impact (Tomić and Schneider, 2020; Paliwal, 2022).

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Primary aim of this study is to investigate the integration of solid waste management into the circular economy model in Surabaya City, Indonesia. An examination of existing methods was conducted to identify obstacles in incorporating solid waste management into the circular economy framework. Study findings indicate that the solid waste management in Surabaya City does not comply with current regulations. Problems can be found in nearly all aspects of waste management, including the generation, containerization, collection, transportation, and disposal of solid waste. Primary issue in solid waste management in Surabaya City is the conduct of the community in handling waste directly at its origin. Analysis of sustainable solid waste management identified issues in various dimensions, including technical, community participation, environmental, financial, institutional, and political factors. Nevertheless, the endorsement of legislation and regulations might exert a favorable influence on the execution of sustainable solid waste management in Surabaya City.

Estimation of waste generation indicates that approximately 2,032.61 tonnes/ day (equivalent to 5,761.37 m^3/ day) of waste is produced in Surabaya City. Amount of waste that can be transported to the landfill is 5071.94 m^3/ day, which accounts for 88.12% of the total. Out of the total waste generated, 54.31% is organic waste that can be easily decomposed. Remaining waste consists of paper/ paper materials (14.63%), plastic (19.44%), metal (0.48%), glass (1.12%), rubber (1.14%), wood/ wood products (1.61%), leather (1.19%), fabric/ textiles (1.47%), ceramics (0.17%), toxic hazardous materials (0.86%), and other miscellaneous items (3.59%). Solid waste management activities, which include collection, transportation, and disposal, result in annual emissions of 3,088.436 tonnes $CO_{2\text{-eq}}$. Landfilling is the primary source of pollution in solid waste disposal, releasing 619,626.185 tonnes $CO_{2\text{-eq}}$/ year.

The study has discovered multiple participants engaged in recycling activities throughout Surabaya City. Individuals mentioned are actors who reside in a certain area, engage in waste picking, purchase waste materials, collect waste, manage waste banks, work in creative industries, and attend schools. Majority of these actors are situated at the lowest level of the recycling hierarchy. However, the actions of these stakeholders are still insufficient to effectively enhance the execution of solid waste management in Surabaya City. Incorporation of solid waste management into the circular economy model holds significant promise as a means to enhance the efficacy of solid waste management in Surabaya City. Findings also indicate that by using the circular economy model, there are possibilities to achieve sustainable performance in solid waste management. Integrating solid waste management with a circular economy model

might provide avenues for generating new employment possibilities and enhancing the economic value of waste management.

Challenges in integrating solid waste management with a circular economy model in Surabaya City include limited economies of scale in waste recycling, limited access to capital for informal actors, low adoption of technology, high transaction costs, ambiguous regulations, and insufficient community participation. Proposed solutions to solve these problems include receiving assistance from the city administration, seeking new corporate partnerships, enhancing infrastructure, facilitating public procurement, and raising public knowledge regarding solid waste recycling. Active participation of citizens can enhance the likelihood of the private sector being able to utilize resources that have been recovered from solid waste.

To integrate solid waste management into the circular economy model, it is recommended to emphasize the connection between regeneration efforts and this integration. Analysis findings suggest that an effective approach to improve regeneration efforts in Surabaya City is to incorporate informal recycling participants into solid waste management methods. Nevertheless, the majority of informal participants in the recycling industry occupy the lowest position in the recycling hierarchy. This condition creates limitations for them to exploit opportunities in solid waste management recycling to grow bigger. It also restricts their involvement in the management of solid waste in Surabaya City. Enhancing the involvement of informal actors in waste management is necessary. A framework is suggested to integrate solid waste management with the circular economy model in Surabaya City. This framework facilitates Public-Private Partnership by engaging the informal sector, city administration, and community to collaboratively tackle solid waste concerns. These strategies discusses three ways for establishing a Public Private Partnership. Strategies involve the coordination of non-official participants, enhancing the waste recycling hierarchy, and maximizing the extraction and utilization of recyclable resources.

Waste bank schemes were suggested as an appropriate form of organization in the field of coordinating informal actors. Organization requires government intervention in the form of supplying recycling equipment, allocating space for composting, enhancing soft skills, and providing financial assistance in order to ensure its success. Establishing cooperation between the recycling sector and end-users of reclaimed items, such as the creative industry, can be utilized to ascend the recycling hierarchy. Furthermore, the utilization of technological methods, such as employing plastic extruder machines, can enhance the worth of the reclaimed resources.

Analysis of waste absorption footprint reveals that the solid waste management procedures in Surabaya City necessitate 7,128.9596 Ha of land for absorption from 7,358.87 Ha out of the total possible carbon absorption land. If the circular economy model is adopted in Surabaya City, the

requirement for sequestration land can be decreased to 467.424 Ha, which is comparable to 1.62 m^2/ capita. This calculation demonstrates the potential environmental benefits of implementing a circular economy model in Surabaya City. Analysis of the economic potential of implementing a circular economy model in the informal sector focusing on the 5Rs in Surabaya City shows that there is a saving of 0.7% of the total environmental management budget of Surabaya City. Economic potential is relatively low but still contributes to revenue.

6.2 Recommendations

This study's suggestions have two components. Initial section pertains to the proposed measures for municipal governance. Second element pertains to the need for further research.

6.2.1 Recommendations for future actions

Recommendations for activities to be undertaken are derived from the findings and ideas provided to the city government, which is responsible for coordinating solid waste management in Surabaya City. The suggestions are as follows:

(a) Incorporate the principles of the circular economy model into the strategic plan for waste management in Surabaya City, specifically focusing on solid waste management. Strategy plan serves as a framework for organizing, executing, and assessing the implementation of effective waste management strategies in Surabaya City. Presence of a strategic plan helps enhance stakeholders understanding of waste management. Accelerating the integration of solid waste management with the circular economy model is a strategic option for achieving sustainable solid waste management. Consequently, the focus of stakeholders in solid waste management will be heightened in relation to adoption of the circular economy model.

(b) Acknowledging the significance of informal actors as crucial stakeholders in the attainment of sustainable solid waste management. By recognizing informal players as significant stakeholders in solid waste management, it may be established as a key strategy in the prioritization of solid waste management in Surabaya City.

(c) Collecting data on individuals or groups involved in the management of solid waste in Surabaya City. Data collected on players involved in solid waste recycling and their production capacity can be utilized to identify the feasibility of implementing a circular economy model in Surabaya City. Collected data can also be utilized to investigate novel prospects for cooperation in the regeneration of solid waste.

(d) Promote the formation of Public Private Partnerships between individuals and non-official participants in initiatives aimed at recycling solid waste. Autonomous, disorganized, and ill-informed characteristics of informal actors render them challenging to collaborate with.

Moreover, the actors involved in establishing a lucrative Public Private Partnership scheme will encounter numerous obstacles. Therefore, it is imperative for them to possess comprehensive knowledge regarding these issues and devise viable methods to surmount them.

(e) Schedule frequent meetings for stakeholders in the solid waste management industry. Regular meetings provide a platform to distribute novel knowledge or expertise to participants in the solid waste management business. Additionally, it can serve as a venue for solid waste management business participants to exchange challenges and possibilities. Integrating perspectives on waste concerns and enlightening participants about their crucial role in solid waste management might be a valuable addition to the meeting.

(f) Establish the Public Private Partnership through cooperative teamwork. Once the group is created, it will require frequent activities. Municipal authorities have the ability to devise a mutually advantageous partnership framework for the organization to facilitate its expansion. An example activity that can be utilized is the allocation of small-scale waste collection and treatment to informal sector organizations.

(g) Advocate for the implementation of Public Private Partnership initiatives. Employment within an organization can be challenging, particularly for those who are unaccustomed to collaborative efforts. They may find it quite challenging to navigate and comply with rules and regulations. Informal sector must be persuaded of the advantages of collaborating in collectives. Hence, it is vital for the government to bolster the sustainability of the organization.

(h) In order to advance in the hierarchy, recyclers should consider forming partnerships with entities in industries that are not typically associated with their own, such as the creative sector. This can help decrease recyclers' reliance on intermediaries.

(i) Promoting waste segregation campaigns, providing sufficient facilities, and enforcing rules are examples of measures that can be implemented to encourage community engagement in waste segregation at its source.

6.2.2 Recommendations for further research

This study highlights the significance of integrating solid waste management with a circular economy model in Surabaya City. Additional investigation into this subject, including the potential job prospects resulting from the adoption of the framework and the potential conflicts of interest among the stakeholders arising from its implementation, will be necessary, as this study cannot address all elements comprehensively. This research exclusively concentrates on the process of regeneration, neglecting other forms of activities such as sharing, looping, and

virtualization, which are not within the scope of this study. Hence, investigating these activities would be intriguing. Furthermore, this study might provide insight into the environmental possibilities and economic value that can arise from integrating solid waste management with circular economy model in Surabaya City. Additional investigation into the environmental benefits and economic value of incorporating solid waste management into a circular economy framework must be undertaken. This would involve extensive data collection and a thorough understanding of the subject matter, which are some of the constraints of this study.

7 NEW SCIENTIFIC RESULTS

This dissertation explores the integration of solid waste management into a circular economy framework, taking into account the actual circumstances at the research site. Prior studies have also examined the integration of solid waste management into a circular economy framework. The dissertation's innovation stems from the suggested framework and the calculation of economic potential, which provides strong justification for the high likelihood of the framework's adoption. Proposed framework is derived from the researcher consideration of the difficulties pertaining to solid waste management in Surabaya City. Specific findings that may be inferred from this research are as follows:

(a) Identification of the current solid waste management in Surabaya City is needed to know the details of the problems that occur. Researcher findings state that although nationally, Surabaya City is the city with the best solid waste management, solid waste management problems still occur. Solid waste management stakeholders in Surabaya City still do not collaborate and synergize in waste management. Amount of waste generated by the community continues to increase from year to year but is not accompanied by optimal management. Process of waste collection, transportation, treatment, disposal, recycling and recovery materials can only overcome 88.12% of the total waste in Surabaya City. Looking at the five aspects of urban waste management, the most important problem in Surabaya City is the lack of community participation in managing waste. This finding is supported by the researcher investigation of the circular economy situation of solid waste management in Surabaya City. Informal sector (scavenging operations, itinerant waste buyers, waste trading organizations, waste banks, and creative industries) still does not have an optimal contribution to solid waste management. Absence of collaboration between the informal sector and other stakeholders has resulted in the potential of waste management not being maximized. This condition is supported by the middle and lower position of the informal sector in the hierarchy of waste management.

