MASTER THESIS

The Integration of Circular Economy into Municipal Solid Waste Management in Metro City, Indonesia

Challenges and Environmental Opportunities

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List of Abbreviations

CBO	Community based organization
CE	Circular Economy
COD	Chemical Oxygen Demand
EF	Ecological Footprint
EU	European Union
FPS	Final Processing Site
GDRP	Gross Domestic Regional Product
HKTI	Association of Indonesian Farmers
KLHK	The Ministry of Environment and Forestry
KUR	Citizen's Business Credit
MSEs	Micro or Small Enterprises
MSW	Municipal Solid Waste
P4S	Self-support Farmers and Villages Training Centre
PPP	Public-Private partnership
SNI	Indonesian National Standard
SOKLI	Community Support
SW	Solid Waste
SWM	Solid Waste Management
SWM	Solid Waste Management
MC	Metro City
TPS3R	Solid Waste Management Site that applies Reduce, Reuse and Recycle principles
TpY	Tonnes per Year
UPT	Technical Implementation Unit
WAC	Waste Absorption Capacity
WAF	Waste Absorption Footprint

ABSTRACT

Increasing generation of solid waste is one of the most serious problems in the world. A solid waste generation has a strong relationship with major environmental issues such as climate change, resource depletion and ecosystem damage. Therefore, solid waste must be managed to reduce the negative impacts produced by solid waste. However, many studies revealed that adequate solid waste management (SWM) with the current approach is costly. For municipalities in developing countries such as Metro City, which was used as a representative case in Indonesia, the delivery of adequate SWM with the current approach is hardly achievable. Therefore, another approach such as the implementation of reduce, reuse and recycle (3Rs) operations need to be explored. As part of such exploration, studies have reported that the involvement of the private sector in the SWM can be a suitable option in countries like Indonesia. Moreover, the 3Rs are in the core of the Circular Economy (CE) principles which general purpose is the elimination of waste generation by emphasizing on retaining the materials value through collaborative schemes between private and public sectors. The intention to explore CE in connection with SWM exposed the need to have a suitable framework to integrate CE principles within SWM, in Metro. Therefore the main goal of the current study is to determine the suitable framework of CE integration in SWM of Metro City.

The current practice of SWM in Metro, as well as the challenges to integrating CE in SWM in Metro, were firstly analyzed. By doing this, several problems were identified which originally come from the poor performance of sustainable SWM aspects. However, well-established legal frameworks and community willingness to participate brought the idea of a positive supportive setting to enable sustainable SWM. While the relatively small economic scale of recycling solid waste, the lack of access to the capital of informal actors, the low technological base of solid waste management, high transaction costs, poorly defined regulations and lack of actual citizens participation are among the most important challenges to integrate CE into SWM in the Metro City context. To overcome these challenges, a framework to increase the role of informal sectors, enabling Public-Private Partnership by involving informal sectors and the municipality to work together is proposed for Metro.

Additionally, this study also investigated the environmental opportunities that can be obtained from CE integration in SWM. By applying Waste Absorption Footprint methodology, it was estimated that current SWM activities, i.e. collection, transportation and disposal, emit 24,145.90-ton CO2-eq per year which corresponds to a WAF_{CO2} as big as 100 m^2 per capita. However, as an alternative scenario, it was also calculated the WAF_{CO2} as CE was already integrated to SWM which resulted in a reduction of 14,743,935.69-ton CO2-eq per year (WAF_{CO2} 40 m^2 per capita).

I. INTRODUCTION

In this chapter, several important arguments about the research purpose of this project are deployed. Firstly, a brief background about the current situation of municipal solid waste in Indonesia is described.

1.1. Background

According to a report by the World Bank (2012), Municipal Solid Waste (MSW) is one of the most serious problems in the world. Furthermore, the MSW generation will annually increase from 1.3 billion tons in 2012 to 2.2 billion tons in 2025. 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, 2012). Tanaka (2014), also agreed MSW has a strong relationship with those major environmental issues such as climate change, resource depletion and ecosystem damage.

More than half of the expected increase of MSW generation will take place in developing countries as the result of economic booming and the population growth (Minghua, et al., 2009). Indonesia is one of those countries, becoming a huge producer of MSW. 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 MSW generators in the world (Shekdar, 2009; BPS, 2012).

Solid Waste Management (SWM) practice in Indonesia itself is still inadequate if it is compared to sustainable SWM[1] (Damanhuri E. , 2005). The Ministry of Environment and Forestry (KLHK) had reported that 90% of Indonesian municipalities still practice open dumping and can only collect 60-70% of their generated solid waste (KLHK, 2015). According to the law no 18/2008, the government is mentioned as the key player in SWM in Indonesia which need to ensure proper and sustainable SWM.

However, the limited budget for the solid waste management, the lack of interest from local authorities, low level of knowledge among solid waste managers to apply adequate treatment and low level of understanding, awareness and participation among community members about the importance of proper solid waste treatment, were enlisted as general obstacles for government to conducts proper SWM in Indonesia (Damanhuri E. , 2005). Furthermore, the law also mandates governments are required to achieve sustainable

[1] Sustainable Solid Waste Management is the management of solid waste that aim to balance the social acceptability, economic feasibility and technology viability (source: Shekdar, 2009)

SWM. And by "sustainable" is meant that SWM should be operated in a way that it can benefit the environment, economic and society simultaneously and in a balanced manner. Therefore, SWM in Indonesia is regarded to overcome these problems so that the goals of SWM which are the increasing of public health and environmental quality and also making solid waste as a resource can be achieved. Several methods have been proposed in the previous studies about SWM in Indonesia. One of the suitable approaches is the involvement of the private sector as part of SWM stakeholders management (Aye & Widjaya, 2006). Moreover, Damanhuri mentions that the viable options for MSWM in Indonesia should emphasise on the reduce, reuse and recycle (Damanhuri E. , 2005).

However, the implementation of reduce, reuse and recycle requires paradigm change for SWM in Indonesia, from the current end of the pipe approach to cradle to cradle approach. For example, change from landfill emphasising SWM to the utilisation of Circular Economy (CE) concept in municipal SWM. Circular Economy is a principle that maintains material at their highest value and utility through a systematic approach and distinguishing technical and biological cycles (Ellen MacArthur Foundation, 2015).

CE has gained popularity in the developed countries like those within the European Union (EU). In the EU, CE has been applied to address not only the manufacturing sector which highly correlates with the economy but also for their MSW problems as part of the systematic economic cycle. Municipal SWM with the integration of CE is believed not only to address the economic issues of high expenses municipal SWM but can bring environmental and social benefits as well (European Comission, 2017).

On the other hand, in order to trigger a change toward sustainable SWM, the measurement of environmental opportunities prediction of CE integration in SWM is also done in this study. As it can enhance the cognition of local government regarding the choice of municipal SWM strategy. Therefore, increase in motivation and resource strategy allocation of resources like funds, policies and organisational changes can be increased. Therefore, this study will also count the Waste Absorption Footprint (WAF) of current SWM and predict the environmental opportunities of CE integration to SWM from the perspective of WAF (Bressers & Lulofs, 2010; Jiao, Min, Cheng, & Li, 2013).

1.2. Problem Statement

Metro city has the obligation to deliver solid waste management that can guarantee public health, maintain the environmental conditions and can recover the resource through enabling solid waste streams. However, the lack of financial support and expensiveness of conducting proper solid waste treatment made adequate management unachievable currently. Moreover, the government was found as the only actor to ensure the adequate solid waste management in Metro. Therefore, affordable management to guarantee the achievement of sustainable solid waste management needs to be explored.

On the other hand, circular economy (CE) principles that prevent waste from being generated by economic approach seem to offer attractive solutions for solid waste management problems in Metro. However, CE implementation is a relatively new concept in Indonesia, therefore a framework with CE integration with the SWM in Metro requires to be analysed and discussed.

1.3. Research Objectives

The objective of this research is to generate suitable recommendations to improve the sustainability of the MSWM in the City of Metro. This latter is foreseen by assessing the MSWM current practices and its environmental impacts from the perspective of WAF to proffer strategies to maximize the MSWM benefits of applying Circular Economy tenets.

II. LITERATURE REVIEW

In this chapter, several concepts regarding integration of Municipal Solid Waste Management with circular economy principles are discussed. Furthermore, the environmental impact measurement by Waste Absorption Footprint accounting was presented, as well.

2.1. Municipal Solid Waste Management

In order to understand the concept of municipal Solid Waste Management (SWM), the definitions of several related terms of municipal SWM have a prominent position in this section. The first concept to be described is solid waste, in most of the literature of the Solid Waste (SW) field, it is defined as discarded useless materials as the consequences of every activity (Tchobanoglous, Theisen, & Vigil, 1993). While Municipal Solid Waste (MSW) is assumed the sum of all community solid waste streams, i.e. residential, commercial, institutional, construction and demolition municipal services and municipal utility treatment plants activities (Tchobanoglous, Theisen, & Vigil, 1993). While Municipal Solid Waste Management (MSWM) is a set of activities defined by the municipality(ies) in order to achieve proper and effective handling of solid waste. The objectives of proper and effective municipal SWM are to provide human beings health protection, environmental preservation, and resource conservation. Therefore, proper and effective MSWM is a very crucial aspect if the goal is to achieve sustainable development (Brunner & Fellner, 2007; Tseng, 2011).

Equivalent definition, to some extent, but different category of solid waste to be handled is when deeply looking at the Indonesian law number 18/2008 because in there, the MSW is defined as the daily residual of human and/or natural process which formed in solid phases of residential, commercial, institutional, road sweeping or landscaping and non-hazardous industrial waste.

Even though it seems to be consensual understanding of the MSW concepts on its meaning at different governmental levels, the generation of MSW tendency is gradually increasing, and some prognosis even point out that according to the current (2012) growth rates, it can be expected to move from 1.3 billion Tonnes per Year (TpY) (2012 baseline year) to 2.5 billion TpY by 2030. Therefore, radical changes in the way MSW is understood and operated are seriously discussed and promoted to prevent such situation. Even further, from a production-consumption perspective, this implies the increase of natural resources extraction because consumption pushes companies to keep extracting them and, the more waste is generated

with no reintegration to the productive processes the more natural resources will need to be extracted from their natural environment in order to cope with the production demands. At this regard, waste generation and natural resource relationships, Global Footprint Network reported that in 2012 global resources and waste assimilation demand has surpassed the maximum sustainable capacity of the earth by 1.5. This statement means that if every person in the world maintains 2012 consumption and wastage pattern, 1.5 piles of earth would be required to achieve sustainability. Therefore, systematic changes that imply waste assimilation reduction such as the one suggested by Circular Economy (CE) at the municipal SWM need to be integrated to the traditional concept of SWM.

Looking deeper to the role of municipalities regarding SWM, municipal SWM is not an easy task for the municipalities since it is an intensive task especially for municipalities that come from low and middle-income countries like Indonesia (Damanhuri E. , 2005). The increasing waste generation, the inadequate budget for proper SWM, lack of understanding of factors that influence the successfulness of SWM are the major challenges that must be conquered by waste managers (Guerrero, Maas, & Hogland, 2013). Then, to shift paradigms in terms of waste assimilation reduction of CE integration to the current SWM represents an additional challenge for municipalities. Municipal solid waste itself consists of a combination of materials from biodegradable[2], non-biodegradable, and hazardous materials[3] with different characteristics from one place to other and come from different sources with various compositions. Thereby, it is not possible to handle MSW with only one generic treatment (UNEP, 2009, p. 21). In order to avoid waste and to maximise the efficient use of resource set of priorities regarding material usage was made, this set of priorities known as a waste hierarchy (Lansink, 1980). There are many waste hierarchy definitions and set of actions for waste hierarchy implementation. In figure 1, there is a representation of the waste hierarchy, currently used and promoted by the European Commission. Waste hierarchy becomes a guideline of SWM practices in many countries including Indonesia.

[2] Biodegradable material is the material that can be easily degraded by biological process (Source: Tchobanoglous, Theisen, & Vigil, 1993)

[3] Hazardous material is substances, energies, and/or other components that due to their nature, concentration, and/or quantity, either directly or indirectly, may pollute and/or damage the environment, and / or endanger the environment, health, and human and other living things (source: Indonesian Government Regulation 101/2014)

Figure 1 Waste hierarchy (European Comission, 2016)

In the waste hierarchy model, a barrier of waste criteria was put, the threshold to distinguish when a certain material can be categorised as waste or a secondary material/non-waste which can be called end-of-waste criteria (European Comission, 2016).

The elements of the waste hierarchy consist of prevention, preparing for reuse, recycling, recovery and disposal. Prevention is the most preferred operation in the waste hierarchy. This hierarchy includes reducing and reusing operations. The proper manipulation of the generation sources of solid wastes is crucial to prevent decharging of still valuable materials with commercial value. The next hierarchy level is preparing for reuse which preparing products or part(s) of the products that have become waste can be reused. Checking, cleaning or repairing actions are included in this stage. If the products cannot be reused the next stage is recycling which reprocesses waste materials into products, substances or materials for the original product or other purposes. For example, the solid waste that generated from an activity can be recovered through physical or/and chemical transformation in order to regain the valuable material. The next step in the waste hierarchy is recovery which meaning suggests using waste to serve a purposeful service by replacing materials that intended to be used so those materials can fulfil another particular function. And the least preferred operation is the "Disposal", which corresponds to the re-introduction of wastes to nature, which might have negative consequences when the landfill is not engineer-wisely well managed (Pariatamby & Fauziah, 2013; European Comission, 2016).

The main purpose of waste hierarchy implementation is to provide a step-wise framework to avoid waste generation. As priory here indicated, the wastes hierarchy processes can also be used as a connector between the waste generation process and the production process through the creation of new products. Hence if the quality of the materials recycled and recovered from waste streams can substitute virgin materials, this would imply that the

demand for virgin resources can be minimised through the implementation of the waste hierarchy. A direct connection between this hierarchy and Circular Economy has been reported by several authors, arguing for reduction of waste generation from our economic system (Hultman & Corvellec, 2012; Ellen MacArthur Foundation, 2014).

The implementation of waste hierarchy is varying per country, the most notable difference is observed between developed and developing countries. In developed countries, the implementation of SWM has moved upward from the hierarchy. Some of these movements were driven by technological breakthroughs like mechanical waste separator or waste incineration which is considered as an expensive treatment for weak economic countries. While in developing countries despite being formally adopted as a guideline to manage the solid waste, many of them do not use waste hierarchy in a daily practice.

However, good SWM practice that has been implemented in developed countries is the result of SWM evolution for decades. And it is not possible for developing countries to take a great leap and implement such beyond the needed baseline provided by a current practice SWM. Nevertheless, developing countries can benefit from the experience of developed countries to develop their own SWM-waste hierarchy. Moreover, the implementation of waste hierarchy is based on best practicable environmental options which also take into account the social and economic aspects. Therefore, just rely on the adoption of technological approach without being accompanied with appropriate context adaptation is not a suitable solution to develop better SWM (Hansen, Christopher, & Verbuecheln, 2002; Marshall & Farahbakhsh, 2013).

2.2. Circular Economy Integration in Solid Waste Management

Earth as a *material closed system*[4] has only finite resources to fulfil human need. On the other hand, the increase in world population brings consequence to the increase of global consumption. With the current economic pattern relying still on take-make-dispose [5] production and consumption,the increasing rate of resource consumption will consequently increase the rate of waste generation (Day, 2015). However, many wastes which still contains valuable materials directly dumped before receive any proper treatment to maintain the optimum value of the materials. Consequently, new virgin resources need to be extracted from the finite earth to replace the discharged materials (Ellen MacArthur Foundation, 2015).

In fact, production and consumption paradigms will need to leave up to ways that can maintain longer the value of materials all along the value chain, from operations in the raw material extraction till consumers use of discharge of products. Businesses have therefore a crucial role in the production stage(s) in order to try to maintain the value of technical nutrients[6] while return biological nutrients[7] to re-digest in the earth as safe as possible. The distinction between the two types of nutrients was framed within the CE (Day, 2015). Without a doubt a very important lobbyist of CE has been the Ellen MacArthur Foundation who in 2015 formulated a CE concept, which is here quoted: "*A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles*." The conceptual scheme of CE model also developed by Ellen MacArthur Foundation is displayed in Figure 2.

[4] Earth as material closed system means that there is no material that come out or come in from the earth system except for the rare occurrence such as meteorite (sources: Mehrtens, 2008)

[5] This is what Ellen MacArthur refers as linear economy (sources: Ellen Macarthur Foundation, 2014)

[6] Technical nutrients refer to the material durable material which is unsuitable to returned to the biosphere

[7] Biological nutrients refer to consumable that can safely to be returned to the biosphere.

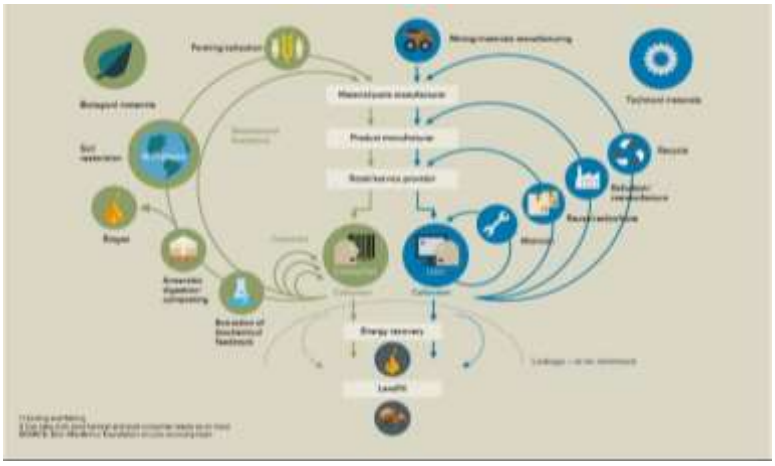


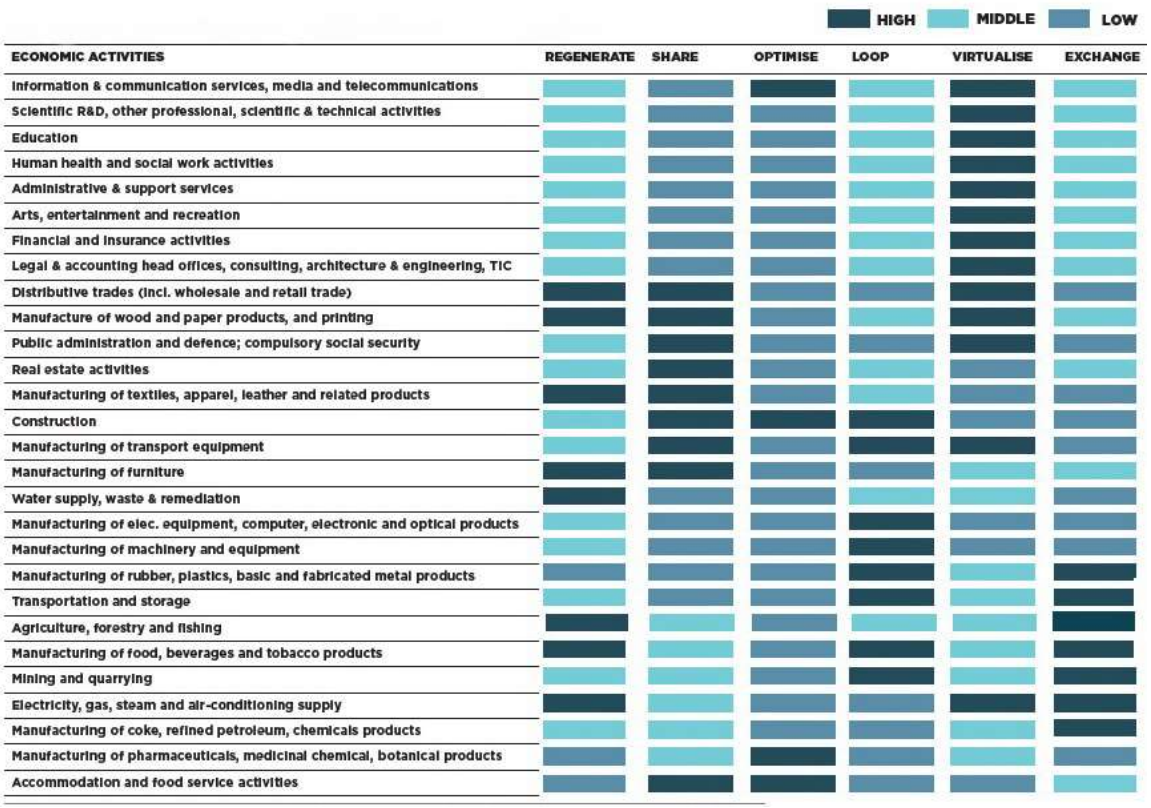
Figure 2: Circular Economy Framework *(Ellen MacArthur Foundation, 2014)*

At the core concept of CE, the existence of waste must be designed out from the economic system. Therefore, materials should strictly distinguish between biological and technical. The biological nutrients should be returned into biosphere safely while the technical materials, which are durable nutrients, must be kept and avoid the disposal by practising maintenance, reuse, refurbish and recycle. In order to operate these cycles, the utilisation of renewable energy must be used, consequently, the dependency on resource consumption can be minimised and the system can be more resilient (Ellen MacArthur Foundation, 2014).

