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Cost Analysis of Municipal Solid Waste Management in Major Indonesian Cities

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This paper assessed the solid waste management (SWM) service cost estimate system for major Indonesian cities and develop standards for major SWM service costs, which consist of: collection, transfer and treatment, transportation, landfill management costs. This paper also presents the results of economic assessments that compare the options available for SWM in major Indonesian cities. The options compared are: collection and transport efficiency (CTE), communal waste treatment (CWT), and a centralized composting and recycling facility (CRF). An expenses–benefit calculation is used for the economic assessment. The results of our study show that composting at a centralized plant is the most economically feasible option under the current conditions prevailing in Indonesia.

Key Words : *cost, analysis, municipal solid waste, Indonesian cities*

1. INTRODUCTION

Solid waste management systems are needed to ensure human health and safety. They must be safe for workers, and they must also safeguard public health by preventing the spread of disease. In addition to these prerequisites, a sustainable system for solid waste management (SWM) must be environmentally effective, economically affordable and socially acceptable. Economically affordable means that waste management systems must operate at an acceptable cost to the community, which includes all private citizens, businesses and governments. The costs of operating an effective SWM system will depend on existing local infrastructures, but ideally should be little or no more than existing waste management costs (McDougall, et al, 2001).

Along with the progress in development, the population growth rate for major Indonesian cities is increasing at rapid rate of about 3% per year, which results in an increase in waste generation that has a direct impact on deterioration of the environment.

Despite the recent introduction by the Indonesian government of Waste Management Law No. 18/2008: public service principles, waste minimization and handling of domestic solid waste and specific waste, incentives and disincentives mechanism, local government responsibility, financial system, private and public sector participation, and sanctions (Indonesian Ministry of Environment IMoE, 2008) , to date there are no technical regulations regarding an accounting system for municipalities in implementing solid waste cost management accounting. The cost of SWM is generally reported by municipalities every year, as part of the annual general reports and cost reports for the annual Local Government Cleanliness Agency (LGCA) or *dinas kebersihan* responsibilities, which include fields other than SWM field, so SWM service costs are actually contained in among other fields in annual LGCA cost reports. In addition, costs mostly operational costs are taken into account, however SWM costs should take asset costs and future costs into account. LGCA is the agency that handles solid waste management in major cities, mostly this agency responsibility not only SWM but also landscape and the city beauty, except LGCA on

Bandung city, that status as local government company or *perusahaan daerah*, LGCA on other major cities are include in the local government organizational structure.

Therefore, it is necessary to develop an effective SWM service cost accounting system suitable for major cities in Indonesia that have more complex solid waste issues. The aim of this study is to develop SWM standard costs for use in estimating SWM service cost for major Indonesian major cities. Such a standard should be comprehensive, taking into account the costs of: assets and operations, so a SWM standard cost could identify the actual major service costs of Indonesian SWM, explain SWM costs more clearly, and help municipalities to achieve SWM goals by providing a tool accurate cost analysis.

2. METHODOLOGY

This study was conducted by analyzing data obtained through: documents, questionnaires and direct interviews with local governments and waste authorities in nine cities; “DKI Jakarta”, “Palembang”, “Medan”, “Bandung”, “Bekasi”, “Makassar”, “Surabaya”, “Semarang” and “Depok”. **Fig. 1** shows the location of these cities and **Table 1** shows basic information about costs in these cities.

SWM as used in this study includes all types of solid waste that are usually collected, treated, transported, and used as landfill by the major cities municipalities. This includes both residential and commercial waste but excludes hazardous waste.

As an early first step in this study, questionnaires were sent to major cities in Indonesia (about 12 cities which the aim of ascertaining data availability and the possibility of obtaining data related to SWM in general. Questionnaires were sent to municipality departments responsible for handling solid waste in each city, and included questions about: (1) SWM organization; (2) a solid waste (SW) flow chart from source to landfill; (3) SW generated, collected, landfill and classification of waste; (4) SWM assets inventory; (5) SWM budget, types of expenditure that directly associated to the operation or service of solid waste (direct cost) and expenditure that indirectly associated to the operation or service of solid waste (indirect cost).

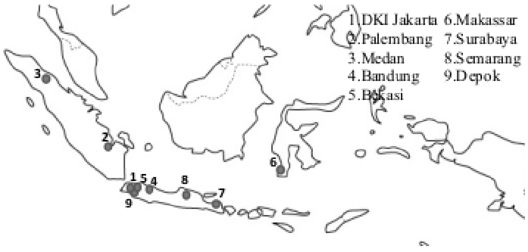

Fig.1 Location of Indonesian cities study

In addition, interviews and direct observations were conducted in the nine municipalities that responded or had relied to the initial questionnaires, to confirm that the answers were basically complete and clear, while at the same time collecting secondary data related to the studies being conducted, in addition to poor data base held by LGCA making it difficult to get the data series of the same year from each city

To obtain valid interview data, the process required that personnel interviewed were at head of department level or at minimum chiefs who oversee the technical field of handling of SWM activity in the municipalities.

These field interviews and observations were conducted in the cities during April 2011.