(b) Before integrating solid waste management into the circular economy model in Surabaya City, researchers need to identify the current barriers. Researchers found that there are several barriers in integrating solid waste management into the circular economy model. Net profitability of waste management business in Surabaya City is quite low when compared to its population. This is reinforced by the fact that only the informal sector is involved in this business. Lack of financial resources is another barrier that prevents the informal sector from managing waste with a circular economy model. In addition, the current recycling method in Surabaya City is limited to sorting and selling materials to external waste

collectors without any further processing due to inadequate infrastructure and technology. Results also found that the purchasing decisions of Surabaya City residents are significantly influenced by price sensitivity thus forming consumptive habits. Lack of information and unclear regulations result in the targets and goals of the informal sector in waste management not being achieved. Finally, the lack of capacity that makes informal sector financing dependent on the price of the buyer adds to the obstacles in the integration of waste management with the circular economy model in Surabaya City.

(c) To overcome the barriers and challenges of integrating solid waste management into the circular economy model in Surabaya City, a framework inspired by the Ellen MacArthur Foundation is proposed by the researcher. Some solutions from the proposed framework that can be implemented include utilizing economic factors so as to accelerate the integration of waste management with the circular economy model in Surabaya City. Providing regular training to organizations on waste management by utilizing the latest technology. Maximizing community involvement in municipal waste management. As well as facilitating cooperation between citizens, local government and the informal sector. From these solutions, the researcher designed a circular waste management framework that is suitable for Surabaya City. The way to activate it requires city government initiatives, increasing the capacity of informal actors and increasing community participation. Integration of waste management into the circular economy framework requires collaboration between waste banks, citizens, informal actors, local government, and creative industries. If the integration of waste management into the circular economy framework is adopted in Surabaya City, the absorption land requirement can be reduced to 467.424 Ha, which is comparable to 1.62 m^2 /capita. While the economic potential shows a saving of 0.7% of the total environmental management budget in Surabaya City.

8 SUMMARY

Problem of solid waste management in developing countries is a serious challenge and requires special attention. Sub-optimal solid waste management can cause various problems that affect the environment, health, and human life. Circular economy is an innovative solution in addressing environmental crises, including waste management issues. The application of circular economy in waste management is expected to provide significant economic benefits, such as minimizing waste, maximizing yields, and reducing environmental pollution. To understand how solid waste management with a circular economy model can be developed in Surabaya City, this dissertation first investigates the current solid waste management practices in Surabaya City. Results stated that solid waste management in Surabaya City is not optimal in terms of all aspects. Second study investigated the situation of solid waste management with the circular economy model and identified the barriers of the model integration. Barriers identified included net profitability, capital, technology, infrastructure, skill, habit, and others. Solutions were then developed by adopting a framework inspired by the Ellen MacArthur Foundation. Proposed integrated model of waste management with a circular economy approach in Surabaya City was analyzed for its environmental and economic impacts. Overall, the proposed integrated model of waste management with a circular economy approach has a significant impact on the environment and economy.

9 APPENDICES

Appendix 1: Bibliography

Abdel-Shafy, H. I. and Mansour, M. S. M. (2018) 'Solid waste issue: Sources, composition, disposal, recycling, and valorization', *Egyptian Journal of Petroleum*, 27(4), pp. 1275–1290. doi: 10.1016/j.ejpe.2018.07.003.

Abdul, M. and Syafrudin, S. (2018) 'The Importance of Integration Waste Management Aspects as a System in Good and Sustainable Waste Management', *E3S Web Conf.*, 73(07012), pp. 1–5. doi: 10.1051/e3sconf/20187307012.

Abubakar, I. R. *et al.* (2022) 'Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South', *International Journal of Environmental Research and Public Health*. doi: 10.3390/ijerph191912717.

Achillas, C. *et al.* (2011) 'Social acceptance for the development of a waste-to-energy plant in an urban area', *Resources, Conservation and Recycling*, 55(9), pp. 857–863. doi: 10.1016/j.resconrec.2011.04.012.

Agamuthu, P. and Babel, S. (2023) 'Waste management developments in the last five decades: Asian perspective', *Waste Management & Research*. SAGE Publications Ltd STM, 41(12), pp. 1699–1716. doi: 10.1177/0734242X231199938.

Aljuwaiber, A. (2016) 'Communities of practice as an initiative for knowledge sharing in business organisations: a literature review', *Journal of Knowledge Management*. Emerald Group Publishing Limited, 20(4), pp. 731–748. doi: 10.1108/JKM-12-2015-0494.

Ambat, R. E. (2020) 'Design of End of Waste Disposal With Sanitary Landfill Method', in *International Seminar of Science and Applied Technology*. Atlantis Press, pp. 82–89. doi: 10.2991/aer.k.201221.016.

Amheka, A. *et al.* (2015) 'An overview of current household waste management in Indonesia: development of a new integrated strategy', *International Journal of Environment and Waste Management*. Inderscience Publishers, 15(1), pp. 86–98. doi: 10.1504/IJEWM.2015.066953.

Aparcana, S. (2017) 'Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: Review of barriers and success factors', *Waste Management*, 61, pp. 593–607. doi: 10.1016/j.wasman.2016.12.028.

Arneth, A. *et al.* (2017) 'Historical carbon dioxide emissions caused by land-use changes are possibly larger than assumed', *Nature Geoscience*, 10(2), pp. 79–84. doi: 10.1038/ngeo2882.

Arockiam JeyaSundar, P. G. S. *et al.* (2020) '6 - Waste treatment approaches for environmental sustainability', in Chowdhary, P. et al. (eds). Elsevier, pp. 119–135. doi: 10.1016/B978-0-12-819001-2.00006-1.

Aye, L. and Widjaya, E. R. (2006) 'Environmental and economic analyses of waste disposal options for traditional markets in Indonesia', *Waste Management*, 26(10), pp. 1180–1191. doi: 10.1016/j.wasman.2005.09.010.

Ayilara, M. S. *et al.* (2020) 'Waste Management through Composting: Challenges and Potentials', *Sustainability* . doi: 10.3390/su12114456.

Bark, R. *et al.* (2017) *Supporting the circular economy transition*.

Behrooznia, L., Sharifi, M. and Hosseinzadeh-Bandbafha, H. (2020) 'Comparative life cycle environmental impacts of two scenarios for managing an organic fraction of municipal solid waste in Rasht-Iran', *Journal of Cleaner Production*, 268, p. 122217. doi: 10.1016/j.jclepro.2020.122217.

Beraud, H., Barroca, B. and Hubert, G. (2012) 'Functional analysis, a resilience improvement tool applied to a waste management system – application to the "household waste management chain"', *Natural Hazards and Earth System Sciences*, 12(12), pp. 3671–3682. doi: 10.5194/nhess-12-3671-2012.

Bratianu, C. (2015) 'Organizational Knowledge Dynamics: Managing Knowledge Creation, Acquisition, Sharing, and Transformation', in *Knowledge Sharing and Communities of Practice*, pp. 259–285. doi: 10.4018/978-1-4666-8318-1.ch011.

Braungart, M., McDonough, W. and Bollinger, A. (2007) 'Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design', *Journal of Cleaner Production*, 15(13), pp. 1337–1348. doi: 10.1016/j.jclepro.2006.08.003.

Brunner, P. H. and Fellner, J. (2007) 'Setting priorities for waste management strategies in developing countries', *Waste Management & Research*. SAGE Publications Ltd STM, 25(3), pp. 234–240. doi: 10.1177/0734242X07078296.

Bulto, T. W. (2020) 'Impact of Open Burning Refuse on Air Quality: In the Case of "Hidar Sitaten" at Addis Ababa, Ethiopia', *Environmental Health Insights*. SAGE Publications Ltd STM, 14, p. 1178630220943204. doi: 10.1177/1178630220943204.

Campitelli, A., Kannengießer, J. and Schebek, L. (2022) 'Approach to assess the performance of

waste management systems towards a circular economy: waste management system development stage concept (WMS-DSC)', *MethodsX*, 9, p. 101634. doi: 10.1016/j.mex.2022.101634.

Castellani, V., Sala, S. and Mirabella, N. (2015) 'Beyond the throwaway society: A life cycle-based assessment of the environmental benefit of reuse', *Integrated Environmental Assessment and Management*. John Wiley & Sons, Ltd, 11(3), pp. 373–382. doi: 10.1002/ieam.1614.

Central Bureau of Statistics (2020) *Indonesian environmental statistics*, *Central Bureau of Statistics, Republic of Indonesia*. Jakarta.

Central Bureau of Statistics (2023) *Statistical Yearbook of Indonesia 2023*, *Statistical Yearbook of Indonesia*.

Central Bureau of Statistics Surabaya City (2021) *Sukolilo District in Figures 2021*. Surabaya. Available at: https://surabayakota.bps.go.id/publication.

Charonis, G.-K. (2021) 'Degrowth, steady state and circular economies: alternative discourses to economic growth', *Society Register*, 5(3), pp. 75–94. doi: 10.14746/sr.2021.5.3.05.

Clauss, T. *et al.* (2021) 'Organizational ambidexterity and competitive advantage: The role of strategic agility in the exploration-exploitation paradox', *Journal of Innovation & Knowledge*, 6(4), pp. 203–213. doi: 10.1016/j.jik.2020.07.003.

Cordova, M. R. (2020) 'Marine Plastic Debris: Distribution, Abundance, and Impact on Our Seafood', in Wani, K. A., Ariana, L., and Zuber, S. M. (eds) *Handbook of Research on Environmental and Human Health Impacts of Plastic Pollution*. Hershey, PA, USA: IGI Global, pp. 94–121. doi: 10.4018/978-1-5225-9452-9.ch006.

Corral-Marfil, J.-A. *et al.* (2021) 'Recycling Technology Innovation as a Source of Competitive Advantage: The Sustainable and Circular Business Model of a Bicentennial Company', *Sustainability*. doi: 10.3390/su13147723.

Damanhuri, E., Handoko, W. and Padmi, T. (2014) 'Municipal Solid Waste Management in Indonesia', in Pariatamby, A. and Tanaka, M. (eds) *Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions*. Singapore: Springer Singapore, pp. 139–155. doi: 10.1007/978-981-4451-73-4_8.

Davies, A. R. (2012) 'Geography and the matter of waste mobilities', *Transactions of the Institute of British Geographers*. John Wiley & Sons, Ltd, 37(2), pp. 191–196. doi: 10.1111/j.1475-5661.2011.00472.x.

Departemen Pekerjaan Umum (1990) *SK SNI-T 13-1990-F about Technical Procedures for*

Urban Waste Management, Yayasan LPMB Bandung. Indonesia.

