IOP Conference Series: Earth and Environmental Science

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Conference on Sustainability Science 2018 9–10 October 2018, Bandung, Indonesia

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Conference on Sustainability Science 2018 9–10 October 2018, Bandung, Indonesia

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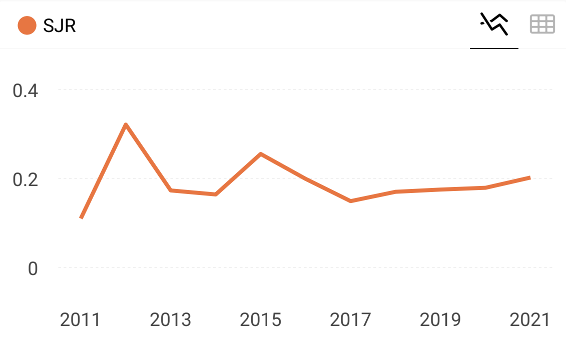

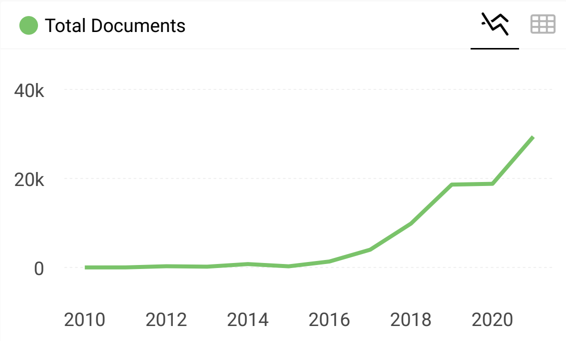

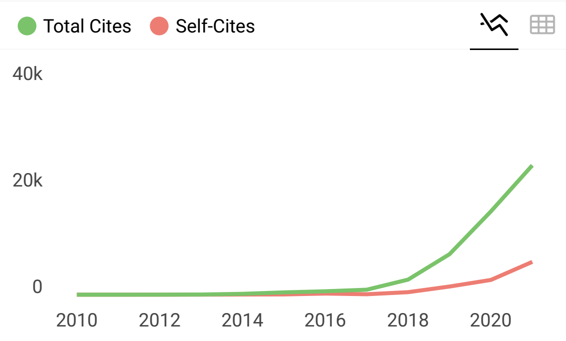

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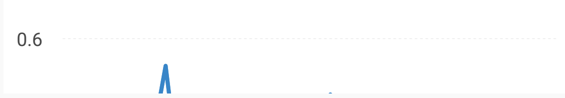

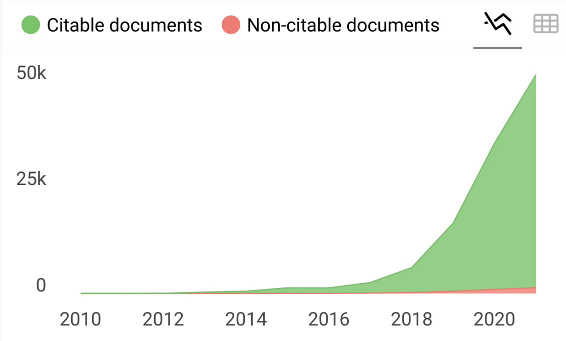

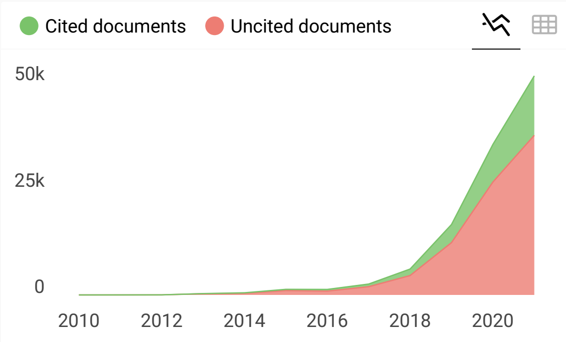

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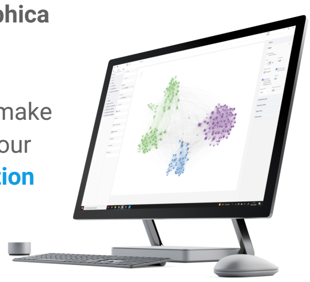

