Re-development of a city-scale waste bank assessment index: Case studies Bandung and Cimahi Cities

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Re-development of a city-scale waste bank assessment index: Case studies Bandung and Cimahi Cities

M Pranaditya* and I Juwana

Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Institut Teknologi Nasional Bandung, Jl. PKH Mustopha No.23 Bandung 40124, West Java, Indonesia

E-mail: megapranaditya11@gmail.com

Abstract. The waste bank is one application of waste management by utilizing waste that can be reused, which in the end can be used to reduce the waste dumped into landfills. In order to reduce the significant amount of waste dumped into landfills, there should be at least one waste bank operates at a city-scale. Thus, a tool to assess the readiness of a waste bank to function at a city-scale is needed. In the past, studies on the development of index were undertaken simply based on a desk-study method. This study aimed to refine the previous index. This was done by first reviewing the previous indicator through a literature review, which was then verified by the application of the Analytical Hierarchy Process (AHP) method to determine the weights for each indicator. The respondents for AHP applications were selected from four categories namely professional experts, academics, institutions and management representatives of the waste bank. At the end of the study, three components, thirteen indicators and sixty-one sub-indicators were identified. The name of the components and their respective weights were Management System (55%), Operating System (25%) and Waste Bank Facility (20%). Each component had 4-5 indicators and 2-8 sub-indicators. In the near future, the index developed from this study will be used to assess the readiness of Resik Bandung and Cimahi City Waste Bank to be developed as city-scale waste banks.

1. Introduction

The waste bank is an integrated waste management, implementing the Reduce, Reuse and Recycle (3R) activity, which aims to reduce waste from its source [1-3]. The development design of waste bank has a very important role in the waste management system to reduce the amount of city waste delivered to landfills.

Currently, there is already an index about waste banks which contains three main components, namely building construction quality, the management system and the operational system [1]. In that study, there was no discussion of the waste management facility, and the index weighting process of each indicator was done using descriptive analysis by dividing the maximum score with the number of indicators. This means that each indicator had the same weight, which might be invalid since each of the indicators should have their own respective weight.

According to the analysis, it is necessary to develop the city-scale waste bank index which reviews what components can influence the success of a city-scale waste bank. Next, the index should be validated using Analytical Hierarchy Process (AHP). This method can be done by creating a paired-comparison questionnaire that should be answered by four respondent categories who have significant

activities in waste management. These four categories are professional experts, institutes, academics, and waste bank administrators.

The purpose of this study was to arrange a city-scale waste bank index based on the previous index development. The purpose of specifying components, indicators and sub-indicators added from the previous index was to decide the weight of each identified indices, as well as testing the indices on the waste banks used as the subject of this research.

2. Methodology

2.1. Data collection

To identify parameters used in city-scale waste bank index, a desk study was done from the main literature and supporting literature. Main literature was the reference from the previous index while supporting literature included rules about waste, a book of waste bank concept, and other research journals.

Primary data were collected from questionnaires, of which the data was a collection of indices given to the specified components and indicators. Moreover, another primary data was obtained from the test result indices done on the research subjects. The data was produced based on direct field observation.

2.2. Index Preparation

The index was prepared using the following steps [3].

2.2.1. Reidentifying components. This includes reviewing the main literature, followed by reviewing supporting literature. These actions were done so the components said to be adequate to represent city-scale waste bank index could be set.

2.2.2. Identifying indicators. During the identification, reviewing the main and supporting literature were done simultaneously. Table 1 shows an example of a schema which shows the ways of identifying indicators in a management system component. It can be seen in Table 1 that there are several similar indicators between each reference. These similarities are based on contents from each of the indicator point, which is marked with the same color from each of the columns. These similarities could be merged into a single indicator each.

Table 1. Management System Component's indicators.