Desrochers, P. (2004) 'Industrial symbiosis: the case for market coordination', *Journal of Cleaner Production*, 12(8), pp. 1099–1110. doi: 10.1016/j.jclepro.2004.02.008.

Djuric Ilic, D. *et al.* (2018) 'No zero burden assumption in a circular economy', *Journal of Cleaner Production*, 182, pp. 352–362. doi: 10.1016/j.jclepro.2018.02.031.

Doussoulin, J. P. and Colther, C. (2022) 'Evaluating the Efficiency of Municipal Solid Waste Collection Services in Developing Countries: The Case of Chile', *Sustainability*. doi: 10.3390/su142315887.

Dutta, D. *et al.* (2021) 'Electronic waste pollution and the COVID-19 pandemic', *Environmental Chemistry Letters*. doi: 10.1007/s10311-021-01286-9.

Eka, O. *et al.* (2023) 'Waste Bank in Indonesia: Problem and Opportunities', in *Proceedings of the Business Innovation and Engineering Conference (BIEC 2022)*. Atlantis Press, pp. 284–290. doi: 10.2991/978-94-6463-144-9_27.

Ellen MacArthur Foundation (2012) *Towards the circular economy*. Ellen MacArthur Foundation.

Ellen MacArthur Foundation (2015) *Growth within: a circular economy vision for a competitive Europe*. Available at: https://unfccc.int/sites/default/files/resource/Circular economy 3.pdf.

European Commision (2015) *Closing the loop-An EU action plan for the Circular Economy*. Brussels. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614.

Ezeudu, O. B. and Ezeudu, T. S. (2019) 'Implementation of Circular Economy Principles in Industrial Solid Waste Management: Case Studies from a Developing Economy (Nigeria)', *Recycling*. doi: 10.3390/recycling4040042.

Faaij, A. P. C. (2004) 'Biomass Combustion', in Cleveland, C. J. B. T.-E. of E. (ed.) *Encyclopedia of Energy*. New York: Elsevier, pp. 175–191. doi: 10.1016/B0-12-176480-X/00355-7.

Fadhullah, W. *et al.* (2022) 'Household solid waste management practices and perceptions among residents in the East Coast of Malaysia', *BMC Public Health*, 22(1), p. 1. doi: 10.1186/s12889-021-12274-7.

Fahmi, W. and Sutton, K. (2010) 'Cairo's Contested Garbage: Sustainable Solid Waste Management and the Zabaleen's Right to the City', *Sustainability*, pp. 1765–1783. doi: 10.3390/su2061765.

Fatimah, Y. A. *et al.* (2020) 'Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia', *Journal of Cleaner Production*, 269, p. 122263. doi: 10.1016/j.jclepro.2020.122263.

Ferronato, N. and Torretta, V. (2019) 'Waste Mismanagement in Developing Countries: A Review of Global Issues', *International Journal of Environmental Research and Public Health*, 16(6). doi: 10.3390/ijerph16061060.

Ford, B. A. and Daviso, A. W. (2010) 'Community Integration and Employment of Youth with Special Needs', in Peterson, P., Baker, E., and McGaw, B. B. T.-I. E. of E. (Third E. (eds) *International Encyclopedia of Education*. Oxford: Elsevier, pp. 550–554. doi: 10.1016/B978-0-08-044894-7.01128-3.

Ghisellini, P., Cialani, C. and Ulgiati, S. (2016) 'A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems', *Journal of Cleaner Production*, 114, pp. 11–32. doi: 10.1016/j.jclepro.2015.09.007.

Giarini, O. and Stahel, W. R. (1993) 'Introduction', in Giarini, O. and Stahel, W. R. (eds) *The Limits to Certainty*. Dordrecht: Springer Netherlands, pp. 1–9. doi: 10.1007/978-94-011-1775-3_1.

Global Alliance on Health and Pollution (2019) *Pollution and Health Metrics*.

Gondek, M. *et al.* (2020) 'Soluble Salts in Compost and Their Effects on Soil and Plants: A Review', *Compost Science & Utilization*. Taylor & Francis, 28(2), pp. 59–75. doi: 10.1080/1065657X.2020.1772906.

Günther, I. and Launov, A. (2012) 'Informal employment in developing countries: Opportunity or last resort?', *Journal of Development Economics*, 97(1), pp. 88–98. doi: 10.1016/j.jdeveco.2011.01.001.

Gupta, D. and Gaur, S. K. (2019) '19 - Carbon and biofuel footprinting of global production of biofuels', in Verma, D. et al. (eds) *Woodhead Publishing Series in Composites Science and Engineering*. Woodhead Publishing, pp. 449–481. doi: 10.1016/B978-0-08-102426-3.00019-9.

Gustiabani, Z. and Lingga, Y. S. (2023) 'Issues relating to waste transport system in Sekupang Batam City', *SIGMA TEKNIKA*, 6(1), pp. 214–222. doi: 10.33373/sigmateknika.v6i1.5146.

Gutiérrez-Galicia, F. *et al.* (2021) 'A System for the Inclusion of the Informal Recycling Sector (IRS) in Mexico City's Solid Waste Management', *Sustainability*. doi: 10.3390/su132212490.

Handayani, N., Dewi, S. N. F. and Satriawan, E. (2020) *The mechanism of micro, small, and medium enterprise's data integration in Indonesia for targeting social sssistance and empowerment programs policy brief primary messages*.

Hannon, J. (2020) 'Exploring and Illustrating the (Inter-)Disciplinarity of Waste and Zero Waste Management', *Urban Science* . doi: 10.3390/urbansci4040073.

Hemidat, S. *et al.* (2022) 'Solid Waste Management in the Context of a Circular Economy in the MENA Region', *Sustainability* . doi: 10.3390/su14010480.

Hettiarachchi, H. *et al.* (2018) 'Municipal Solid Waste Management in Latin America and the Caribbean: Issues and Potential Solutions from the Governance Perspective', *Recycling*. doi: 10.3390/recycling3020019.

Hina, M. *et al.* (2022) 'Drivers and barriers of circular economy business models: Where we are now, and where we are heading', *Journal of Cleaner Production*, 333, p. 130049. doi: 10.1016/j.jclepro.2021.130049.

Hoornweg, D., Bhada-Tata, P. and Kennedy, C. (2013) 'Environment: Waste production must peak this century', *Nature News*, 502(7473), p. 615. doi: 10.1038/502615a.

Horne, R. and Andrade, M. C. de (2017) 'Mixed picture for Indonesia's garment sector', *Indonesia Garment and Footwear Sector Bulletin*, (1), pp. 1–12.

Hysa, E. *et al.* (2020) 'Circular Economy Innovation and Environmental Sustainability Impact on Economic Growth: An Integrated Model for Sustainable Development', *Sustainability*. doi: 10.3390/su12124831.

International Labour Organization (2015) *Gender Equality And Green Jobs: Policy Brief*.

International Monetary Fund (2020) *World Economic Outlook Update June 2020, International Monetary Fund*.

IPCC (2019) *Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva: International Panel on Climate Change (IPCC). Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

Jayasinghe, P. A., Derrible, S. and Kattan, L. (2023) 'Interdependencies between Urban Transport, Water, and Solid Waste Infrastructure Systems', *Infrastructures*. doi: 10.3390/infrastructures8040076.

Jiao, W. *et al.* (2013) 'The Waste Absorption Footprint (WAF): A methodological note on footprint calculations', *Ecological Indicators*, 34, pp. 356–360. doi: 10.1016/j.ecolind.2013.05.024.

Johannesson, P. and Perjons, E. (2014) 'Research Strategies and Methods', in Johannesson, P.

and Perjons, E. (eds) *An Introduction to Design Science*. Cham: Springer International Publishing, pp. 39–73. doi: 10.1007/978-3-319-10632-8_3.

Johansson, N., Velis, C. and Corvellec, H. (2020) 'Towards clean material cycles: Is there a policy conflict between circular economy and non-toxic environment?', *Waste Management & Research*. SAGE Publications Ltd STM, 38(7), pp. 705–707. doi: 10.1177/0734242X20934251.

Kabir, Z. and Kabir, M. (2022) 'Solid Waste Management in Developing Countries: Towards a Circular Economy', in Baskar, C. et al. (eds) *Handbook of Solid Waste Management: Sustainability through Circular Economy*. Singapore: Springer Nature Singapore, pp. 3–36. doi: 10.1007/978-981-16-4230-2_1.

Kadafa, A. A. *et al.* (2014) 'Applications of System Analysis Techniques in Solid Waste Management Assessment', *Polish Journal of Environmental Studies*, 23(4), pp. 1061–1070. Available at: http://www.pjoes.com/Applications-of-System-Analysis-Techniques-r-nin-Solid-Waste-Management-Assessment,89282,0,2.html.

Kala, K., Bolia, N. B. and Sushil (2022) 'Analysis of informal waste management using system dynamic modelling', *Heliyon*. Elsevier, 8(8). doi: 10.1016/j.heliyon.2022.e09993.

Katusiimeh, M. W., Burger, K. and Mol, A. P. J. (2013) 'Informal waste collection and its co-existence with the formal waste sector: The case of Kampala, Uganda', *Habitat International*, 38, pp. 1–9. doi: 10.1016/j.habitatint.2012.09.002.

Kementerian PPN, Embassy of Denmark and UNDP (2021) *Summary for Policymakers - the Economic, Social and Environmental Benefits of a Circular Economy*. Jakarta.

Kerstens, S. M. *et al.* (2016) 'Potential demand for recoverable resources from Indonesian wastewater and solid waste', *Resources, Conservation and Recycling*, 110, pp. 16–29. doi: 10.1016/j.resconrec.2016.03.002.

Kibria, M. G. *et al.* (2023) 'Plastic Waste: Challenges and Opportunities to Mitigate Pollution and Effective Management', *International Journal of Environmental Research*, 17(1), p. 20. doi: 10.1007/s41742-023-00507-z.

Kinantan, B., Rahim Matondang, A. and Hidayati, J. (2018) 'Waste management as an effort to improve urban area cleanliness and community income (journal review)', *IOP Conference Series: Materials Science and Engineering*. IOP Publishing, 309(1), p. 12017. doi: 10.1088/1757-899X/309/1/012017.

Kirchherr, J. *et al.* (2023) 'Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions', *Resources, Conservation and Recycling*, 194, p. 107001. doi: 10.1016/j.resconrec.2023.107001.

Kirchherr, J., Reike, D. and Hekkert, M. (2017) 'Conceptualizing the circular economy: An analysis of 114 definitions', *Resources, Conservation and Recycling*, 127, pp. 221–232. doi: 10.1016/j.resconrec.2017.09.005.