However, the existence of generated waste is still occurring today and become one of the complex problems in the modern world. Therefore, to design out waste from the economic system, waste sector is considered as one of the circular economic activities. An indicative priority for the economic actions that was derived from qualitative scoring to rank the circular economy opportunities is presented in Table 1. Although this table is created for CE implementation in European countries, but this prioritization could suggest the first indication to guide the effort.

From the prioritization, regeneration actions are indicated to be highly prioritised when it deals with the SWM practices. It can be seen also that looping and virtualisation actions become the middle priority in the circular economy implementation in SWM while sharing and optimization are the least priority (Ellen Macarthur Foundation, 2014). Therefore, the regeneration actions are needed to be identified as the main entrance for achieving sustainable SWM.

Table 1Indicative prioritization of RESOLVE action areas (Ellen MacArthur Foundation, 2014)



2.3. Integrated Approach to Achieve Sustainable Solid Waste Management

The integration of CE to SWM system will require some conceptual baseline and the concept of sustainable SWM system can serve for such purpose. Therefore, and as a precondition of an integrated CE to the SWM system in Indonesia (or other developing country), it is a priority to firstly improve the performance of the current municipal SWM. In order to identify the characteristics of the problem, it is important to study the operational elements and the sustainability aspects of the conventional SWM. In this section, the researcher discusses the operational elements of SWM first and then moved to sustainability aspects of SWM (Schübeler, Christen, & Wehrle, 1996; Shekdar, 2009; Guerrero, Maas, & Hogland, 2013).

According to Guerrero, Maas & Hogland (2013) there are five operational elements contributing to SWM performance (i) generation and separation; (ii) collection and transport; (iii) treatments; (iv) final disposal; and (v) recycling. The first element is solid waste generation and separation, the generation of solid waste in household's level correlated with incomes, on

average families that have better income tend to generate more solid waste. Economic status may influence solid waste generation but not with separation, many factors that influence the willingness to separate the garbage, the most important factors are awareness, knowledge, and equipment. The second element is collection and transport of solid waste, route planning, proper bin collection, time and schedule for collection and infrastructure were identified as the most important factors that influence the performance of this element. By taking a good route planning, as an example might considerably increase the performance of waste collection since it can carry more generated solid waste with the same effort.,

The third element is treatment, knowledge of treatment systems by authorities, suitable infrastructure and the availability of local knowledge on waste management issues are factors that have impacted the performance of waste treatment. Next element is disposal element, interested leaders in solid waste and environmental preservation are the most influential factor and then the other factor is suitable infrastructure. The last element is recycling as stated by Guerrero, Maas & Hogland (2013), they refer to an early study in which they identified citizen participation is crucial for recycling because only when the citizens receive adequate information and knowledge regarding solid waste recycling, the recycling can really deploy its potential. The summary of these elements is presented in Figure 3.

Besides operational elements performance, the delivery of sustainable SWM also determined by the sustainability aspects support. Sustainable sound SWM able to address all aspects of SWM. Guerrero, Maas & Hogland (2013) mentioned the aspects for sustainable SWM are: (i) technical; (ii) environmental; (iii) financial; (iv) socio-cultural; (v) institutional; and (vi) legal. The technical aspect of SWM performance is determined by the availability of local-based solutions, the availability of technical skill and the infrastructure. While environmental aspect is determined by environmental control systems, membership to environmental organisations and evaluation of environmental impacts. The third aspect is financial, which is determined by economic instruments of SWM, private sector participation, a number of resources availability and willingness to pay for SWM services.

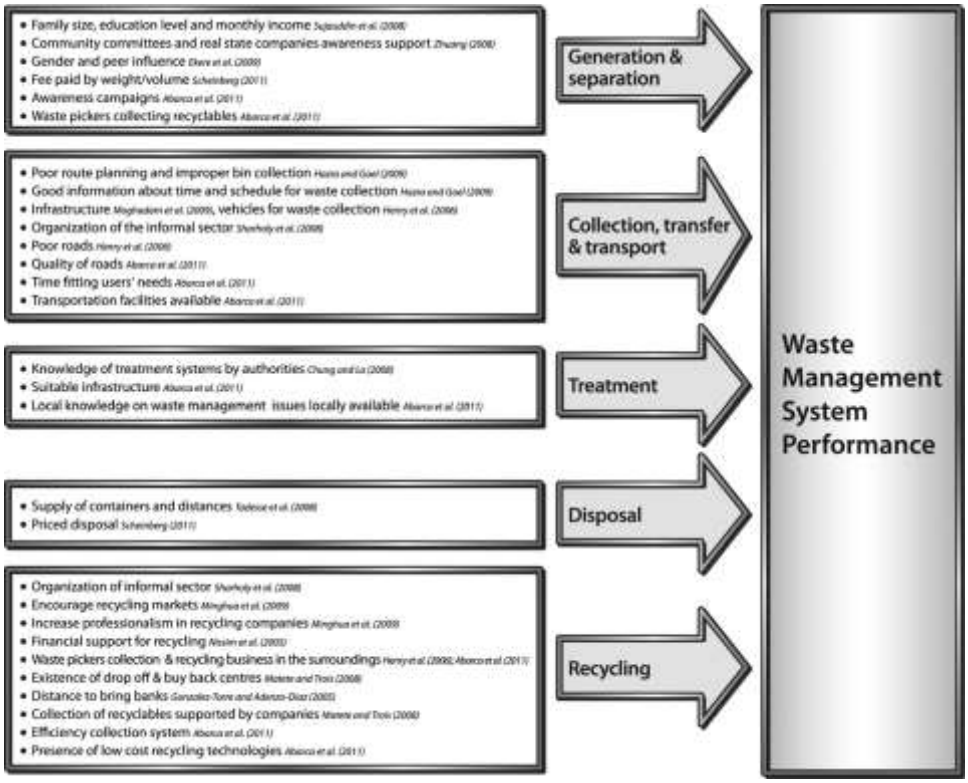


Figure 3 Factors that influence the elements of SWM (Guerrero, Maas, & Hogland, 2013)

Coordination and cooperation between service users and service provider, the adequacy of education and awareness campaign and citizen's participation in decision making are among factors that determine the performance of SWM from the aspect of socio-cultural. While the institutional aspect is determined by the support from the municipal authorities, the knowledge of municipal waste administrator, the existence of strategic plan and priority from the politician. The summary of determining factors for sustainability aspects of SWM is presented in Figure 44.

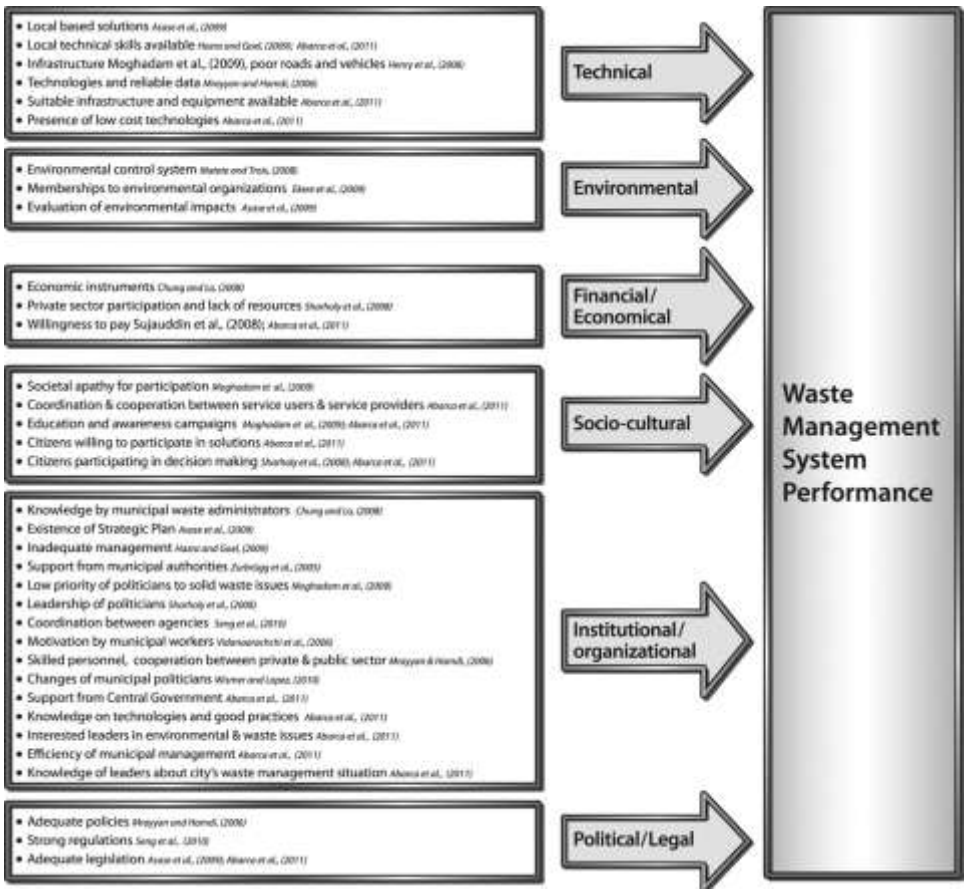


Figure 4 Factors that influence the aspects of SWM (Guerrero, Maas, & Hogland, 2013)

2.4. Waste Absorption Footprint

Waste Absorption Footprint (WAF) is a sustainability indicator to measure the assimilation of waste in the ecosystem which is based on footprint accounting. WAF accounting translates the amount of area to absorb the impact that is generated by waste into the total area of productive land and water (Jiao, Min, Cheng, & Li, 2013). The concept of WAF is an area-based measurement which derives from the concept of Ecological Footprint.

WAF accounting adopts the methodology of Ecological Footprint accounting. The methodology that built on the land and water area's capacity to produce resources or assimilate waste. However, WAF accounting only focuses on waste absorption services that provided by nature and developed separately from resource production. Hence it can simulate waste absorption not only in forest land but also other types of land (Jiao, Min, Cheng, & Li, 2013).

The difference between WAF and EF accounting lies on the usage of the land type for waste absorption service. In EF accounting the only waste type that counted the only carbon dioxide (CO_2) and the area that considered able to provide waste absorption service is only forest land, while others are excluded from the waste assimilation accounting. This is due to the basic assumption of EF, that not count ecosystem services more than once. This step is done to avoid exaggeration of human demand area (Wackernagel M. , 2000; Jiao, Min, Cheng, & Li, 2013).

While WAF accounting accommodates multiple calculations of different ecosystem services that provided by a certain area.There are four land types that used in WAF accounting those are cropland, grazing land, fishing grounds, and forest land. The built-up land was excluded from the accounting because it was assumed do not have the capability to provide waste absorption services (Jiao, Min, Cheng, & Li, 2013).

Within WAF concept ecosystem services of waste absorption further separated into two big types of ecosystem services. The first type is based on the bio-productive capacity of the land or water area, which called waste bio-productive provision footprint or Waste Absorption Capacity (WAC). The second type is WAF itself which further categorised into two categories.Those categories are carbon sequestration footprint and nutrient removal footprint (Jiao, Min, Cheng, & Li, 2013).

Waste Absorption capacity is the available bio-productive area that can provide waste absorption service and able to absorb the adverse impact that generated by the occurrence of waste. For counting the capacity of waste absorption of carbon dioxide or certain type of nutrient ($\mathrm{WAC_i}$), the equation can be written as follow

$$WAC_i = A_i \times rSF_i$$

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. The minimum criteria of sustainability are achieved whenever total WAC is bigger or equal with total WAF (Jiao, Min, Cheng, & Li, 2013).

Carbon sequestration footprint is equivalent with carbon footprint concept in EF accounting which is also based on CO_2 sequestration capacity. But it is different with the Carbon Footprint concept that used by several organisations which refer to the weight of CO_2 or equivalent emission that required to produce a product, run a process, or do an activity. For carbon sequestration footprint (WAF_{CO_2}) the equation was given by

$$WAF_{CO_2} = \frac{W_{CO_2}}{LA_{CO_2}} \times rSF_{CO_2}$$

Equation 2 Carbon Sequestration Footprint

where W_{CO_2} is the amount of carbon dioxide or the equivalents discharged into the ecosystem (kg); LA_{CO_2} is the local absorptivity of carbon dioxide or the equivalents (kg/Ha); and rSF_{CO_2} is regional supply factor for carbon dioxide or the equivalents absorptivity.

While nutrient removal footprint is the area required to absorb nutrient such as COD, excess N or P. Unlike carbon footprint, Nutrient Absorption footprint is not covered in EF accounting. However, it is a bit similar with water footprint concept, another type of footprint family, that measure the volumetric amount of water required to produce a product, run a process, or an activity.

$$WAF_{NR} = \frac{W_{NR}}{LA_{NR}} \times rSF_{NR}$$

Equation 3 Nutrient Removal Footprint

Where W_{NR} is the amount of a certain nutrient discharged into the ecosystem (kg); LA_{NR} is the local absorptivity of that certain nutrient (kg/Ha); and LA_{NR} is regional supply factor for that type of nutrient absorptivity.

2.4.1. WAF for Municipal Solid Waste Management

WAF was developed for the same purpose with EF. The main message of WAF is not to count the exact impact of waste but more to deliver an understandable ecological message

about potential effects of remedial policies regarding waste management (Jiao, Min, Cheng, & Li, 2013). In this paper, the current practice of SWM in Metro City is going to be assessed by using the concept of WAF. Furthermore, the environmental opportunities of Circular Economic implementation in SWM were studied by applying the WAF perspective. This step was done to answer the question whether the circular economy integration to SWM gives smaller or bigger WAF. In this paper, the identified waste generators of SWM activities are the operational elements of SWM. Therefore, the waste generated from these activities was investigated.

2.4.2. Vehicles emission

The emission of vehicles activities will be calculated using tier 1 of IPCC method. In this method, the emission is the result of total fuel consumption multiplied by given emission factor (IPCC, 2006). The formula to calculate the emission of CO_2 and CH_4 will be presented in

$$Emission_{CO_2/CH_4/N_2O} = \sum_a [Fuel_a \times EF_a]$$

Equation 4 The emission of $CO_2/CH_4/N_2O$ using IPCC tier 1 method

Where the 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.

2.4.3. Landfill gas emission

The unavailability of data for solid waste characteristics and landfill performance made the calculation method is limited to the use of Inter-Governmental Panel on Climate Change (IPCC) default method instead of using First Order Decay Method which is able to incorporate time factors. While the default methodology assumes that all the potential methane is released in the time solid waste disposed (IPCC, 2006). The amount of methane generated is calculated using Equation 5

$$Y_{methane} = (MSW_T \cdot MSW_F \cdot MCF \cdot DOC \cdot DOC_F \cdot F \cdot 16/12 - R) \cdot (1 - OX)$$

Equation 5 The 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

$$DOC = (0,4 \cdot A + 0,17 \cdot B + 0,15 \cdot C + 0,3 \cdot D)$$

Equation 6 Degradable Organic Carbon

Where A is % portion of paper and textiles in SW; B is % portion of garden-park and non-food organic putrescible; C is % portion of food waste; D is % portion of wood and straw waste.

Meanwhile, to calculate CO_2 emissions from un-recovered FPS the equation from United States Environmental Protection Agency (EPA) is used. This calculation is based on methane gas generation on landfill (RTI International, 2010)

$$Y_{CO_2} = Y_{methane} \cdot \left(\frac{1-F}{F} + OX \right) \cdot \frac{44}{16}$$

Equation 7 The amount of CO_2 generated on un-recovered Landfill Gas Site

Where $Y_{methane}$ is the amount of generated methane (Gg/year); F is the fraction of CH_4 in landfill gas (IPCC default is 0.5) and OX is oxidation factor (IPCC default is 0)

2.4.4. Landfill Gas Sequestration

The composition of landfill gas consists of carbondioxide (CO_2) and methane (CH_4), while the concentration of other gases are negligible (IPCC, 2006). CO_2 sequestration has already take into account ecological footprint accounting. Hence its accounting in WAF methodology will be more established than the sequestration of GHGs such as methane.

Methane as a green house gasses (GHGs) has global warming Potential (GWP) of 25, which mean 1 tonnes of methane has equal capacity of 25 tonnes of CO_2 to increase the net irradiance in the atmosphere over a period of 100 years (IPCC, 2006). Hence it is important to estimate the requirement of biosorption area of methane. The translation of methane into carbon equivalent is based on the fact that almost 90% of methane removal is caused by the oxidation of methane with hydroxyl radical to form carbondioxide (Walsh, O'Regan, & Moles, 2009). The reaction of methane conversion into carbondioxide is presented in Equation 8. By considering the molecular weight of methane and carbondioxide, the requirement of biosorption area of methane can be calculated.

$$CH_4 + 5O_2 + NO + 2OH \xrightarrow{UV-A} CO_2 + H_2O + NO_2 + 4HOO$$

Equation 8 The Conversion of Methane into Carbon dioxide in Atmosphere

However, Walsh, O'Regan & Moles (2009) also suggest an alternative to translate methane into carbondioxide using GWP equivalent before translate it to the requirement of biosorption area. This step is done to present the adverse impact of methane to the environment. Moreover, several scientists also use GWP equivalency to convert methane into carbon dioxide (Lenzen & Murray, 2001; Niccolucci, Rugani, Botto, & Gaggi, 2010). Hence this study will choose to use GWP equivalent to calculate the biosorption area needed by methane.

2.4.5. Carbon dioxide uptake rate

Carbon dioxide can be absorbed by biomass because of photosynthesis process on the clorophyled leaves. During the process carbon dioxide and water with the help of sunlight converted into sugar, oxygen and water through various metabolic processes. Therefore carbon dioxide uptake rate is depend on the speed of photosynthesis process. The speed of photosynthesis process itself depend on internal and external factors such as sunlight intensity, carbon dioxide concentration in the atmosphere, water and nutrients availability (Kusumaningrum, 2008).

Carbon dioxide uptake rate for various type of land cover is presented in

Table 2. In this table trees is the biggest sink for carbon dioxide. While paddy contribute smaller amount of carbon dioxide uptake service.

Table 2 Carbon dioxide uptake rate from various types of land cover

(source:Prasetyo, et.al (2002) in Permana 2006)

No.	Land Cover type	CO_2 uptake rate (ton/Ha.year)
1.	Trees	569.07
2.	Bushes	55
3.	Pasture Land	12
4.	Paddy field	12

2.5. Municipal Solid Waste Management in Indonesia.

The municipal SWM in Indonesia had reached environmentally sound management during the period 1990-1995, but then the severe economic crisis in 1997-1998 hamper the condition of SWM in Indonesia. Ever since the hyperinflation occurred, things became more complicated for a waste manager to adopt adequate management efforts to merely achieve compliance to legal obligations (Damanhuri E. , 2005). This, added to the political system change that happened in almost at the same time. The political system changed are changing the organisational structure of SWM in Indonesia. Initially, municipal SWM was authorised by the national government, but in 1999 the management of solid waste was decentralised to the local governments. This decentralisation resulted in narrowing down the institutional scope of municipal SWM because many local governments only copied the institutional structure from central government (Damanhuri E. , 2005; Damanhuri, Handoko, & Padmi, 2013). Nevertheless, the municipal SWM is also represented at the national level and divided into several authorities: Ministry of Public Works (for the implementation planning and the implementation), Ministry of Environment and Forestry (for environmental control and monitoring) and some other related ministries and national boards. While at the municipal level, the authority of the municipal SWM is held mostly by the cleansing division that functions as the operator of municipal SWM. There are though some exemptions, in particular large cities, governments were hire private companies to operate and provide the services (Damanhuri, Handoko, & Padmi, 2013, p. 140).

About 90% of municipal SWM in Indonesian Municipalities relies on open dumping or even waste burning and only 60-70% of generated waste can be handled by the responsible institutions. Mostly local authorities are only practising collect-transport-dispose as their

municipal SWM method. While the inadequate budget for SWM mostly is used for covering the operational expenses and tend to ignore the maintenance and investment requirements (Damanhuri, Handoko, & Padmi, 2013; KLHK, 2015).

