Feasibility Study of Municipal Solid Waste Management System (MSW-MS) in Sidoarjo District

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***Abstract*—Sidoarjo MSW-MS currently facing a problem to fulfill their needs of Municipal Solid Waste (MSW) processing, as the data shown by Dinas Lingkungan Hidup dan Kebersihan (DLHK) of Sidoarjo district stated that their service cover only 48% of Sidoarjo total area with the amount of potentially unmanaged MSW per day reach about 83% of it or equal to 1032 ton of MSW per day. In regards to this condition, there is a need to determine a new integrated approach of MSW-MS so that MSW in Sidoarjo district can be more properly managed to reduce its potential implied expense, gain potential benefits from it, and prevent potential negative impacts from improperly managed MSW. In this research, the implementation of proposed integrated MSW-MS will be carried out by a private business entity in collaboration with DLHK of Sidoarjo district in a Public Private Partnership (PPP) scheme represented in form of Business Plan Scenario (BPS). This research focused on determining the best BPS to be implemented in Sidoarjo district which targeted to optimize implied benefits from Sidoarjo District regional government perspective as its priority but still considering BPS feasibility to be implemented by related private business. This process is done by making a financial model according to the proposed BPS that are complemented with linear regression-based for its waste generation input variable and Benefit-Cost Analysis (BCA). Feasibility for each BPS implementation for private business entity perspective determined according to its financial valuation parameters value and Benefit Cost Ratio (BCR) for DLHK of Sidoarjo district perspective. Furthermore, an adjustment of several private business parameters is made according to sensitivity and incremental analysis approach to ensure the feasibility of its implementation in terms of private business entity perspective.**

***Keywords*— Feasibility Study, Financial Modelling, Benefit Cost Analysis, Municipal Solid Waste Management System.**

I. INTRODUCTION

SIDOARJO is one of the district in Indonesia located in East Java Region. They are the fourth most populated city in there with the total population of 2.262.440 people in 2019, also with the highest population growth rate in that region, which reach 1,53% in 2017 [1]. They also the second largest economic contributor in there that contributes as much as 8.57% of the total East Java region Gross Regional Domestic Product (GRDP) mainly from their manufacturing, trading, and retail sector [2]. These conditions represent Sidoarjo level of consumption, population growth, and economic activity which is the major factors that influence MSW generation in certain area [3]. With consideration to these factors, especially population growth, back in 2017 DLHK of Sidoarjo district already made a projection of MSW generation potential in their area. It is projected that Sidoarjo district generate approximately 1280 ton of MSW/day [4]. To manage this routine-generated MSW in their area, Sidoarjo government through DLHK of Sidoarjo district, already implement several MSW-MS facilities including 1 *Tempat Pemrosesan Akhir* (TPA) in Griyomulyo, 86 active *Tempat Pengolahan Sampah Terpadu,* and 17 facilities of TPS, Bank Sampah, which complemented with several different MSW transporting media.

However, their existing MSW-MS only able to cover only 48% of their total service area. It also only able to process approximately 17% of the total routine-generated MSW in there. Meanwhile, 83% of them, which is equal to 1032 ton of MSW per day, is consisted of residual MSW that will be treated in TPA, unmanaged MSW, or illegally burnt MSW. In regards to this condition. Because of this condition, there is a need to determine a new integrated approach of MSW-MS so that MSW in Sidoarjo district can be more properly managed to reduce its potential implied expense, gain potential benefits from it, and prevent potential negative impacts from improperly managed MSW.

In this research, the implementation of proposed integrated MSW-MS will be carried out by a private business entity in collaboration with DLHK of Sidoarjo district in a PPP scheme represented in form of BPS in accordance to Indonesia government policy. This research focused on determining the best BPS to be implemented in Sidoarjo district which targeted to optimize implied benefits from Sidoarjo District regional government perspective as its priority but still considering BPS feasibility to be implemented by related private business. This process is done by making a financial model according to the proposed BPS that are complemented with linear regression-based for its waste generation input variable and BCA. Feasibility for each BPS implementation for private business entity perspective determined according to its financial valuation parameters value and BCR for DLHK of Sidoarjo district perspective.