Kitinoja, L. and AlHassan, H. Y. (2012) 'Identification of Appropriate Postharvest Technologies For Small Scale Horticultural Farmers and Marketers in Sub-Saharan Africa And South Asia - Part 1. Postharvest Losses and Quality Assessments', in *Acta Horticulturae*. International Society for Horticultural Science (ISHS), Leuven, Belgium, pp. 31–40. doi: 10.17660/ActaHortic.2012.934.1.

Kılıç, C., Soyyiğit, S. and Bayrakdar, S. (2023) 'Economic Complexity, Ecological Footprint, and the Environmental Kuznets Curve: Findings from Selected Industrialized Countries', *Journal of the Knowledge Economy*. doi: 10.1007/s13132-023-01411-9.

Klein, N., Ramos, T. B. and Deutz, P. (2020) 'Circular Economy Practices and Strategies in Public Sector Organizations: An Integrative Review', *Sustainability*. doi: 10.3390/su12104181.

Korhonen, J., Honkasalo, A. and Seppälä, J. (2018) 'Circular Economy: The Concept and its Limitations', *Ecological Economics*, 143, pp. 37–46. doi: 10.1016/j.ecolecon.2017.06.041.

Korsunova, A. *et al.* (2022) 'Necessity-driven circular economy in low-income contexts: How informal sector practices retain value for circularity', *Global Environmental Change*, 76, p. 102573. doi: 10.1016/j.gloenvcha.2022.102573.

Kretschmer, T. *et al.* (2022) 'Platform ecosystems as meta-organizations: Implications for platform strategies', *Strategic Management Journal*. John Wiley & Sons, Ltd, 43(3), pp. 405–424. doi: 10.1002/smj.3250.

Kubota, R., Horita, M. and Tasaki, T. (2020) 'Integration of community-based waste bank programs with the municipal solid-waste-management policy in Makassar, Indonesia', *Journal of Material Cycles and Waste Management*, 22(3), pp. 928–937. doi: 10.1007/s10163-020-00969-9.

Lam, C. H. K. *et al.* (2010) 'Use of Incineration MSW Ash: A Review', *Sustainability* . doi: 10.3390/su2071943.

Latanna, M. D. (2022) 'The evaluation of the community-based solid waste management (waste bank) program in Makassar, South Sulawesi, Indonesia'. Available at: http://essay.utwente.nl/92595/.

Lauder, A. R. *et al.* (2013) 'Offsetting methane emissions — An alternative to emission equivalence metrics', *International Journal of Greenhouse Gas Control*, 12, pp. 419–

429. doi: https://doi.org/10.1016/j.ijggc.2012.11.028.

Leksono, S. (2016) 'The Implementation of Kredit Usaha Rakyat Granting on Market Traders Who Are the Customers of Bank Rakyat Indonesia in Tawangalun Banyuwangi', *Journal of Marketing and Consumer Research (An International Peer-reviewed Journal)*, 19(1), pp. 63–69.

Lissah, S. Y. *et al.* (2021) 'Managing urban solid waste in Ghana: Perspectives and experiences of municipal waste company managers and supervisors in an urban municipality', *PLOS ONE*. Public Library of Science, 16(3), p. e0248392. doi: 10.1371/journal.pone.0248392.

Liu, J. *et al.* (2019) 'The Impact of Consumption Patterns on the Generation of Municipal Solid Waste in China: Evidences from Provincial Data', *International journal of environmental research and public health*. MDPI, 16(10), p. 1717. doi: 10.3390/ijerph16101717.

Liu, X. *et al.* (2022) 'Recycled WEEE plastics in China: Generation trend and environmental impacts', *Resources, Conservation and Recycling*, 177, p. 105978. doi: 10.1016/j.resconrec.2021.105978.

Luna-Nemecio, J., Tobón, S. and Juárez-Hernández, L. G. (2020) 'Sustainability-based on socioformation and complex thought or sustainable social development', *Resources, Environment and Sustainability*, 2, p. 100007. doi: 10.1016/j.resenv.2020.100007.

Lynch, J. *et al.* (2020) 'Demonstrating GWP*: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and long-lived climate pollutants', *Environmental Research Letters*. IOP Publishing, 15(4), p. 44023. doi: 10.1088/1748-9326/ab6d7e.

Mairizal, A. Q. *et al.* (2021) 'Electronic waste generation, economic values, distribution map, and possible recycling system in Indonesia', *Journal of Cleaner Production*, 293, p. 126096. doi: 10.1016/j.jclepro.2021.126096.

Mally, K. (2007) 'Linking socio-economic developmet and environmental pressures', *Dela*, 27, p. 149. doi: 10.4312/dela.27.8.149-162.

Mancini, M. S. *et al.* (2018) 'Exploring ecosystem services assessment through Ecological Footprint accounting', *Ecosystem Services*, 30, pp. 228–235. doi: 10.1016/j.ecoser.2018.01.010.

Mandpe, A. *et al.* (2022) 'Circular economy approach for sustainable solid waste management: A developing economy perspective', *Waste Management & Research*. SAGE Publications Ltd STM, 41(3), pp. 499–511. doi: 10.1177/0734242X221126718.

McDonough, W. and Braungart, M. (2002) 'Design for the Triple Top Line: New Tools for

Sustainable Commerce', *Corporate Environmental Strategy*, 9(3), pp. 251–258. doi: 10.1016/S1066-7938(02)00069-6.

Meidiana, C., Tomoo, S. and Subagiyo, A. (2020) 'Municipal Waste and Its Management', in *The Palgrave Handbook of Global Sustainability*. Cham: Springer International Publishing, pp. 1–14. doi: 10.1007/978-3-030-38948-2_51-1.

Menyuka, N. N., Sibanda, M. and Bob, U. (2020) 'Perceptions of the Challenges and Opportunities of Utilising Organic Waste through Urban Agriculture in the Durban South Basin', *International Journal of Environmental Research and Public Health*. doi: 10.3390/ijerph17041158.

Mihelcic, J. R. *et al.* (2003) 'Sustainability Science and Engineering: The Emergence of a New Metadiscipline', *Environmental Science & Technology*. American Chemical Society, 37(23), pp. 5314–5324. doi: 10.1021/es034605h.

Milios, L. (2018) 'Advancing to a Circular Economy: three essential ingredients for a comprehensive policy mix', *Sustainability Science*, 13(3), pp. 861–878. doi: 10.1007/s11625-017-0502-9.

Minister of National Development Planning (2021) *General Statements: Urban Development to Decrease Disparity, Alleviate Poverty and Create Jobs*.

Ministry of Environment and Forestry (2018) 'Indonesian Domestic Solid Waste Statistic Year 2018'. State Ministry of Environment the Republic of Indonesia Jakarta, Indonesia.

Ministry of Environment and Forestry Directorate General of Climate Change (2021) *Updated Nationally Determined Contribution Republic of Indonesia 2021*.

Ministry of Health of the Republic of Indonesia (2018) *Basic health research 2018 (RISKESDAS 2018), Jakarta: Balitbang Kemenkes RI*.

Mmereki, D., Baldwin, A. and Li, B. (2016) 'A comparative analysis of solid waste management in developed, developing and lesser developed countries', *Environmental Technology Reviews*. Taylor & Francis, 5(1), pp. 120–141. doi: 10.1080/21622515.2016.1259357.

Moleong, L. J. (2018) *Metodelogi Penelitian Kuantitatif*. Bandung: PT Remaja Rosdakarya.

Muhamad, A. F. *et al.* (2020) 'Strategy of landfilled waste reduction by a distributed materials recovery facility system in Surabaya, Indonesia', *Waste Management & Research*. SAGE Publications Ltd STM, 38(10), pp. 1142–1152. doi: 10.1177/0734242X20932217.

Muheirwe, F., Kombe, W. J. and Kihila, J. M. (2023) 'Solid Waste Collection in the Informal Settlements of African Cities: a Regulatory Dilemma for Actor's Participation and Collaboration in Kampala', *Urban Forum*. doi: 10.1007/s12132-023-09482-2.

Muhyiddin, M. and Nugroho, H. (2021) 'A Year of Covid-19: A Long Road to Recovery and Acceleration of Indonesia's Development', *Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning*. Ministry of National Development Planning Republic of Indonesia/Bappenas, 5(1), pp. 1–19.

Munawar, E. *et al.* (2018) 'The development of landfill operation and management in Indonesia', *Journal of Material Cycles and Waste Management*, 20(2), pp. 1128–1142. doi: 10.1007/s10163-017-0676-3.

Mushtaq, J., Dar, A. Q. and Ahsan, N. (2020) 'Spatial–temporal variations and forecasting analysis of municipal solid waste in the mountainous city of north-western Himalayas', *SN Applied Sciences*, 2(7), p. 1161. doi: 10.1007/s42452-020-2975-x.

Nguyen, A. T. *et al.* (2023) 'Residents' waste management practices in a developing country: A social practice theory analysis', *Environmental Challenges*, 13, p. 100770. doi: 10.1016/j.envc.2023.100770.

Nguyen, K. L. P. *et al.* (2020) 'Impacts of socioeconomic changes on municipal solid waste characteristics in Taiwan', *Resources, Conservation and Recycling*, 161, p. 104931. doi: 10.1016/j.resconrec.2020.104931.

Oberman, R. *et al.* (2012) *The archipelago Economy: Unleashing Indonesia's potential*, *McKinsey Global Institute*.

OECD (2020) *Mainstreaming Gender and Empowering Women for Environmental Sustainability, 2020 Global Forum on Environment*.

Ogunmakinde, O. E. (2019) 'A Review of Circular Economy Development Models in China, Germany and Japan', *Recycling*. doi: 10.3390/recycling4030027.

Paliwal, R. (2022) 'From Waste to Wealth: Stepping Toward Sustainability Through Circular Economy', in Baskar, C. et al. (eds) *Handbook of Solid Waste Management: Sustainability through Circular Economy*. Singapore: Springer Nature Singapore, pp. 441–463. doi: 10.1007/978-981-16-4230-2_82.

Pemerintah Republik Indonesia (2017) *Presidential Regulation No. 97/2017 on Regional Policy and Strategy for the Management of Household Waste and Waste Similar to Household Waste*. doi: https://peraturan.bpk.go.id/Home/Details/73225/perpres-no-97-tahun-2017.

Pemerintah Republik Indonesia (2018) *Presidential Regulation No. 83/2018 on Marine Debris Handling*. Available at: https://peraturan.bpk.go.id/Home/Details/94716/perpres-no-83-tahun-2018.

Pemerintah Republik Indonesia (2020) *Presidential Regulation No. 18/2020 on the National*

Medium-Term Development Plan 2020-2024. Available at: https://jdih.setkab.go.id/PUUdoc/176020/Perpres_Nomor_18_Tahun_2020.PDF.