The second step was to conduct a cost breakdown analysis for each activity that had been set and for each city to determine an overall generic SW flow chart of each city, which was subsequently merged into a flow chart representing the flow of SW systems

Table 1 Basic information of target cities

City	Population	Area (km^2)	GRP/ capita (US$)	Waste generated (m^3/d)	Waste collected (m^3/d)	Coverage rate (%)	LGCA Budget		Source
							Direct (Service) cost (US$)	Indirect (Overhead) cost (US$)	
DKI Jakarta	9,223,000	662.33	9,222	28,286	24,322	80	59,223,758	9,747,298	DKI Jakarta Cleanlines Agency,2010
Palembang	1,438,938	400.61	2,906	4,995	2,443	76	2,616,703	785,011	Calculation in 2009
Medan	2,067,288	265.10	2,318	7,514	2,115	60	1,292,429	374,804	Medan statistic bureau 2007
Bandung	2,417,288	167.45	3,267	7,500	4,623	60	7,615,077	1,218,412	Bandung statistic bureau 2010
Bekasi	1,882,869	210.49	1,502	7,431	3,397	58	1,606,304	535,435	Bekasi Cleanlines Agency,2010
Makassar	1,272,349	175.77	2,761	3,822	3,278	78	1,021,108	747,629	Makassar Cleanlines Agency,2009
Surabaya	2,932,318	326.81	5,640	9,181	5,333	82	17,925,177	943,430	Surabaya Cleanlines Agency,2010
Semarang	1,507,826	373.67	1,444	5,110	3,083	58	1,937,660	1,758,675	Semarang Cleanlines Agency,2011
Depok	1,536,980	200.29	3,100	5,577	1,671	76	1,292,863	308,176	Depok Cleanlines Agency,2009

Note : currency US$1.00 = IDR8,900

in major Indonesian cities.

The third step is this study was to produce flowchart disaggregating the entire SWM system. In this study, we focused on the various activities that were constituted the building blocks of the system. These SWM activities are: Waste collection, temporary transfer of waste, waste transport, and landfill management.

The fourth step was to calculate the unit cost of each cost by means of a bottom-up analysis. In this stage, we obtained the annual unit cost (mean, median and range) for each part of each SWM activity.

In the fifth and last step, we obtained the resume activity cost per ton for each city, based on the cost per activity divided by the amount (ton) of SW generated then the result of these calculations were then made into basic scenarios as scenario assessments in assessing the most economically beneficial scenarios.

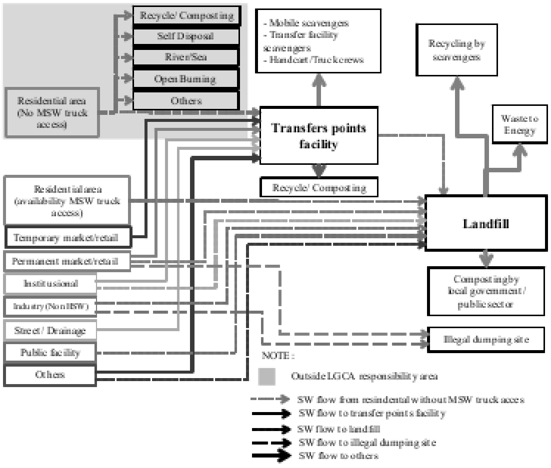

Fig.2 General solid waste flow in major Indonesian cities

3. SOLID WASTE SERVICECOST ANALYSIS

Based on general the SW flow analysis obtained (**Fig.2**), the SW service cost for a major city is divided into four cost centers or service categories plus uncertainty cost. A service category is defined as: a collection activity, a transfer activity, a transport activity, or landfill management, using the equation is C = C1 + C2 + C3 + C4+ Cu, where C = solid waste service cost, C1 = collection cost, C2 = transfers cost, C3 = transportation cost, C4 = landfill management cost, and Cu = uncertainty cost.

This cost center later to breakdown into smaller components so that when put together will be the frame work of solid waste service cost .

(1) Collection cost (C1)

Collection cost is the expenditure required to collect garbage from source and bring it to temporary shelters/transfer point facilities, as shown in **Table 2**. In major cities, SWM cost is the accumulation of expenditure per year for road sweepers/garbage collectors using simple equipment (C11), manual pull cart with a capacity of 1.0-1.3m^3 operated by one or two workers (C12), and a motor cart, a modified of motorcycle with a cart fitted to the rear with a capacity 1.0-1.3m^3(C13).

Sweeper or waste collector costs (C11) are assumed to be the salary for one year plus 10% of salary for daily equipment and work clothes. Manual pull cart costs (C12) brokendown into three component sub-unit expenditure: annual capital depreciation (assumed operational life time = 5 years,

Table 2 Breakdown cost and annual unit cost of collection

Cost Category		unit	n	Mean	Median	Standard deviation	Range	Calculation method
Sweeper (C11)	Sweeper/Collector	US$/person	9	637	659	69	485 - 723	SE=Annual sweeper/collector expenditure
Manual pull cart (C12)	Capital depreciation (C121)	US$/cart	9	17	16	2	15 - 20	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	Repair and maintenance (C122)	US$/cart	9	63	62	5	56 - 71	RM=(2.5% to 3.5%) x Procurement price (Pp)
	Operator (C123)	US$/cart	9	1,017	1,044	104	793 - 1,153	OS=Annual operator expenditure
Motor cart (C13)	Capital depreciation (C131)	US$/cart	6	645	649	23	604 - 664	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	License and assurance (C132)	US$/cart	6	129	130	5	121 - 133	LA=(2.0% to 2.5%) x Procurement price
	Repair and maintenance (C133)	US$/cart	6	106	105	3	102 - 109	RM=(2.5% to 3.5%) x Procurement price (Pp)
	Replacement tire (C134)	US$/cart	6	154	153	3	151 - 158	Tire price (Tp), Annual miles driven,km (Ad), Tire life time =5000km (Lt). RT = 4 x (Ad/Lt)
	Fuel and lubrication (C135)	US$/cart	6	121	149	43	65 - 149	Fuel price/ltr (Fp), Annual miles driven,km (Ad), Fuel consumption,ltr/km (Fc). FL=Fp x Ad x Fc x 1.05
	Operator (C136)	US$/person	6	1,203	1,191	82	1,106 - 1,293	OS=Annual operator expenditure