Regulation	Book of waste bank concept	Other Literature
• Waste Depositor	• Institutional	• Institutional
• Waste Bank Executor's Role	• Financing	• Institutional Structure
• Waste Buyer	• Community Service	• Capital
• Waste Management	• Partnership	• Partnership
• Promotion and Socialization	• Promotion and Socialization	• Promotion and Socialization
• Waste Bank Administrator HR	• Waste Bank Administrator HR	• Waste Bank Administrator HR
• Waste Bank Executor	• City Waste Management Integration	• Administrator's Job Desk
		• City Waste Management Integration

2.2.3. Identifying sub-indicators. Identifying sub-indicators were done using the same method in reidentifying components, in which the method was done by reviewing the main literature followed by reviewing the supporting literature.

2.2.4. Arranging scoring criteria. The arranging of scoring criteria was done by reviewing the literature. The criteria were composed of scoring points based on some conditions that might happen to the research subjects.

2.2.5. Weighting. There were two methods that could be used on weighting city-scale waste bank index, namely the AHP method and Equal Rating method. AHP method was used in component and indicator weighting from the questionnaire. The questionnaire was based on the number of components that would be compared to the level of importance, each component was compared to get the importance level. Table 2 shows the questionnaire using the AHP method. The respondents should fill paired comparison matrices each with a number which represented importance scale level [4]. Table 3 shows the importance scale level used in the AHP method.

Table 2. Questionnaire.

Components	**Weight of Paired Comparisons Matrix**																	**Components**
Operational System	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Management System
Management System	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Facility
Facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Facility

Table 3. Importance level scale.

Importance level	**Definition**
1	Equally important
3	A little more important
5	Clearly more important
7	Much clearly more important
9	Certainly, more important
2,4,6,8	Chosen if in doubt between two levels
1/(1-9)	Opposite of importance level score on the scale of 1 to 9

The respondents were randomly selected, consist of eight persons divided into four categories. These four categories were professional experts (2 persons), institutes (2 persons), academics (4 persons), and waste bank administrators (2 persons). These four are considered to have adequate experience in waste management, especially waste banking.

The questionnaire data was processed using Expert Choice II application. Computation of the consistency of each respondent was done automatically [5]. Next, respondents with high consistency could be merged using the application. Meanwhile, sub-indicator weighting was done by dividing the maximum score with the number of sub-indicators. This was because, to keep the consistency of the weighting result, not all index level was evaluated using AHP.

2.2.6. Data processing. After arranging the indices, the data was processed as index aggregations and interpretations. Aggregation was a form of merging indices to obtain their final score [6]. There were two ways to aggregate indices: using the arithmetic method and the geometric method. In this study, both methods are discussed.

Indicator score was calculated using the following equation:

$$Indicator\ score = \sum wiSi$$

wi = Scoring criteria of each sub-indicator

Si = Maximum score of each sub-indicator

The component score was calculated by adding up all its indicators' scores using the following equation:

$$Component\ score = \sum Component\ indicator\ score$$

The score of the index was calculated by adding up all its components' scores using the following equation:

$$Index\ score = \sum Component\ score$$

Index interpretation was a process of adapting indices with the research subject, as well as showing the readiness or score of the studied subject. In this study, it was necessary to interpret the indices and how to determine it is discussed.

3. Results and analysis

3.1. Component identification

Component identification was done by reviewing the main literature, followed by the supporting literature. The schema that describes how to identify the components is presented in Figure 1.

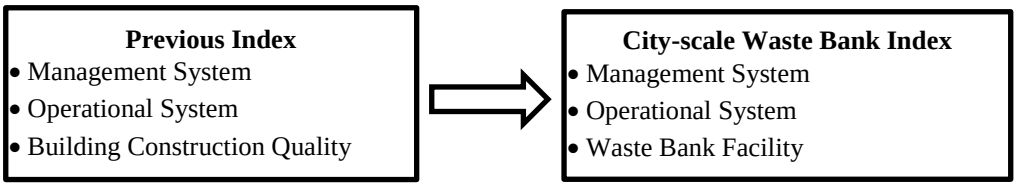

Figure 1. Schema of components identification.

Table 4 lists the potential components from discussions found in the supporting literature.

Table 4. Components from *desk study* result.