Phan, L. T. *et al.* (2021) 'Quality of Life and Factors Affecting It: A Study Among People Living Near a Solid Waste Management Facility', *Frontiers in Public Health*, 9, pp. 1–9. doi: 10.3389/fpubh.2021.720006.

Phonchi-Tshekiso, N. D., Mmopelwa, G. and Chanda, R. (2020) 'From public to private solid waste management: Stakeholders' perspectives on private-public solid waste management in Lobatse, Botswana', *Chinese Journal of Population, Resources and Environment*, 18(1), pp. 42–48. doi: 10.1016/j.cjpre.2021.04.015.

Pieroni, M. P. P., McAloone, T. C. and Pigosso, D. C. A. (2019) 'Business model innovation for circular economy and sustainability: A review of approaches', *Journal of Cleaner Production*, 215, pp. 198–216. doi: 10.1016/j.jclepro.2019.01.036.

Pires, A. and Martinho, G. (2019) 'Waste hierarchy index for circular economy in waste management', *Waste Management*, 95, pp. 298–305. doi: 10.1016/j.wasman.2019.06.014.

Plant Chicago (2020) *The Circular Economy Toolkit For Small Business*.

Purba, L. A. H. and Erliyana, A. (2020) 'Legal Framework of Waste Management in Indonesia', in *Proceedings of the International Conference on Law, Governance and Islamic Society (ICOLGIS 2019)*. Atlantis Press, pp. 104–108. doi: 10.2991/assehr.k.200306.191.

Purchase, C. K. *et al.* (2022) 'Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits', *Materials*. doi: 10.3390/ma15010076.

Qomariyah, P. and Hamid, E. S. (2023) 'Community-based waste management: Best practice for waste management in Panggungharjo Village, Sewon District, Bantul Regency', *IOP Conference Series: Earth and Environmental Science*. IOP Publishing, 1180(1), p. 12009. doi: 10.1088/1755-1315/1180/1/012009.

Rajput, R., Prasad, G. and Chopra, A. K. (2009) 'Scenario of solid waste management in present Indian context', *Caspian J. Env. Sci*, 7(1), pp. 45–53.

Ranta, V. *et al.* (2018) 'Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe', *Resources, Conservation and Recycling*, 135, pp. 70–82. doi: 10.1016/j.resconrec.2017.08.017.

Rizos, V. *et al.* (2016) 'Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers', *Sustainability*. doi:

10.3390/su8111212.

Robert, M. (2021) ‘The role of community participation in solid waste management in Zimbabwe: The case of Nyanga township’, *The Dyke*. Midlands State University, 15(1), pp. 116–130. doi: 10.10520/ejc-dyke_v15_n1_a9.

Roy, D. and Tarafdar, A. (2022) ‘Solid Waste Management and Landfill in High-Income Countries’, in Pathak, P. and Palani, S. G. (eds) *Circular Economy in Municipal Solid Waste Landfilling: Biomining & Leachate Treatment : Sustainable Solid Waste Management: Waste to Wealth*. Cham: Springer International Publishing, pp. 1–23. doi: 10.1007/978-3-031-07785-2_1.

Rynk, R. *et al.* (2022) ‘Chapter 1 - Why compost?’, in Rynk, R. B. T.-T. C. H. (ed.) *The Composting Handbook*. Academic Press, pp. 1–26. doi: 10.1016/B978-0-323-85602-7.00001-7.

Sala, S., Ciuffo, B. and Nijkamp, P. (2015) ‘A systemic framework for sustainability assessment’, *Ecological Economics*, 119, pp. 314–325. doi: 10.1016/j.ecolecon.2015.09.015.

Salvia, G. *et al.* (2021) ‘The wicked problem of waste management: An attention-based analysis of stakeholder behaviours’, *Journal of Cleaner Production*, 326, p. 129200. doi: 10.1016/j.jclepro.2021.129200.

Samiha, B. (2013) ‘The Importance of the 3R Principle of Municipal Solid Waste Management for Achieving Sustainable Development’, *Mediterranean Journal of Social Sciences*, 4(3), p. 129. doi: 10.5901/mjss.2013.v4n3p129.

Sand, M. *et al.* (2023) ‘A multi-model assessment of the Global Warming Potential of hydrogen’, *Communications Earth & Environment*, 4(1), p. 203. doi: 10.1038/s43247-023-00857-8.

Sari, D. P., Masruroh, N. A. and Asih, A. M. (2021) ‘Consumer Intention to Participate in E-Waste Collection Programs: A Study of Smartphone Waste in Indonesia’, *Sustainability* . doi: 10.3390/su13052759.

Schneider, P. *et al.* (2017) ‘Solid Waste Management in Ho Chi Minh City, Vietnam: Moving towards a Circular Economy?’, *Sustainability*. doi: 10.3390/su9020286.

Sharma, K. D. and Jain, S. (2020) ‘Municipal solid waste generation, composition, and management: the global scenario’, *Social Responsibility Journal*. Emerald Publishing Limited, 16(6), pp. 917–948. doi: 10.1108/SRJ-06-2019-0210.

Shekdar, A. V (2009) ‘Sustainable solid waste management: An integrated approach for Asian

countries', *Waste Management*, 29(4), pp. 1438–1448. doi: 10.1016/j.wasman.2008.08.025.

Sherratt, A. (2013) 'Cradle to Cradle', in Idowu, S. O. et al. (eds) *Encyclopedia of Corporate Social Responsibility*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 630–638. doi: 10.1007/978-3-642-28036-8_165.

Shukla, S. and Khan, R. (2022) '23 - Sustainable waste management approach: A paradigm shift towards zero waste into landfills', in Hussain, C. and Hait, S. B. T.-A. O. W. M. (eds) *Advanced Organic Waste Management: Sustainable Practices and Approaches*. Elsevier, pp. 381–395. doi: 10.1016/B978-0-323-85792-5.00006-X.

Sinthumule, N. I. and Mkumbuzi, S. H. (2019) 'Participation in Community-Based Solid Waste Management in Nkulumane Suburb, Bulawayo, Zimbabwe', *Resources*. doi: 10.3390/resources8010030.

Sitanggang, H. and Siahaan, E. W. B. (2021) 'Pemanfaatan Mesin Pencacah Sampah Organik Portabel untuk Keperluan Rumah Tangga di Kecamatan Simanindo Kabupaten Samosir', *JUITECH: Jurnal Ilmiah Fakultas Teknik Universitas Quality*, 5(2), pp. 63–67. doi: 10.36764/ju.v5i2.632.

Skinner, J. H. (2004) 'VII.2 - Solid waste management policies for the 21st century', in Twardowska, I. B. T.-W. M. S. (ed.) *Solid Waste: Assessment, Monitoring and Remediation*. Elsevier, pp. 1091–1098. doi: 10.1016/S0713-2743(04)80043-6.

Soukiazis, E. and Proença, S. (2020) 'The determinants of waste generation and recycling performance across the Portuguese municipalities – A simultaneous equation approach', *Waste Management*, 114, pp. 321–330. doi: 10.1016/j.wasman.2020.06.039.

Stahel, W. R. (2016) 'The circular economy', *Nature*, 531(7595), pp. 435–438. doi: 10.1038/531435a.

Su, B. *et al.* (2013) 'A review of the circular economy in China: moving from rhetoric to implementation', *Journal of Cleaner Production*, 42, pp. 215–227. doi: 10.1016/j.jclepro.2012.11.020.

Sudibyo, H. *et al.* (2017) 'Municipal Solid Waste Management in Indonesia - A Study about Selection of Proper Solid Waste Reduction Method in D.I. Yogyakarta Province', *Energy Procedia*, 143, pp. 494–499. doi: 10.1016/j.egypro.2017.12.716.

Suryani, A. S. (2014) 'Role of Waste Banks in Effectiveness of Waste Management (Case Study of Waste Banks in Malang)', *Aspirasi: Jurnal Masalah-masalah Sosial*, 5(1), pp. 71–84. doi: 10.46807/aspirasi.v5i1.447.

Suthar, S., Rayal, P. and Ahada, C. P. S. (2016) 'Role of different stakeholders in trading of reusable/recyclable urban solid waste materials: A case study', *Sustainable Cities and Society*, 22, pp. 104–115. doi: 10.1016/j.scs.2016.01.013.

Syafrudin, S., Masjhoer, J. M. and Maryono, M. (2022) 'Characterization and quantification of solid waste in rural regions', *Global Journal of Environmental Science and Management*. GJESM Publisher, 9(2), pp. 337–352. doi: 10.22034/gjesm.2023.02.12.

Taelman, S. E. *et al.* (2018) 'A Holistic Sustainability Framework for Waste Management in European Cities: Concept Development', *Sustainability* . doi: 10.3390/su10072184.

Tambunan, T. (2019) 'Recent evidence of the development of micro, small and medium enterprises in Indonesia', *Journal of Global Entrepreneurship Research*, 9(1), p. 18. doi: 10.1186/s40497-018-0140-4.

Thyberg, K. L. and Tonjes, D. J. (2015) 'A Management Framework for Municipal Solid Waste Systems and Its Application to Food Waste Prevention', *Systems* . doi: 10.3390/systems3030133.

Toha, M. and Rahman, M. M. (2023) 'Estimation and prediction of methane gas generation from landfill sites in Dhaka city, Bangladesh', *Case Studies in Chemical and Environmental Engineering*, 7, p. 100302. doi: 10.1016/j.cscee.2023.100302.

Tomić, T. and Schneider, D. R. (2020) 'Circular economy in waste management – Socio-economic effect of changes in waste management system structure', *Journal of Environmental Management*, 267, p. 110564. doi: 10.1016/j.jenvman.2020.110564.

Tong, Y. D., Huynh, T. D. X. and Khong, T. D. (2021) 'Understanding the role of informal sector for sustainable development of municipal solid waste management system: A case study in Vietnam', *Waste Management*, 124, pp. 118–127. doi: 10.1016/j.wasman.2021.01.033.

Trivedi, M. *et al.* (2020) 'Waste Management: A Paradigm Shift', in Shukla, V. and Kumar, N. (eds) *Environmental Concerns and Sustainable Development: Volume 2: Biodiversity, Soil and Waste Management*. Singapore: Springer Singapore, pp. 337–363. doi: 10.1007/978-981-13-6358-0_14.

UNDP (2019) *Supporting Indonesia in developing a National Circular Economy Strategy - 1st Phase*. Available at: https://info.undp.org/docs/pdc/Documents/IDN/PIP_CIRCULAR ECONOMY_signed.pdf.