Note : currency US$1.00 = IDR8,900; n = number of city which provided data; based on 2010 year condition

Table 3 Breakdown cost and annual unit cost of transfers

Cost category		Unit	n	Mean	Median	Standard deviation	Range	Calculation method
Permanent masonry (C21)	Capital depreciation (C211)	US$/unit	5	111	110	4	105 - 117	Construction cost,US$ (Cc), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Cc-Sv))
	Repair and maintenance (C212)	US$/unit	5	21.8	21.7	0.2	21.4 - 22.1	RM=(3.0% to 4.0%) x Construction cost (Cc)
Semi-permanent masonry (C22)	Capital depreciation (C221)	US$/unit	6	122	121	4	116 - 129	Construction cost,US$ (Cc), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Cc-Sv))
	Repair and maintenance (C222)	US$/unit	6	12.0	11.9	0.1	11.8 - 12.2	RM=(1.5% to 2.5%) x Construction cost (Cc)
Container 6m^3 (C23)	Capital depreciation (C231)	US$/unit	8	554	511	161	405 - 953	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	Repair and maintenance (C232)	US$/unit	8	168	169	18	135 - 189	RM=(5% to 6%) x Procurement price (Pp)
Container 8m^3 (C24)	Capital depreciation (C241)	US$/unit	4	585	532	164	441 - 987	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	Repair and maintenance (C242)	US$/unit	4	202	204	23	165 - 228	RM=(5% to 6%) x Procurement price (Pp)
Container 10m^3 (C25)	Capital depreciation (C251)	US$/unit	6	590	614	164	462 - 658	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	Repair and maintenance (C252)	US$/unit	6	246	243	26	206 - 274	RM=(5% to 6%) x Procurement price (Pp)

Note : currency US$1.00 = IDR8,900; n = number of city which provided data; based on 2010 year condition

Table 4 Breakdown cost and annual unit cost of transportation

Cost category		Unit	n	Mean	Median	Standard deviation	Range	Calculation method
6m^3 truck (C31)	Capital depreciation (C311)	US$/truck	9	7,480	6,863	1,310	6,474 - 9,879	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
	License and assurance (C312)	US$/truck	9	957	908	158	816 - 1,245	LA=(2.0% to 2.5%) x Procurement price (Pp)
	Repair and maintenance (C313)	US$/truck.km	9	46	45	8	39 - 68	Annual miles driven,km (Ad), Daily distance trip,km (Dt). RM=(US$0.025 to US$0.035) x Ad/Dt
	Tires (C314)	US$/truck.km	9	22	19	5	18 - 31	No.tires (Nt), Tire price,US$ (Tp), annual miles driven (Ad), Tire economic use,km (Tu), Daily distance trip,km (Dt). TC=Nt x Tp x Ad/(Tu x Dt)
	Fuel (C315)	US$/truck.km	9	43	41	7	38 - 61	Fuel price/ltr (Fp), Annual miles driven ,km (Ad), Fuel consumption,ltr/km (Fc), Daily distance trip,km (Dt). F=Fp x Ad x Fc/Dt
	Lubrications (C316)	US$/truck.km	9	7	5	5	3 - 16	Lubrication price/ltr (Lp), Annual miles driven,km (Ad), Lubrication consumption,ltr/km (Lc), Daily distance trip,km (Dt). L=Lp x Ad x Lc/Dt
8m^3 truck (C32)	Capital depreciation (C321)	US$/truck	5	13,349	12,909	1,310	11,681 - 15,067	Same with Capital depreciation (C311) calculation method
	License and assurance (C322)	US$/truck	5	1,477	1,626	587	448 - 1,898	Same with License and assurance (C312) calculation method
	Repair and maintenance (C323)	US$/truck.km	5	40	41	20	8 - 64	Same with repair and maintenance (C313) calculation method
	Tires (C324)	US$/truck.km	5	21	22	6	13 - 28	Same with tires cost (C314) calculation method
	Fuel (C325)	US$/truck.km	5	45	43	13	32 - 66	Same with fuel cost (C315) calculation method
	Lubrications (C326)	US$/truck.km	5	10	9	6	2 - 17	Same with lubrication cost (C316) calculation method
10m^3 truck (C33)	Capital depreciation (C331)	US$/truck	5	14,543	14,483	1,060	13,127 - 16,119	Same with Capital depreciation (C311) calculation method
	License and assurance (C332)	US$/truck	5	1,348	1,825	753	503 - 2,031	Same with License and assurance (C312) calculation method
	Repair and maintenance (C333)	US$/truck.km	5	28	40	19	7 - 45	Same with repair and maintenance (C313) calculation method
	Tires (C334)	US$/truck.km	5	22	22	2	20 - 24	Same with tires cost (C314) calculation method
	Fuel (C335)	US$/truck.km	5	37	38	5	31 - 43	Same with fuel cost (C315) calculation method
	Lubrications (C336)	US$/truck.km	5	14	13	7	8 - 23	Same with lubrication cost (C316) calculation method
All truck type (C34)	Driver and crew	US$/truck	6	3,461	3,608	458	2,571 - 3,944	Number of trucks operated by local governments (Nv), Annual driver expenditure (salaries,allowance,etc) include crew,US$/truck (S). DC=Nv x S