The characteristic of MSW in Indonesia is dominated by organic fraction which mainly comes from kitchen waste and contributes to 65% water content in MSW. Households were identified as the biggest MSW generators which generate 50-60% of generated MSW (Damanhuri, Handoko, & Padmi, 2013). Unlike people in developed countries such as united states which tend to throw unused materials such as newspaper, old magazine and old clothes and create a problem in the waste generation. In Indonesia people have the different terminology of the end of life of goods, materials such as unused glass, paper or plastic will be well collected either by household him/herself to earn pocket money or by members of the informal sector, such as scavengers (Damanhuri, Handoko, & Padmi, 2013).

III. RESEARCH DESIGN

The research design is functioned as a strategy to answer the research question or to test research hypothesis (Pollit et al, 2001). This chapter will describe several activities to find the answers to the research questions. As such, activities to make recommendations to The Mayor regarding the improvement of SWM in Metro City using circular SWM approach.

3.1. Research Framework

According to Vershuren and Doorewaard (2010) research framework means the schematic presentation of the research objective. It includes step by step activities to achieve research objective. Research framework consists of seven steps as seen as follow:

Step 1: Characterising briefly the objective of the research project

The aim of this research is to make a recommendation to Mayor with regard to improving solid waste management toward feasible and sustainable management.

Step 2: Determining the research object

The research object in this research is the current practice of municipal SWM in Metro City

Step 3: Establish the nature of research perspective

This study proposes circular solid waste management framework as a feasible and sustainable solution to cope with poor performance of SWM in Metro City. However, the environmental opportunities of municipal SWM will be analysed from the perspective of Waste Absorption Footprint as a communication tool for local government in order to consider the suggestions generated from this research. Due to those reasons, the research is categorised as change type of research (Verschuren & Doorewaard, 2010).

Step 4: Determining the sources of the research perspective

The research uses scientific literature to develop a conceptual model. Theories to be used in this research are shown in table 3:

Table 3. Sources of the Research Perspective

Key concepts	Theories and documentation
Circular Solid Waste Management	Theory on Sustainable MSWM
	Circular Economy Framework
	Theory on Waste Absorption Footprint

Step 5: Making a schematic presentation of the research framework

The research framework is described through Figure 5

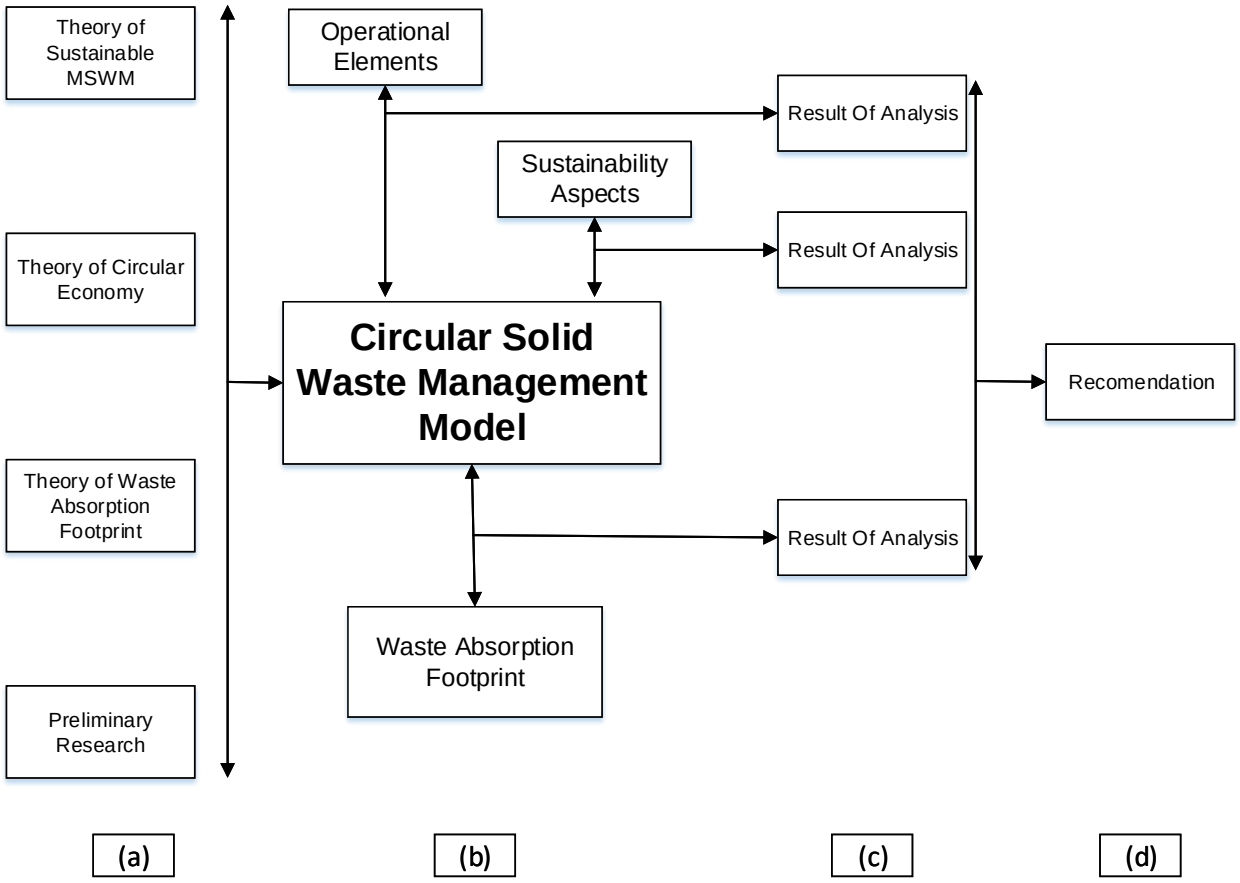


Figure 5 The Research Framework

Step 6:Formulating the research framework.

This Research formulated as follow:

(a) Analysis the theories of Sustainable SWM, WAF, Circular Economy Framework, preliminary research and generate Circular SWM model.
(b) This model is used as criteria to assess the MSWM practice in Metro.
(c) Confronting the result of analysis as a basis for the potential recommendation.
(d) Recommendation for improving sustainability of MSWM in Metro

Step 7: Checking whether the model requires any change

There is no indication that any change is required.

3.2. Research Question

In this research, the central question is how can the circular solid waste management be developed in Metro City? This question lead to several sub-questions, those are:

1. What are the current municipal SWM practices?
2. What are the challenges for integrating CE principles in SWM in Metro City?
3. What are the feasible circular SWM Frameworks to Metro City? How to enable it?
4. What is the environmental impact of current municipal SWM practice from the perspective of WAF? Is there any environmental opportunity by integrating the CE principles in SWM from the perspective of WAF?

3.3. Defining Concept

For the purpose of this research, the following key concepts are defined:

Sustainable Solid Waste Management : a solid waste management scheme that socially equitable, environmentally acceptable and economically feasible (source: Shekdar, 2009)

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 inter-generation justice.

Solid Waste is discarded useless materials as the consequences of every activity (source: Tchobanoglous, Theisen, & Vigil, 1993). In this study solid waste term is used interchangeable with garbage.

Circular Solid Waste Management is a management of solid waste that emphasising on circular economy principles. (source: Tchobanoglous, Theisen, & Vigil, 1993; Ellen MacArthur Foundation, 2015)

Waste Absorption Footprint is the required area for absorbing the impact that is generated by waste into the total area of productive land and water (source: Jiao, Min, Cheng, & Li, 2013).

Waste Absorption Capacity is the available bio-productive area that can provide waste absorption service and able to absorb the impact of the waste (source: Jiao, Min, Cheng, & Li, 2013).

3.4. Research Strategy

According to Verschuren and Doorewaard (2010), research strategy is the coherent body of decisions concerning the way in which the researcher gathers relevant material and processing the material in order to get valid answers for the research questions. This research uses single case study approach as the general research strategy. However, desk research approach is also applied to identify sources of data that will be used to measure the environmental impact of the MSWM.

3.4.1. Research Unit

The Research unit for this research is the Municipal SWM and the observation unit is the practice of SWM. While Metro City will function as a the case study of this research.

3.4.2. Selection of Research Unit

Informants and respondents in SWM were selected according to their influence to have actual effects towards sustainable MSWM, and represent the following interest or projects:

- Waste Management Authorities
- Agricultural agency
- Youth, Sport, Tourism Agency
- The actors related to solid waste management in Metro City
- Respondents, there are two types of data that require respondents, the elaborations of each type of data are follow:

a. For analysing the current practice of SWM in Metro, *random sample*[8] of citizens of Metro were asked regarding their routine wastage activities by dispatching questionnaires. The size of the sample was determined by the Slovin's formula

$$n = \frac{N}{1 + N \cdot e^2}$$

Equation 9 Slovin's formula

Where n = the number required samples, N=Total population of Metro (158,415), e=margin of error (10%). From the calculation, it was known that the required sample is 99.93 citizens≈100 citizens. However, due the time consideration the sample size was reduced to 46 citizens, consequently the margin of error got bigger to the level of 15%. The obtained data from the questionnaires then analysed using SPSS 24.

b. For estimating solid waste generation and composition, solid waste from sample households are collected. Indonesia National Standard (SNI) 19-3964-1994 is used as the baseline to determine the required number household sample. *Stratified random sampling*[9] is used to fulfill the requirement of the methodology. From the calculation of sample that was presented in **Error! Reference source not found.**, it was known that the required sample is 43 households

3.4.3. Research Boundary

Research boundary is determined to define the limitation of the study and its consistency. Thus, the aim of the research can be achieved within a limited timeframe. The following boundary is set for this research:

- The administrative boundary of Metro 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)
- The environmental opportunity was discussed from the perspective of WAF.
- The study was not covered issues that require further research

[8] random sample is a sample in which every individual in the population has equal opportunity to be selected, regardless their characteristic (Source: Verschuren & Doorewaard, 2010)

[9] Is the same with random sample, however the sample were grouped regarding their characteristic/strata

3.5. Research Material

For this research, data materials were obtained from interviews, questionnaire and data collections. Semi-structured interviews were designed for interviewing 12 informants regarding SWM in Metro City, they interviewees were:

- 4 informants from the Environmental Agency of Metro City
- 1 informant from Agricultural Agency of Metro City
- 1 informant from Youth, Sport and Tourism Agency of Metro City
- 2 informants from garbage banks in Metro City
- 2 informants from compost businesses
- 1 informant from waste collection sector
- 1 informant from local creative industry

While Questionnaire is used to gather data to understand public awareness and participation in SWM. The number of the respondent was chosen by Solvin Formula that have presented in section 3.4.2. For WAF accounting, the data about solid waste generation is estimated using Standard Method of Indonesia number 19-3964-1994 as the baseline. The required data and its accessing method that were identified through the set of sub-research questions are presented in *Table 3*

Table 3 Research methodology

Research Question	Required Information	Sources of Information	Method to Access Data
What are those current MSWM practices?	Factors that influence the elements of SWM	Primary Data Interviewee: The head of environmental department, cleanliness division, waste sub-division, landfill operation unit and the citizen of Metro	Questionnaire and Semi-structured interviews
What are the challenges for circular SWM implementation in Metro City?	Circular Economic implementation Barriers	Primary and Secondary Data Document, interviewee: The head of environmental department, people from garbage banks, waste collection, composting sector and creative industry.	Content Analysis, Semi-structured interviews, and questionnaire
What are those feasible CSWM Frameworks to Metro City? And how to enable it	Factors that influence the aspects of SWM	Primary Data Interviewee: The head of environmental department, agriculture department officer, youth, sport and tourism department, people from garbage banks, waste collection, composting sector and creative industry	Questionnaire and Semi-structured interviews

What is the environmental impact of current municipal SWM practice from the perspective of WAF? Is there any environmental opportunities by integrating the CE principles in SWM from the perspective of WAF?	The characteristic and amount of waste generation	Primary Data Data collection	Survey: using Standard Method of Indonesia number 19-3964-1994
	The amount of manageable solid waste	Secondary Data Document	Content Analysis
	The fuel consumption for waste handling	Secondary Data Document	Content Analysis
	The method of waste collection, treatment, and disposal	Primary Data Interviewee: The head of cleanliness division waste sub-division and the landfill operation unit	Questioning: Semi-structured interview
	The environmental condition	Secondary Data Document	Content Analysis
	The environmental impact of solid waste, operation	Secondary Data literature	Content Analysis

3.6. Data Analysis

Data evaluation process through the analytical framework was presented in this section. It includes two components: the method of data analysis and the analytical framework.

3.6.1. Method of Data Analysis

Mixed method will be used for this research, it is based on qualitative and quantitative research methods which was chosen because of through them this research can provide a more complete, balanced and validated findings. Furthermore, embedded mixed methods were used as the detail type of mixed method research, where the qualitative and quantitative data is embedded within the larger design (Creswell, 2014).

Table 4 Data and Method of Data Analysis

Sub Research Questions	Required Information	Sources of Information	Research Method
What are those current MSWM practices?	Current implementation of SWM practice	The head of environmental department, cleanliness division, waste sub-division, landfill operation unit and the citizen of Metro	Semi-structure interviews, document analysis
What are the challenges for circular SWM implementation in Metro City?	The barriers to achieving high-performance SWM	Garbage banks, Organic fertilizer producers, Waste collector, creative industry, The head of environmental department, cleanliness division, waste sub-division, landfill operation unit and the citizen of Metro	Semi-structure interviews, observation Content Analysis, and questionnaire

What are those feasible CSWM Frameworks to Metro City? And how to enable it	The suitable solution to overcome the barriers	Garbage banks, Organic fertilizer producers, Waste collector, creative industry, The head of environmental department, cleanliness division, waste sub-division, landfill operation unit and the citizen of Metro	Document analysis, semi-structured interviews
What is the environmental impact of current municipal SWM practice from the perspective of WAF? Is there any environmental opportunities by integrating the CE principles in SWM from the perspective of WAF?	Parameters for WAF Measurement	Data collection, documents and literature	Measurement, Semi-structure interviews, and content analysis

3.6.2. Analytical Framework

Schematic presentation of Analytical Framework is presented in Table 4

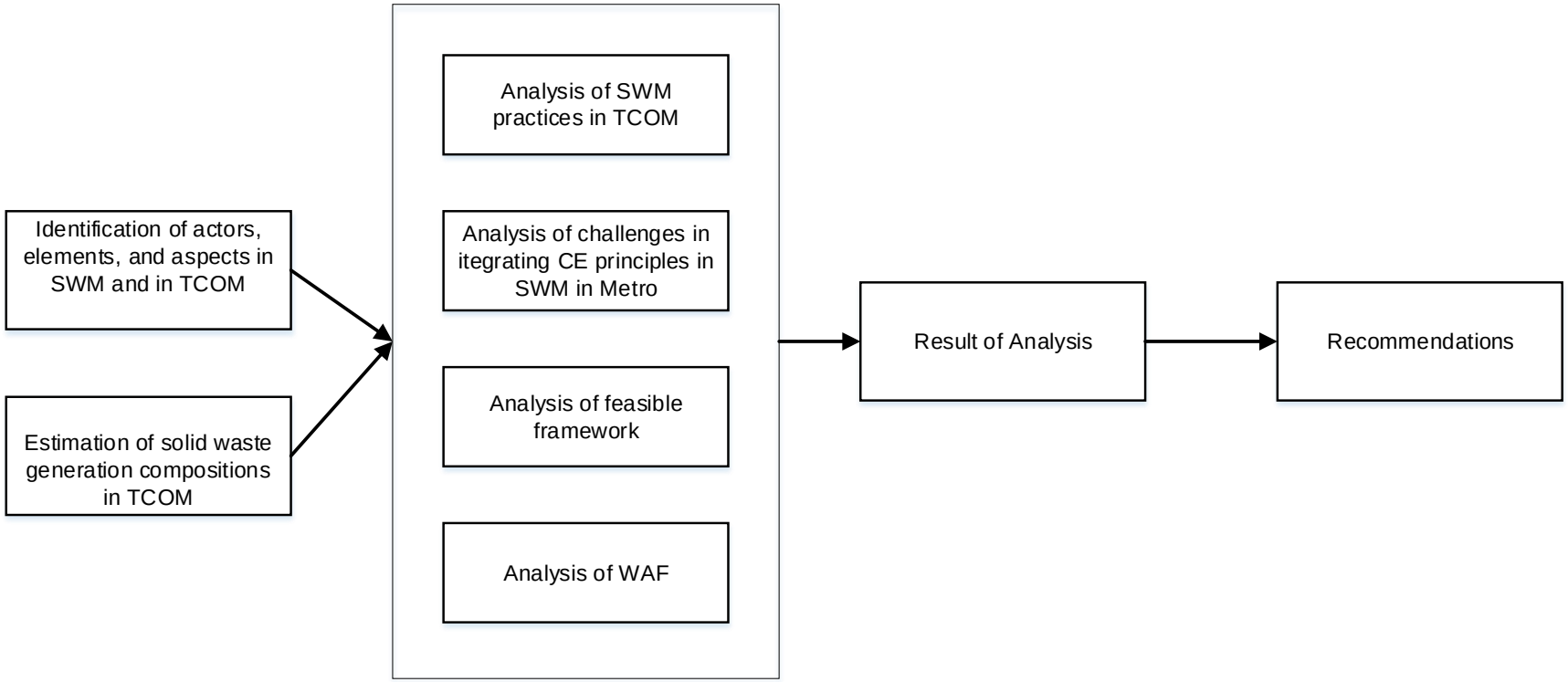


Figure 6 Analytical framework scheme

The data analysis was directed as follow:

a. The first stage of data analysis is to understand the current practice of SWM in Metro. It was analysed through the current practice of each element that influences the performance of SWM. In addition, a survey was also conducted to support the collected information from the informants
b. This stage is to identify the challenges of the private sector that need to be overcome in order to integrate Circular Economy principles in Metro City
c. In this stage, the researcher identified the necessary decisions and/or policies in order to implement Circular SWM in Metro. This result is intended to build the recommendation for the Mayor regarding Circular Solid Waste Management implementation.
d. The final stage is to analyse the WAF of SWM in Metro, in order to acquire data regarding solid waste emission, calculation to estimate the waste generation and composition is carried out. To provide the baseline for the calculation National Indonesian Standard number is 19-3964-1994 is used. the data regarding collection, transport, treatment, disposal, and recycling practices was gathered during the first stage. The next step is estimating the rate of environmental pollution of current practice SWM, calculate the amount of WAF and calculate the environmental consequences if CE is integrate in SWM in Metro City

All in all, through the above mentioned steps, the main research question was to some extent responded. The limitations of this research were discussed as part of the conclusions and recommendations section.

IV. FINDINGS AND DISCUSSIONS

In this chapter, current conditions of SWM in Metro are described according to the findings during the data collection phase. In addition, the appropriate framework to integrate CE in SWM in Metro also discussed.

4.1. The Condition of The Studied Area

In order to discuss the current condition of SWM in Metro City, a brief history of Metro City will be presented. Metro City was established in 1999 as a result of Central Lampung District expansions. The city is the former capital city of Central Lampung District before it expanded into two districts and one city, Central Lampung District itself, East Lampung District and Metro City.

Metro City is situated in the center of Lampung Province; the geographical location of Metro City is between -105°15' to -105°20' Longitude and -5°5' to -5°10' Latitude. Metro accounts an area of 6874 hectares which is inhabited by 158,415 people or 35,906 households. The common types of businesses in Metro City are the service businesses, small scale industries and agricultures. More than one third of the city area, 2,922 hectares, is technically irrigated paddy field (BPS Kota Metro, 2016).

The City has Gross Domestic Regional Product (GDRP) of Rp. 27,306,000/€1,820.5 per capita per year. There is no big scale or high infestation industry in Metro City. The city also has no natural resources such as minerals, oil or gasses stocks (BPS Kota Metro, 2016). The map of the city is presented in **Error! Reference source not found.**.