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Development of a solid waste service level index

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Development of a solid waste service level index

A A Rumakat[1],*, I Juwana[1], and S Ainun[1]

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Abstract. The performance of municipal solid waste management (MSWM) system can be determined by assessing its level of services. In Bandung City, the level of solid waste service was determined based on the amount of solid waste being transported to the final disposal site. According to the data from Cleaning state Company of Bandung City in 2017, the percentage of solid waste service level was 98.14%. However, it is visible that a large amount of solid waste at some of the temporary collection sites, riverbanks and runnels remains un-transported. This, and other evidences, indicated that the existing service level performance value was not representative for the overall solid waste service. Thus, this study aims to develop a solid waste service level index which can be used to assess performance of the MSWM Level of Service (LoS). This study was undertaken by selecting components, indicators and sub-indicators which are related to MSWM services, determining the weights for the components, indicators and sub-indicators, as well as defining the aggregation and interpretation of the final index. During the selection of components, indicators and sub-indicators, main literatures used were the Indonesian Government Regulation Number 81 of 2012, the Ministry of Environment Regulation Number 6 of 2014, Integrated Waste Management Scoreboard (IWMS) and Key Performance Index (KPIs) for MSWM. Through this study, 5 components, 26 indicators and 21 sub-indicators were identified and were rigorously analysed. The components were Technical Operation, Institution, Regulation, Finance and Public Participation. Weighting technique used for the index was the subjective weighting. Aggregation index using arithmetic method with the interpretation of the final index was made based on 5 categories and resulted is 76% LoS of Bandung City. In the near future, the developed index can be used to assess better the LoS of the MSWM of Bandung City.
Keywords: component, index development, indicator, service level, sub-indicator.

1. Introduction

Performance of municipal solid waste management (MSWM) can be represented by the level of service (LoS) in this study area. The LoS can reflect the efficiency of the MSWM. Another way to know whether the solid waste has been well managed can be determined based on the amount of solid waste being transported to the final disposal site [1]. According to the data from *PD. Kebersihan Kota Bandung* (Cleaning State Company of Bandung City) in 2017, the percentage of solid waste LoS was 98.14% [2]. However, the value could not well represent the overall solid waste service because of large amount of solid waste dumped at some Temporary Collecting Sites (TPS) or illegal TPS, riverbanks and runnels which was not accounted and remained un-transported [2,3].

Another way to assess the city solid waste performance is through the procedures applied in Adipura award. However, this award does not include only on solid waste aspect, but also on the green open space, clean water and air quality monitoring [4]. Lack of focus on its regulations on the solid waste assessment, is the main reason for not using this tool to assess the level of service (LoS) of the MSWM.

Those issues indicate that the current assessment tools for solid waste performance has not represented the performance of the overall LoS of MSWM. Therefore there is a need to develop new methodology which can be easily used in an integrated manner to cope with all aspects of MSWM. The purpose of this research is to develop an integrated MSWM LoS index at city-scale with the aims of identifying components, indicators, and sub-indicators, weighting the index, determining aggregation and index interpretation.

2. Methodology

2.1. Identification of the components, indicators and sub-indicators as well as determination of the assessment criteria

The identification processes of the components, indicators, and sub-indicators as well as determining the assessment criteria are given on figure 1.