Note : currency US$1.00 = IDR8,900; n = number of city which provided data; km = average daily distance trip

salvage value = 40%, interest rate = depending on city varies between 7.82% to 9.48%); repair and maintenance costs; and annual operator costs (one or two operators per cart). Motor cart costs (C13) brokendown into six component sub-unit expenditure: annual capital recovery cost (operational life time = 5 years, salvage value = 20%, interest rate = depending on city varies between 7.82% to 9.48%); annual license, tax, insurance, etc; annual repair and maintenance costs; annual tire replacement costs; annual fuel and lubrication costs; annual operator costs.

The influence factor in collection cost is expenditure of human resources (salary, work clothes, allowance, etc)

(2) Transfers costs (C2)

Transfers costs are expenditure to build temporary shelter facilities or the procurement of steel containers for use as transfer points facility (TPs) and operate them for one year, as shown in **Table 3**. Based on the results of a previous report, TPs in major cities can be divided into three types : A) A permanent building shelter, which serve as temporary waste storage, constructed with masonry walls and equipped with a roof or cover, a SW storage capacity of 6-8m^3 SW storage capacity ; B) A semi-permanent building without a roof, which is a typical permanent building shelter, with a storage capacity of 6-8 m^3 ; C) Steel containers is a steel containers used by the LGCA with capacities of 1 m^3, 6 m^3, 8 m^3 and 10 m^3 .

In major cities transfer costs consist of an accumulation of the expenditure per year for all type of TPs used by cities. Transfers costs (C2) brokendown into five component unit cost: permanent masonry TPs (C21), semi-permanent masonry TPs (C22), 6m^3 containers (C23), 8m^3 containers (C24) and, 10m^3 containers (C25).

All types of TPs expenditure are brokendown into two components sub-unit expenditure: capital depreciation and repair/maintenance.

The influence factor in transfer cost is capital depreciation expenditure (construction or purchasing cost)

(3) Transportation cost (C3)

Transportation activity cost is the expenditure to collect garbage from source or transport garbage from TPs and take it to landfill sites, as shown in **Table 4**. In major cities, SWM cost is the accumulation of expenditure per year for transportation costs brokendown into six component sub-unit expenditure: annual capital depreciation cost of truck (operational life time = 7 years, salvage

Table 5 Breakdown cost and annual unit cost of landfill management

Cost category	Unit	n	Mean	Median	Standard deviation	Range	Calculation method
Landfill capital depreciation (C401)	US$ / ha	9	3,973	2,528	943	1,058 - 10,969	Acquisition price,US$ (Ap), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Ap-Sv))
H.E capital depreciation (C402)	US$ / unit.HE	8	50,597	47,490	9,123	41,477 - 70,028	Procurement price,US$ (Pp), Salvage value,US$ (Sv), Operational life time,year (Lt), Interest rate,% (Ir). CD=PMT(Ir,Lt,(Pp-Sv))
H.E Repair & Maintenance (C403)	US$ / unit.hour	9	1,038	1,116	217	665 - 2,461	Procurement price,US$ (Pp), HE Operational life time (HElt) = 10.000 hours/(daily working hour x working day per year), RM=30% x Pp / HElt.
H.E fuel & oil (C404)	US$ / unit.hour	7	2,680	2,427	575	2,063 - 3,402	H.E.oil consumption,ltr/year (Lc), Oil price,US$/ltr(Lp), H.E.Fuel consumption,ltr/year (Fc), Fuel price,US$/ltr(Fp), Daily working hour (Dw), Annual working day (Aw). FLhe=((Lc x Lp)+(Fc x Fp))/(Dw x Aw)
Others equipment fuel & oil (C405)	US$ / ton.SWM	5	0.010	0.008	0.005	0.008 - 0.018	Annual Lubrication expenditure (Al), Annual Fuel expenditure (Af), Annual waste dumped (Aw). FL= (Al + Af)/ Aw
Operator expenditure (C406)	US$ / person	8	3,548	2,826	1,457	2,372 - 5,751	OS=Annual operator expenditure
Non-operator expenditure (C407)	US$ / person	8	1,313	1,284	174	1,011 - 1,560	NOS=Annual non-operator expenditure
Administration (C408)	US$ / ha	6	339	321	135	180 - 524	Adm = Annual administration expenditure / Landfill area
Landfill maintenance (C409)	US$ / ha	5	764	628	524	221 - 1,610	LM = Annual landfill maintenance expenditure / Landfill area
Material cover (C410)	US$ / ton.SWM	8	0.18	0.18	0.18	0.01 - 0.35	Mc = Annual soil for material cover expenditure / Annual waste dumped
Leachate treatment and pest control (C411)	US$ / ton.SWM	9	0.016	0.015	0.001	0.015 - 0.020	LT = Annual soil for dumping expenditure / Annual waste dumped
Environmental monitoring & Report (C412)	US$ / ha	9	394	368	241	126 - 730	EM = Annual environmental monitoring and report expenditure / Landfill area

Note : currency US$1.00 = IDR8,900; n = number of city which provided data; H.E = heavy equipment; hour = average daily working hour; ha = landfill area value = 20%, interest rate = depending on city varies between 7.82% to 9.48%); annual license, tax, insurance, etc; annual repair and maintenance costs; annual tire replacement costs; annual fuel and oil costs; annual driver and crew costs (three or four persons).