Component	Source
Management System	Regulation, concept book of waste bank, other literature
Operational System	Regulation, concept book of waste bank, other literature
Facility	Regulation, other literature
Waste Bank Development Concept and Potency	Concept book of waste bank

Components that commonly present in every reference were Operational System Component and Management System Component. They indicated how important the components were, and they should be parts of city-scale waste bank index. While other components such as Facility, Building Construction, Building Construction Quality, and Supporting Infrastructure are discussed in Facility Component.

3.2. Indicator identification

Indicator identification was done on each chosen component from the previous step, namely Management System Component, Operational System Component and Waste Bank Facility Component.

3.2.1 Indicator identification on Management System Component. From the four references used to determine the Management System Component indicator, several indicators could be grouped (Table 5).

It can be seen from Table 5 that there were several indicators that could be grouped to represent Management System Component, namely Institutional Indicator, Capital and Partnership Indicator, Socialization and Promotion Indicator and City Waste Manager Integration Indicator. Figure 2 shows the schema that shows indicator changes in Management System Component from the previous index to city-scale waste bank index.

Table 5. Management System Component's indicator.

Indicator	Source
Institutional, institutional structure, human resource, job desk	Regulation, concept book of waste bank, other literature
Financing, capital, partnership	
Socialization and promotion	
City waste bank management integration	

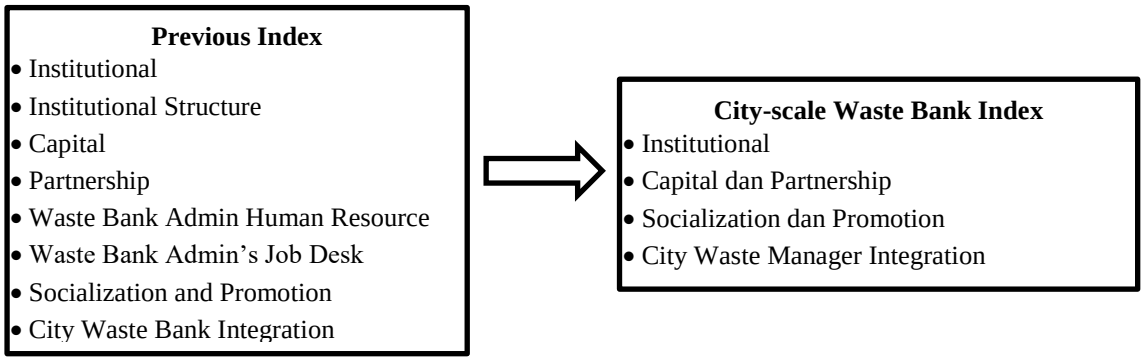

Figure 2. Schema of Management System Component indicator changes from the previous index to city-scale waste bank index.

3.2.2 Indicator identification on Operational System Component. From the four references used to determine the Operational System Component indicator, several indicators could be grouped (Table 6).

Table 6. Operational System Component's indicator.

Indicator	Source
The operational mechanism, operational executor, collection and management, waste type, waste pick up, price fixing, operational time	Regulation, concept book of waste bank, other literature
Monitoring, monitoring and evaluation system	
Self-protection kits, work health and safety	
Waste bank client, community service	

There were several indicators that can be grouped to represent Operational System Component, namely Client Indicator, Operational Mechanism, Work Health and Safety, Monitoring and Evaluation System, and Information System. Figure 3 shows the schema that shows indicator changes on Operational System Component from the previous index to city-scale waste bank index.

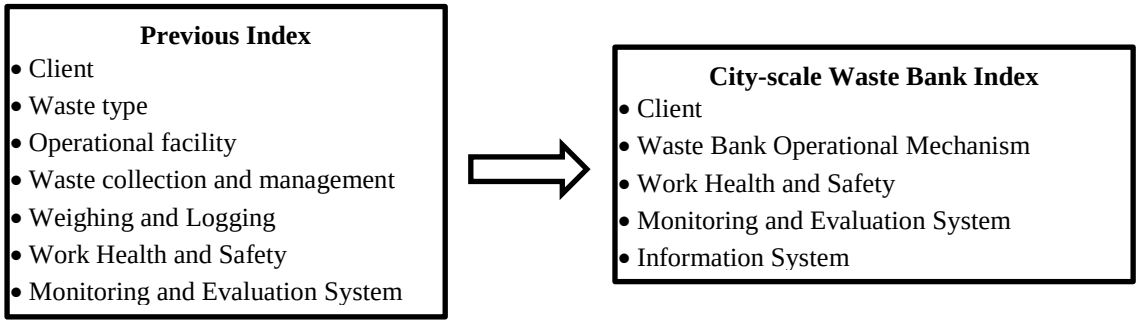

Figure 3. Schema of Operational System Component indicator changes from the previous index to city-scale waste bank index.