Hence, according to previously stated background, the formulated problem that will be the focus in this research is about how to determine the best MSW-MS BPS for Sidoarjo district according to feasibility study with consideration to financial and benefit-cost aspect.

II. RESEARCH METHODOLOGY

A. Preliminary Phase

This phase started with two different activities which are literature review and field study that will be used to identify

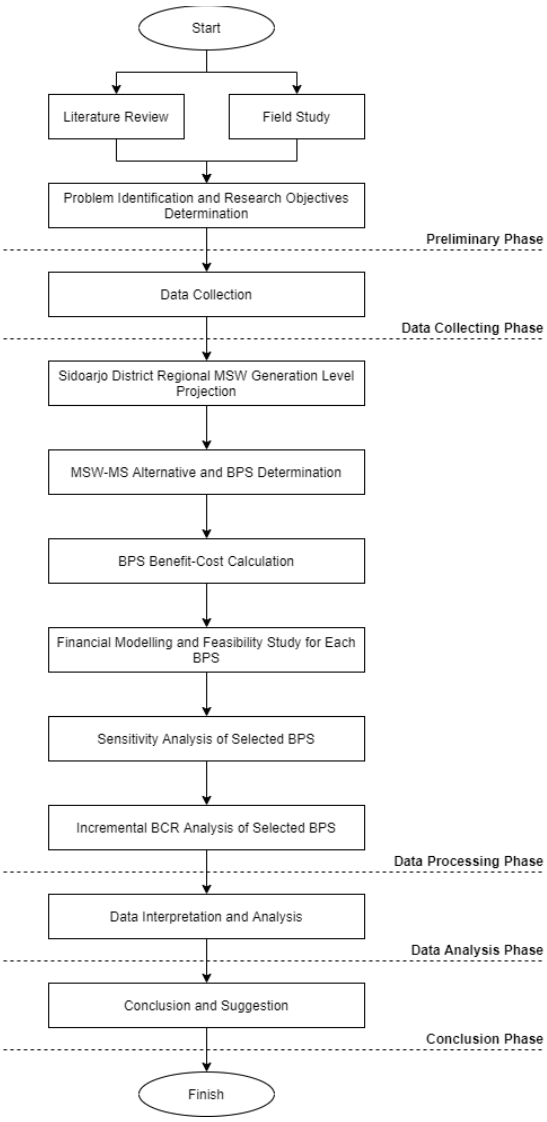

Figure 1. Flowchart of Final Project Research Methodology

Table 1.
Sidoarjo District MSW Generation Initial Projection (Ton/Year)

2017	2018	…	2024	2025
435,118	443,820	…	498,828	508,805

Table 2.
MSW Generation Linear Regression Projection in Sidoarjo District (Ton/Year)

2026	2027	…	2074	2075
517,470	526,688	…	959,918	969,136

Table 3.
BPS Determination

BPS Name	MSW-MS Process	PPP Scheme	Output
BPS 1	WTE Plant	BOT-AP	Electricity
BPS 2	Integrated MSW Recycling Plant	BOOT-AP	Recycled Goods
BPS 3	Combination of BPS 1 and BPS 2 WTE Plant managed by PT X Integrated MSW Recycling Plant managed by PT Y		

Table 4.
Private Business Entity Benefit-Cost Implication for Each BPS

Factors	BPS 1	BPS 2	BPS 3	
			PT X	PT Y
Benefits (Revenue Stream)	AP	Recycled Goods Sales, AP, Tipping Fee	AP	Recycled Goods Sales, AP, Tipping Fee
Costs	CAPEX + OPEX + Other Expenditure			

Table 5.
Private Business Entity Benefits Amount per Period for Each BPS (in IDR, mil)

BPS Name		2026	…	2075
BPS 1		Rp1.111.289	…	Rp3.738.814
BPS 2		Rp276.427	…	Rp4.236.670
BPS 3	PT X	Rp1.109.760	…	Rp3.309.895
BPS 3	PT Y	Rp276.427	…	Rp4.236.670

and formulate problem of this research. Literature review related to it includes the topics of MSW definition, characteristic, and other attributes; general MSW-MS regulation and operational standards in Indonesia and in benchmarked country; waste-based business process of the benchmarked country and or institution; and the related methodology that will be used in this research including, linear regression, BCA, financial modelling, and sensitivity analysis. Meanwhile, the field study related to it includes a direct meeting and discussion also online interview with the stakeholders of DLHK of Sidoarjo district.