The influence factor in transportation cost is capital depreciation expenditure, but in fact the fuel expenditure, because mostly local government accounting system, assets depreciation not take into account in their annual report.

(4) Landfill management cost (C4)

Although landfill design for major cities can initially be classified into open-dumping and sanitary landfill types, on implementation they are operated as open-dumping or semi-sanitary landfills so we assume no difference in operational cost calculations between an open-dumping landfill and a sanitary landfill. Landfill management cost consist following expenditure : annual capital depreciation of an open -dumping or (controlled) sanitary landfill (operational life time = 20 years, and the interest rate depends on the city); annual capital depreciation of heavy equipment (H.E) (operational = 10,000 working hours, salvage value = 25%, interest rate depends on the city), and others expenses broken-down into 10 ten component unit costs; H.E repair and maintenance, H.E fuel and oil, others equipment fuel & oil (light vehicle and electrical generator), operator costs, non-operator costs (landfill employees), administration, landfill maintenance, material cover, leachate treatment and pest control, and environmental monitoring and reporting as shown in **Table 5**.

The influence factor in landfill management cost is landfill capital depreciation expenditure, but in fact the H.E fuel expenditure, because mostly local government accounting system, assets depreciation of landfill and H.E not take into account in their annual report

(5) Cost analysis result

An analysis of the nine major cities (**Table 6**) concluded that the transportation cost is the largest cost (35.5%-73.6%) component in SW service cost compared with the three other components, and that component transfers is the smallest cost component (0.2%-9.1%). A comparison of unit cost percentage in each city shows cities can be divided into two characteristics cities : cities with a dominant percentage of transportation cost (DKI Jakarta, Palembang, Medan, Bekasi, Makassar, Surabaya and Semarang) and cities that have landfill cost percentages greater than or nearly equal to the percentage of transportation costs (Bandung and Depok). A high percentage for the landfill unit cost for Bandung city landfill (Sarimukti) resulted in the operating costs being shared by three cities, Bandung city, Cimahi city and Bandung district; while the high percentage of Depok city landfill (Cipayung) costs results in high landfill facility construction costs, but this generally does not work.

Table 6 Summary of solid waste service cost analysis

City	Solid waste service cost (US$)	Unit cost				
		Collection US$/ton (%)	Transfers US$/ton (%)	Transpor-tation US$/ton (%)	Landfill US$/ton (%)	Total US$/ton (%)
DKI Jakarta	20,754,854	0.73 7.9%	0.84 9.1%	6.07 65.5%	1.62 17.5%	9.26 100%
Palembang	1,814,600	1.0 17.0%	0.1 1.2%	3.5 60.4%	1.3 21.4%	5.8 100%
Medan	3,216,876	0.59 9.0%	0.02 0.3%	4.85 73.6%	1.13 17.1%	6.59 100%
Bandung	2,801,359	0.47 9.7%	0.01 0.2%	2.33 47.8%	2.06 42.3%	4.87 100%
Bekasi	1,348,813	0.39 20.0%	0.01 0.5%	1.02 52.6%	0.52 26.8%	1.94 100%
Makassar	1,614,278	0.46 9.6%	0.06 1.3%	3.28 68.3%	1.00 20.8%	4.81 100%
Surabaya	4,713,820	0.96 15.7%	0.04 0.7%	3.99 64.9%	1.16 18.8%	6.15 100%
Semarang	2,257,199	0.75 19.6%	0.06 1.6%	2.41 63.3%	0.59 15.5%	3.81 100%
Depok	1,209,453	0.65 20.6%	0.24 7.7%	1.12 35.5%	1.14 36.2%	3.16 100%

Note : currency US$1.00 = IDR8,900; based on 2010 year condition

4. SCENARIOS CONSTRUCTED

As implementation of Waste Management Law No. 18/2008, Indonesian ministry of environment (IMoE) introduce some strategy to solving SW problem in major Indonesian cities, are : waste reduction at source, 3Rs and composting at transfer collection station and final disposal, and conversion of open dumping to sanitary landfills with or do not utilize methane gas to electricity. Other than to renew and increase number of garbage truck is still the mainstay of all major cities.

Based on these conditions in effort to solving SW problem in major Indonesian cities hereinafter constructed scenarios.

This study compared three scenarios constructed for handling waste in major cities (**Fig.3**). The current operations conducted by these cities were included as the baseline existing condition scenario for comparison, the overall scenario is assumed to be a 10 year project with 2010 as the base year calculation. **Table 7** shows prerequisites for scenario constructed, percentage composition of waste is dominated by organic material (range of 47.4-64.3), waste collection route (range of 60-137 km), and percentage of waste service coverage (range of

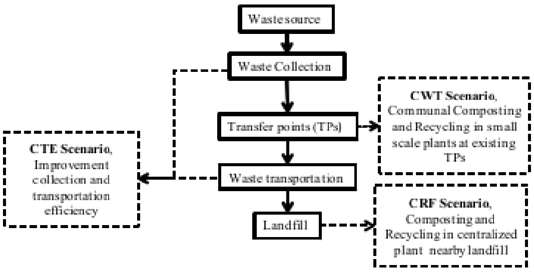

Fig 3 Scenario constructed

46.5-89.2), The three scenarios constructed were: collection and transport efficiency (CTE). In this scenario assume collection and transport processes undertaken by the municipality are not yet at maximum, so that additional collectors equipment and garbage trucks are required.