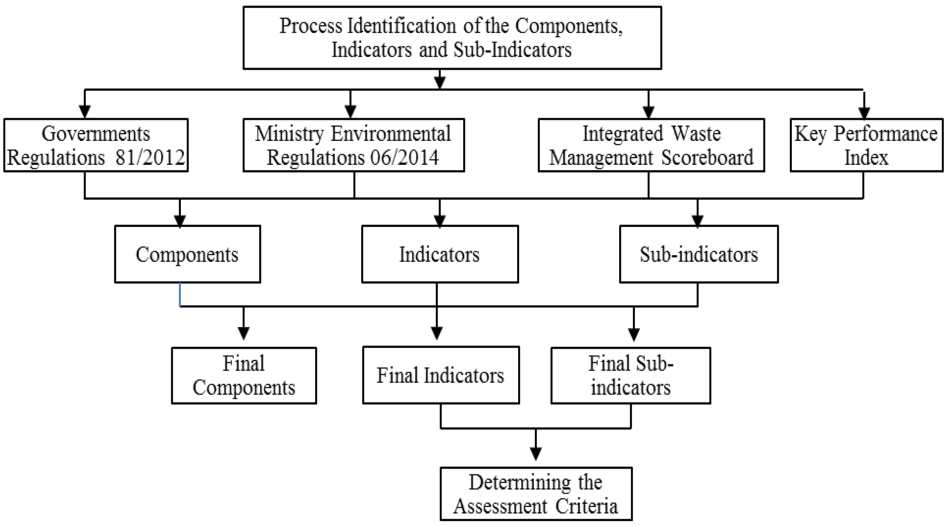

Figure 1. Identification processes of the components, indicators and sub-indicators as well as determining the assessment criteria.

Based on figure 1. the process consist two stages : (1) the first stage focuses identification process based on four main literatures, namely Indonesian Government Regulation (IGR) Number 81 of 2012, the Ministry of Environment (MoE) Regulation Number 6 of 2014, Integrated Waste Management Scoreboard (IWMS) [5], and Key Performance Index (KPIs) for Solid Waste Management [6], which will produce an initial interim framework of the components, indicators and sub-indicators and (2) the second stage classifies the identified components into the five planned components such as technical operation, institution, regulation, finance and public participation. This classification process is considered based on the theoretical and similarity discussion on the main literatures. The next step is to classify indicators and sub-indicators into the five components which was developed previously. The classification process is considered based on the scope discussion of the components. Thus, it will be producing a final framework consisting the final of the components, indicators and sub-indicators is identified. The final step is determining of the assessment criteria by analyzing all selected indicators and sub-indicators, which one can be assessed optimally.

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2.2. Weighting

In the index development, weighting was used to determine the weight value of the components, indicators and sub-indicators. The weighting was performed using this solid waste service level index by assigning different weighting values to the components, indicators and sub-indicators. This is because determining the weigh value needs to consider the criteria and expert judgment. This evidence makes the weighting of the components, indicators and sub-indicators be different [7,8]. Ranges of weighting values can be a fraction (0-1) or percentage (0%-100%) [8]. The processes of determining the weighting value were started with the components and then were followed by the indicators and sub-indicators [8,9].

2.3. Aggregation

Index aggregation process was done by combining components, indicators and sub-indicators. The flow diagram of index aggregation process is presented in figure 2.

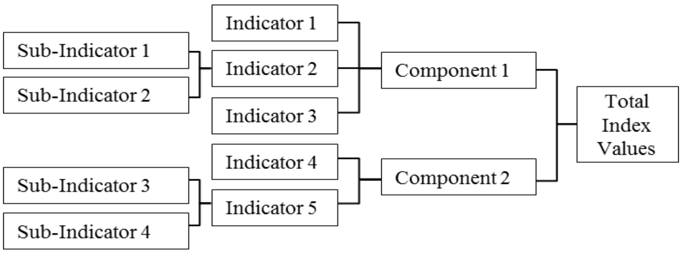

Figure 2. Index aggregation processes

This aggregation was performed to find out the final value of the LoS [9]. Two most common methods for aggregation of sub-indices are the arithmetic and geometric methods (Nardo et al., 2005 *cited in* [9]). These methods are applied through the summation of weighted sub-index values [9,10]. Equation of the arithmetic method is given in equation (1).

$$I = \sum_{i=1}^{N} wiSi \tag{1}$$

where (I) represents the aggregated index, (N) is the number of indicators to be aggregated, (Si) is the sub-index for indicator i and (wi) is the weight of indicator i. The other common method used for aggregation is the geometric method as given in equation (2).

$$I = \prod_{i=1}^{N} Si^{Wi} \tag{2}$$

the symbols for equation (2) are the same as for equation (1).

The difference between the arithmetic method and the geometry method is that the resulting aggregation value is not the same from the components, indicators, and sub-indicators if it has a significant differently sub-index value. e.g. indicators 1 and 2 have the same sub-index value is 30 and in other cases indicator 1 have a sub-index value 0 and indicator 2 have a sub-index value of 60 with equal weighting. Using arithmetic methods for both cases will produce the same aggregation values is 30. Whereas if using geometric method, the aggregation value of the first case was 30 and 0 for the second case. Thus, the index aggregation method using in this study is arithmetic method because it is not affected by different significant sub-index values [9,10].