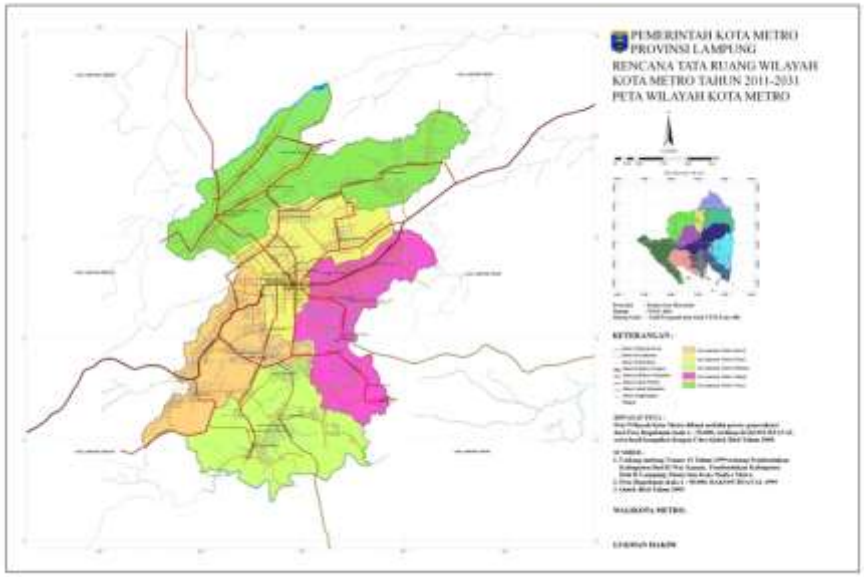


Figure 7 The Map of Metro City (sources: Peta Kota, 2017)

As the former capital city of the old district, Metro was the administration center (administrative town) in the district. Metro City also became the center of excellence in the district whose educational, cultural, and trade was better developed than other sub-districts in Lampung Tengah District. Metro City has almost all of public services in the district, such as solid waste collection, transportation and disposal services. Therefore, the presence of current SWM system in Metro City is the inheritance of Central Lampung District era.

In 1998 Indonesia was suffering from a severe financial crisis, which was followed by governmental reforms and decentralization. These events gave impact public sector services growth such as waste management in the districts/municipalities which was also mentioned as the common SWM problem in Indonesia (Damanhuri, Handoko, & Padmi, 2013). The implementation of solid waste services in the city is not significantly improved in comparison with other services in Metro.

4.2. Current Practice of Municipal SWM in Metro City

Several stakeholders were identified in the SWM practice in Metro City, starting with the main generators, the citizens, followed by government, private sector, educational sectors such as schools and universities. Currently almost all of the SWM practices in Metro are done by the cleaning division that operates under the Environmental Agency mandate. The subordination of the division has changed in 2016, formerly the cleaning division was under City Planning and Tourism agency. Cleaning division is divided into 3 sub-divisions, they are solid waste management sub-division, infrastructure sub-division and income sub-division. The organizational structure of environmental agency is displayed in Figure 8.

The head of environmental agency admitted[10], despite the current condition of SWM in Metro City there are not sustainable practices yet implemented. However, he wants to move forward to achieve the sustainability level of SWM. In addition, Mr. Yerri Noer Kartiko, as the secretary of the agency, stated that in order to achieve sustainable SWM, two approaches are currently used: The first approach is improving current performance of SWM, while the second one is focusing on the reduction of waste generation. The private

[10] Interview was conducted in May 29 2017

sector involvement is one of different scenarios with the purpose to reduce waste disposal in Metro. The other scenario is promoted by building Solid Waste Management Site that applies Reduce, Reuse and Recycle principles (TPS3R). Although initiated by the central government, TPS3R is as a result of negotiations between the Municipality and the Central Government aiming to accelerate the settlement of solid waste problems in Metro City.

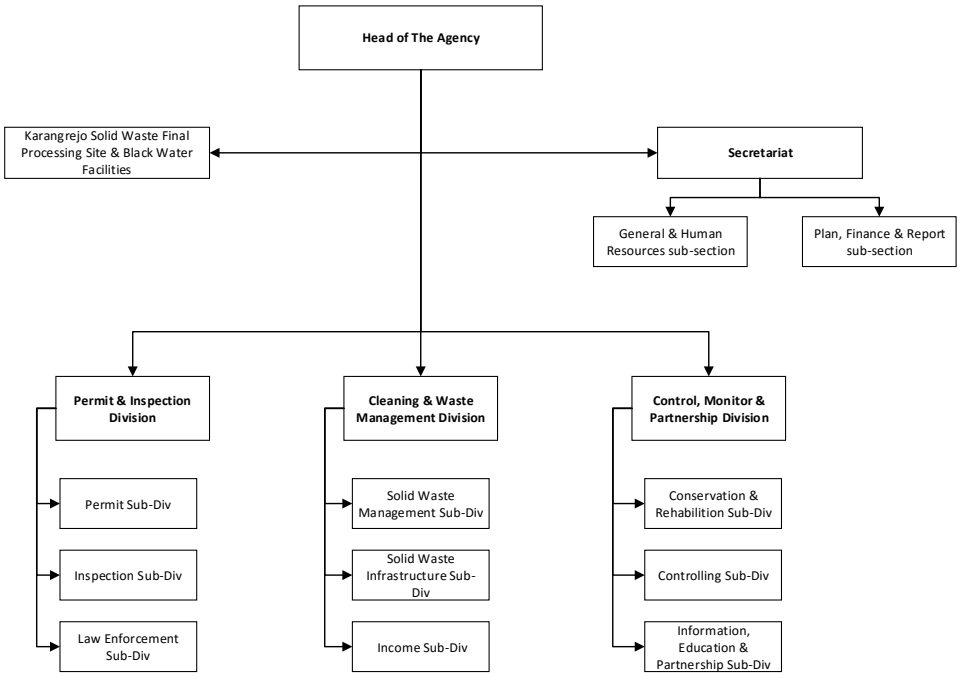


Figure 8 Structure of Environmental Agency in Metro City (Source: Environmental Agency of Metro City, 2017)

Mr. Yerri Noer Kartiko also said that TPS3R is a facilitation program which meant that TPS3R was only built on the request from the local community. Therefore, the active participation from the local community is required during the project. The participation includes the provision of land where the TPS3R will be built and once the construction is finished the local community will also be responsible for the operation of TPS3R. On the other hand, the municipality provides the supporting equipment and capacity development through soft skills training.

Overall the current practice of SWM in Metro City is almost similar with the typical SWM practice in many Indonesian municipalities. Although, those management approaches are emphasizing on *Collect-Transport-Dispose* (Damanhuri, Handoko, & Padmi, 2013).

4.2.1. The solid waste management elements in Metro City

This section discusses the findings of the elements and aspects of SWMs in Metro City according to the frameworks shown in Figure 3 and Figure 4. Firstly, the generation, collection and transportation, treatment, disposal and recycling elements are described.

Solid Waste Generation

There are two types of solid waste generated that become part of the concerns of municipal SWM in Metro City and these are residential generated solid waste and non-residential generated solid waste. According to Ministerial Regulation of Public Work Number 3/2013 the residential solid waste (or equivalent) is the daily solid waste that is regarded as produced by household, office, commercial, industrial, other public activities which does not include fecal slurry and specific solid waste. Residential solid waste is collected from residential areas throughout the city, while non-residential solid waste is collected from commercial area, offices, schools, hospital, markets and other public facilities.

The production of MSW in Metro City is estimated to be 0.47 kg/cap/day, generating 105 ton/day which is 479 m^3/day, as presented in **Error! Reference source not found.**. These figures are based on the calculation shown in appendix 1. More than half (56.47%) of the solid waste is in the form of putrescible organic (kitchen refuse), the other components are: plastics and rubber (24.07%), paper (9.40%), wood (6.24%), clothes (1.52%), glasses (0.88%), metals (0.56%) and other (0.86%).

Table 5 Generation rate, composition and density of solid waste in metro city

		High Income	Middle Income	Low Income	City Average
Period I	Weight per cap	0.51	0.44	0.33	0.43
	Volume per cap.	2.74	2.72	2.71	2.72
	Weight generated	97 ton per day			
	Volume generated	443 m^3 per day			
Period II	Weight per cap	0.53	0.47	0.51	0.50
	Volume per cap.	3.05	2.64	2.47	2.72
	Weight generated	113 ton per day			
	Volume generated	515 m^3 per day			
CITY AVERAGE	Weight per cap	0.43 - 0.50 kg/day.cap (0.47 kg/day.cap)			
	Volume per cap.	2.72 l/day.cap			
	Weight generated	97 – 114 ton per day (105 ton per day)			
	Volume generated	443 – 515 m^3 per day (479 m^3 per day)			
Composition	Plastic & Rubber	24.07%			
	Paper	9.40%			
	Kitchen Refuse	56.47%			
	Woods & Garden	6.24%			
	Cloths	1.52%			
	Glasses	0.88%			
	Metals	0.56%			
	Other	0.86%			
	Average Density	0.22 (ton/m^3)			

The monthly fee paid by households to municipality is about Rp. 10.000/ € 0.67 while the fee for non-residential generators varies according to the amount of solid waste that needs to be disposed. This fee includes all the services offered from the collection, transportation and disposal of waste. Fees are collected by government officers who are assigned to specific zones. The fee has been determined by local government with the approval of local legislators. However, there is no standard regulation for monthly fee of Community Support (SOKLI)[11] services. The common practice to determine monthly fee of SOKLI is based on the agreement within the community.

From interviews, it was found out that solid waste that is collected is not sorted. The results of the survey as presented in Figure 9 also support this statement that only 28.3% people

[11] SOKLI was established as support initiatives from the community to collect and transport waste within community

are able to sort their solid waste. Furthermore, from those numbers, 46% of them did not receive collection service.

already sort the solid waste

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	13	28.3	28.3	28.3
	No	33	71.7	71.7	100.0
	Total	46	100.0	100.0	

Figure 9 The number of citizens that already conducted solid waste separation

From interviews, it was mentioned that solid waste sorting operations are carried out by diverse groups, among them, scavengers, households who sell their sorted wastes to itinerant waste buyers; students and households that sell them to garbage banks[12] and solid waste officers that work as truck crews who pick the recyclables from SW stream. It was also known that the truck crews can sort 340 kg each day and the scavengers in landfill can recover around 600 kg of recyclables each day. The data for other activities is unavailable, therefore the calculation of sorted waste amount in Metro City cannot be conducted in this study.

Solid Waste collection and transportation

Unlike large cities like Jakarta or Bandung, the solid waste collection and transportation in Metro is mostly handled by the municipality (Damanhuri E. , 2006). The solid waste collection, transportation, road sweeping and market cleanliness are the responsibility of solid waste management sub-division as part of cleaning division. In additional to the responsibility of conducting solid waste collection and solid waste transportation to Karangrejo FPS the tasks of solid waste management sub-division are conducting road sweeping in around the city center, markets and other public places. To perform these tasks solid waste management sub-division is equipped with 17 transportation trucks which consist of 5 arm-roll trucks and 12 dump-trucks, 9 motorized

[12] Garbage bank is a place where recyclables and reusable collected and sorted. Garbage bank operate like conventional bank which have members accounting and management activities. The difference lied on the saving material, if conventional bank use money as the means for transaction, garbage bank uses solid waste as the means for transaction (Suryani, 2014)

carts and dozens of hand carts. In addition, there are also 2 trucks that are used for black water suction.

This sub-division employs 181 persons, 59 of them are permanent employees while 132 employees are contracted. Some of them are responsible for truck operations such as drivers and the crews, while others are assigned as road sweeper.

Typically, solid waste collections are conducted in the morning until mid-day. Dump trucks used for door to door solid waste collection, while arm-roll truck is used for non-residential solid waste collection such as traditional markets. While motorized carts and hand carts used as feeder for un-covered areas in the city by SOKLI.

Not all of the city area is covered by solid waste collection service from the municipality. The served area is not much different than the served area when Metro was capital city of Central Lampung District. Currently the served area are Central Metro, East Metro, part of West Metro and very small part of North and South Metro. Based on the information from the environmental agency, municipality can only transport around 225-245 m^3 solid waste daily, this is about 35%-45% of the generated waste in the city.

In order to help the municipality to collect solid waste, 8 SOKLI are formed by the community to conduct door to door service in non-covered area. However, the service of SOKLI also cannot cover the entire city because of the service range limitations. SOKLI operates the collection of solid waste using handcarts and transport the collected solid waste into solid waste container or transport it directly to FPS. There are citizens who still did not receive any solid waste collection service. In survey result analysis, it was known that more than 50% respondents did not receive solid waste collection neither from municipality nor SOKLI. This finding was supported Mr. Supriyanto statement that only 225 m^3 solid waste can be transported to FPS[13]. Table 6 shows the survey result of public acceptance of solid waste collection service in Metro City.

[13] The estimation of daily generation is 479 m^3 in average (**Error! Reference source not found.**) hence only 44% waste can be collected

		Received Solid Waste Services		
		Yes	No	Total
sub district	Metro Pusat	4	1	5
	Metro Utara	1	5	6
	Metro Timur	6	3	9
	Metro Selatan	3	16	19
	Metro Barat	5	1	6
Total		19	26	45

Table 6 Collection Service Acceptance by Sub-district

Citizens and other activities (e.g. private hospital, schools, offices, shops) need to pay a monthly fee to the municipality as such amount is regulated by local government. Furthermore, in order to compensate the unserved citizens there are many solid waste containers that have been placed all over the city for collecting the solid waste which can be accessed for free.

There is no solid waste transfer station in the city, because all of the collected solid wastes are transported directly to Karangrejo FPS that is only 8 km away from the city center. Figure 10 shows the disposal process of solid waste in a landfill. The solid waste that is transported to FPS is in mixed state.

Figure 10 Disposal of Solid Waste in Landfill

Several informal sectors that are involved in solid waste collection in Metro City also identified as scavengers, itinerant solid waste buyers. Scavengers and itinerant solid waste buyers only collect recyclables from the households. Beside informal sectors there are also garbage banks which collect recyclables from their members. Some garbage banks also collect the biodegradables beside recyclables solid waste.

Treatment and Disposal

The Karangrejo FPS is the destination of the solid waste after transportation phase. Karangrejo FPS is located in north-eastern part of the city, next to East Lampung district. The FPS is operated by Technical Implementation Unit (UPT) that is tasked to conduct proper treatment for solid waste and dispose it safely. The site is consists of 7 hectares of land and beside the landfill zone, there are also leachate catchment basins, composting facility and blackwater installation.

In Karangrejo FPS solid waste is directly disposed by landfilling without any kind of pre-treatment. The only sorting which is done to solid waste is by informal scavengers who only pick the valuable solid waste like plastic, metals, papers, glasses and leave the others dumped. As mentioned above multiple scavenging activities are done by the scavengers and officers from the source. Therefore, the officers assume that the landfilled solid waste has high content of degradable organics. However local government never measures the composition or the characteristic of the solid waste that goes to the landfill.

Although Karangrejo FPS has composting facility, there is no activity which was shown in the facility. The Head of Karangrejo FPS mentioned that there is no budget to operate the composting facility. Furthermore, he also mentions that the current budget of FPS operation is only enough to cover routine activities like solid waste leveling and compaction on landfill site only. This budget is also not enough to fully cover the routine soil covering activity.

To conduct the tasks, the unit is equipped with 2 excavators, 2 bulldozers and one shovel. But only an excavator, a bulldozer and the shovel which able to operate the other two equipment have been seriously damaged for years. The condition of those equipment is breaking down due to the unavailability of heavy maintenance budget.

Beside the sub-division coordinator, there are 12 staffs that are assigned to help to manage the FPS administration and operate the heavy equipment in the site. None of the staffs that are assigned to FPS, except the Section Head has received formal technical upgrading training on SWM. Therefore, the landfilling practices still apply the first method of what they have learned from the previous staffs or from the technical briefing at the opening of the landfill in 1989.

Several stakeholders, particularly the government assumes that operating sanitary landfill will be the best solution to overcome solid waste problem in Metro City. This is because they assume that the environmental impact of solid waste landfilling can be minimized. One of the proposed solutions is the closing of current FPS and build a new sanitary landfill FPS. On the other hand, another solution is to upgrade the condition of current FPS until it becomes sanitary landfill because there is no new landfill site location in the spatial planning of Metro City.

Several informal businesses such as organic fertilizer producers are also taking part in solid waste treatment particularly for the biodegradable solid waste.

Recycling & Material Recovery

Almost all of solid waste recycling in Metro City is done by non-governmental parties such as private sectors, community and schools. Actually, local government acknowledges the recycling practices in the city. In several occasions, local government display the recycle products as one of mainstay products of the city. However, only garbage banks that already receive attention by government while none of informal activities have been acknowledged. The common recycling activities that exist are the sorting and re-selling of recyclable solid waste, plastics shredding, handcrafting. Recycling process begin with collection of recyclable solid waste such as plastics, glasses and metals. Generally, these types of solid waste are collected by scavengers, but there are households and garbage banks which also collect the solid waste. From the observation during the data collection period there are several actors of recycling and material recovery in Metro City, the actors are sown in the table below;

Table 7 Actors of Circular Economy in SWM in Metro City

Actors in technical material's loop	Actor in Biological material's loop
Scavengers	Organic Fertilizer producers
Solid waste/Garbage Collectors	Farmers
Garbage banks (community and school)	Garbage banks
Solid Waste dealers	
Garbage grinders	

There are two types of scavenging activities in the Metro, the first one involves the scavengers who collect the recyclable refuse before the solid waste has been collected by the municipality or SOKLI, this activity is done late in the night or early in the morning. The second one is the scavengers which collect recyclable solid waste after the solid waste has transported to landfill, this scavenging activity is done from the morning until the afternoon. Almost all of the scavengers are scavenging as the last choice of the jobs because of the unavailability of jobs. However, some of them choose to scavenge as their secondary job. The scavenging activities are done in an unhygienic and unsafe manner.

Beside the scavengers, there are solid waste collectors who buy the saleable solid waste from the households directly. However, they have different purchasing mechanism. They send the payment to the garbage bank account instead of paying them by cash. Some of the garbage banks also ask the members of the bank who are households or students, to bring their solid waste to the bank instead of doing door to door collection.

The development of garbage banks in Metro City begun with the establishment of garbage bank in the schools particularly in Adiwiyata schools, the schools that are acknowledged by the government as the schools which have concern to environmental preservation. The mission of the banks is to familiarize and encourage students to sort out the solid waste. There are 25 school's garbage banks in Metro of which some of them are becoming members to community garbage banks.

Mr. Kartiko said that there are 9 active community garbage banks in Metro City. The garbage banks begun to realize the economic opportunity from conducting solid waste business in community scale. The bank activity is sorting the garbage into specific types which can increase the selling price of collected solid waste. This scenario allows banks to take the benefit from the price difference between selling price and the credited price to the members.

The other activity done is creating handcrafts from the solid waste, which can add the value of the waste significantly. However, there is lack of variety in handcrafting products. The handcraft products are mostly the same with products from other cities or provinces. Moreover, the sale of handcraft products in Metro is very low which generally can only be sold in the exhibition events. Overall, the practice of solid waste management in Metro City can be illustrated as shown in Figure 11. The data regarding the number of recycled

materials is unavailable and the amount of unmanaged waste can reach to more than 50% of generated waste in Metro City.

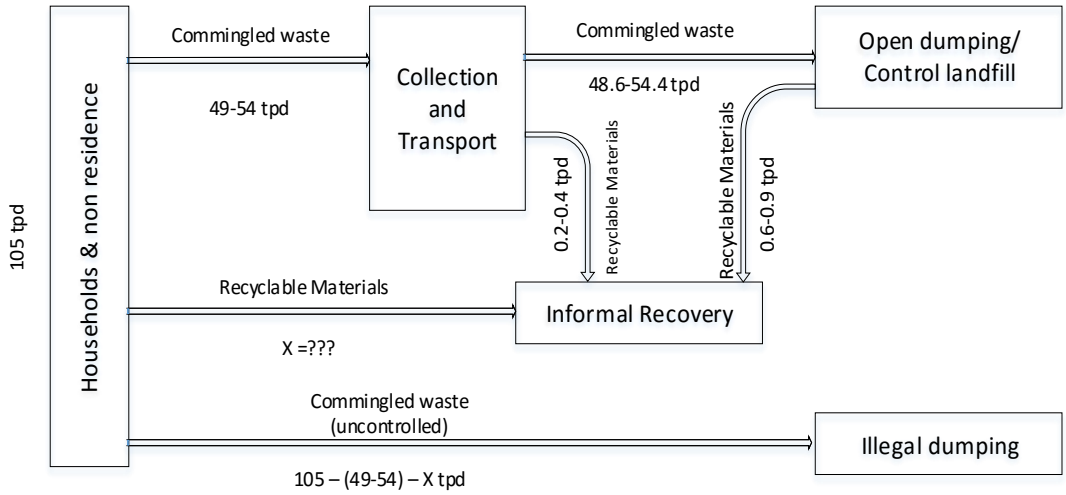


Figure 11 Material Flow of Generated Solid Waste in Metro City (adapted from : Brunner and Fellner 2006)

4.2.2. The Aspects of Current Solid Waste Management Practice in Metro City

This section will discuss the findings based on the elements and aspects of SWM in Metro City. Firstly, the generation, collection and transportation, treatment, disposal and recycling elements will be discussed.