Communal waste treatment (CWT): This scenario assumes the composting of the organic fraction in communal plants using open-windrow composting. Each plant requires 200m^2 of land, each unit requires a capacity of 4.5 tons/day or 135 tons/month of incoming waste, if the composition of the SW is organic: the non-organic contain will be 60:40. 28.4 tons/month of compost, 40.5 tons/month of recyclables material and 13.5 tons/month of residue be disposed of to landfill. This facility is referred to as an "integrated waste management reactor system or communal composting and recycling facility" (Kastaman -et al, 2002). Assuming the number of facilities to be built is tailored to the land area used for the existing TPs, the current average economic value of compost is IDR500,000 (US$56.2)/ton and separated recyclables (non-organic) waste is IDR100,000 (US$11.2)/ton. Capital depreciation per unit CWT plant is US$8,469 (10years, interest 10% and 10% salvage value) and expenses are US$11,953/year.

Centralized composting and recycling facility (CRF) of organic fraction in a centralized plant using open windrow composting, recyclables are sold directly by the waste separators to agents at the facility, and residues are deposited in an existing landfill next to the facility. A centralized waste treatment facility chosen for handling 100 tons/day of incoming SW. Each unit (facility) requires 5,000 m^2 of land (Temesi, 2004), assuming the number of units to be constructed has a maximum area equal to an existing landfill. 100 tonnes/day or 3.000 tonnes/month of incoming waste, if the composition of the SW is organic : the non-organic contain will be 60:40 : 532 tons/month compost, 913 tons/month recyclables material and 304 tons/month residue then be disposed of to landfill). Capital depreciation per unit CRF plant is US$103,448 (10years, interest 10% and 20% salvage value) and expenses US$296,901/year.

The waste collection and transport method assumed in this study except for the CTE scenario follows the existing method used in each city. All scenarios applied non-source separation except CWT and CRF that perform waste separation on site in which case these activities are part of expenses. In this scenario the role of scavengers is formalized by hiring them to perform separation of materials that are still economically valuable.

5. EXPENSES ANALYSIS.

This analysis aims to determine the changes (increase or decrease) of between the unit costs of:

Table 7 Prerequisites for scenarios constructed

		Existing									CTE	CWT	CRF
		A	B	C	D	E	F	G	H	I	All cities	All cities	All cities
Waste Composition (%)	Organic	55.4	47.4	48.2	58.5	62.9	64.3	49.0	61.2	63.0	No change	The percentage of organic composition reduced for composting material. The percentage of recyclable material (plastic, metal, paper, glass) reduced for recycling or resale.	The percentage of organic composition reduced for composting material. The percentage of recyclable material (plastic, metal, paper, glass) reduced for recycling or resale.
	Textile	0.6	2.1	2.0	1.7	6.4	1.2	4.0	1.3	2.4			
	Woods	0.1	5.9	4.5	2.5	7.1	0.6	3.5	3.1	3.7			
	Plastic	13.3	14.5	13.5	5.9	17.6	14.1	16.0	14.3	8.6			
	Rubber/leather	0.2	1.6	2.3	1.7	0.5	0.2	2.0	0.4	1.2			
	Metal	1.1	5.1	3.5	6.2	0.2	1.3	2.0	1.8	1.4			
	Glass	1.9	0.3	2.3	4.3	0.5	1.4	3.0	1.9	1.3			
	Paper	20.6	15.0	17.5	14.8	4.2	12.3	19.0	13.0	12.1			
	Others	7.0	8.1	6.2	4.4	0.6	4.6	1.5	2.9	6.5			
Waste collection route (km)		96	108	60	84	77	80	137	130	80	Waste collection routes will be reduced due to the addition of waste trucks and waste collection equipment	Waste collection routes will be reduced due to reduced volume of waste transported to landfill	No change
Waste service coverage (%)		83.5	69.3	85.0	46.5	52.0	89.2	61.6	67.9	61.4	Waste service coverage will increase due to the addition of waste trucks and waste collection equipment	No change	No change

Note City A=DKI Jakarta, B=Palembang, C=Medan, D=Bandung, E=Bekasi, F=Makassar, G=Surabaya, H=Semarang and I=Depok, km= average daily distance = (distance from landfill site to downtown x 2 x average daily rotation); 2010 condition

Table 8 Scenarios framework compared with existing condition

Scenarios	Collection	Transportation	Transfer	Landfill	Remarks
Existing	No change	No change	No change	No change	
CTE	- Reducing of un-collection rate from (between: 3.3% - 28.8%) to 2.0%		- No change of recycling rate	- Increasing landfill rate (between: 1.3% to 26.8%)	Reducing un-collection rate by additional number of collection equipment and transportation trucks
	- Increasing of collection cost 5%.	- Increasing of transportation cost (between: 14% to 157%)	- Increasing of transfers cost 5%.	- Increasing of landfill cost (between: 0.2% to 121%)	
CWT	No change	- Decreasing of transportation rate - Reducing of transportation cost (between: 0.9% to 14.2%)	- Increasing of recycling rate (between: 0.7% to 10.3%) - Reducing of transfers costs (between: 41% to 60%) and increasing of transfers costs (between: 92% to 2,398%)	- Reducing of landfill rate (between: 0.7% to 10.3%) - Reducing of landfill cost (between: 0.4% to 6.9%)	Construct communal composting & recycling facilities in existing TPs (Transfers points facility)
CRF	No change	No change	No change	- Reducing of landfill rate (between: 37% to 96%) - Reducing of landfill cost (between: 30% to 97%)	Construct centralized composting & recycling facilities nearby existing landfill