2.4. Index Interpretation
Index interpretation is required to determine the readiness value of the final index development. In the case of city-scale waste-bank assessment, the index interpretation was made into 2 categories. The result given if were the index value obtained in the ranges of 0-<55,20 is not to be developed, but if the range of index values were >55,20-100 the waste-bank is ready to be developed [11]. Furthermore, there are several other indices that perform similar interpretation processes, but are divided into several categories, as well as 5 categories such as the Canadian Water Quality Index (CWQI) [12], and the National Sanitation Foundation Water Quality Index (SFWQI) [13] and 4 categories such as the West Java Water Sustainable Index (WJWSI) [9].

3. Methodology

3.1. Identification of the Components, Indicators and Sub-Indicators.
The process of identifying components, indicators and sub-indicators refers to Indonesian Government Regulation (IGR) Number 81 of 2012 on household solid waste management [14], the Ministry of Environment (MoE) Regulation Number 6 of 2014 on Guidelines for Implementation of Adipura Programs, Integrated Waste Management Scoreboard (IWMS) and Key Performance Index (KPIs) for Solid Waste Management. The identification also considers the structure of each main literature. For example, Indonesian Government Regulation Number 81 of 2012 and the Ministry of Environment Regulation Number 6 of 2014 consist at chapters, verses and clauses. These three factors one used to analyze the components, indicators and sub-indicators for the new index. To simplify this discussion, Figure 3. shows the relationship between the components, indicators and sub-indicators which are represented by Indonesian Government Regulation Number 81 of 2012 and the Ministry of Environment Regulation Number 6 of 2014.

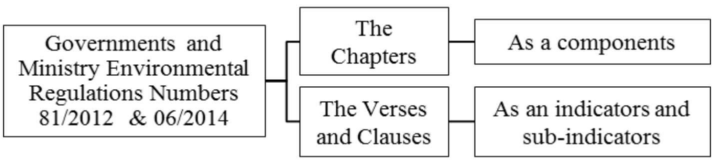

Figure 3. Flow Chart of determining the Component, Indicator and Sub-Indicator

A chapter is considered as a component, because basically the chapters have more general information than the verses and the clauses. The given name of components means that the name can represent some indicators and sub-indicators which have similar characteristic of discussion. However, the chapter can also be served as an indicator if the previous components are more common to represent the existing indicators. The verse of the clauses in those rules can be used as an indicator because the clauses generally have more detailed explanation of the chapter. Furthermore, it can also be used as a sub-indicator if the determining of the indicators have still general meaning, so there is a need to have further explanation.

3.1.1. Identification of the Components. The selection of components in the MSWM LoS refers to the four main literatures was used previously. According to the Ministry of Public Works Regulation Number 3 of 2013 on the Implementation of Infrastructure and Solid Waste Facility in the Household Solid Waste Management as mentioned in verse 5 paragraph 2 point c, there are 5 aspects related to MSWM i.e. technical operation, institution, regulation, finance and public participation [15]. These aspects were used as a component in the service level index. Because these aspects are expected to be implemented easily, as well as represented the handling and reduction factors that have been implemented.

3.1.2. Identification of the Components. The next step after determining the components is to identify the indicators to be matched with the components considering the discussion of the components itself. For example, identification of indicators has been done to be matched with the component of technical operation from the MoE Regulation Number 6 of 2014. Basically, the components of technical operation discussed about limitation of solid waste, waste recycle, waste recovery, storage, collection, transportation and process of solid waste as well as the final disposal site. Based on the description, indicators were identified from MoE that included into the component of technical operation is solid waste recovery, 3R (reuse, reduce, recycle) and disposal site. The same processes to determination indicators to be matched with the components of technical operation were done also for the IGR, IWMS and KPIs. Final indicators were finally determined based on the component of technical operation and are presented in table 1.