B. Data Collecting Phase

Data collecting done in this research aims to collect two types of data which are quantitative and qualitative data. The quantitative data that will be used in this research includes Sidoarjo district regional waste generation level that acquired from DLHK of Sidoarjo district report; BI inflation target level in 2020; CAPEX and OPEX of each MSW-MS alternative that acquired from literature review and field study; benefit and cost component for all MSW-MS alternative that acquired from literature review and field study which; income component of MSW-MS alternatives; and financial report of similar industry. Meanwhile, the qualitative data that will be used in this research includes existing condition of MSW-MS, waste processing, and waste utilization in Sidoarjo district that acquired from field study; existing condition of waste-based business in Sidoarjo district that acquired from literature review and field study; benchmarked WMS from other countries that acquired from literature review; benchmarked business process from similar industry that acquired from literature review; and regulation and law about MSW-MS in Indonesia that acquired from literature review.

C. Data Processing Phase

Data processing done in this research include the process of Sidoarjo district regional MSW generation level projection as the input for each BPS financial model. Next, there is MSW-MS alternative and BPS determination complemented with the calculation of its implied benefit and cost. After that, there will be financial modelling and feasibility study for each BPS with the output of financial statements, financial valuation parameters, and BCR result for each BPS. These output will be used to determine the preferred alternative of BPS to be implemented by DLHK of Sidoarjo district and will undergo further sensitivity and incremental analysis. Sensitivity analysis is done to the preferred BPS alternative

Table 6.
Private Business Entity Costs Amount per Period for Each BPS (in IDR, mil)

BPS Name		2025	2026	…	2075
BPS 1		Rp8.076.389		…	
BPS 2		Rp98.095		…	
BPS 3	PT X	Rp8.058.825		…	
	PT Y	Rp98.095		…	

Table 7.
DLHK of Sidoarjo District Benefit-Cost Implication for All BPS

Factors	BPS 1	BPS 2	BPS 3	
			PT X	PT Y
Benefits	1. Private Business Sales (Only for WTE Plant) 2. Private Business Plant Acquisition 3. Avoided Operational Cost of MSW-MS in TPA Jabon 4. Avoided Land Acquisition Cost due to Dedicated Landfill Area Needs Increase 5. Carbon Credit Savings Gained through WTE Operation			
Costs	1. Operational Cost of Remaining MSW-MS in TPA Jabon 2. Transportation and General Sorting Cost of Generated MSW in Sidoarjo District 3. AP and or Tipping Fee for Private Business Entity 4. Projected Land Acquisition Cost due to Dedicated Landfill Area Needs Increase Potential			

Table 8.
DLHK of Sidoarjo District Benefit-Cost Amount per Period for Each BPS (in IDR, mil)

BPS Name	2026	…	2075
BPS 1			
Benefits	Rp196.409	…	Rp13.970.162
Costs	Rp1.152.432	…	Rp3.889.483
BPS 2			
Benefits	Rp2.850	…	Rp147.117
Costs	Rp212.411	…	Rp65.335.328
BPS 3			
Benefits	Rp199.259	…	Rp12.177.972
Costs	Rp1.178.539	…	Rp3.755.030

parameters to ensure feasibility in all parties included in it and also to determine its feasibility boundaries. The minimum threshold in the feasibility boundary will be used as the input for incremental BCR analysis to determine the best BPS alternative to be implemented. After that, there will be data analysis and interpretation made according to the result of data processing phase and ended with conclusion and suggestion formulation acquired from this research.

D. Data Analysis and Interpretation Phase

Data analysis and interpretation done in this research include the analysis of selected BPS and sensitivity analysis. Selected BPS analysis will includes the analysis of reasoning behind its selection as the preferred alternative of BPS to be implemented by DLHK of Sidoarjo district according to financial and benefit cost approach. Sensitivity analysis is done to consider a critical aspect in terms of independent variables included in the financial model and feasibility calculation of it and how it change may affect the decision making of the selected solution. It will also include incremental analysis to determine the best BPS alternative to be implemented by DLHK of Sidoarjo district.