Note : assuming no policy change by local government to: reuse, recycling, composting, collection and transportation of waste

Table 9 Condition of each scenario comparison with existing condition

Scenarios	Un-collection rate (%)									Recycling rate (%)									Landfill rate (%)								
	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I
CTE	6.4 to 2.0	6.0 to 2.0	6.3 to 2.0	28.8 to 2.0	24.8 to 2.0	4.0 to 2.0	8.0 to 2.0	3.3 to 2.0	14.0 to 2.0	10.1 to 10.1	24.7 to 24.7	8.8 to 8.8	23.2 to 23.2	17.4 to 17.4	6.8 to 6.8	30.5 to 30.5	28.7 to 28.7	24.6 to 24.6	83.5 to 87.9	69.3 to 73.3	85.0 to 89.3	46.5 to 73.3	52.0 to 74.8	89.2 to 91.2	61.6 to 67.6	67.9 to 69.3	61.4 to 73.4
CWT	6.4 to 6.4	6.0 to 6.0	6.3 to 6.3	28.8 to 28.8	24.8 to 24.8	4.0 to 4.0	8.0 to 8.0	3.3 to 3.3	14.0 to 14.0	10.1 to 20.4	24.7 to 28.1	8.8 to 9.5	23.2 to 27.2	17.4 to 24.8	6.8 to 8.9	30.5 to 32.0	28.7 to 38.1	24.6 to 26.0	83.5 to 73.2	69.3 to 65.9	85.0 to 84.3	46.5 to 44.0	52.0 to 50.3	89.2 to 87.1	61.6 to 60.0	67.9 to 58.6	61.4 to 60.0
CRF	6.4 to 6.4	6.0 to 6.0	6.3 to 6.3	28.8 to 28.8	24.8 to 24.8	4.0 to 4.0	8.0 to 8.0	3.3 to 3.3	14.0 to 14.0	10.1 to 77.4	24.7 to 82.1	8.8 to 75.1	23.2 to 55.9	17.4 to 32.8	6.8 to 80.1	30.5 to 71.5	28.7 to 83.1	24.6 to 64.1	83.5 to 16.2	69.3 to 11.9	85.0 to 18.6	46.5 to 15.3	52.0 to 42.4	89.2 to 15.9	61.6 to 20.5	67.9 to 13.6	61.4 to 22.0

Note City A=DKI Jakarta, B=Palembang, C=Medan, D=Bandung, E=Bekasi, F=Makassar, G=Surabaya, H=Semarang and I=Depok ; based on 2010 condition

Table 10 Comparison of expenses of scenarios

City	Collection (US$/ton)				Transfers (US$/ton)				Transportation (US$/ton)				Landfill (US$/ton)				Total (US$/ton)			
	Existing	CTE	CWT	CRF	Existing	CTE	CWT	CRF	Existing	CTE	CWT	CRF	Existing	CTE	CWT	CRF	Existing	CTE	CWT	CRF
DKI Jakarta	0.73	0.77	0.73	0.73	0.84	0.88	0.34 (1.10)	0.84	6.07	8.72	5.31	6.07	1.62	1.63	1.51	0.42 (6.96)	9.26	12.00	7.89	8.06
Palembang	1.00	1.05	1.00	1.00	0.07	0.07	0.13 (0.35)	0.07	3.53	4.36	3.34	3.53	1.25	1.90	1.22	0.80 (5.17)	5.85	7.37	5.69	5.40
Medan	0.59	0.62	0.59	0.59	0.02	0.02	0.07 (0.03)	0.02	4.85	5.84	4.81	4.85	1.13	1.70	1.12	0.57 (6.44)	6.59	8.19	6.60	6.03
Bandung	0.47	0.50	0.47	0.47	0.01	0.01	0.26 (0.08)	0.01	2.33	5.99	2.19	2.33	2.06	2.52	2.01	0.05 (3.31)	4.87	9.01	4.93	2.86
Bekasi	0.39	0.41	0.39	0.39	0.01	0.01	0.06 (0.18)	0.01	1.02	2.42	0.98	1.02	0.52	1.15	0.51	0.13 (2.93)	1.94	3.99	1.94	1.55
Makassar	0.46	0.48	0.46	0.46	0.06	0.06	0.22 (0.07)	0.06	3.28	3.62	3.20	3.28	1.00	1.44	0.99	1.93 (6.51)	4.81	5.61	4.88	5.74
Surabaya	0.96	1.01	0.96	0.96	0.04	0.04	0.15 (0.05)	0.04	3.99	5.60	3.87	3.99	1.16	1.76	1.14	0.01 (4.01)	6.15	8.42	6.12	5.01
Semarang	0.75	0.78	0.75	0.75	0.06	0.06	0.97 (0.34)	0.06	2.41	2.75	2.07	2.41	0.59	0.88	0.55	0.41 (5.32)	3.81	4.47	4.34	3.63
Depok	0.65	0.68	0.65	0.65	0.24	0.26	0.14 (0.05)	0.24	1.12	2.51	1.09	1.12	1.14	1.78	1.13	0.25 (3.88)	3.16	5.23	3.01	2.27

Note : expenses of CWT at " Transfers" and CRF at "Landfills" is the value after subtracting revenue; revenue (values in parentheses) while 50% of compost produced by CWT and CRF has been sold; ton = solid waste generated; based on 2010 condition.

existing condition with each scenario have been developed (**Table 10**), the results are reported in the range (highest and lowest) of changes (percentage) from target cities.