Table 1. Indicators of the Component of Technical Operational

Components	Indicators	Final Indicators
Technical Operation	Handling and reducing waste	Storage
Technical Operation	Waste processing	Collecting
Technical Operation	3R (reuse, reduce, recycle)	Transportations
Technical Operation	Final disposal site	Final disposal site
Technical Operation	Storage and collecting	Solid waste reduction
Technical Operation	Transportations	-
Technical Operation	Recycle	-
Technical Operation	Access	-
Technical Operation	Final disposal site	-
Technical Operation	Collecting and transportation	-
Technical Operation	Collecting and transportation frequently	-

Some identified indicators given on Table 1. have similar discuss between one indicator and others, so it needs to be integrated. The processes of integration were done by identifying the indicators which have the same or similar category of discussion. In the determination of indicators, it is allowed to change the name of indicators because the new name can represent some integration of the indicator. For example, indicator 3R (reuse, reduce, and recycle) and waste processing from the MoE Regulation Number 6 of 2014 and recycle from IWMS are discussing the similar thing i.e. solid waste reduction. The similarity of the category makes it necessary to change the name of the indicators, so the new name can represent these three indicators previously is reducing of solid waste. The same identifying processes were done also for the components of institution, regulation, finance and public participation. The recapitulation of the indicators is given in table 2.

Table 2. Recapitulation of the Components and Indicators

Components	Indicators
Regulation	Content of the rules Rules disclosure information Legal Policy
Finance	Compensation of the impacts in disposal site Expenditure of the solid waste services Labour healthy
Technical Operation	Storage Collecting Transportations Final disposal site Solid waste reduction
Institution	Monitoring and supervision Solid waste policies and strategies City cleanliness

Table 2. Recapitulation of the Components and Indicators

Components	Indicators
	Provision of the fleet transport Solid waste-related research Municipal solid waste management programs Sanitary landfill Temporary collecting sites of B3 medical Development of TPS and TPST Improved the transport system Solid waste disclosure information
Public Participation	Implemented of solid waste management Society awareness Community participation School awareness

3.1.3. Identification of the sub-indicators. The processes of sub-indicator identification were done based on selected of the final indicators. Some of identified indicators have sub-indicators, but some do not because they have been discussed already. Based on the description, it is shown that all of the components necessarily have the associated indicators and sub-indicators. E.g. identification of the sub-indicators of the components of technical operation. Basically, identifying indicator previously shown as the components of technical operation have 5 selected indicators, one of them is transportation. When solid waste has been produced in a city, generally it has to be transported by conveyance to the final disposal site. Furthermore, frequency and access of the transportation would affect the amount of solid waste being transported to the final disposal site, because both are considered to be the transportation-relevant indicator. The same processes were done for the identification of the sub-indicators as well as the indicators of the components of institution, regulation, finance and public participation. The recapitulation of the sub-indicators is presented in table 3.

Table 3. Recapitulation of the Sub-Indicators

Components	Indicators	Sub-Indicators
Regulation	Content of the rules	-
	Rules disclosure information	-
	Legal Policy	-
Finance	Compensation of the impacts in disposal site	-
	Expenditure of the solid waste services	Solid waste transporting cost Solid waste facilities cost for collecting and transportation Salary of the labours
	Labour healthy	-
Technical Operation	Storage	-
	Waste collecting	-
	Transportation	Waste transported Transportation frequently Transportation access
	Final disposal site	Land Waste throw away in disposal site Landfill distance to the residential, watershed, and beach area. Lifetime of the disposal site Support facilities in disposal site

Table 3. Recapitulation of the Sub-Indicators

Components	Indicators	Sub-Indicators
	Solid waste reduction	Number of conveyances in disposal site Waste processing 3R (reuse, reduce, recycle)
Institution	Monitoring and supervision	-
	Solid waste policies and strategies	Target of reducing waste Target of handling waste
	City cleanliness	-
	Provision of the fleet transport	-
	Solid waste-related research	-
	Municipal solid waste programs	Waste-banks Programs 3R Programs
	Sanitary landfill	-
	Temporary collecting sites of B3 medical	-
	Development of TPS and TPST	-
	Improved the transport system	-
	Solid waste disclosure information	-
Public Participation	Implemented of solid waste management	Participation of solid waste management Willingness to pay of solid waste services
	Society awareness	-
	Community Participation	-
	School awareness	-

3.1.4. Determination of the Assessment Criteria. Assessment criteria was determined in order to be able to assess the MSWM LoS index. The determination was done by identification of all selected indicators and sub-indicators and then the indicators and sub-indicators can be assessed optimally. This assessment criteria are equipped with some values, that means all of the criteria have been made are associated with their own assumption. For example, the assessment criteria of the solid waste disclosure information indicator as one indicator of the component of institutions is presented in table 4.