3.2.3. Indicator identification on Waste Facility Component. From the four references used to determine Waste Facility Component indicator, several indicators could be grouped (Table 7).

Table 7. Waste Bank Facility Component's indicator.

Indicator	Source
Supporting building, warehouse, operational facility	Regulation, concept book of waste bank, other literature
Building construction, building construction quality	
3R facilities, organic waste processor, inorganic waste processor	

There were several indicators that could be grouped to represent Waste Bank Facility Component, namely Public Facility, Building Facility, Operational Facility, and Supporting Facility. Figure 4 shows the schema that shows indicator changes on Waste Bank Facility Component from the previous index to city-scale waste bank index.

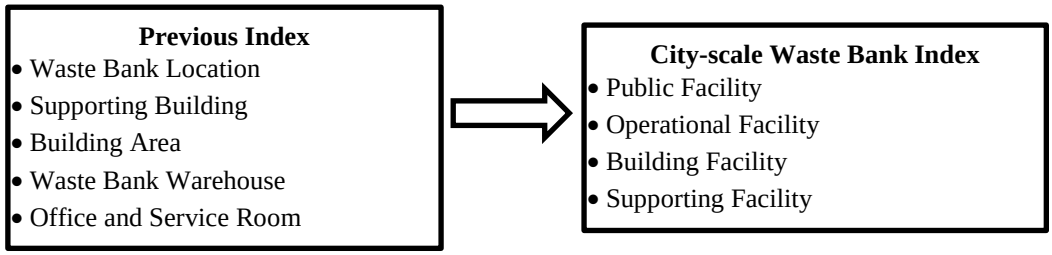

Figure 4. Schema of Waste Bank Facility Component indicator changes from the previous index to city-scale waste bank index.

3.3. Sub-indicator identification

Sub-indicator identification was done using a desk study method. Their decision referred to discussions in each selected indicator. If there were similar discussions, then they could be merged into a single sub-indicator. Client Indicator was discussed on every reference used in developing a city-scale waste bank index, but there were some points needed to be merged in assembling the indicators. Table 8a and 8b show a schema about Client Indicator's discussion.

Table 8a. Client indicator.

Indicator	Sub-indicators	Source
Client	1. Client increases 5-10 per month	Regulation No. 13 2012
	2. Own individual client	Previous Index
	3. Own grouped client	
	4. Own institution client	
	5. Own commercial client	
	6. Own more than 100 clients	Other Literature

Table 8b. Improved client indicator.

Indicator	Sub-Indicators
Client	1. Client Class
	2. Number of Clients
	3. Client Addition

3.4. Scoring criteria preparation

Scoring criteria was based on scoring points, which also included considerations from some possible condition on the research subject. Therefore, preparing the criteria required very detailed choices until

every single possible condition presented in the criteria. Table 9 presents an example of scoring criteria preparation of Human Resource sub-indicator.

Table 9. Scoring criteria preparation.

Sub-indicator	Scoring criteria	Score
Waste Bank's Human Resource	a. HRs are competent and experienced	100
	b. HRs are competent but inexperienced	50
	c. HRs are incompetent but experienced	50
	d. HRs are incompetent and inexperienced	0

It can be seen in Table 9 that there were two main points that can be used as a reference in scoring, namely "competency" and "experience". Both points were related to waste bank human resource, so both were used as scoring criteria on waste banks in the research subjects. If both points were fulfilled, the subject gained a score of 100, whereas if only one point is fulfilled, it gained 50. However, if neither of those points was fulfilled, it received a score of 0.