Table 9.
Feasibility Parameters Result for Each BPS at Initial Condition

Parameters	BPS 1	BPS 2	BPS 3	
			PT X	PT Y
NPV (in IDR, mil)	(Rp1.565.773)	Rp380.061	(Rp1.562.608)	Rp380.061
IRR	6.65%	16.83%	6.65%	16.83%
PP	<15 Years	<8 Years	<15 Years	<8 Years
DPP	None	<12 Years	None	<12 Years
BCR	1.64	0.001	1.45	

Table 10.
Sensitivity Analysis Parameters and Minimum Threshold for Each Preferred BPS

BPS Name		Parameters	Baseline	UUJK
BPS 1		AP Escalation Rate	30%	70%
BPS 3	PT X	AP Escalation Rate	30%	70%
	PT Y	Tipping Fee Rate	Rp175.000	Rp250.000

Table 11.
Feasibility Parameters Result for Each Preferred BPS at Adjusted Condition

Baseline Condition			
Parameters	BPS 1	BPS 3	
		PT X	PT Y
NPV (in IDR, mil)	Rp266.932	Rp266.125	Rp21.361
IRR	8.72%	8.72%	8.96%
PP	<12 Years	<12 Years	<17 Years
DPP	<38 Years	<38 Years	<42 Years
BCR	1.47	1.34	
UUJK Condition			
Parameters	BPS 1	BPS 3	
		PT X	PT Y
NPV (in IDR, mil)	Rp2.087.973	Rp2.083.156	Rp105.577
IRR	10.71%	10.71%	10.93%
PP	<10 Years	<10 Years	<13 Years
DPP	<19 Years	<19 Years	<26 Years
BCR	1.29	1.20	

E. Conclusion Phase

The conclusion acquired from this research made according to pre-determined research objectives in preliminary phase.

III. DATA COLLECTING AND PROCESSING

A. Sidoarjo District Regional MSW Generation Projection

The amount of managed MSW-MS in Sidoarjo district projected by consultant for Sidoarjo District regional policy and strategies (*Kebijakan dan Strategi Daerah* (Jakstrada)) for 2017-2025 can be seen in Table 1.

Data in Table 1 will be used for projection using linear regression approach using Minitab software. Linear regression formula acquired from there is:

$$y = -18{,}158{,}509 + 9217{,}66 \times Year \quad (1)$$

Using Formula 1, Sidoarjo MSW generation made according to predetermined planning horizon for each BPS feasibility study from related research, which is 50 years [5].

Table 12.
Incremental Benefits and Costs between BPS 1 and BPS 3 (in IDR, mil)

BPS Name	2026	…	2075
Baseline Condition			
Incremental Benefits	(Rp2.850)	…	Rp1.893.872
Incremental Costs	(Rp14.106)	…	Rp318.909
UUJK Condition			
Incremental Benefits	(Rp2.850)	…	Rp2.035.700
Incremental Costs	(Rp16.311)	…	Rp276.907

Table 13.
Incremental BCR Result

Condition	Information	Value	Incremental BCR
Baseline	PV Benefits	Rp10.241.448	4.28
	PV Costs	Rp2.393.867	
UUJK	PV Benefits	Rp10.241.448	5.01
	PV Costs	Rp2.042.175	

Table 14.
Selected BPS Sensitivity Analysis Result

Baseline Condition			UUJK Condition		
AP Escalation Rate	**Incremental BCR**	**Decision**	**AP Escalation Rate**	**Incremental BCR**	**Decision**
30% (Bottom Line)	4.28	Select BPS 1	60% (Bottom Line)	5.01	Select BPS 1
70%	1,07	Select BPS 1	100%	1,11	Select BPS 1
71%	1,05	Select BPS 1	101%	1,09	Select BPS 1
72%	1,03	Select BPS 1	102%	1,07	Select BPS 1
73%	1,01	Select BPS 1	103%	1,05	Select BPS 1
74%	0,99	Select BPS 3	104%	1,03	Select BPS 1
75%	0,98	Select BPS 3	105%	1,02	Select BPS 1
76%	0,96	Select BPS 3	106%	0.99	Select BPS 3
77%	0,94	Select BPS 3	107%	0,98	Select BPS 3
78%	0,93	Select BPS 3	108%	0,96	Select BPS 3
79%	0,91	Select BPS 3	109%	0,95	Select BPS 3
80%	0,90	Select BPS 3	110%	0,93	Select BPS 3

It will be starting from 2026-2075. MSW generation projection result can be seen through Table 2.