Technical Aspect

Most of CE actors in SWM do the work manually using their skills. In solid waste collection, scavengers and waste pickers only collect the valuable solid waste. The determination whether it is valuable or not is based on the economic value that has been set by the garbage dealership as middle men. While non-valuable solid waste such as plastic bag and or dirty paper is left uncollected. In solid waste sorting activities, the scavengers and garbage dealership counting on their skilled sorting experience. In material recycling activities, handcrafting is the most common activity that is done by the community to recycle solid waste. Moreover, most of the actors that have been interviewed agree that solid waste recycling is identical with solid waste handcrafting.

In material recovery, organic fertilizer producers only use passive type of composting. The players use anaerobic composting for composting biodegradable solid waste. One of the reasons to choose anaerobic composting method is because its simplicity that does not require extra work for composting. The organic fertilizer producers only choose vegetables solid waste from traditional market because its homogeneity and relatively easy to compost. Moreover, the leachate that produced from vegetables decompositions can be used as raw material for liquid fertilizers.

In technical material's loop, more complex processes are identified along the chain.. Moreover, those activities lies on the bottom of recycling industry which do not require high technological input. Several interviewees revealed that the inexistence of such process is mainly caused by the need of bigger economy of scale. The activities are sorting, washing and grinding of plastics. While for other materials such as glasses, metals and papers only sorting activity is found in Metro City.

The first step of plastic solid waste recycling process is collection. There are four types of collecting actors in Metro City. Scavengers, they collect the recyclables throughout the city, mostly late in the night or early in the morning; Itinerant waste buyers, they buy recyclables

door to door; garbage collectors, they buy solid waste from scavengers and itinerant buyers and sell it to bigger garbage dealership; garbage banks they collect solid waste from their member's house and pay the money that is saved in their savings account in those banks.

Environmental aspect

Environmental aspect is not the main driver for most of CE actors in SWM in Metro City. They consider the economic opportunity from the business instead of environmental preservation as their main goal. Therefore, their focus is on the economic benefit instead and not on environmental preservation. However, activists such as the Cangkir Hijau garbage bank boards are motivated to run solid waste recycling business by their environmental concern.

From the governmental side, environmental monitoring for SWM in Metro is routinely conducted. However, the monitoring is only limited to the measurement of control well and leachate basin outlet quality in FPS and only measure the physical parameter such as pH, Turbidity and Conductivity. Other measurements such as the amount of solid waste that is generated by citizens or the number of adequate round-trip that needed to collect all generated waste daily is not available.

Economic – financial

All the stakeholders in local government such as FPS manager, solid waste management sub-division or solid waste infrastructure sub-division argue that the adequate financial budget is the main prerequisite to establishing sustainable sound SWM. The main source of the budget for SWM operations funds come from the central government. Hence, the budget of SWM practice is determined on how big the city receives development fund from the Central government.

Mr Kartiko said that the effectivity of monthly fee collection is questionable, he has calculated that the municipality can collect bigger income even if the fee of €0.67 per month was applied. Moreover, the monitoring system for the collection activities are stil unavailable. On the other hand, the willingness to pay by the citizens shows that 19 out of 30 respondents agree to pay the fee higher than €1 per month representing 63% of the respondents.

The private sector in solid waste regeneration chain said that financial factor is not one of the most crucial factors in their business. However, most of them said that they need financial

support such as loans or grant from government, in order to grow their business regarding solid waste management. However, they can still operate normally and gain noticeable benefit from their businesses. Moreover, there are such soft loan schemes from the government to support the informal business development such as Citizen's Business Credit/Kredit Usaha Rakyat (KUR). This scheme allows the informal sector to access loans from assigned banks and the guarantee will be borne by the government.

Socio-Cultural

Result of questionnaires shows that 44% respondents did not agree that SWM is solely government obligation. However, 28% of respondents were still confused whether to agree or disagree, while 28% said they agree that SWM is solely government obligation. These results show that almost half of the citizens still have social concern regarding their role in SWM of the city.

The findings on the survey also show that the awareness of the citizens regarding the solid waste value and the perception of solid waste trade is high. These findings are supported with the interviews with Wijaya Kesuma Garbage Bank where it was mentioned that citizen attention toward solid waste value utilization is getting higher, this could be seen from the number of members in Wijaya Kesuma garbage bank. The membership has increased from 30 households to more than 50 households in the sub-district. The amount of solid waste collected also increased to 2-3 tons of recyclables solid waste each month.

Institutional

Almost all of the interviewed actors in SW recycling in Metro City are working individually. They do not have organization where they can make communication and coordination. Therefore, there is no formal communication among actors, the only regular communication is done by personal communication between actors.

In the municipality, solid waste manager is a job that is attached to structural position under environmental agency. This means that the waste manager position is held by the head of the cleaning division. Every government officer that already reaches a particular rank can be assigned for the position even though they did not have adequate knowledge on SWM. Moreover, there is no specific requirements to determine the eligibility of the solid waste manager such as the SWM knowledge or specific technical courses. Hence it is often found

that solid waste managers are unable to explain or even formulate a good solid waste management strategy for achieving waste management objectives. Furthermore, there is no routine training for solid waste employees in the city, the only routine training regarding SWM is held by the Central government for waste managers and in administrative level. And when it comes to implementer such as sweepers, operators or drivers there is no training for them.

There are several initiatives from the Central government that support CE implementation hence the local agency can play a more significant role for CE acceleration, such as the grant scheme for garbage banks from industrial and cooperative business agency in the city or anaerobic bio-digester for farmers from agricultural agency or the plan to build TPS3R which is done by public work agencies of the province.

Political/Legal

Legal concern has been identified as the main driving force for SWM in Metro City. The obligations from the central government that are stated in the law, governmental and ministerial regulations as well as the obligations from the province are shaping the form of SWM practice in Metro. Hence, the municipal practices depend on the firmness of higher level governments to force the sustainable SWM in the city. Actually, the Central government has an initiative to improve the implementation of a sustainable city which includes SWM as one of the key parameters for the assessment. The initiative is ADIPURA, a tribute for cities that are successful in in keeping the cleanliness as well as managing the urban environment. Although Metro City has been one of the winners for several times, the existence of ADIPURA cannot drive a significant change in SWM practices in the Metro.

SWM regulations in Metro City or generally in Indonesia has covered almost all sectors of SWM practice from the planning phase, the operation phase until monitoring and evaluation phase. **Error! Reference source not found.** shows the list of the regulations in municipal SWM in Indonesia which exclude hazardous waste management. These regulations have provided clear strategy and direction about how to conduct proper SWM in Indonesia. On the other hand, Metro City has their own regulations of SWM that stated in City Regulations number 5/2012 which mentions the obligations of local government to conduct the sustainable SWM in the city. However, these regulations cannot fully be implemented, as an example is the level of solid waste separation in Metro City. From the Figure 9 we can see that only 13 out of 46 respondents (28.3%) sort their waste even if it is compulsory activity by the citizens.

Table 8 List of regulations on solid waste management

Num	Title	Subject
1.	The Law 18/2008	about Solid Waste Management
2.	The Law 32/2009	about Environmental Protection and Management
3.	Government Regulation 81/2012	about Solid Waste Management
4.	Ministry of Public Work Reg. 21/PRT/M/2006	about National Policies and Strategies for Development of Solid Waste Management System
5.	Ministry of Home Affairs Regulation 33/2010	about Solid Waste Management Guidelines
6.	Ministry of Environment Reg. 16/2011	about Content guidelines of Local Regulation Design about Domestic Solid Waste
7.	Ministry of Environment Reg. 13/2012	about Implementation Guidelines of Reduce, Reuse, Recycle Through Garbage Banks
8.	Ministry of Public Work Reg. 03/2013	about Domestic solid Waste Management
9.	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

4.3. The circular Economy situation in SWM in Metro City

Circular Economy is a relatively new concept for many people in Metro City and they do not know about the CE benefits so it is not evident for them if they can and want implement CE principles. This situation made CE practices identification in Metro City difficult. Moreover, in such linear economic society such as the one in Indonesia or Metro City in particular, where the take-make-dispose practice is considered as cheaper and easier solution for daily activities, CE or similar terms (closing the loop or cradle to cradle) have never been heard before.

To study the current practice of CE principles implementation in SWM in Metro City, several activities regarding the SWM are identified. From the observation during data collection period, recycling business is the most common business type that is found in Metro. There are several solid waste regeneration businesses found in the city. Although the implementation of the regeneration is done to limited extent. Ellen Macarthur foundation mentions that regeneration activities in SWM sector is highly related to CE implementation (Ellen Macarthur Foundation, 2014).

However almost all of the actors that implement the regeneration for SW are in the informal businesses. Wilson, Whiteman, & Tormin (2001) characterized these informal businesses as small-scale, labor-intensive, unregulated and unregistered with low-technology manufacturing or low provision of services (Wilson, Velis, & Cheeseman, 2006). This characterization can illustrate the current condition of informal recycling businesses in Metro.

The related businesses to SWM are scavenging activities, itinerant garbage buyer, garbage dealership, garbage bank and organic fertilizer producers. Although many players have been identified, the variety of activities are not different one from another. Almost all business rely on the bottom to middle hierarchy of solid waste recycling sectors. Moreover, most of them, especially individual scavengers, depend on daily earnings from solid waste activities. The overview of the hierarchy is presented in Figure 12.

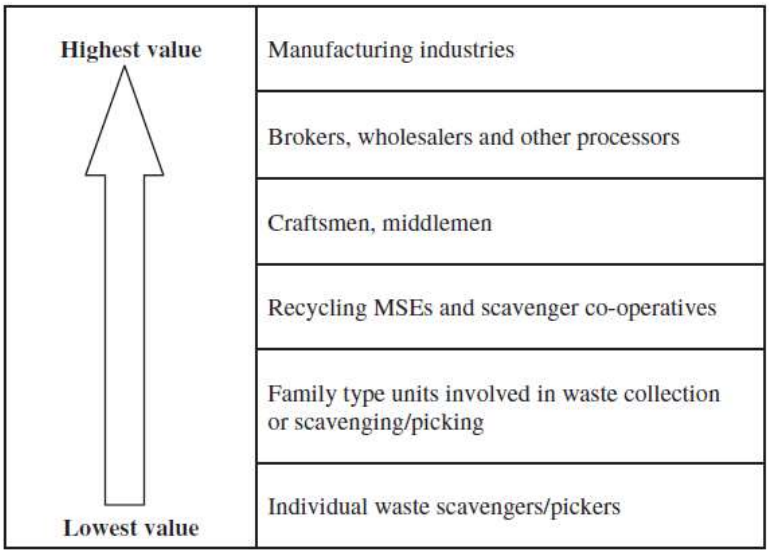


Figure 12 Hierarchy of informal sector recycling (source: Wilson, Velis & Cheeseman, 2006)

In the recycling hierarchy, the biggest added value will be gained by the actors whose place the top of the hierarchy (Wilson, Velis, & Cheeseman, 2006). While the positions of SWM related businesses in Metro City are in the bottom to the middle of hierarchy which means the economical aspect of those businesses does not play significant role in recycling industries compared to the actors in the top hierarchy.

However, some businesses such as garbage bank and Mr Sunarno's organic fertilizers production are driven by different motives. The founders of Cangkir Hijau garbage bank are driven by social motivation, they are concerned about the poor delivery of SWM in Metro City. They choose garbage bank scheme as an approach to disseminate awareness for the people in Metro City regarding the hidden value of solid waste. On the other hand, Mr Sunarno as an

organic fertilizer producer focuses on farmers training for his main job. Mr Sunarno own Metro Lestari Self-support Farmers and Villages Training Centre (P4S) where organic fertilizers production is one of the several curricula in his training center. However, high demand for his organic fertilizers by the farmers has made him decided to produce organic fertilizers such as compost and liquid fertilizer regularly.

On the other hand, the SWM related businesses in Metro City are operated individually and do not have an organized union which allow them to make regular communication among each other. The only chances to meet each other are when they are invited to meetings of the government agenda that are held only once per year. Hence their position, particularly the players that are placed at the bottom of recycling hierarchy, is weaker than the buyers. The only chance to obtain better price is to compare the offered prices from one big garbage dealership to another.

Moreover, from interviews and discussion with several officers in EA, those businesses are actually sufficient knowledge to produce bigger added value for the recovered materials. However, they do not have adequate supports such as financial, technical or managerial aspects. Hence to implement CE in Metro, it will need more than traditional collaboration across sectors. The implementation of CE cannot just be the responsibility of the environmental sector but it will require inter sectorial collaborations such as access to capital investment, strategic marketing and other strengthening factors for CE actors that could not be achieved by sole support of environmental agency.

4.4. The challenges of SWM integration in Metro City

In this section, the challenges to integrate CE tenets in SWM in Metro are discussed through the identification of the existing barriers. Some of the most important barriers in CE integration in SWM such as net profitability, capital and transaction cost are further elaborated in this section.

Net profitability

From **Error! Reference source not found.** we can see that the potential amount of plastic waste is reaching 24.07% from the total generated solid waste of 105 tons per day (25.4 tons of plastic per day). Paper waste only reaches 9 tons, 0.9 tons glass and 0.6 tons of metals per day. If these were converted to their economic value, that of plastic would be Rp.50.000.000/€3,550 per day, and that of paper would be 9,000,000/€600 per day and of

glass Rp. 3,600,000/€240 and of the metal Rp. 600,000/€40 per day[14]. This shows that the economic scale of non-degradable recycling is relatively small, however, opportunity for recycling plastic types is promising. Composting activity is the common activity that is used to recover biodegradable materials. The amount of organic material from municipal solid waste is about 60 tons per day twice than the plastic waste. Lopez-Real (1990) states that the compost yield is only 50% from its biodegradable material weight, or can only produce 30 tons of compost (Van Ginkel, Raats, & Van Haneghem, 1999). The current price of compost is Rp. 350 / kg[15], then the economic potential of the compost can reach Rp 10,500,000/€700 per day. Moreover Mr. Sunarno said that to achieve these results it requires a massive effort because to get the compost it takes 21-40 days of composting process.

As seen above the scale of economy of SWM related businesses in Metro City is not very high. This statement is also supported by the reality that only the informal sectors are involved in such business. Almost all of these businesses are categorized as Micro or Small Enterprises (MSEs) which recruit less than 20 people. Moreover, as mentioned above the businesses that take part in SW recycling in Metro City are on the bottom of the waste recycling hierarchy.

Moreover, the formal sector involvement in Solid Waste Management will depend on the subsidy (Fatimah, 2009). This subsidy comes from the government but in the case of Metro City government it is not available. However, the opportunities for informal businesses involvement to SWM related business are relatively high. This scenario can happen if the informal sectors can manage all of the solid waste that is generated in Metro City.

Capital

As mentioned above the involved businesses in solid waste regeneration are informal businesses. Although some businesses said that they do not need investment, most of the businesses admitted that financial capital is their biggest barrier to absorbing more solid waste in Metro City. However, some business such as garbage bank have relatively higher resilient in the capital factor. This is due to their unique purchasing mechanism that they can buy and keep the collected solid waste without cash which will be required for conventional waste collector.

[14] These prices were obtained from the interview with garbage dealership
[15] Based on interview with Mr Sunarno

Technology

Informal sector involvement is characterized with low technological adaptation which is substituted by the use of cheap human resources (Wilson, Velis, & Cheeseman, 2006). Hence technological adaptation will be required to improve effectivity of informal sectors.

Moreover, the recycling practice in Metro City is limited to material preparation which is sold to big garbage dealership outside the city and the circularity of material to the city itself is unexplored yet. The absence of big scale industry in the city limits the options of this circularity. Hence the involvement of creative industry as the end user of recovered materials is explored. However, from the interview with Mr Wijaya in the creative industry, it can be deduced that the challenge is about the lack of skilled human resources and the availability of technology in the city.

Technological breakthrough is a requirement to enable creative industry to cooperate with recycling businesses. The possession of plastics recycling technology can be one of the examples. This technology will enable SWM to move upper within the recycling hierarchy, hence CE integration in SWM can be improved. Moreover, creative industries is one of the few players to circulate the solid waste in Metro City which can be developed with technological breakthrough such as 3D printing system.

Externalities

Price sensitivity is significant factor in the purchasing decision of the citizens in Metro City. This conclusion is retrieved from the results of the survey in Figure 13, which shows that 70% of respondent agreed that affordable price is considered as an important criteria to purchase recycle goods. Moreover, the uniqueness and the artistic value of those goods is also highly required by the citizens to purchase them.

	Very unimportant factor Row N %	unimportant factor Row N %	fairly important factor Row N %	important factor Row N %	very important factor Row N %
can be used for daily activities	10.0%	5.0%	20.0%	25.0%	40.0%
durable	7.5%	2.5%	20.0%	25.0%	45.0%
affordable price	7.5%	2.5%	20.0%	32.5%	37.5%
artistic value	10.0%	5.0%	22.5%	42.5%	20.0%
uniqueness	12.5%	7.5%	25.0%	40.0%	15.0%
fashionable/trendy	10.0%	15.0%	25.0%	32.5%	17.5%
branded	13.6%	13.6%	34.1%	20.5%	18.2%
can be used as symbol as env conservation symbol	2.5%	12.5%	22.5%	25.0%	37.5%

Figure 13 Criteria to Purchase Recycled Goods

Infrastructure

The absence of infrastructure is a major obstacle for garbage entrepreneurs in Metro City, especially to attract investors engaged in composting and the separation of biodegradable waste. Mr Irianta said that waste separation will reduce the operational costs of waste management and this will attract investors. The survey results show that one of the important factors that cause the reluctance of people to sort the waste is the absence of waste sorting facilities. The mechanism such as procurement of separate waste bins for citizens will increase the opportunity for private sector involvement in wastemanagement

Mr. Muji who owns a garbage dealership stated that the absence of modes of transportation is a barrier for him to achieve optimum profit for his business. He said that the presence of cheap transportation will reduce the production costs of his business.

For garbage banks such as cangkir Hijau and wijaya kesuma, the existence of modes of transportation is very helpful in developing their business. The availability of transportation modes is proven in increasing their range and capacity of garbage collection much greater than before. This shows the importance of the existence of infrastructure for garbage entrepreneurs.

For garbage banks, the existence of waste separation infrastructure can be a driving force for the growth of their waste management business. This is as it is found in the survey that more than 60% of respondents consider the importance of the existence of waste separation facilities, this is supported also by the results of the survey which showed that 76% of respondents agreed to make sales of waste generated. Moreover, the survey also shows that

citizen prefer door to door collection of solid waste even if they will be paid lower for the collected solid waste.

Based on the information that was retrieved from the interview, the farmers have realized the benefit of organic fertilizer application for their field, the transportation access barrier is huge challenge for farmers particularly paddy field farmers as they apply organic fertilizers to their field.

Insufficient Competition

One of the biggest challenge for CE implementation in SWM sector, particularly for biodegradable materials loop is the existence of national policy which subsidize the synthetic fertilizer for the farmer, while there is no such scheme for organic fertilizer. This policy made the difference between organic and synthetic fertilizers become bigger. Moreover, the green market for organic products is still very small because the expensive price of organic products.

Imperfect information

The implementation of CE principles will require creative and unconventional approach in order to identify the available opportunities (Ellen Macarthur Foundation, 2014). The significant function of information is inevitable on these opportunities translation in to practical actions. Almost every actor in Solid waste recycling businesses could not identify the new approach regarding solid waste regeneration opportunities, they still capture the conventional opportunities of solid waste regeneration business. Hence the information acceleration is also the challenge in CE integration in SWM in Metro City.

Transaction cost

As mentioned earlier, the informal actors in solid waste recycling business in Metro typically lied at the bottom of the recycling business hierarchy. This factor made the actors are highly dependent on the buyers. The actors cannot determine the selling price of recovered materials. On the other hand, the price was set by buyers as middlemen. Such mechanisms cause the informal actors in solid waste recycling only have few options, namely by comparing the highest price offered by the buyers or storing and selling the stored raw material when the offered price is increasing.

Inadequately defined legal

From the interviews, it was revealed that legislation is not an obstacle for the informal sector to run SWM related business in MC. Government, particularly environmental agency,

encourage the informal sectors to take more significant role in SWM. The Environmental agency support the informal actors by giving them the equipment to run their business. However not every sector in the municipality could adequately define solid waste related regulations, public procurement regarding fertilizer supply is one of the examples. Although has been regulate as one of the strategy to increase the involvement of private sector[16], the gardening division still use synthetic fertilizer as a regular nutrient intake for shading trees and ornamental plants that exist in MC instead of using organic fertilizer produced by SW organic fertilizer businessmen.