Ustohalova, V. (2011) 'Management and Export of Wastes: Human Health Implications', in Nriagu, J. B. T.-E. of E. H. (Second E. (ed.) *Encyclopedia of Environmental Health*. Oxford: Elsevier, pp. 219–228. doi: 10.1016/B978-0-444-63951-6.00573-8.

Varshney, R., Singh, Pratichi and Yadav, D. (2022) ‘Chapter 2 - Hazardous wastes treatment, storage, and disposal facilities’, in Yadav, D. et al. (eds) *Hazardous Waste Management*. Elsevier, pp. 33–64. doi: 10.1016/B978-0-12-824344-2.00009-4.

Vaverková, M. D. (2019) ‘Landfill Impacts on the Environment—Review’, *Geosciences*. doi: 10.3390/geosciences9100431.

Vegter, D., van Hillegersberg, J. and Olthaar, M. (2020) ‘Supply chains in circular business models: processes and performance objectives’, *Resources, Conservation and Recycling*, 162, p. 105046. doi: 10.1016/j.resconrec.2020.105046.

Velenturf, A. P. M. and Purnell, P. (2021) ‘Principles for a sustainable circular economy’, *Sustainable Production and Consumption*, 27, pp. 1437–1457. doi: 10.1016/j.spc.2021.02.018.

Velis, C. A. *et al.* (2023) ‘Socio-economic development drives solid waste management performance in cities: A global analysis using machine learning’, *Science of The Total Environment*, 872, p. 161913. doi: 10.1016/j.scitotenv.2023.161913.

Vis, M. (2017) ‘Chapter 8 - Assessing the Potential From Bio-waste and Postconsumer Wood’, in Panoutsou, C. B. T.-M. and O. of B. S. C. (ed.) *Modeling and Optimization of Biomass Supply Chains*. Academic Press, pp. 199–218. doi: 10.1016/B978-0-12-812303-4.00008-2.

Viva, L. *et al.* (2020) ‘Designing Circular Waste Management Strategies: The Case of Organic Waste in Amsterdam’, *Advanced Sustainable Systems*. John Wiley & Sons, Ltd, 4(9), p. 2000023. doi: 10.1002/adsu.202000023.

Walsh, C., O’Regan, B. and Moles, R. (2009) ‘Incorporating methane into ecological footprint analysis: A case study of Ireland’, *Ecological Economics*, 68(7), pp. 1952–1962. doi: 10.1016/j.ecolecon.2008.07.008.

Waluyo, and Kharisma, D. B. (2023) ‘Circular economy and food waste problems in Indonesia: Lessons from the policies of leading Countries’, *Cogent Social Sciences*. Cogent OA, 9(1), p. 2202938. doi: 10.1080/23311886.2023.2202938.

Wang, H. *et al.* (2019) ‘China’s CO2 peak before 2030 implied from characteristics and growth of cities’, *Nature Sustainability*, 2(8), pp. 748–754. doi: 10.1038/s41893-019-0339-6.

WIEGO (2018) *Violence and Informal Work: Brief Note*.

Wikurendra, Edza Aria *et al.* (2022) ‘Evaluation of the Commercial Bio-Activator and a Traditional Bio-Activator on Compost Using Takakura Method’, *Journal of Ecological Engineering*, 23(6), pp. 278–285. doi: 10.12911/22998993/149303.

Wikurendra, E.A. *et al.* (2022) 'Strengths, weaknesses, opportunities, and threats of waste management with circular economy principles in developing countries: A systematic review', *Environmental Quality Management*, 32(1), pp. 87–94. doi: 10.1002/tqem.21846.

Wikurendra, E. A. *et al.* (2023) 'Forecast of Waste Generated and Waste Fleet using Linear Regression Model', *Polish Journal of Environmental Studies*, 32(2), pp. 1867–1876. doi: 10.15244/pjoes/158779.

Wikurendra, E. A. *et al.* (2024) 'Urbanization and Benefit of Integration Circular Economy into Waste Management in Indonesia: A Review', *Circular Economy and Sustainability*. doi: 10.1007/s43615-024-00346-w.

Wikurendra, E. A., Abdeljawad, N. S. and Nagy, I. (2023) 'A Review of Municipal Waste Management with Zero Waste Concept: Strategies, Potential and Challenge in Indonesia', *International Journal of Environmental Science and Development*, 14(2). doi: 10.18178/ijesd.2023.14.2.1427.

Williams, H. *et al.* (2020) 'Avoiding food becoming waste in households – The role of packaging in consumers' practices across different food categories', *Journal of Cleaner Production*, 265, p. 121775. doi: 10.1016/j.jclepro.2020.121775.

Wilson, D. C. *et al.* (2017) 'Operator models for delivering municipal solid waste management services in developing countries. Part A: The evidence base', *Waste Management & Research*. SAGE Publications Ltd STM, 35(8), pp. 820–841. doi: 10.1177/0734242X17705723.

Wilson, D. C., Velis, C. and Cheeseman, C. (2006) 'Role of informal sector recycling in waste management in developing countries', *Habitat International*, 30(4), pp. 797–808. doi: 10.1016/j.habitatint.2005.09.005.

World Bank Group (2018) *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Edited by S. Kaza et al. World Bank Publications. doi: 10.1596/978-1-4648-1329-0.

World Bank Group (2022) *Solid Waste Management*. Edited by D. Hoornweg and P. Bhada-Tata. doi: 10.1201/9781315593173-4.

Wulandari, D., Utomo, S. H. and Narmaditya, B. S. (2017) 'Waste Bank: Waste Management Model in Improving Local Economy', *International Journal of Energy Economics and Policy*, 7(3 SE-Articles), pp. 36–41. Available at: https://econjournals.com/index.php/ijeep/article/view/4496.

Xu, X. and Yang, Y. (2022) 'Municipal hazardous waste management with reverse logistics

exploration', *Energy Reports*, 8, pp. 4649–4660. doi: 10.1016/j.egyr.2022.02.230.

Yahia, E. M. *et al.* (2019) 'Chapter 3 - Photosynthesis', in Yahia, E. M. B. T.-P. P. and B. of F. and V. (ed.) *Postharvest Physiology and Biochemistry of Fruits and Vegetables*. Woodhead Publishing, pp. 47–72. doi: 10.1016/B978-0-12-813278-4.00003-8.

Yakubu, Y. and Zhou, J. (2019) 'Novel approach to quantify municipal solid waste management hierarchy based on analytical hierarchy process', *International Journal of Environmental Science and Technology*, 16(4), pp. 1897–1908. doi: 10.1007/s13762-018-1768-x.

Yana, S. *et al.* (2022) 'Biomass waste as a renewable energy in developing bio-based economies in Indonesia: A review', *Renewable and Sustainable Energy Reviews*, 160, p. 112268. doi: 10.1016/j.rser.2022.112268.

Yang, M. *et al.* (2022) 'Circular economy strategies for combating climate change and other environmental issues', *Environmental Chemistry Letters*. doi: 10.1007/s10311-022-01499-6.

Yoada, R. M., Chirawurah, D. and Adongo, P. B. (2014) 'Domestic waste disposal practice and perceptions of private sector waste management in urban Accra', *BMC Public Health*, 14(1), p. 697. doi: 10.1186/1471-2458-14-697.

Yu, Y. *et al.* (2022) 'Relationship between environmental pollution and economic development in late-developing regions shows an inverted V', *Science of The Total Environment*, 838, p. 156295. doi: 10.1016/j.scitotenv.2022.156295.

Yukalang, N., Clarke, B. and Ross, K. (2017) 'Barriers to Effective Municipal Solid Waste Management in a Rapidly Urbanizing Area in Thailand', *International Journal of Environmental Research and Public Health* . doi: 10.3390/ijerph14091013.

Zhang, A. *et al.* (2019) 'Barriers to smart waste management for a circular economy in China', *Journal of Cleaner Production*, 240, p. 118198. doi: 10.1016/j.jclepro.2019.118198.

Zhijun, F. and Nailing, Y. (2007) 'Putting a circular economy into practice in China', *Sustainability Science*, 2(1), pp. 95–101. doi: 10.1007/s11625-006-0018-1.

Zisopoulos, F. K. *et al.* (2023) 'Informal recyclers as stakeholders in a circular economy', *Journal of Cleaner Production*, 415, p. 137894. doi: 10.1016/j.jclepro.2023.137894.

Zorpas, A. A. (2020) 'Strategy development in the framework of waste management', *Science of The Total Environment*, 716, p. 137088. doi: 10.1016/j.scitotenv.2020.137088.

Appendix 2: Questionnaire and Interview questions

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCE
FACULTY OF ECONOMIC SCIENCE
Doctoral School of Management and Organizational Science

I am a student at the Hungarian University of Agriculture and Life Science Kaposvar Campus, Hungary, and I am conducting this survey as part of my thesis of the Doctoral School of Management and Organizational Science. This research aims to analyse the current practice of waste management, identifying the challenges and looking for the suitable framework to integrate Circular Economy (CE) in waste management in Surabaya City. Waste management is an important aspect for creating healthy conditions for people and the environment. Indeed successful waste management are crucial for human wellbeing, environment protection and economic beneficial effects. Moreover, when waste management is framed under the Circular Economy (CE) principles, more tangible economic benefits can be expected.

In the case of Surabaya City, there are evidences showing that waste management is poorly implemented. Therefore, our interest to analyze the waste management situation in Surabaya City. From this analysis, I am to identify the waste management challenges and possible improvement strategies towards Circular Economy (CE) integration. Your opinion at this regard is very important, your participation will be anonymous and treated with confidentiality. You are kindly asked to respond to this survey which might take at least 20 minutes of your time. Your answers will be statistically analysed and only used for this research purpose.

Thank you in advance for your contribution to this research.

Doctoral School of Management and Organizational Science

Edza Aria Wikurendra

1. Solid waste collection service

   Tick the answer/s (√) below based on your experience

   1.1 Did you receive solid waste collection service?

   ☐yes ☐No

   1.2 Who is your solid waste collection service provider

   ☐from government ☐from the community ☐private person ☐not collected

   1.3 What is the frequency of solid waste collection in your area?

   ☐once or more a day

   ☐more than once in a week

   ☐once a week

   ☐less than once in a week

   ☐not collected

   1.4 Do you pay taxes to cover the costs of wastes collection and management?

   ☐yes ☐No ☐I do not know

   1.5 Do you agree with to pay for waste collection service?

   ☐yes ☐No

   If not go to question 2.1

   1.6 How much should the monthly fee for waste collection service be?

   ☐<15.000 ☐15.000-30.000 ☐30.000-50.000 ☐50.000-75.000 ☐ >75.000

   1.7 Do you agree to pay more for increasing waste management service (e.g. composting and biogas utilisation by the government)?