B. BPS Determination

MSW-MS BPS alternative included in this research can be seen in Table 3.

BPS 1 will be able to process all residual MSW into electricity. BPS 2 will only able to process recyclable residual MSW. Meanwhile BPS 3, will combine both of them which means that unrecyclable MSW will processed into electricity.

C. BPS Benefit-Cost Implication Calculation

Benefit-cost implication for each BPS will be differentiateed into two persepectives which are for private business entity and DLHK of sidoarjo district. Here are benefit-cost implication for private business entity for all BPS shown through Table 4 until 6.

Here are benefit-cost implication for DLHK of Sidoarjo District for all BPS shown through Table 7 and 8.

Benefits and costs factors with no specific implied growth rate will have growth rate equal to Bank Indonesia's infaltion rate target in 2020 which 3% [6].

D. BPS Financial Modelling and Feasibility Study

Financial modelling for each BPS made with the input of each BPS benefit-cost implication. The result of it structured using financial statements logic and will be the input for feasibility study. Feasibility study result for each BPS at unadjusted initial condition recapped in Table 9.

Discount rate used in calculating NPV is 8.43% acquired from Weighted Average Cost of Capital (WACC) calculation. There also several micro and macro assumption implemented in calculating these value. The result acquired from this process is that BPS 1 and BPS 3 considered feasible to be implemented from DLHK of Sidoarjo district perspective. But, it needs an adjustment in its several private business parameters to ensure the private business included in each BPS will feasible to implement it as well through sensitivity analysis as the next process.

E. Preferred BPS Sensitivity Analysis

Sensitivity anaylysys required that all parties included in the PPP scheme must have a feasible value of their feasibility parameters. Feasibility parameters condition in this research diffirentiated into two which are baseline condition where private business IRR must be higher or equal to WACC, and UUJK condition [7] where private business IRR must be higher or qual to WACC+2%. Independent variables used as the sensitivity anaylsis parameters and minimum threshold for both BPS to fulfill both requirements can be seen through Table 10 and 11.

F. Preferred BPS Incremental BCR Analysis

Incremental BCR analysis will be done for both BPS for their implied benefit and cost in DLHK of Sidoarjo district perspective per period for both baseline and UUJK condition. BPS 1 will be the challenger as it has higher initial investment in terms of PV costs amount. The recapitulation of incremental benefits and cost calculation per period can be seen in Table 12. Incremental BCR calculation result can be seen in Table 13.

It means that BPS 1 will be more benefial to be implemented by DLHK of Sidoarjo district as a relative best

solution for minimum threshold in baseline and UUJK condition. The feasibility boundaries of this relative best solution tested again using sensitivity analysis resulted as can be seen through Table 14.

IV. RESULT AND DISCUSSION

The calculation of each BPS alternative implementation feasibility consider financial valuation parameters value of NPV, IRR, payback period, and discounted payback period for private business sector perspective; and BCR for DLHK of Sidoarjo district perspective. BPS 1 has NPV amount of (Rp1.565.773.189.507) with IRR rate of 6.65%, payback period less than 15 years, and unidentifiable discounted payback period with BCR value of 1.64; BPS 2 amount of NPV is Rp380.060.973.186 with IRR equal to 16.83%, payback period less than 8 years, land discounted payback period less than 12 years with BCR value of 0.001; BPS 3 amount of NPV is (Rp1.562.608.332.775) with IRR rate of 6.65%, less than 15 years payback period, and unidentifiable discounted payback period for PT X; and NPV is Rp380.060.973.186 with the IRR of 16.83%, payback period less than 8 years, and less than 12 years discounted payback period with a BCR value of 1.45. Hence, BPS 1 and BPS 3 are the alternatives considered feasible in DLHK of Sidoarjo district perspective in this research. Hence, at an unadjusted initial condition it resulted that only BPS 1 and BPS 3 considered to be feasible to be implemented in DLHK of Sidoarjo district perspective.