Poorly defined target and objectives

Community participation in SWM such as the likelihood of citizens to separate their solid waste can provide better recoverable materials for recycling activities. Therefore, bigger economic value will be obtained if the materials can be sorted from the source (Ellen Macarthur Foundation, 2014). Organic fertilizer business for example, Mr. Sunarno state that better quality compost can be produced from uncontaminated biodegradable waste. Furthermore, Mr. Wijaya, from creative industry, mentioned that if better quality recovered material from solid waste are found in Metro, it will increase the likelihood of his art gallery to utilize the recovered materials for his products. However, law enforcement regarding solid waste separation is never considered by the government.

Capabilities and skills

One of the most serious problems in integrating CE principles is to improve the capabilities and skills for informal businesses in SWM. Therefore, the usage of new knowledge and/or technologies can open a new insight in their business practices. Hence the SWM related business can become an attractive business even for formal business to participate.

Custom and habit

Custom and habits have significant effect for CE principles integration in SWM. The survey shows that they support waste reduction and reuse habit. However, the sorting waste habits is still low among the citizens, therefore building a supporting habit is also the challenge in integrating CE principles in SWM in Metro City

[16] Written in Ministry of Public Work Regulation 21/prt/m/2006

4.5. The solution to the challenges

In order to overcome the challenges for integrating CE principles in SWM in Metro City described in section 4.4, the Ellen MacArthur Foundation framework is here used. The table of The Suggested solutions for Barriers in CE is presented in Table 9. However, the implementation of CE in municipal scope can be limited by higher governmental policy and regulations. Therefore, not every possible suggestion in the framework can be discussed. Moreover, it is not possible to propose solutions for only a specific sector, therefore possible solutions are presented as follows.

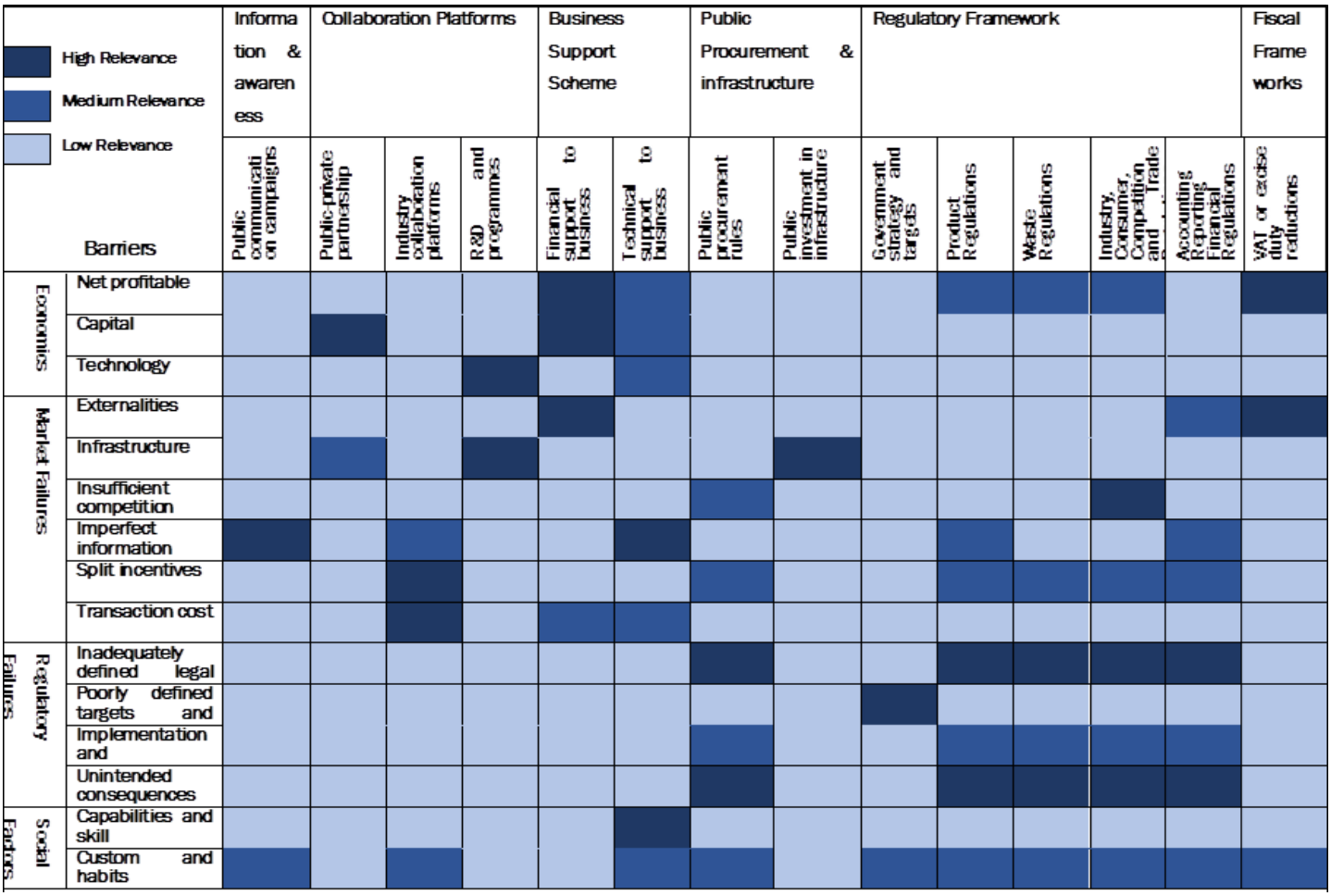


Table 9 The Suggested solutions for Barriers in CE (Source: Ellen MacArthur Foundation, 2014)

The emphasize on economical aspect can be used for accelerating integration of CE principles in SWM in Metro City. It is derived from the fact that the main motivation for many recycling business in Metro is came from economic reason. As discussed above the financial support

from the government such as tipping fee is the most common form to involve the formal private sectors in SWM management. This scheme is applied in metropolitans in Indonesia such as Jakarta, Bandung and Surabaya (Damanhuri, Handoko, & Padmi, 2013). However, Metro City cannot provide such financial support. Therefore, the involvement of formal sectors will not be discussed in this study.

From the interviews, it is known that the informal sectors play important role in SWM in Metro City from the collection until recycling activities. One of the biggest challenge for informal sectors is the access of the capital. Lack of capital is the major challenge for informal sectors to take bigger role in SWM. However, one of the possible solution to tackle this problem is by providing facilitation to the capital owners in this case are the banks.

Currently, the central government has introduced KUR. This is a soft loan scheme for informal businesses or individual businesses which will not require collateral for the basic credit of Rp. 25,000,000/€1,667. However, many informal recycling businesses did not know about KUR scheme. Moreover, they were reluctant to apply for credit to the bank since they assumed that they are not bankable[17]. On the contrary, this scheme will accept the credit proposal even though they are not bankable yet (BRI, 2016). Therefore, municipality can actively facilitate them by hold meetings of informal sectors with the banks. Therefore, the informal sectors will have better access to capital and hopefully can grow their business and absorb bigger amount of generated solid waste in Metro City.

Current business pattern in solid waste recycling in Metro did not create big additional economic value for the players. On the other hand, the condition of current solid waste handling requires more actors to take part in SWM. However, it is not suitable to take many economical driven actors to take part in solid waste recycling in Metro, since the economic scale of the business is not very high. Proposing Public Private Partnership (PPP) is one of the possible solutions to solve this dilemma. By increasing public participation bigger amount of solid waste can be handled by existing actors. Therefore, bigger economic benefit can be obtained by the existing businesses.

The technological barriers can be overcame by providing regular trainings for SW related business. however, these trainings should not only cover technical aspects but also cover financial solutions, legal requirements and managerial skills. Moreover, such trainings can be used also as regular meetings for informal sectors to identify new opportunities and development barriers and for strengthens the cooperative activities such as collective selling of solid waste to wholesalers. Moreover, this regular meeting can be used also to open the

[17] acceptable for processing by a bank (sources: http://www.dictionary.com/browse/bankable)

knowledge broaden the recycling network such as establish business relationship with the end users.

Although informal sectors in recycling business able to deliver an effective performance if they were adequately supported (Wilson, Velis, & Cheeseman, 2006). It is inevitable that the involvement of the citizens is play a significant role in the successfulness of SWM in the city (Guerrero, Maas, & Hogland, 2013). Garbage bank as a community based organization is also important sector that need to be developed. Garbage bank can provide collaboration scheme among citizens and informal sectors. Garbage bank able promote awareness and educational programs for members citizens regarding their obligation in SWM and disseminate information such as the drawback of solid waste illegal activity such as solid waste open burning. Garbage bank also able to use social pressure instrument to the members such as enforce the common commitment to separate solid waste that has been agreed in the earlier. In addition, garbage bank also can be functioned as host organization for the informal sectors to be important stakeholder in SWM in the city (Wilson, Velis, & Cheeseman, 2006; Utami, 2013; Suryani, 2014).

4.6. The Suitable Circular SWM Framework in Metro and How to Enable It

As mentioned above, regeneration activities such as recycling and material recovery are indicated to have high relationship with CE principles implementation in SWM, compared to other activities such as share, optimize, loop, virtualize and exchange activities (Ellen Macarthur Foundation, 2014). Therefore, to integrate CE principles in SWM, the optimization of recycling and material recovery activities in SW stream is important. Many countries such as Japan and Germany have successful frameworks to optimize recycling and material recovery in their SWM. However, not every solid waste management framework can successfully be applied to another region. Capacity and capability determination is required to set the priorities in SWM (Brunner & Fellner, 2007).

In many industrialized countries, the involvement of formal sectors is seen to be able to increase the performance of SWM. However, lack of budget to deliver adequate SWM is one of the barriers to enable formal private sector involvement in SWM in Metro City. Although involving citizens to conduct adequate SWM is the cheapest and better solution to overcoming the solid waste problem, rely only on their involvement will require lot of effort and time (Rathi, 2006).

On the other hand, as in many municipality in developing countries, there are informal sectors that already involved in recycling and material recovery of Solid Waste in Metro City. Most of

them are driven by economic motives, hence involving them in formal SWM delivery will meet less resistant (Brunner & Fellner, 2007; Wilson, Velis, & Cheeseman, 2006). For the case of Metro City the actors are scavengers, itinerant waste buyers, waste collectors, and organic fertilizers producers. While there are also garbage banks that are active in SWM activities.

Although they are characterized as labor-intensive, low-technology, low-paid, unrecorded and unregulated businesses, they are capable of delivering significant benefits for municipal SWM. Therefore, it is important for municipality such as Metro City to consider the opportunity to cooperate with these informal sectors in SWM (Wilson, Velis, & Cheeseman, 2006). However, create profitable condition for SWM businesses in Metro will require the involvement of local government and citizens. Therefore, the collaboration between government, informal actors and citizens is proposed as suitable framework to integrate CE into SWM in Metro.

4.6.1. Initiative from the municipality

The nature of informal actors is work independently, unorganized and illiterate (Wilson, Velis, & Cheeseman, 2006). Therefore, it is difficult to form an organization to unite actors in informal businesses even though it is for obtaining bigger economic benefits. However, routine meetings to disseminate the advantages of working in group can be used as cognition builder for informal actors to form an organization. Moreover, supporting policies such as legalization of informal organization business activities in SWM, providing incentives for solid waste collection and treatment service that conducted by the organization can be used to increase the contribution of informal actors in SWM (Scheinberg, 2012).

4.6.2. Increase the capacity of informal actors

To increase the role of informal sectors in SWM there are steps that are suggested by Wilson, Velis & Cheeseman (2006). The steps are to facilitate them to organize, to move up the recycling business hierarchy and to improve the capabilities of adding and extracting the value from recovered solid waste.

a. Organizing

Forming organizations is important for most of informal sectors in recycling businesses particularly for individual scavengers or itinerant waste buyers. Forming organizations make them more resilient to the exploitation from intermediate dealers because with an organization they will have stronger bargaining position in the market (Wilson, Velis, & Cheeseman, 2006). Organization can also be the place to hold discussions among members regarding their challenges or opportunities (Suryani, 2014). However, there

is no standard guideline to forming informal businesses organization, hence it will be more difficult to formulate the type of organization for informal sectors.

On the other hand, Community Based Organization (CBO) such as garbage bank already have this scheme. In Indonesia, garbage bank as a cooperative type of organization has a standard guideline to form an organization as mentioned in Ministry of Environment Regulation 13/2012. There is also a guideline that derived from the success stories of garbage banks in Indonesia. There are many successful role models for garbage bank in Indonesia that face almost similar obstacles in the establishment and development process (Utami, 2013; Suryani, 2014)Therefore, it will be easier to develop the working scheme for garbage bank organization and operation.

Informal actors in solid waste recycling and can be active members of garbage banks. Hence, they will have equal right and obligation like other members. The board of the organization discussed in routine meetings such as annual meeting and can be selected from government, citizens or informal sectors. With this cooperative organization, the businesses of the informal sectors can be integrated into an organization (Utami, 2013).

With this scheme of organization partnership program such as collaboration with government to produce compost can be enabled. Since Public-Private partnership (PPP) with garbage bank is a possible scheme for the municipality according to chapter 39 of City Regulations 8/2015. Moreover, there is a former example of PPP scheme in Metro City regarding SWM. In addition, collaboration partnership with other industries such as creative industries also can be explored. Moreover, the local government already acknowledge garbage bank as the important SWM actors. Many support from local government has given to garbage bank development..

a. Move up the hierarchy

Once informal sectors of SWM have been organized, the next step is about how to increase the performance of the informal sectors in solid waste recycling hierarchy. A possible solution can be done by circumventing the role of middlemen in solid waste recycling chain (Wilson, Velis, & Cheeseman, 2006). Once informal sectors of SWM have been organized, the next step is how to increase the performance of the informal sectors in solid waste recycling hierarchy. A possible solution can be done by circumventing the role of middlemen in solid waste recycling chain (Wilson, Velis, & Cheeseman, 2006). Circumventing the middlemen means that garbage bank needs to collaborate directly with the end users of recovered material. This step can be done by

exploring and establishing new business collaborations with the end users. The user can be farmers or creative industries.

b. Improve the capability to add and extract value from recovered solid waste
Typical role of middlemen in TCOM is to accumulate the volume of collected solid waste so they can transport the collected solid waste to wholesalers or industry for higher price. This step cannot be done by a single actor from the informal sector because it will require a lot of time to collect large amount of solid waste, they also cannot receive money during the time of collection. This condition is exacerbated with the economic level of the most informal sectors which are categorized as poor people. These reasons made most of the informal actors fail to grow their business. However, this step is possible for them if they have single organization where they collect a substantial number of recyclables in short period of time and collectively sell those recovered resources to the manufacturers, hence bigger added value from collected solid waste will be obtained.

4.6.3. Increase the participation of community

To increase the participation of the community, adequate awareness, the organizational and technical capacity of the community must be built. Garbage bank as a CBO must be encouraged and supported to disseminate the knowledge among the community regarding the importance of supporting better SWM. Moreover, the knowledge that disseminated by CBO such as garbage bank can be more acceptable to the community compared to government submitted information (Schübeler, Christen, & Wehrle, 1996).

One of the possible example to integrate CE into SWM is the collaboration between garbage bank, citizens, informal actors, municipality and organic fertilizer producers. This collaboration framework can be seen in Figure 14. Garbage bank is a waste collector for its members can provides separate collection for the members. Therefore, the recyclables and biodegradable solid waste are separated. The sales of recyclables saved in member's garbage bank account while their biodegradables are collected by the municipality in a certain location that has been agreed before. Their members need to pay monthly fee to the municipality for biodegradable collection service and the fee is paid to garbage banks. The amount of charged fees depends on the frequency of solid waste collection and the agreement between garbage bank and municipality. However, the garbage bank can provide subsidy schemes from their sorted solid waste deposit. Moreover, the bank can also cooperate with organic fertilizer producers for collecting the biodegradables. Hence the need for solid waste collection service by the

municipality can be reduced or even eliminated which means they do not need to pay collection service from the municipality anymore.

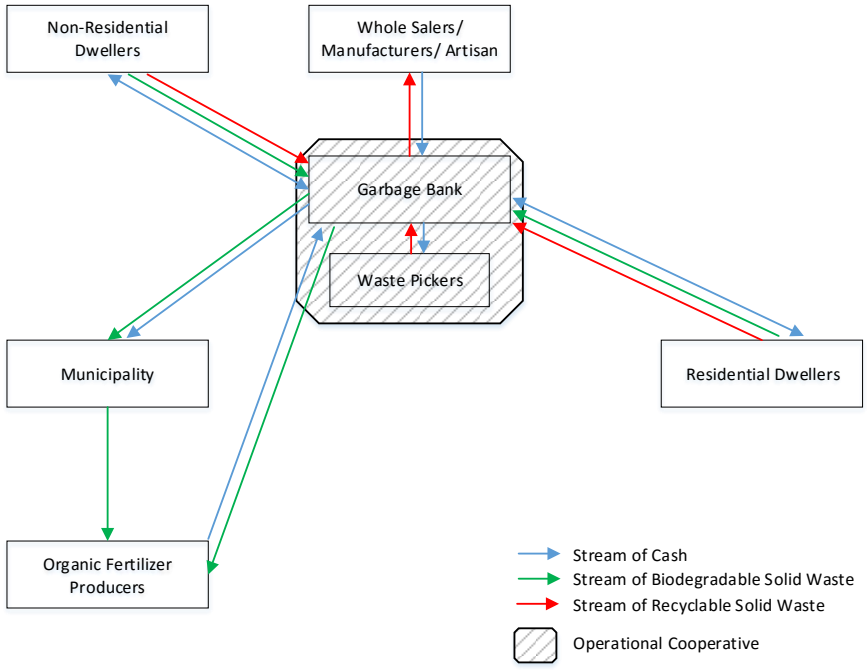


Figure 14 Proposed collaboration for CE integration into SWM in Metro City

On the other hand, organic fertilizer producers will also obtain benefits from this scheme. Centralized composting is proven to give bigger profit for organic fertilizer producer (Aye & Widjaya, 2006). The organic fertilizer producers also do not need to separate the solid waste, since it has been separated from the source. Moreover, source separated solid waste is considered to have better quality than solid waste that is separated after being transported (Ellen MacArthur Foundation, 2014).

4.7. The Waste Absorption Footprint

In this section, the environmental impact of the current SWM from the perspective of waste absorption footprint is estimated. Although it was possible to calculate the waste absorption footprint of SWM in Metro City, a comprehensive accounting of WAF, which includes nutrient footprint, is not here presented in this study. The latter is due to the unavailability of the required data. Therefore, the environmental impact of SWM in this study is limited to the emission of gasses (CH_4, N_2O and CO_2) quantification. The analysis of WAF_{CO2} is done through the analysis of the SWM operations.

4.7.1. Collection, transportation (emissions)

The emission of the collection and transportation operations were calculated by using Equation 4 The emission of CO2/CH4/N2O using IPCC tier 1 method. From the interview with Mr Jaya, it was mentioned that fuel consumption for collection and transportation activities demands 135,050 litres per year and the fuel consumed corresponds to Pertamina Dex/ diesel type fuel. Suyanto, Siswanto & Wakid (2015) mentioned that for this type of fuel, has a calorific power of 7769 Joule/cc. From the IPCC method of mobile combustion (2006) the emission factors for the diesel engine are 74,100 kg CO_2/TJ; 3.9 kg CH_4/TJ and; 3.9 kg N_2O/TJ. Hence, the emissions per year of the collection and transportation activities are 77,746 kg CO_2; 4.09 kg CH_4; and 4.09 kg N_2O.

The current collection of solid waste only covers 45% of the city generation, thus to fully cover the city it will require an increase in the collection and transportation activities which consequently will consume more fuel and release higher emissions of CO_2, CH_4, and N_2O. However, the calculation of such scheme was not considered in this study since there is no data, available at present regarding the collection and transportation activities.

4.7.2. Disposal activity emission

The same methods applied to estimate the emissions of the collection and transportation activities were also carried out for the disposal activity. From an interview with Mr Supriyanto, it was discovered that the fuel consumption corresponds to 73,000 litres per year. Even further, the same type of fuel than for the collection and transportation phases was reported, i.e. Pertamina Dex. Hence, the emissions of disposal activities were estimated as follows: 42,025 kg CO_2; 2,21 kg CH_4; and 2,21 kg N_2O.