   ☐yes ☐No

2. Solid waste disposal behaviour

   Tick the answer/s (√) that applied to your routine activity

   2.1 What do you do with your waste?

   ☐Burry the waste

   ☐Burning the waste

   ☐Throw in the river

   ☐Throw to the collected

   ☐Picked by community groups

   ☐Picked by cleanliness division

2.2 Reuse

Tick the answer/s (√) according to your level of agreement

The tendency for reuse	Disagree	Neutral	Agree
I prefer to buy usable secondhand goods but cheaper than the more expensive new goods	☐	☐	☐
I prefer to use good quality secondhand goods than new good with lower quality	☐	☐	☐
I prefer to use my own shopping bag than receiving plastic bag from the shop/ market	☐	☐	☐
I prefer to carry my own drinking water bottle than to buy mineral water in shops	☐	☐	☐
I will accept and use secondhand gifts from my friends/ relatives	☐	☐	☐
As long as it is economically feasible, I prefer to repair my goods than buy new ones	☐	☐	☐

2.3 Please choose three reasons of why you avoid to repair your goods.

☐Will be more expensive than buy the new one

☐It is already outdating

☐I prefer to use the new goods

☐Hard to find service center/ spare parts

☐It is impossible to repair

☐Other, write down what is……

3. Recycle

3.1 I knew that my household solid waste has economic value

☐yes ☐No

3.2 I sort my household solid waste

☐yes ☐No

3.3 **What is your opinion about sorting your household solid waste** (Tick the answer/s (√) according to your level of agreement)	**Disagree**	**Nor Agree or Disagree**	**Agree**
I am obliged to sort out my household solid waste	☐	☐	☐
I have solid waste sorting facilities	☐	☐	☐
I knew how to sort my household solid waste	☐	☐	☐
I knew why solid waste must be sorted	☐	☐	☐
I can get bigger economic value if the solid waste is sorted	☐	☐	☐
I can contribute to solid waste management in my country	☐	☐	☐

3.4 **How important these factors can affect your solid waste separation activity** (Choose (√) 1 for the most un-important factor to 5 for the most important factor)	**1**	**2**	**3**	**4**	**5**
Solid waste sorting knowledge	☐	☐	☐	☐	☐
Proper solid waste sorting facility	☐	☐	☐	☐	☐
Strict penalties	☐	☐	☐	☐	☐
Common activity (My neighbors also sorted out the solid waste)	☐	☐	☐	☐	☐
Pay more expensive fees if the solid waste is not sorted	☐	☐	☐	☐	☐
Economic benefits	☐	☐	☐	☐	☐

3.5 **Choose** (√) **three most important factors** that prevent you from sorting your household solid waste

☐No strict penalty was given

☐Do not have adequate knowledge

☐Do not have sorting facility

☐No incentive was given

☐Not common activity

☐have the same economic value with unsorted solid waste

3.6 **The trade of solid waste**	**Disagree**	**Neutral**	**Agree**
I agree to sell my household solid waste	☐	☐	☐
The only choice for me is to sell my solid waste to waste collector	☐	☐	☐
If I sell my solid waste, I prefer to sell it to door to door buyer who buy at a cheaper price than have to bring it to a collection place that buy for a higher price	☐	☐	☐
I prefer to use the revenue from the sale of waste to be used as solid waste fee deduction than receive it in cash	☐	☐	☐
I know what a waste bank is	☐	☐	☐
The waste bank is the same as the waste collector	☐	☐	☐
There is no profit I can get by becoming a waste bank member	☐	☐	☐

3.7 I will become waste bank member if: **(Choose** (√) **three reasons)**

☐I can earn noticeable benefit

☐I do not have to invest a lot of time in waste bank's activities

☐My neighbors/ friends are members of waste bank also

☐It is obliged to me

☐I can get solid waste collection service for free

☐Other……

3.8 **If I buy recycle products, I will consider these factors** (Choose (√) 1 for the most un-important factor to 5 for the most important factor)	**1**	**2**	**3**	**4**	**5**
Can be used for daily activities	☐	☐	☐	☐	☐
Durability	☐	☐	☐	☐	☐
Reasonable price	☐	☐	☐	☐	☐
Artistic value	☐	☐	☐	☐	☐
Uniqueness	☐	☐	☐	☐	☐
Fashionable/ trendy	☐	☐	☐	☐	☐
Guarantee from reputable brand	☐	☐	☐	☐	☐

Represent environmental preservation action	☐	☐	☐	☐	☐

3.9 The types of recycled products that I consider to use are: **(Choose two answers)**

☐Household appliances (ex: broom, mat, napkin)

☐Fashion (ex: shirt, bag, sandal)

☐Furniture (ex : chair, table)

☐Household accessories (ex : decorative lamp, photo frame, decorative jar)

☐Souvenir (ex : gift box, key chain)

☐Other……

4. Recovery

4.1 Composting

What is your opinion regarding composting	**Disagree**	**Nor Agree or Disagree**	**Agree**
I know how to compost my household solid waste	☐	☐	☐
I have/can make composting facility	☐	☐	☐
I can use my own compost	☐	☐	☐
Composting the solid waste will require a lot of my time	☐	☐	☐
I can sell my compost for reasonable price easily	☐	☐	☐
I have composted my solid waste	☐	☐	☐
By composting my solid waste, I can contribute in environmental preservation	☐	☐	☐

4.2 Biogas by anaerobic bio digestion

What is your opinion regarding energy recovery from solid waste	**Disagree**	**Nor Agree or Disagree**	**Agree**
I know my household solid waste can produce energy	☐	☐	☐
I know how to produce energy from my solid waste	☐	☐	☐
I would like to tap the energy from solid waste even though it will require time to operate	☐	☐	☐

5. Personal data

5.1 What is your educational background?

☐Elementary school

☐Junior high school

☐High school

☐College

☐Universities

5.2 How much your monthly income?

<1 jt/65 €

1jt-3jt/ 65-200 €

3jt-5jt/ 200-355 €

5jt-7jt/ 355-465 €

>7jt/ 465 €

5.3 Where do you live?

City……

Thank you for your participation!

INTERVIEW QUESTIONS

ENVIRONMENTAL AGENCIES

1. Can you explain the role of Environmental Agencies in solid waste management of Surabaya City?
2. What kind of strategies that have been or will be issued to improve the effectivity and efficiency of solid waste management in Surabaya City and how to achieve it?
3. How will local government take the responsibility regarding the possible negative impact from the solid waste management practice?
4. How will local government deal with solid waste reduction target? What are the obstacles?
5. How is the role of private sectors or waste generator in solid waste management in Surabaya City?
6. In your opinion what kind of drivers that can improve their strategic role in solid waste management?
7. Are there any initiatives that supported by the government regarding solid waste management?
8. How environmental department did or will encourage the collaboration among stakeholders in solid waste management?
9. Some problems for private sector to take part in solid waste management are economic feasibility, regulatory barriers, market condition and socio-cultural challenges. How can government overcome these challenges in order to take private sectors as part of waste management in Surabaya City?
10. Have you ever heard about circular economy?

CLEANSING DIVISION

1. What is the role of cleansing division in solid waste management in Surabaya City?
2. What kind of challenges to deliver the adequate solid waste services?
3. How is the condition of the households participation regarding solid waste management?
4. Is there any program that have prepared to improve the participation of households? How will the program work?
5. How will private sector be able to help cleansing division tasks regarding solid waste management?
6. Is there any program that have prepared to reduce the barriers of private sector participations in solid waste management? How will the program work?
7. Is there any participant regarding the delivery of solid waste management service? What are the

roles of other sectors participations in solid waste management?

SUB-DIVISION OF SOLID WASTE COLLECTION AND TRANSPORTATION

1. Please explain the main tasks of your sub-division regarding solid waste management in Surabaya City?
2. What kind of services that your sub-div delivers regarding solid waste management? And how delivers those services?
3. To what extent the performance of your sub-div have fulfil the solid waste management objectives?
4. How it should be maintained/ improved in the future?
5. Is there any non-compliance practice from the solid waste collection and transportation? Why?
6. What kind of strategies that or will be used for optimisation of the tasks delivery?
7. Is there any barrier for these strategies implementation? What are they?
8. How is the participation level of households regarding the fulfilment of your tasks? To what extent the participation level has been explored?
9. Can you identify the opportunities of private sector collaboration in solid waste management especially collection and transportation?
10. What kind of barriers that hinder partnership or collaboration of private sector regarding solid waste collection and transportation? And how government can support the partnership?
11. Have you ever heard about circular economy?

DISPOSAL SITE MANAGEMENT UNIT

1. Please explain the disposal unit routine tasks and how is the condition of disposal site?
2. What kind of strategies can be used to improve disposal site regarding your main tasks/ how to achieve it?
3. Are there any challenges to fulfil your task?
4. What are the obstacles (inside/ outside) you think to achieve the successful disposal?
5. Is there any strategy that have/ will be/ can be used to reduce the volume of solid waste that reachesthe disposal site? What will be the requirements?
6. Please tell me about the condition of scavenging activities in the disposal site? How can it be improved?
7. What is your opinion regarding solid waste management collaboration with the private sectors particularly regarding solid waste disposal activity?
8. Can you identify the opportunities of private sector collaboration in solid waste

management especially the disposal element?

9. What are the barriers of private sectors in order to take part as mutual partner in solid waste management especially in disposal activities? How can government enable the partnership?

CREATIVE INDUSTRIES

1. Please explain your business focus?
2. What are the significant factors for the growth of your business?
3. How can you manage your business to fulfil those factors?
4. What kind of challenges must you face for expanding your business?
5. How to overcome these challenges?
6. What constraints must be overcome so that you can use solid waste as an industrial raw material? How these constraints can be overcome?
7. In order to overcome those challenges, what kind of strategic cooperation will you need?
8. Have you heard about circular economy? What is your opinion regarding this concept?

WASTE BANK

1. Please explain your business focus especially regarding solid waste management in Surabaya City? How can it be expanded in the future and how will it influence the solid waste management practice in Surabaya City?
2. How is the response of other actors in solid waste management regarding the existence of your business?
3. What kind of barrier you must face in solid waste commercialization?
4. What is the interest level of households in your business field? How can it be improved?
5. Do you have any cooperation with another business which provide profitable opportunities? Please explain the strategic position of the cooperation?
6. What will be the challenge for long term partnership that benefitable for both sides?
7. What kind of cooperation you wish to have in your business? How it can be achieved? What can of barriers need to be overcome?
8. Is there any incentive/ support you wish to receive in the future?