From the result before it can be seen that there is a need of several adjustments of private business parameters to ensure the feasibility of BPS implementation for the included private business entity in each BPS. This process is done using sensitivity and incremental BCR analysis as its base. The parameters included in sensitivity analysis for BPS 1 is private business entity AP escalation rate. Meanwhile, for BPS 3 it includes PT X AP escalation rate and PT Y Tipping Fee for its sensitivity analysis parameter. In this process, there are two conditions that should be fulfilled which are baseline condition which states that private business IRR > WACC; and UUJK condition which states that private business IRR > WACC + 2%. The minimum amount to fulfill both condition will be used as the input for incremental BCR analysis for both BPS. These minimum thresholds for baseline and UUJK condition are fulfilled at AP escalation rate of 30% and 60% for BPS 1; and PT X AP escalation rate of 30% and PT Y tipping fee of Rp 175.000, and PT X AP escalation rate of 60% and PT Y tipping fee of Rp 250.000 for BPS 3.

Incremental BCR analysis will be done using the result of minimum thresholds for fulfilling baseline and UUJK condition for BPS 1 and BPS 3 as its input. It will be done for baseline and UUJK condition using BPS 3 as the challenger as it implies a higher initial investment than BPS 1. The result of it can be seen in Table 13, which shows that incremental BCR value of 4.28 for baseline condition and 5.01 for UUJK condition. Hence, it can be concluded that from this research it is found out that BPS 1 which is WTE plant is the most beneficial MSW-MS method to be implemented in Sidoarjo district. After that, further sensitivity analysis for BPS 1 as the selected alternative will take place which uses its AP escalation rate as the parameter once again. And from there it is found out that the feasibility threshold for BPS 1 as the relative best solution lies on the range of its AP escalation rate until 73% for baseline condition and 105% for UUJK condition.

V. CONCLUSION

Business plan scenario alternative that will be proposed to be implemented in Sidoarjo district through this research inlcuding BPS 1 with the implementation of WTE plant, BPS 2 with the implementation of integrated MSW recycling plant, and BPS 3 which are the combination of two previous BPS resulted to integrated WTE and MSW recycling plant.

Feasibility study of each BPS results at the initial unadjusted condition show that BPS 1 has NPV amount of (Rp1.565.773.189.507) with IRR rate of 6.65%, payback period less than 15 years, and unidentifiable discounted payback period with BCR value of 1.64; BPS 2 amount of NPV is Rp380.060.973.186 with IRR equal to 16.83%, payback period less than 8 years, land discounted payback period less than 12 years with BCR value of 0.001; BPS 3 amount of NPV is (Rp1.562.608.332.775) with IRR rate of 6.65%, less than 15 years payback period, and unidentifiable discounted payback period for PT X; and NPV is Rp380.060.973.186 with the IRR of 16.83%, payback period less than 8 years, and less than 12 years discounted payback period with a BCR value of 1.45. Hence, BPS 1 and BPS 3 are the alternatives considered feasible in DLHK of Sidoarjo district perspective in this research.

Sensitivity analysis results for BPS 1 show that the minimum threshold point for baseline condition lies on AP escalation rate of 30%; and 60% for the UUJK condition. Meanwhile, for BPS 3 the minimum threshold point for baseline condition lies on PT X AP escalation rate of 30% and PT Y tipping fee of Rp 175.000; and PT X AP escalation rate of 60% and PT Y tipping fee of Rp 250.000 for UUJK condition. All of these condition already accommodate feasibility for public and private parties included in the PPP scheme. From there, incremental BCR analysis is performed between defender (BPS 1) and challenger (BPS 3) which resulted to the incremental BCR value of 4.28 for baseline condition and 5.01 for UUJK condition. Hence, it can be concluded that from this research it is found out that BPS 1 which is WTE plant is the most beneficial MSW-MS method to be implemented in Sidoarjo district at the feasibility threshold for BPS 1 AP escalation rate until 73% for baseline condition and 105% for UUJK condition.

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