Based on the CTE scenario (**Table 8**), which aims to push un-collection rate from existing condition (3.3% in Semarang case and 28.8% in Bandung case) down to 2% (**Table 9**). The result is (**Table 10**): collection unit cost will be increased of 5.0%, transfers unit cost will be increased of 5.0%, transportation unit cost will be increased of between 14% (US$ 2.41–2.75/tons to 157% (US$ 2.33–5.99/tons), and landfill unit cost will be increased of between 0.2% (US$ 1.62–1.63/tons) to 121% (US$ 0.52–1.15/tons). Impact on total CTE unit costs will be increased of between 17% (US$ 4.81–5.61/tons) to 105% (US$ 1.94–3.99/tons). This means that an a policy using a CTE scenario, every 1% decrease in the un-collected rate will be increased of total unit costs between US$ 0.09/ton to US$ 0.62/ton from existing unit costs.

The CWT scenario is designed to improve recycling rates by building communal waste treatment facilities that process organic waste into compost and non-organic waste through sorting processes for resale (**Table 8**). This scenario will increase the percentage of the SW recycling rate between 0.7% (8.8-9.5) to 10.3% (10.1-20.4) from existing condition (**Table 9**).

The result is : no impact (change) on collection unit cost between CWT and the existing cost, impact on transfers unit cost will vary according to the percentage of compost sales (assuming 50% sold), DKI Jakarta and Depok transfers unit costs are reduced 60% (US$ 0.84–0.34/ton) and 41% (US$ 0.24–0.14/ton) respectively but in other cities will be increased 92% (US$ 0.07–0.13/ton) to 2,398% (US$ 0.01–0.26/ton), transportation unit cost will be reduced between 0.9% (US$ 4.85–4.81/tons) to 14.2% (US$ 2.41–2.07/tons) and landfill unit cost will be decreased between 0.4% (US$ 1.13–1.12/tons) to 6.9% (US$ 1.62–1.51/tons). Total unit costs decrease between 0.5% (US$ 6.15–6.12/tons) to 14.8% (US$ 9.26–7.89/tons), but some cities have increased the total unit costs between 0.1% (US$ 6.59–6.60/tons) to 14.0% (US$ 3.81–4.34/tons). This means that in a policy of using CWT scenario when 50% of compost were sold, each 1% increasing of recycling rate can lead to: total unit cost will increased to a maximum US$ 0.06/ton or decreased up to a maximum US$ 0.13/ton from existing.

As with the CWT scenario, the CRF scenario made is designed to improve recycling rates by building communal waste treatment facilities that process organic waste into compost and non-organic waste through sorting processes for resale (**Table 8**). This scenario aims to increase SW recycling rate, between 15.4% (17.4–32.8) to 73.4% (6.8–80.1) see table 9. The result is no impact (change) on collection, transfers, and transportation unit cost between CRF and existing. The landfill unit cost change will vary according to the percentage of compost sales (this study assuming 50% compost is sold), and most cities have reduced landfill unit cost between 30% (US$ 0.59–0.41/tons) to 97% (US$ 2.06–0.05/tons) except for Makassar case, unit cost increase 93% (US$ 1.00–1.93/tons). Totally CRF scenario will reducing total service costs 5% (US$ 3.81–3.63/tons) to 41% (US$ 4.87–2.86/tons) from the existing unit costs but Makassar case unit cost will increase 19% (US$ 4.81–5.74/tons). This means that in a policy using the CRF scenario when 50% of compost were sold, each 1% increase in the recycling rates will reduce total unit cost between US$ 0.061/tons to US$ 0.023/tons from existing unit costs.

6. CONCLUSION

In SWM service cost in major Indonesian cities, transportation cost account for the largest percentage (35.5%-76.3%) of component cost compared to the three other components and while component transfer and treatment is the smallest percentage cost component (0.01%-0.84%).

Based on a comparison of the unit cost percentage in each city, cities can be divided into two characteristics cities : cities where transportation cost is the dominant percentage (DKI Jakarta, Palembang, Medan, Bekasi, Makassar, Surabaya and Semarang) and cities that have landfill costs percentage greater than or nearly equal to the percentage of transportation costs (Bandung and Depok). High percentage of landfill unit cost caused Bandung city landfill (Sarimukti), currently shared operation by three cities, Bandung city, Cimahi city and Bandung distric and high percentage of Depok city landfill (Cipayung) costs due to higly landfill facility construction costs, but generally does not work.

The CTE scenario aims to push the SW uncollected rate by 2% of the existing conditions between 3.3% to 28.8%. It means policy using CTE scenario that every every 1% decrease in the uncollected rate will increase total unit costs between US$ 0.09/ton to US$ 0.62/ton from existing unit costs.

CWT scenario made to improve recycling rates by building communal waste treatment facilities that will process organic waste into compost and non-organic waste for resale. Policy using CWT scenario depends on the percentage of compost sale, in case of 50% compost sale scenario that each 1% increasing of recycling rate can lead to: total unit cost will increased to a maximum US$ 0.06/ton or decreased up to a maximum US$ 0.13/ton from existing.

Similar with CWT, CRF scenario made to improve recycle rates by building communal waste treatment facilities that will process organic waste into compost and non-organic waste for resale. Policy using CRF scenario in case 50% compost were sold, each 1% increase in the recycling rates will reduce total service cost US$ 0.061-0.023/ton (except Makassar city case).

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