3.5. Component and indicator weightings

Component and indicator weightings were performed using AHP method, in which in its implementation, the method was used in finding out ranks to each indicator [7,8]. The process was done by answering questionnaires in the form of a matrix of paired comparisons by respondents who had adequate activity in waste management. They were professional experts, academics, agencies and waste bank administrators.

The questionnaire's answers were calculated using *Expert Choice II* application. In this application, there was a selection before combining opinions from all four categories. The selection was based on the value of consistency (R≥0.1) calculated automatically in the application.

3.5.1. Component weighting result. Component weighting was done using 4 respondent categories. Figure 5 presents a diagram showing the opinions of each respondent and the used final weighting.

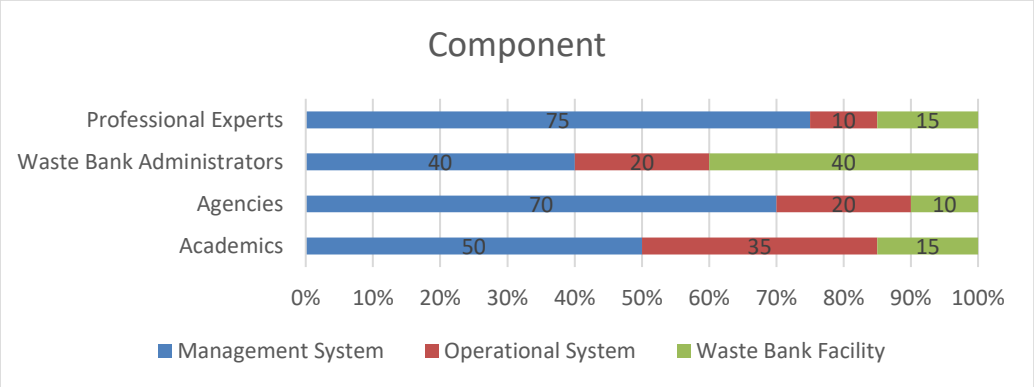

Figure 5. Component weighting diagram.

The component weighting result from each respondent was analyzed and only respondents with high consistency were selected and had its answers merged. Consistency calculation was done automatically using Expert Choice II. After doing the analysis, the consistency of components weighting from all respondent categories met the standard (≤0.1), this means all the answers can be merged. The results of the merged answer for component weighting are: System Management Component (55%), Operational System (25%), and Waste Bank Facility (20%).

3.5.2. *Indicator Weighting Result.* Indicator weighting was calculated using the same method as the previous, but the result had a more varying consistency from each respondent. The result from each respondent categories is shown in Figure 6.

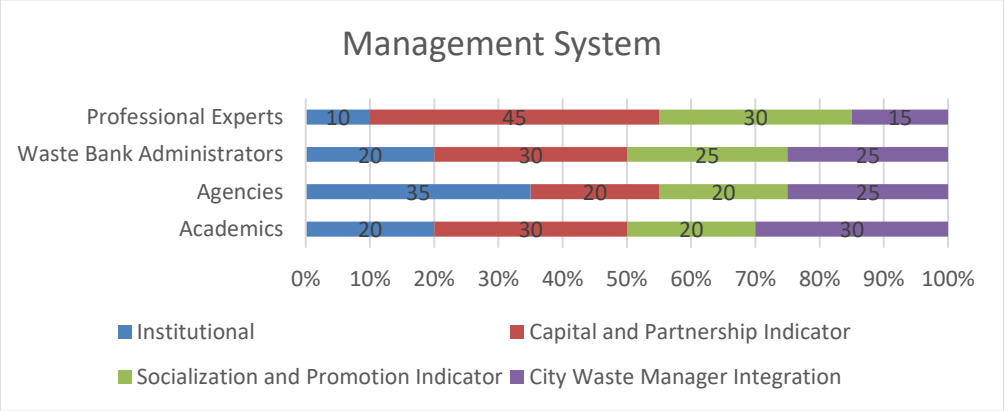

Figure 6. Management System weighting diagram.

There were only 3 consistent respondent categories in answering Management System indicator; they are agencies, academics, and waste bank administrators. The weighting results are: Capital and Partnership Indicator (35%), City Waste Manager Integration Indicator (30%), Institutional Indicator (20%), and Socialization and Promotion Indicator (15%).