4.7.3. Landfill emission

In order to calculate the emissions of the landfill, the operational details of the landfill were mentioned during interviews. The informants indicated that the site is in the process of changing from open dumping towards a controlled landfill. But there is no gas recovery facility on the site, and the pile height is about 4 m. According to the ICCP methodology, Equation 5 and Equation 6 are more appealing to such characteristics and the generated methane can be calculated with the following formula:

$$Y_{me\tan} = (\mathrm{MSW}_T \cdot \mathrm{MSW}_F \cdot \mathrm{MCF} \cdot \mathrm{DOC} \cdot \mathrm{DOC}_F \cdot \mathrm{F} \cdot {}^{16}\!/_{12}\text{-R}) \cdot (1\text{-OX})$$

Table 4 shows some numbers about the MSW generation, 105 ton/day or equal with 38.325 Gg/year, from this number it can be said that only 44% were actually dumped in the landfill (Interview With Mr Jaya and Mr Supriyanto). While the MCF for shallow-

unmanaged landfill is 0.4. The DOC was calculated by using ICCP Equation 6 and this resulted 0.229. For the DOCf, F, OX parameters, their values were provided by using the IPCC default values of 0.77, 0.5 and 0. Even further, there is no gas recovery on the site which causes R value is of 0. From this data, it can be calculated that the generation of methane in the landfill is 865,733 kg CH_4 per year. While the amount of carbon dioxide that is generated by the landfill amounts to 2,380,767 kg CO_2 per year.

4.7.4. Waste Absorption Capacity of carbon sequestration in Metro City

In order to estimate the amount of CO_2 which can be absorbed by biomass, it is necessary to identify the potential sink for carbon dioxide uptake. The Waste absorption capacity for carbon sequestration in Metro City is provided by Green open space (GOS) and crop land. The green open space in Metro City consists of city parks and city forest. In fact, the total area of city parks in Metro is 3.4766 Ha. and the total area of city forest is 13.2 Ha. While paddy field as crop land is 2,922 Ha.

The amount of absorbed CO_2 by the GOS can be estimated using table 2. From

Table 2 we can calculate that the GOS in Metro can absorb 9,485-ton CO_2 per year. While the paddy field is able to absorb 35,064 ton-CO_2 per year. Therefore, the capacity of the city to absorb CO_2 is 44,549-ton CO_2/Ha/year. The Local absorptivity for CO_2 is the division between the total capacity to absorb CO_2 divide by the total area for CO_2 sequestration or 44,549 ton CO_2/ year divided by 2,938.67 Ha or 15.16 ton CO_2 . While the total capacity for carbon sequestration in Metro City is 44,549-ton CO_2/year. Since the calculation is limited to city area then "1" is used as the regional supply factor. The Waste Absorption Capacity to sequestrate CO_2 is determined by using Equation 1. The amount of waste absorption capacity for $CO_{2\text{-eq}}$ in Metro City is 2938,67 Ha.

$$WAC_{CO_2} = A_{CO_2} \times rSF_{CO_2} = \left(A_{city\ forests} + A_{city\ parks}\right) \times rSF_{CO_2}$$
$$= (16.67 + 2922)Ha \times 1 = 2938.67\ Ha$$

4.7.5. WAF_{CO2} of SWM in Metro City

The emissions in current SWM practices are the sum of emissions that are generated by each particular activity in SWM chain. Those numbers are 2,500.538-ton CO_2; 865.739-ton CH_4; 6.3-kg N_2O and their conversion to $CO_{2\text{-eq}}$ correspond to the equivalencies: 25-ton $CO_{2\text{-eq}}$/ton CH_4 and 298-kg $CO_{2\text{-eq}}$/kg N_2O (IPCC, 2006). Therefore, the amount of the emission will be 2,500.538-ton $CO_{2\text{-eq}}$ from CO_2; 21,643.483-ton $CO_{2\text{-eq}}$ from CH_4; 1.187-ton $CO_{2\text{-eq}}$ from N2O. All that makes a total per year of 24,145.90-ton $CO_{2\text{-eq}}$ generated from SWM practices. This clearly points out that the biggest CO2 emissions' contributor in the management chain corresponds to the landfilling practices. After obtaining the total emission from the SWM practices, the WAF_{CO2} of SWM activities can be calculated using Equation 2.

$$WAF_{CO_2}\ for\ SWM\ practices\ in\ TCOM = \frac{W_{CO_2}}{LA_{CO_2}} \times rSF_{CO_2} = \frac{24{,}145.90}{15.17} \times 1 = 1{,}592.14\ Ha$$

Where WAF_{CO2} is the total amount of $CO_{2\text{-eq}}$ generated, 24,145.9- ton $CO_{2\text{-eq}}$; LA_{CO2} is the local absorptivity of CO_2 which is 15.17 ton CO_2/Ha; rSF_{CO2} is the regional supply factor of CO_2 absorption, which in this case is 1. The result of this analysis shows the amount of WAF_{CO2} for SWM activities in Metro City is 1,592.14 Ha which means that 1592.14 Ha area is needed to absorb the entire emissions of SWM practices in Metro City.

4.7.6. Current WAF_{CO2} status

From the WAF accounting of the SWM practices in Metro City, WAC_{CO2} which is 2,938.67 Ha is still bigger than the WAF_{CO2} (1,592.14 Ha). Therefore, the current practice of SWM in Metro City still meets the minimum criteria of sustainability because the city is capable to absorb the adverse impacts of CO_2 emission from SWM practice. However, the environmental impact that comes from unmanaged solid waste is not calculated in this study. The environmental impact of the unmanaged solid waste is indicated to contribute significantly to the emission generation of SWM since the percentage of unmanaged solid waste is the 56% of the total solid waste generated in Metro City. Moreover, the capacity for capturing carbon dioxide is not only to absorb the emissions from SWM but also other activities such as transportation.

Therefore, in order to maintain the carbon emission sustainability of SWM practice in Metro City the potential direct solution is to have areas (by land acquisition) large enough to absorb the carbon dioxide emitted by the current SWM. With city's current carbon absorptive capacity of 15.17 tonCO2-eq/Ha. every person in Metro needs to have 0.01 Ha carbon absorptive land or equal to 100 m2 per capita. However, land procurement of such area will involve very high investment and land availability.

4.7.7. Environmental opportunities of the CE integration from the perspective of WAF

As mentioned here before the integration of CE principles in SWM put emphasis on regeneration activities such as encouraging PPP in SWM management. By encouraging PPP schemes in SWM, a business might consider utilizing solid recovered discharged materials (currently named "wastes"). Hence the amount of solid waste reaching the landfill can be reduced or even eliminated. One of the activities is by linking garbage banks with organic fertilizer producers to produce compost from solid waste. By producing compost from SW, the economic value of the undesired biological material can be increased. Moreover, the amount of methane generated from the landfill can be reduced. For environmental opportunities illustrating purpose an example from a garbage bank in Malang, East Java is used.

Malang Garbage bank (BSM) is handling 2.5-ton recyclables every day or equal to 7.16-ton MSW every day (Suryani, 2014)[18]. Therefore, a single garbage bank can reduce 6.8% of solid waste to reach the landfill. By using this scenario the annual emission of solid waste that can be avoided from reaching landfill can be calculated using Equation 5. From

[18] The conversion from recyclables into MSW use **Error! Reference source not found.**

the calculation, annual emission of 59.034-ton methane and 162.346-ton carbon dioxide from landfilling activities can be avoided. Such an amount is equivalent to 1,638.22-ton$_{CO2-eq}$. If 9 garbage banks in the city are encouraged to have such capacity the integration of CE in SWM in Metro City would be able to reduce 14.743,94 ton$_{CO2-eq}$ emission per year or can reduce the WAF$_{CO2}$ until it is 619.77 Ha or equal to 0.004 Ha/cap (40 m2/cap). This estimation shows that the integration of CE into SWM can provide environmental opportunities for Metro City. This estimation shows that the integration of CE into SWM can provide environmental opportunities for Metro City. Moreover, the CE integration into SWM which emphasizes the collaboration between community, private sectors and government which in line with national strategies to manage the solid waste. These strategies are included in Ministry of Public Works Regulation 21/PRT/M/2006 about national policies and development strategies in SWM.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

The main goal of this study was to examine the integration of Circular Economy principles in SWM in Metro City, Indonesia. However, the current practice was also analyzed in order to find challenges in CE integration in SWM. This study has identified that the SWM performance in Metro City is still cannot comply with the available regulations. During the identification of solid waste elements, the problems are found in almost all of the elements of SWM from the generation, passing by separation, collection, transportation, until disposal. However, the most notable problem in SWM in Metro is the absence of solid waste treatment. While the analysis sustainable SWM aspects found problems in technical, environmental, financial, institutional and political aspects. However, several aspects such as support of legislations and community willingness to participate can give positive affluence to the delivery of sustainable SWM in Metro.

The estimation of solid waste generation shown that around 97–114 ton per day (443–515 m3 per day) solid waste is generated in Metro. While only about 225-245 m3 per day solid waste can be transported to the landfill. While other solid waste left unmanaged. From these number, more than half (56.47%) of the solid waste is in the form of putrescible organic (kitchen refuse), the other components are: plastics and rubber (24.07%), paper (9.40%), wood (6.24%), clothes (1.52%), glasses (0.88%), metals (0.56%) and other

(0.86%). The SWM activities, that consist of collection, transportation and disposal emit 24,145.90-ton CO2-eq per year. While the biggest polluter from SWM activities is Solid waste landfilling which emit 24,066.83- ton CO2-eq per year.

This study has identified several actors involved in recycling practice in Metro City. Those actors are citizens, individual scavengers, itinerant waste buyer, waste collector, garbage banks and organic fertilizer producers and schools. Most of these actors are placed in the bottom of recycling hierarchy. Even so, the practice of these stakeholders is still cannot significantly improve the performance of SWM delivery in Metro City.

The research has also shown that the integration of Circular Economy principles offers a high potential as part of the strategy to improve the performance of SWM in Metro City. Even further, the results showed that there are opportunities to deliver the sustainable performance of SWM by integrating CE principles. Indeed, integration of the circular economy principles in SWM can open the opportunity to create new jobs and add value to the solid waste administration.

However, the relatively small economic scale of solid waste recycling, lack access to the capital of the informal actors, low absorption of technology, high transaction cost, poorly defined regulations and lack of participation of citizens are among the challenges to integrate CE into SWM in Metro. While support from the municipality, exploration of new business collaboration, improving infrastructure, enabling public procurement and improving citizen awareness regarding solid waste recycling are among factors that are proposed to overcome the challenges. Moreover, citizens involvement can increase the likelihood of private sectors to absorb the recovered materials from solid waste.

In order to integrate CE principles in SWM, regeneration activities are indicated to have a strong relationship with CE integration in SWM. The analysis shows that the suitable framework for improving regeneration activities in Metro City is by involving informal actors of recycling into SWM practice. However, most of the informal actors in recycling business are placed at the bottom of recycling hierarchy. This condition creates a limitation for them to capture opportunities in SWM recycling or even to grow bigger. This latter also limits them to have a significant role in the SWM in Metro City.

Therefore, the participation of informal actors in SWM needs to be strengthened. A framework is proposed to integrate CE into SWM in Metro, enabling Public-Private Partnership by involving informal sectors, the municipality and citizens to work together

to overcome SWM problems. Three strategies are discussed to establish Public-Private Partnership. Those strategies are to organize the informal actors, to move up the solid waste recycling hierarchy and improve adding and extraction of recovered materials value.

In the organizational sector of informal actors, garbage bank scheme is proposed as the suitable type of organization. However, the government involvement such as providing recycling equipment, space for composting, soft skills improvement and financial facilitation is required to support the successfulness of the organization. While establishing collaborations between recycling industry and end user of the recovered product, such as creative industry can be used to climb the recycling hierarchy. In addition, using a technological approach such as utilizing plastic extruder machine can be used to add higher value to the recovered material.

From WAF accounting it can be known that the current practice of SWM in Metro requires 1592.14 Ha absorptive land from 2,938.63 Ha carbon absorptive land available or equal to 0.01 Ha/cap. However, the absorptive land requirement can be reduced to 619.77 Ha or equal to 0.004 Ha/cap if the CE integration in SWM can be implemented in the city. This accounting shows the environmental opportunity of CE integration in the city.

5.2. Recommendations

The recommendations of this study consist of two parts. The first part is regarding the actions suggested for local government. While the second part is regarding the requirement for further research.

5.2.1. Recommendations for future actions

The recommendations of activities that need to be implemented are based on the findings and proposals for local government as the implementer of SWM coordination in Metro City. The recommendations are as follows:

a. Integrate CE principles in Solid Waste Management the strategic plan

   The strategic plan is used as a guideline to plan, implement and evaluate the practice of SWM in Metro City. Hence the existence of strategic plan can improve the awareness of SWM stakeholders. Moreover, the integration of CE principles implementation in SWM can be accelerated because it will be considered as a strategic option to deliver sustainable SWM. Hence the SWM stakeholder's attention towards implementation of CE principles will be increased.

b. Recognize informal actors as an important stakeholder to achieve sustainable SWM

By considering informal actors as important stakeholders in SWM their role in SWM can be set as one of the priority strategies in MSWM

c. Collect data regarding the stakeholders in SWM in Metro City

   Collected data regarding SW recycling actors and the capacity of production can be used as a means to identify the exact potential of CE implementation in Metro. Moreover, the collected data can be used also to explore new opportunities for collaboration in the regeneration of SW.

d. Facilitate the formation of PPP between citizens and informal actors in SW regeneration business

   The nature of informal actors works independently, unorganised and illiterate make them resistance to jointly work on. Moreover, there are many challenges that will be faced by the actors to establish profitable PPP scheme, hence they will need clear information regarding the challenges and find possible solutions to overcome the challenges.

e. Hold routine meetings for the actors in SWM business

   The routine meeting is the occasion to disseminate new knowledge or skills for actors in SWM business. It can be used also as problem and opportunities sharing some meetings among the actors in SWM. Unify the perception of solid waste challenges and inform them about their strategic role in SWM can be the addition in the meetings.

f. Initiate the PPP with mutual collaboration

   Once it has been set the organization will need regular activities. The municipality can formulate a mutual collaboration scheme for the organization in order to assist them to grow. Reserve waste collection and small-scale processing for informal sector organizations can be used as an example for the activities.

g. Supporting the PPP scheme

   Working in an organization is not an easy task especially for informal actors which are unaccustomed with group work. Moreover, working with rules and regulations can be considered as a significant challenge for them. However, they need to be convinced about the advantages of working in a group. Therefore, government needs to support the continuity of the organizations

h. Explore new businesses collaboration

   In order to move up the hierarchy, the recycling actors must explore collaboration with actors beyond their traditional business field, such as creative industry. Therefore, the dependency of recycling actor to the middlemen can be reduced.

i. Encourage citizen participation to implement source segregation of solid waste
Promoting solid waste sorting campaign, providing adequate facilities and enforce the legislations are the examples of actions that can be used to increase the citizen participations.

5.2.2. Recommendations for further research

This study shows the importance of integrating Circular Economy principles in Solid Waste Management in Metro City. However, further research on this topic such as the economic feasibility of proposed framework, the job opportunities that can be created from framework implementation and possible conflict of interest of the actors that caused from framework implementation will be required since not all of the aspects could be covered in this study. Furthermore, this research was only focusing on regeneration activities, while other types of activities such as sharing, looping and virtualizing were not discussed in this study. Therefore, the research on the particular activities will be interesting to be studied. Moreover, this research could only suggest the indication of environmental opportunities that can result from CE integration into SWM in Metro. Further research on the environmental opportunities of CE integration into SWM will also need to be explored since the detail calculation will require a plethora of data resources which need longer time to be gathered and more comprehensive knowledge which were some of the limitations of this study.

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ANNEXES

APPENDIX 1

The Estimation of Solid Waste Generation and Composition In Metro City

This estimation measurement is referred to Indonesian National Standard (SNI) No 19-3964-1994 about the sampling and measurement of samples in the calculation of solid waste generation and composition. In this calculation, a 40 L cylinder bucket which has marked with height scale is used. The bucket itself has 36 cm diameter and the area of 1018 cm^3. Hence the volume will be known by multiplying area with height ($(V = A \times H)$. 500 L container also used to identify the solid waste composition and also to predict the density of Other used tool is weight scale with 1-oz increment

Identification of sample number

In this step, the number of household sample is determined using stratified random sampling method. The stratification is according to the level of income which are high, middle and low income. The number of households for each category was gathered from statistical bureau.

The number of sample (people)

$$S = C_d \sqrt{P_s}$$

Where S = number of required sample (people); C_d = housing coefficient (for Metro=0.5); and P_s = Population (people). Hence

$$S = C_d \sqrt{P_s} = 0.5\sqrt{158415} = 197.45 \approx 198\, people$$

From the statistical bureau also the number of people in each household known = 4,66 people/house. Hence the number of minimum required sample is 43 house

group	HH number	Fraction	Σ of min household
S_1 (low income)	2735	0,07	3
S_2 (middle income)	18535	0,47	20
S_3 (high income)	18337	0,46	20

In this measurement however, number of low income household is not sufficient. However, it will not significantly change the average density, volume, weight or composition of solid waste generation.

1. Solid waste generation data from high income residences
   a. Period I (August 2016)

Sample code	Fam mem ber	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
a.01	5	0.20	2.04	1.00	4.89	0.20	5.70	0.50	2.04	0.40	3.26	0.10	1.22	0.40	2.44	0.60	3.26
a.02	4	0.13	1.53	0.25	2.04	0.50	2.04	0.63	2.04	0.25	2.04	0.25	2.04	1.00	2.54		
a.03	4	0.25	2.54	0.25	2.04	0.25	1.53	0.38	2.04	0.25	2.04	0.13	1.53	0.38	2.54	0.50	3.56
a.04	3	0.33	2.71	0.67	2.71	0.67	3.39	0.33	1.36	0.33	2.04	0.33	3.39	1.00	2.71	0.50	4.07
a.05	3	0.67	3.39	1.67	10.18	0.50	4.07	0.50	2.71	0.50	2.71	0.67	4.07	0.50	3.39	1.00	4.75
a.06	4	0.25	2.54	0.50	6.62	0.50	2.04	0.63	2.54	0.38	2.54	0.25	2.54	0.13	1.53	0.38	3.05
a.07	4	0.75	2.54	0.25	2.04	0.25	1.53	0.13	1.53	0.25	2.04	0.13	2.04	0.13	2.04	0.13	1.53
a.08	5	0.40	2.44	0.50	3.26	0.80	2.04	0.40	2.04	0.60	2.04	0.90	2.85	0.60	2.44	0.60	2.04
a.09	3	0.67	3.39	0.67	3.39	0.50	2.71	0.50	2.71	1.00	3.39	0.17	2.04	0.83	3.39	0.83	2.71
a.10	3	0.67	3.39	0.50	4.07	0.67	3.39	0.67	4.07	0.50	4.07	1.67	4.07	1.00	3.39		
a.11	5	0.40	1.63	0.20	2.04	0.30	1.22	0.40	1.63	0.30	1.63	0.20	2.04	0.50	2.44	0.50	1.63
a.12	6	0.50	2.04	0.33	2.04	0.42	2.38	0.50	2.04	0.33	1.70	0.33	2.04	0.42	2.38	0.50	2.04
a.13	5	0.80	2.85	0.20	2.04	0.20	1.22	1.00	2.04	0.20	1.63	0.20	2.44	0.40	1.63	0.30	1.63
a.14	5	0.20	1.63	0.50	4.07	0.10	1.22	0.20	1.63	0.40	2.85	0.20	2.04	0.50	2.44	0.20	2.04
a.15	3	0.67	4.07	0.33	2.04	0.17	1.36	0.33	2.71	0.50	3.39	1.67	4.07	0.17	2.04	0.67	4.07
a.16	4	0.63	3.56	0.50	2.54	0.50	2.54	0.38	2.04	0.38	2.04	1.25	2.54	1.00	2.54	0.75	2.54
a.17	5	0.70	3.26	0.60	4.07	0.60	1.63	0.40	2.04	0.50	2.04	0.50	2.04	0.40	2.04	0.30	2.44
a.18	3	2.33	7.46	1.33	5.43	1.17	8.14	0.33	2.71	1.00	4.07	1.83	4.75	0.83	4.07	0.83	4.75
a.19	6	0.42	2.38	0.17	1.70	0.42	3.39	0.75	4.07	0.42	2.38	0.25	1.70	0.42	2.71	0.17	1.70
a.20	4	0.38	2.54	0.75	3.05	1.00	6.11	1.13	5.09	0.38	2.54	0.50	2.54	1.13	2.54	0.50	3.05
a.21	8	0.25	1.78	0.13	1.02	0.19	1.53	0.56	2.29	0.19	1.02	0.63	3.05	0.13	1.02	0.19	1.53
a.22	4	0.25	2.54	0.38	3.05	0.50	3.56	0.50	3.05	0.25	2.04	0.50	3.05				
a.23	4	0.25	3.56	0.38	2.54	0.25	2.04	0.38	2.54	0.50	3.56	0.25	2.04	0.38	3.05	0.25	2.04

b. Period II (April 2017)