Appendix 3: List of publications

Publications on the topic of the dissertation:

Wikurendra, E.A., Csonka, A., Nagy, I. and Nurika, G., 2024. Urbanization and Benefit of Integration Circular Economy into Waste Management in Indonesia: A Review. *Circular Economy and Sustainability*.
https://doi.org/10.1007/s43615-024-00346-w

Wikurendra, E.A., Abdeljawad, N.S. and Nagy, I., 2023. A Review of Municipal Waste Management with Zero Waste Concept: Strategies, Potential and Challenge in Indonesia. *International Journal of Environmental Science and Development*, 14(2).
https://doi.org/10.18178/ijesd.2023.14.2.1427

Wikurendra, E. A., Syafiuddin, A., Herdiani, N., and Nurika, G. (2023). Forecast of Waste Generated and Waste Fleet using Linear Regression Model. *Polish Journal of Environmental Studies*, 32(2), pp.1867-1876.
https://doi.org/10.15244/pjoes/158779

Wikurendra, E.A., 2022. Waste Management with Circular Economy Approach in Indonesia, *in ECONOMIC AND BUSINESS TRAJECTORY: Indonesia, Asia, and Europe*. Cham: Delta Pijar Khatulistiwa p.19-44.
ISBN: 978-623-5696-19-5

Wikurendra, E.A., Ferto, I., Nagy, I. and Nurika, G., 2022. Strengths, weaknesses, opportunities, and threats of waste management with circular economy principles in developing countries: A systematic review. *Environmental Quality Management, 32*(1), pp.87-94.
https://doi.org/10.1002/tqem.21846

Wikurendra, E.A. and Nagy, I., 2022. Trends in integrated waste management research: A content analysis. *Environmental and Toxicology Management, 2*(1), pp.26-30.
https://doi.org/10.33086/etm.v2i1.2911

Wikurendra, E.A., Nurika, G., Herdiani, N. and Lukiyono, Y.T., 2022. Evaluation of the Commercial Bio-Activator and a Traditional Bio-Activator on Compost Using Takakura Method. *Journal of Ecological Engineering, 23*(6), pp.278-285.

https://doi.org/10.12911/22998993/149303

Abdeljawad, N.S., **Wikurendra, E.A.** and Nagy, I., 2022. Waste-to-Energy Projects for Urban Sustainability of Amman, Jordan: Challenges And Benefits. *Journal of Southwest Jiaotong University*, *57*(6).
https://doi.org/10.35741/issn.0258-2724.57.6.102

Wikurendra, E.A. and Herdiani, N., 2020. Utilization Of Black Soldier Fly (Hermetia Illucens) As A Problem Solve Of Organic Waste. *Human Care Journal*, *5*(4), pp.966-972.
http://dx.doi.org/10.32883/hcj.v5i4.994

Published papers that do not relate to the topic of the dissertation:

Aan Adriansyah, A., Setianto, B., Lukiyono, Y.T. and **Wikurendra, E.A.,** 2023. Proactive method for identification and handling of patient complaints with root cause analysis in Surabaya Islamic Hospital. *Journal of Public Health Research*, *12*(4), p.22799036231208357.
https://doi.org/10.1177/22799036231208357

Nurika, G., Abidah, H.N., **Wikurendra, E.A.** and Ningtyias, F.W., 2023. Microplastic Pollution in Green Shells in Aquatic Ecosystems: A Literature Review of Determinant Factors and Management. *Journal of Environmental Health*, *15*(4).
https://doi.org/10.20473/jkl.v15i4.2023.257-266

Andini, A., Veterini, L., **Wikurendra, E.A.**, Syafiuddin, A., Rimasari, D. and Aida, M.N., 2023. Histopathological findings of the liver and kidneys of wistar rat exposed to insect repellent. *Bali Medical Journal*, *12*(2), pp.1330-1333.
https://doi.org/10.15562/bmj.v12i2.4315

Elisanti, A.D., Jayanti, R.D., Amareta, D.I., Ardianto, E.T. and **Wikurendra, E.A.**, 2023. Macronutrient intake in stunted and non-stunted toddlers in Jember, Indonesia. *Journal of Public Health Research*, *12*(3), p.22799036231197178.
https://doi.org/10.1177/22799036231197178

Kurnianto, A.A., Fehér, G., Tololiu, K.E., **Wikurendra, E.A.**, Nemeskéri, Z. and Ágoston, I., 2023. Analysis of the return to work program for disabled workers during the pandemic COVID-19 using the quality of life and work ability index: cross-sectional study. *International journal of*

environmental research and public health, *20*(4), p.3094.
https://doi.org/10.3390/ijerph20043094

Lukiyono, Y.T., **Wikurendra, E.A.**, Zain, S.S. and Utomo, S.S., 2023. Nutrient analysis of fermented chicken feather fertilizer waste using Bacillus subtilis on the growth of green spinach (Amaranthus tricolor). *Bali Medical Journal*, *12*(3), pp.2855-2858.
https://doi.org/10.15562/bmj.v12i3.4444

Lukiyono, Y.T., **Wikurendra, E.A.**, Zain, S.S. and Utomo, S.S., 2023. Environmental health risk analysis of hydrogen sulfide (H2S) and ammonia (NH3) from vehicle fumes around Purabaya Terminal with a radius of 250 and 500 meters in 2022. *Bali Medical Journal*, *12*(3), pp.3319-3321.
https://doi.org/10.15562/bmj.v12i3.4415

Setiawan, B., Afin, R., **Wikurendra, E.A.**, Nathan, R.J. and Fekete-Farkas, M., 2022. Covid-19 pandemic, asset prices, risks, and their convergence: A survey of Islamic and G7 stock market, and alternative assets. *Borsa Istanbul Review*.
https://doi.org/10.1016/j.bir.2022.11.011

Wikurendra, E.A., Syafiuddin, A., Nurika, G. and Elisanti, A.D., 2022. Water quality analysis of pucang river, sidoarjo regency to control water pollution. *Environmental Quality Management*, *32*(1), pp.133-144.
https://doi.org/10.1002/tqem.21855

Umami, A., Sukmana, H., **Wikurendra, E.A.** and Paulik, E., 2022. A review on water management issues: potential and challenges in Indonesia. *Sustainable Water Resources Management*, *8*(3), p.63.
https://doi.org/10.1007/s40899-022-00648-7

Wikurendra, E.A., 2022. Differences Leadership Styles in Gender Perspective, *in Leadership and Management Theory in Practice*. Cham: Hungarian University of Agriculture and Life Sciences Kaposvár Campus, p.102-109.
ISBN: 978-615-5599-94-1

Wikurendra, E.A., 2022. Kaizen and Implementation in Japan Manufacturing Industry, *in Leadership and Management Theory in Practice*. Cham: Hungarian University of Agriculture and Life Sciences Kaposvár Campus, p.145-158.
ISBN: 978-615-5599-94-1

Osiako, P.O., **Wikurendra, E.A.** and Abdeljawad, N.S., 2022. Concept of green marketing in environment conservation: A Literature review. *Environmental and Toxicology Management*, *2*(2), pp.8-13.
https://doi.org/10.33086/etm.v2i2.3335

Wikurendra, E.A., Aini, S.A., Nagy, I., Nurika, G., Herdiani, N. and Shamsudin, S.B., 2022. Source of Microplastic Pollution Within Human Stool in the Surabaya River Basin Area. *Journal of Chemical Health Risks*, *12*(4), pp.581-586.
https://doi.org/10.22034/jchr.2022.1940009.1406

Wikurendra, E.A., Herdiani, N., Tarigan, Y.G. and Kurnianto, A.A., 2021. Risk factors of pulmonary tuberculosis and countermeasures: A literature review. *Open Access Macedonian Journal of Medical Sciences*, *9*(F), pp.549-555.
https://doi.org/10.3889/oamjms.2021.7287

Wikurendra, E.A, Wijaya, S. and Nagy, I., 2020. Microbiological Quality Analysis of Drinking Water in An-Nuriyah Islamic Boarding School Wonocolo Surabaya. *Journal of Global Research in Public Health*, *5*(2), pp.217-220.
https://doi.org/10.30994/jgrph.v5i2.289

Fakhira, A.D., Pawitra, A.S., Diyanah, K.C., **Wikurendra, E.A.**, Nagy, I. and Abdeljawad, N.S.M., 2021. Awareness of doing 3M (wearing mask, physical distancing, washing hands) during pandemic era in rural and urban families. *Jurnal Kesehatan Lingkungan*, *13*(2), p.94.
https://doi.org/10.20473/jkl.v13i2.2021.94-101

Abidah, H.N., Ismah, H.A., Irmayanti, S., Nurika, G. and **Wikurendra, E.A.**, 2021. The effectivity of solid medical waste management in pandemic era. *Journal of Public Health for Tropical and Coastal Region*, *4*(3), pp.98-107.
https://doi.org/10.14710/jphtcr.v4i3.10618

10 ACKNOWLEDGMENTS

I couldn’t have reached this goal without the help of many people in my life. I’d like to take this opportunity to thank them for their support.

I am grateful for the prolonged support of Prof. Dr. Imre Nagy, CSc, professor in Doctoral School of Economic and Regional Science at the Hungarian University of Agriculture and Life Science. Without their help, guidance, useful comments, and suggestions, I would not have ended up with a well-versed piece of writing. I would also like to thank Zsófia Móga and Dr. Kinga Szabó for their excellent coordination of the doctoral program.

To all the colleagues who have helped to follow this line of inquiry and provided constructive criticism to me. It would be difficult to name them all, but I would like to thank everyone involved in this dissertation.

Of course, I cannot end my acknowledgment without thanking my Indonesian university partners and hosts. Their insights and guidance were a bright light that guided me through this research project.

Last but not least, I’d like to acknowledge the emotional support provided by my wife, family and friends. I made it to the top of the mountain! I look forward to celebrating with all of you. Finally, I thank the Doctoral School of Economic and Regional Science at the Hungarian University of Agriculture and Life Science for their countless support throughout my education.

11 DECLARATION

I hereby declare that I have written this dissertation myself and have not used any auxiliary materials other than those indicated. The dissertation consists of parts of my own published work as first author. I have marked all verbatim or substantive passages as such, which are listed in the bibliography.

I hereby declare that this thesis is my own work, prepared after registration for the Ph.D. degree at the Hungarian University of Agriculture and Life Sciences Kaposvár Campus, and that it has not previously been included or submitted in any work at this or any other institution for a degree, diploma, or other qualification.

I have read the current University Ethics Policy and accept responsibility for the conduct of the procedures. I have attempted to identify all risks associated with conducting this research, have obtained the appropriate ethical and/or safety approval (if applicable), and acknowledge my obligations and the rights of participants.

Kaposvár, January 24, 2024

Edza Aria Wikurendra