Operational System indicator weighting only merged answers from two respondent categories, academics and waste bank administrators. The result from each respondent categories is shown in Figure 7.

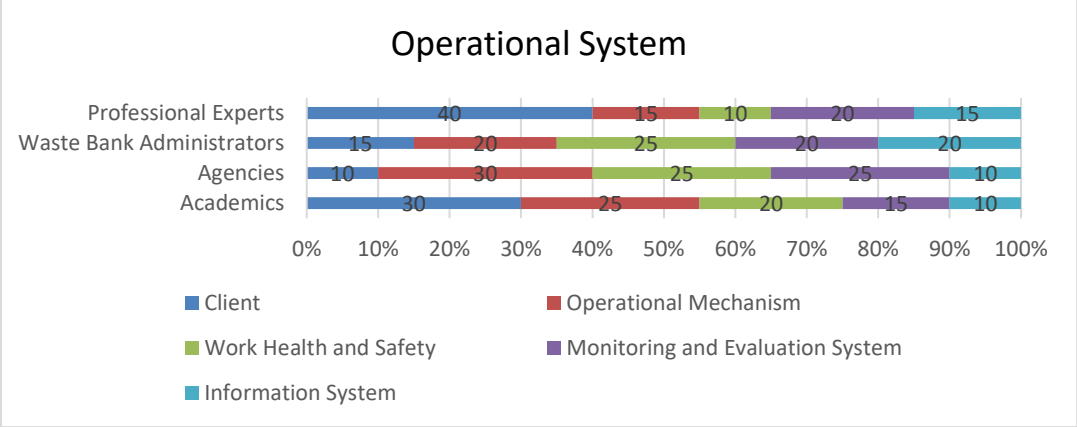

Figure 7. Operational System weighting diagram.

The final Operational System Indicator weighting results are: Work Health and Safety (25%), Operational Mechanism (20%), Monitoring and Evaluation System (20%), Client Indicator (20%), and Information System (15%).

Waste Bank Facility Indicator weighting was done by merging answers from three categories; they are from academics, agencies, and waste bank administrators. The result from each respondent categories is shown in Figure 8. The final results of Waste Back Facility Indicator weighting are: Operational Facility (45%), Building Facility (20%), Supporting Facility (20%), Public Facility (15%).

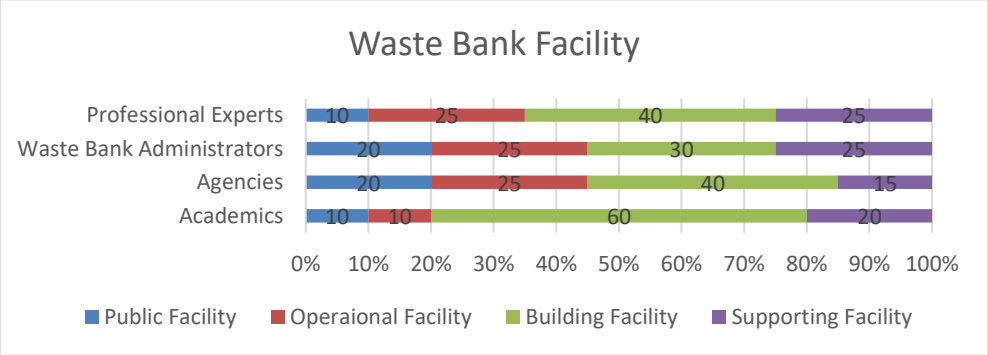

Figure 8. Waste Bank Facility weighting diagram.

3.5.3. *Sub-indicator weighting result.* Sub-indicator weighting was done by dividing the maximum weight score from an indicator with the number of sub-indicators in it. Table 10 shows an example of Monitoring System and Evaluation Indicator weighting.

Table 10. Sub-indicator weighting.