Sample code	Fam member	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
a.01	5	0.2	3.26	1	3.66	0.2	2.44	0.5	2.04	0.4	2.04	0.4	2.04	1	3.66	0.5	2.04
a.02	4	0.13	1.53	0.38	3.06	0.38	3.06	0.63	4.07	1	5.09	0.88	5.6	0.5	3.06	0.63	3.56
a.03	4	0.38	3.06	0.38	2.55	0.5	3.06	0.38	3.56	0.63	3.56	0.38	3.06	0.25	1.53	0.38	3.06
a.04	3	0.33	3.73	0.67	4.07	0.33	4.07	0.33	2.04	1	4.07	1	4.75	0.67	4.07	0.33	2.71
a.05	3	0.83	5.09	1.67	6.11	0.67	4.75	0.5	3.39	0.5	4.07	0.5	4.07	1.67	6.11	0.5	3.39
a.06	4	0.38	3.31	0.5	2.55	0.38	3.56	0.63	3.56	0.13	2.55	0.13	2.55	0.5	3.06	0.63	3.06
a.07	4	0.88	3.82	0.25	2.04	0.75	3.56	0.25	3.06	0.13	1.53	0.13	1.02	0.25	2.04	0.25	1.53
a.08	5	0.4	2.65	0.5	2.85	0.4	2.65	0.4	2.85	0.6	2.44	1	5.7	0.5	2.44	0.4	2.44
a.09	3	0.67	4.41	0.67	4.07	0.5	3.05	0.5	2.71	0.83	4.07	0.83	4.07	0.67	3.39	0.5	3.39
a.10	3	0.67	4.41	0.5	4.07	0.83	4.75	0.67	3.39	1	4.75	1	4.75	0.5	3.39	0.67	4.07
a.11	5	0.4	2.65	0.2	2.44	0.4	2.65	0.4	2.04	0.5	2.04	0.5	2.44	0.2	2.44	0.4	2.04
a.12	6	0.5	2.38	0.33	2.21	0.5	2.72	0.5	2.72	0.42	2.04	0.42	1.7	0.33	2.04	0.5	2.38
a.13	5	0.4	1.83	0.2	2.24	0.4	2.04	0.6	3.26	0.4	1.83	0.4	2.04	0.2	1.63	1	3.66
a.14	5	0.2	1.83	0.5	2.85	0.8	5.29	0.4	2.44	0.5	2.85	0.5	2.04	0.5	2.85	0.2	1.22
a.15	3	0.67	4.07	0.33	3.05	0.67	4.07	0.33	2.04	0.17	2.04	0.17	2.04	0.33	3.39	0.33	2.04
a.16	4	0.88	4.07	0.5	2.04	0.88	4.07	0.38	3.06	1	5.09	1	4.07	0.5	2.04	0.38	2.55
a.17	5	0.7	3.26	0.6	1.83	0.7	3.26	0.4	2.85	0.4	2.04	0.4	2.04	0.6	2.44	0.4	2.85
a.18	3	1.5	6.11	1.33	4.75	1.33	5.77	0.33	3.39	0.83	4.75	0.83	4.75	1.33	5.43	0.33	3.39
a.19	6	0.42	2.38	0.17	2.04	0.42	2.38	0.83	3.73	0.42	2.38	0.42	2.04	0.17	1.36	0.83	3.73
a.20	4	0.63	3.56	0.75	3.06	0.5	3.56	1.13	4.58	0.75	4.07	0.5	3.56	0.75	3.56	1	4.07
a.21	8	0.25	0.96	0.13	1.78	0.31	1.02	0.56	2.55	0.25	1.53	0.38	1.78	0.38	1.53	0.56	1.78
a.22	4	0.25	1.4	0.38	3.06	0.25	1.27	0.5	3.56	0.5	3.56	0.5	3.06	0.38	3.06	0.5	3.06
a.23	4	0.38	3.44	0.38	2.55	0.38	3.56	0.38	2.55	0.38	2.04	0.38	2.04	0.38	2.55	0.38	2.55

2. Solid Waste Generation from Middle Income Category

   a. Period I (August 2016)

Sample code	Fam member	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
k.1	5	0.80	4.07	0.30	2.04	0.20	1.63	0.40	2.85	0.20	1.63	0.40	2.04	0.50	2.44	0.80	2.85
k.2	4	0.50	2.55	0.50	3.05	0.50	2.55	0.25	2.04	0.38	2.04	0.38	2.55	0.50	2.55	0.63	2.55
k.3	5	0.20	3.26	0.10	2.04	0.10	1.22	0.10	2.04	0.20	2.04	0.20	1.63	0.20	2.04	0.20	2.04
k.4	5	0.20	1.63	0.20	1.22	0.20	1.63	0.30	2.85	0.20	1.63	0.40	2.04	0.50	2.44	0.40	2.04
k.5	5	0.20	2.04	0.40	2.44	0.20	1.63	0.10	1.22	0.10	1.22	0.10	1.22	0.20	1.63	0.30	2.44
k.6	3	0.50	3.39	0.67	3.39	0.67	4.07	0.67	4.75	0.50	3.39	2.67	10.18	0.67	3.39	0.50	3.39
k.7	6	0.33	2.38	0.42	2.88	0.67	3.39	0.50	2.71	0.67	2.55	0.58	2.38	0.42	2.04	0.50	1.70
k.9	3	0.17	2.71	0.33	2.71	0.50	3.39	0.33	3.39	0.67	4.07	0.17	2.71	0.50	3.39	0.17	2.71
k.11	3	0.33	2.71	0.33	3.39	0.17	2.04	0.67	3.39	0.17	2.04	0.33	2.04	0.33	2.71	0.17	2.04
k.12	4	0.25	2.55	0.38	2.55	0.25	2.04	0.38	2.04	0.50	2.04	0.25	2.04	0.38	1.53	0.25	1.53
k.13	5	0.90	4.07	0.60	2.44	0.40	2.44	0.50	2.04	0.80	2.44	0.80	2.44	1.40	2.85	0.40	2.85
k.14	3	0.33	2.04	0.50	2.04	0.50	2.71	0.50	2.71	0.33	2.71	0.50	3.39	0.33	2.04	0.33	2.71
k.15	5	0.50	2.04	0.40	2.04	0.20	1.63	0.50	2.04	0.20	1.63	0.20	2.44	0.40	2.04	0.30	1.63
k.16	4	0.13	3.05	0.13	1.53	0.38	2.55	0.38	2.55	0.25	2.55	0.50	2.55	0.75	3.05	0.38	2.04
k.18	2	0.25	3.05	0.25	4.07	1.50	5.09	0.25	2.04	0.25	3.05	0.25	3.05	0.25	3.05	0.50	4.07
k.19	4	0.63	3.05	0.25	3.05	0.63	3.56	0.50	2.55	0.50	3.05	0.38	3.05	0.50	2.55	0.50	3.05
k.22	4	0.25	2.55	0.25	2.04	0.38	2.04	0.38	2.04	0.50	2.55	0.13	1.53	0.25	2.04	0.38	2.55
k.23	2	0.50	5.09	0.25	3.05	0.25	3.05	0.25	2.04	0.25	3.05	0.25	2.04	0.50	5.09	0.25	3.05
k.24	4	0.50	4.07	0.38	2.55	0.88	4.07	0.50	2.04	0.25	2.04	0.25	2.04	0.13	1.53	0.75	3.56
k.25	5	1.40	4.07	0.70	2.44	0.50	2.85	0.60	3.26	0.50	2.44	0.70	2.44	0.30	2.04	0.30	2.04
k.26	2	1.00	6.11	0.75	5.09	1.25	5.09	1.00	4.07	1.50	5.09	1.00	5.09	1.00	5.09	1.00	6.11
k.27	3	1.33	6.11	0.50	3.39	0.17	1.36	0.83	3.39	0.67	2.71	0.33	2.71	0.33	2.71	0.50	2.71
k.28	4	0.63	2.55	0.75	2.55	0.63	2.55	0.50	2.04	0.25	2.55	0.75	2.55	0.38	2.04	0.50	2.55
k.29	3	0.67	3.39	0.33	2.71	0.50	2.71	0.17	2.04	0.67	3.39	0.67	3.39	0.67	2.71	0.33	2.04
k.30	8	0.38	2.04	0.19	1.02	0.13	0.76	0.19	1.27	0.13	1.02	0.13	1.27	0.13	0.76	0.13	1.02
k.31	5	0.60	3.66	0.40	2.04	0.40	2.85	0.10	1.63	0.10	1.22	0.10	1.22	0.20	2.04	0.10	1.22
k.32	2	1.00	5.09	0.50	5.09	0.50	5.09	0.75	6.11	0.50	4.07	0.75	6.11	0.50	4.07	0.25	3.05
k.33	6	0.50	2.55	0.17	1.02	0.25	2.04	0.33	2.04	0.25	2.04	0.58	4.24	0.17	1.70	0.33	1.70

b. Period II (April 2017)

Sample code	Fam mem ber	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
k.1	5	0.5	2.44	0.4	3.26	0.6	2.44	0.6	2.85	0.3	0.8	0.6	2.44	0.4	0.7	0.5	2.85
k.2	4	0.75	4.07	0.63	3.56	0.25	3.56	0.75	4.07	0.63	1.25	0.25	3.31	0.75	1.5	0.75	4.07
k.3	5	0.25	2.55	0.5	3.06	0.38	3.06	0.13	1.02	0.5	0.8	0.38	3.06	0.13	0.2	0.38	3.56
k.4	5	0.5	4.07	0.83	4.07	0.83	4.07	0.33	3.39	0.83	1	0.83	4.07	0.33	0.4	0.5	3.39
k.5	5	0.17	2.71	0.33	3.39	0.33	4.07	0.5	4.75	0.33	0.4	0.5	6.11	0.5	0.5	0.17	4.75
k.6	3	0.25	3.06	0.5	3.56	0.63	2.55	0.25	2.55	0.5	1.17	0.63	2.55	0.25	0.67	0.25	1.53
k.7	6	0.5	3.06	0.63	3.06	1.75	8.15	0.5	6.11	0.63	0.83	0.25	3.56	0.5	0.67	0.5	2.55
k.9	3	0.2	2.44	0.4	2.85	0.2	1.63	0.4	4.48	1	1.17	0.3	3.26	0.6	0.67	0.2	4.07
k.11	3	0.5	3.39	0.5	4.07	0.33	4.07	0.5	3.39	0.5	1	0.5	4.75	0.5	1	0.5	3.39
k.12	4	0.67	4.07	0.67	6.79	0.5	3.39	0.5	4.75	0.67	1	0.5	5.43	0.5	0.75	0.67	4.07
k.13	5	0.4	2.85	0.3	2.44	0.4	2.04	0.7	3.26	0.3	0.7	0.4	2.04	0.7	1.4	0.3	2.44
k.14	3	0.33	2.04	0.33	2.04	0.5	2.38	0.42	2.38	0.33	1.33	0.33	1.36	0.25	1	0.42	3.05
k.15	5	0.8	5.29	0.3	2.44	0.5	2.85	0.3	2.85	0.4	0.63	0.3	2.04	0.3	0.75	0.4	3.26
k.16	4	0.6	4.89	0.3	2.85	0.3	2.44	0.5	2.85	0.4	0.63	0.3	2.04	0.4	1	0.3	3.05
k.18	2	1	9.5	0.5	4.07	0.83	5.43	0.33	4.07	0.33	1.25	0.83	4.75	0.33	1	0.33	4.07
k.19	4	0.38	3.06	0.63	2.55	0.5	3.06	0.5	3.56	0.63	1.25	0.5	3.06	0.5	0.88	0.38	3.56
k.22	4	0.5	2.44	0.4	4.48	0.3	2.44	0.3	3.26	0.3	0.75	0.3	3.26	0.6	0.75	0.5	3.26
k.23	2	0.33	4.07	0.5	3.39	0.67	3.39	0.67	4.07	0.83	1.5	0.67	4.75	0.67	2	0.5	5.43
k.24	4	0.08	1.7	0.5	4.07	0.5	4.41	0.42	2.72	0.5	1.5	0.42	3.05	0.42	1.25	0.08	1.7
k.25	5	1.25	3.56	0.5	3.06	0.13	1.53	0.63	3.56	0.5	0.7	0.25	4.58	0.5	0.9	1.25	2.55
k.26	2	0.38	1.53	0.19	1.53	0.5	2.29	0.31	1.53	0.88	1.5	0.31	2.04	0.31	1	0.44	2.04
k.27	3	0.63	3.56	0.38	2.55	0.75	3.56	0.5	3.06	0.38	1	0.38	3.56	0.63	1.5	0.63	2.55

3. Solid Waste Generation from Low Income Category
   a. Period I (August 2016)

Sample code	Fam mem ber	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
s.1	4	0.25	3.05	0.50	3.05	0.50	3.56	0.38	3.56	0.38	3.05	0.25	2.04	0.25	2.55	0.25	2.55
s.2	5	0.40	2.85	0.60	3.26	0.40	2.85	0.30	2.44	0.30	2.85	0.10	1.63	0.20	1.63	0.30	2.44

   b. Period II (April 2017)

Sample code	Fam mem ber	Day-1		Day-2		Day-3		Day-4		Day-5		Day-6		Day-7		Day-8	
		kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap .day	ltr/cap .day	kg/cap. day	ltr/cap. day
s.1	4	0.50	3.05	0.83	3.05	0.50	3.05	0.67	3.31	0.67	2.55	0.50	2.55	0.67	3.31	0.67	3.56
s.2	5	0.30	2.44	0.70	3.26	0.60	2.65	0.40	2.44	0.40	2.44	0.60	3.05	0.50	2.85	0.40	2.44

Hence the average generation can be calculated

		High Income	Midle Income	Low Income	City Average
Period I	Weight per cap	0.51	0.44	0.33	0.43
	Volume per cap.	2.74	2.72	2.71	2.72
	Weight generated	97 ton per day			
	Volume generated	443 m^3 per day			
Period II	Weight per cap	0.53	0.47	0.51	0.50
	Volume per cap.	3.05	2.64	2.47	2.72
	Weight generated	113 ton per day			
	Volume generated	515 m^3 per day			
CITY AVERAGE	Weight per cap	**0.43 - 0.50 kg/day.cap**			
	Volume per cap.	**2.72 - 2.72 l/day.cap**			
	Weight generated	**97 – 114 ton per day (105 ton per day)**			
	Volume generated	**443 – 515 m^3 per day (479 m^3 per day)**			

4. Solid Waste composition
   - In this measurement 500L container is used, empty container is weighted
   - The container is filled with solid waste until full, then the container is dropped 3 times from the height of 20 cm
   - The total weight is the weight of filled container subtract by eight of empty container
   - the density is the total weight divide by 500L

   a. Period I (August 2016)

Types	Weight	Percent (w/w)	Weight	Percent (w/w)	Weight	Percent (w/w)	Weight	Percent (w/w)
Plastic & Rubber	23.5	19.44%	24.1	21.87%	19.4	19.15%	20.7	19.58%
Paper	12.5	10.34%	9.6	8.71%	8.3	8.19%	10.2	9.65%
Kitchen Refuse	73.4	60.71%	67.3	61.07%	63.7	62.88%	59.7	56.48%
Woods & Garden	6.5	5.38%	5.7	5.17%	5.4	5.33%	11.1	10.50%
Cloths	1.6	1.32%	1.4	1.27%	2	1.97%	1.5	1.42%
Glasses	1.7	1.41%	1.2	1.09%	0.5	0.49%	0.9	0.85%
Metals	0.7	0.58%	0.4	0.36%	0.5	0.49%	1.3	1.23%
Other	1	0.83%	0.5	0.45%	1.5	1.48%	0.3	0.28%
TOTAL WEIGHT (kg)	120.9	100.00%	110.2	100.00%	101.3	100.00%	105.7	100.00%
Density (ton/m3)	0.24		0.22		0.20		0.21	

   b. Period II (April 2017)

Types	Weight	Percent (w/w)	Weight	Percent (w/w)	Weight	Percent (w/w)	Weight	Percent (w/w)
Plastic & Rubber	29.9	23.77%	23.9	23.95%	31.7	31.99%	38.6	32.80%
Paper	12.2	9.70%	12.7	12.73%	7.9	7.97%	9.3	7.90%
Kitchen Refuse	71.3	56.68%	56.5	56.61%	50.4	50.86%	54.7	46.47%
Woods & Garden	6.5	5.17%	3.5	3.51%	5.4	5.45%	11.1	9.43%
Cloths	2	1.59%	1.3	1.30%	1.8	1.82%	1.7	1.44%
Glasses	1.7	1.35%	0.6	0.60%	0.5	0.50%	0.9	0.76%
Metals	0.7	0.56%	0.4	0.40%	0.5	0.50%	0.4	0.34%
Other	1.5	1.19%	0.9	0.90%	0.9	0.91%	1	0.85%
TOTAL WEIGHT (kg)	125.8	100.00%	99.8	100.00%	99.1	100.00%	117.7	100.00%
Density (ton/m3)	0.25		0.2		0.2		0.24	

Hence, the city average composition is

Types	Percent (w/w)
Plastic & Rubber	**24.07%**
Paper	**9.40%**
Kitchen Refuse	**56.47%**
Woods & Garden	**6.24%**
Cloths	**1.52%**
Glasses	**0.88%**
Metals	**0.56%**
Other	**0.86%**
Average Density (ton/m³)	**0.22**

UNIVERSITY OF TWENTE.

APPENDIX 2.

Questionnaire and Interview questions

FACULTY OF BEHAVIOURAL, MANAGEMENT AND SOCIAL SCIENCES
Department of Governance and Technology for Sustainability (CSTM)

YOUR REF FSP
OUR REF CSTM
DATE 05 June 2017

PHONE. +31 (0)53 489
E-MAIL @utwente.nl
www.utwente.nl/bms/cstm

ATTACHMENT(S): :

SUBJECT: : Questionnaire

Metro City

I am a student at the University of Twente, The Netherlands, and I am conducting this survey as part of my thesis of the Masters of Environmental and Energy Management. This research aims to analyse the current practice of solid waste management, identifying the challenges and looking for the suitable framework to integrate Circular Economy (CE) in solid waste management in Metro. Solid Waste Management (SWM) is an important aspect for creating healthy conditions for people and the environment. Indeed successful SWMs are crucial for human wellbeing, environment protection and economic beneficial effects. Moreover, when SWM is framed under the CE principles, more tangible economic benefits can be expected.

In the case of Indonesia, there are evidences showing that SWM is poorly implemented. Therefore, our interest to analyze the SWM Indonesian situation by using as show case Metro City. From this analysis, I am to identify the SWM challenges and possible improvement strategies towards 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.

Master of Environmental and Energy Management student

Fizul Surya Pribadi

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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 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 garbage?

   Burry the garbage ☐
   Burning the garbage ☐
   Throw in the river ☐
   Throw to the collected place ☐
   Picked by community groups ☐
   Picked by cleanliness division ☐

2.2. Reuse

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

.2.1. The tendency for re-use	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

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 city	☐	☐	☐

. **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 garbage 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 garbage to be used as solid waste fee deduction than receive it in cash	☐	☐	☐
I know what a garbage bank is	☐	☐	☐
The garbage bank is the same as the garbage collector	☐	☐	☐
There is no profit I can get by becoming a garbage bank member	☐	☐	☐

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

☐ I can earn noticeable benefit
☐ I do not have to invest a lot of time in garbage bank's activities
☐ My neighbors/friends are members of garbage 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 HS ☐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?

Sub-District : Metro Pusat ☐; Metro Utara ☐; Metro Timur ☐;
Metro Selatan ☐; Metro Barat ☐

Kelurahan/Village : _____

Thank you For Your participation!!!

INTERVIEW QUESTIONS

HEAD OF ENVIRONMENTAL AGENCIES

1. Can you explain the role of Environmental Department in Solid Waste Management in Metro?
2. What kind of strategies that have been or will be issued to improve the effectivity and efficiency of solid waste management in Metro 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 Metro?
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 SWM in Metro?
10. Have you ever heard about circular economy?

CLEANSING DIVISION

1. What is the role of cleansing division in solid waste management in Metro?
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?

THE SUB-DIVISION OF SOLID WASTE COLLECTION AND TRANSPORTATION

1. Please explain the main tasks of your sub-division regarding solid waste management in Metro?
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 Karangrejo 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 reaches the 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?

GARBAGE BANK

1. Please explain your business focus especially regarding solid waste management in Metro? How can it be expanded in the future and how will it influence the solid waste management practice in Metro?
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

WORK PICTURE DOCUMENTATIONS

Pictures during data collection for the estimation of solid waste generation and composition

Picture during the interview with Mr Eka Irianta as the head of Environmental Agency

Picture during the interview with Mrs. Veriza as division head of creative economy

Picture during the interview with Head of Cangkir Hijau Garbage Bank

Picture during the interview with Mr. Wisnu Wijaya from creative Industry