Indicator	Sub-Indicators	Weight
Monitoring and Evaluation System	1. Monitoring System	25%
	2. Evaluation	25%
	3. Repair Supervision System	25%
	4. Arrangement System	25%

The weighting was obtained from the division of the maximum score from the indicator (100%) with the number of sub-indicators owned by the indicator (there were four sub-indicators). Therefore, each sub-indicator gained weight of 25%.

3.6. Index Aggregation

Index aggregation was a process of merging several weights from an index [9]. In this study, aggregation was done using the arithmetic method. The method was based on the previous study [6], which describes that the arithmetic method uses a perfect substitution so that in result it will produce aggregated mean in most cases. This means the arithmetic method will not be affected whether there are differences in merged weights. Furthermore, it is easy to understand the operation of the arithmetic method. Based on these considerations, this study used the arithmetic method in aggregating indices. An example of index aggregation using this method can be seen in Table 11.

Table 11 Index Aggregation Example

Component	Indicator	%	Sub-Indicator	%	Criteria	%	Comment	Score	Final Score
Management System (40%)	City Waste Manager Integration	20	1. Target	50	a. Own target and in accordance with the government's target	100	Target is 25% reduction from source	100	50
					b. Own target but not in accordance with the government's target	50			
					c. Doesn't own target	0			
			2. Coop	50	a. There is cooperation with city waste management operator	100	Hygiene Trading Company	100	50
					b. There is no cooperation with city waste management operator	0			

K = Component, I = Indicator, SI = Sub-indicator

3.7. Index interpretation

Index interpretation shows the final score of each subject, which are used here as research subjects. Table 12 shows an example of index interpretation from some sources that were used as a reference is creating interpretation scale in city-scale waste bank index.

Table 12. Index interpretation example.

CCME WQI[a] [10]		NSF WQI[b] [10]		WJWSI[c] [6]	
Score	**Interpretation**	**Score**	**Interpretation**	**Score**	**Interpretation**
0-44	Poor	0-25	Very Poor	0-<25	Poor Enough
45-64	Poor Enough	25-50	Poor	25-<50	Poor
65-79	Mediocre	50-70	Mediocre	50-<75	Good
80-94	Good	70-90	Good	75-100	Very Good
95-100	Very Good	90-100	Very Good		

[a] *CCME WQI: Canadian Council of Ministers of the Environment*
[b] *NSF WQI: National Sanitation Foundation Index*
[c] *WJWSI: West Java Water Sustainability Index*

The scale used in references above was 0-100, with 0 and 100 as the minimum and maximum score, respectively. The scale was also used in this study since the references in Table 12 were also used. The references also have the same discussion with this study, which is about index preparation. The differences in interpretation from each source were in their scale division. Table 13 shows the interpretation scale to be used in city-scale waste bank index.

Table 13. Index interpretation.

Index Aggregation	Interpretation
0-<25	Very Poor
25-<40	Poor
40-<60	Moderate
60-<80	Good
80-100	Very Good

Table 13 shows that this study had five interpretation levels, similar to the Canadian Council of Ministers of the Environment and National Sanitation Foundation Index [10]. The interpretation result describes the whole score from scoring result, which is an aggregate of component, indicator and sub-indicator scores. The five interpretation levels' confirmation was done so it can describe a waste bank condition in detail [11]. Furthermore, the distance between each level should not be too far to increase the probability of obtaining the best interpretation.

4. Conclusion

City-Scale Waste Bank Index consists of 3 components and 12 indicators, which are further divided into several sub-indicators. The 3 components and their weights are Management System Component (40%), Operational System Component (30%) and Waste Bank Facility Component (30%). Each component is divided into several indicators. There are 4 indicators in Management System Component; they are Capital and Partnership Indicator (35%), City Waste Manager Integration Indicator (30%), Institutional Indicator (20%), and Socialization and Promotion Indicator (15%). Operational System Component consists of 5 indicators; they are Work Health and Safety (25%), Operational Mechanism (20%), Monitoring and Evaluation System (20%), Client Indicator (20%), and Information System (15%). In Facility Component there are 4 indicators; they are Operational Facility (45%), Building Facility (20%), Supporting Facility (20%), Public Facility (15%). The method used in the aggregation was an arithmetic method. There is five interpretation level from the scale of 0-100.

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