Table 4. Examples of the Assessment Criteria

Indicators	Assessment Criteria	Values (%)
Solid waste disclosure information	Key information is available, accessible and regularly updated	100
	Key information is available, accessible and not regularly updated	75
	Key information is available but just few key information accessible	50
	Key information is not available	0

3.2. Weighting

Ranges of the weighting value used was in a range of 0%-100% with given different weighting value on the components, indicators and sub-indicators. Example of weighting for the components is given on table 5.

Table 5. Weighting of the Components

No	Components	Weighting (%)
1	Regulation	15
2	Finance	20
3	Technical Operation	25
4	Institution	25
5	Public Participation	15

Identification process of the weighting value as given on Table 5. considers of the importance level of the components. The components of technical operation and institution have higher value than other, because these components are considered to be more important. Furthermore, both of the components are parts of the planning and implementation aspect of the MSWM and have a higher number of indicators and sub-indicators (e.g. total 16 to the components of technical operation and 12 to the components of institution). The component of regulation and public participation has the lowest value because it has the least number of indicators and sub-indicators (3 each).

3.3. Aggregation

Solid waste service level Index value can be determined by aggregating the sub-indicators, indicators and components. This aggregation value will generate the final index values by using the arithmetic method. Examples of the aggregation step is presented in table 6.

Table 6. Examples of Aggregation Index

Component (weighting)	Max. Value of C[b]	Indicators (Weighting)	Max. Value of I[a]	Criteria	Assessment (%)	Total Values	
						I[a]	C[b]
Regulation (15%)	15	Content of the rules (34%)	5.10	Set up retributions and solid waste deducting target	100	5.1	12
		Rules disclosure information (33%)	4.95	Key information is available, accessible and not regularly updated	100	4.95	
		Legal Policy (33%)	4.95	Law enforcement procedures available, supported by human resources and finance, but not implemented	50	2,48	

[a] Indicators.
[b] Components.

The value of assessment criteria as given on Table 6. is shown as the result of the assessment of MSWM LoS in Bandung City as an example. Thus, the calculation of the aggregation of the final index is given as follows:

Indicators 1 Value = $wiSi$
= 100% x 5,10
= 5,10

Next step is calculation the component values that was done by summing up all of the indicators value on each related component. The calculation of the components of regulation is given below:

Regulation = Σ Indicators values
= Indicators (content of the rules + rules disclosure information + legal policy)
= 5,1 + 4,95 + 2,48
= 12

The final index values can can be calculated as summation of 5 component values. The values were done for the assessment using 13 for the component of regulation, 16 for the components of finance, 14 for the component of technical operation, 21 for the component of institution and 13 for the component of public participation. The calculation of the final index is:

Final Index = Σ components values
= Components (regulation + finance + technical operation + institution + public participation)
= 12 + 16 + 14 + 21 + 13
= 76

3.4. Aggregation
Index interpretation is an important step to understand the aggregated index value. So far to our knowledge, index interpretation of MSWM LoS was not available in any literature. Thus, the approach was done similarity to that used in water interpretation index. These indices are CWQI, SFWQI and WJWSI. The interpretations of these three indices are given on Table 7.

Table 7. Index Interpretation of CWQI, SFWQI and WJWSI

No	CWQI[a]		SFWQI[b]		WJWSI[c]	
	Value	**Performance**	**Value**	**Performance**	**Value**	**Performance**
1	95-100	Excellent	90-100	Excellent	75-100	Excellent
2	80-94	Good	70-90	Good	50-<75	Good
3	65-79	Fair	50-70	Fair	25-<50	Marginal
4	45-64	Marginal	25-50	Marginal	0- <25	Poor
5	0-44	Poor	0-25	Poor		

[a] Saffran, Cash, Hallard, Neary, & Wright, 2001.
[b] Brown, McClelland, Deininger, & Tozer, 1970.
[c] Juwana, 2012

The existing indices (i.e. CQWI, SFWQI and WJWSI) are the interpretation made based on the maximum range of the three values. They used the 0-100 indices scale. The value of an indicator is considered to be preferable if it is closer to 100 and not preferable if the value is closer to 0. For the MSWM LoS, the interpretation index was made based on 5 categories with the maximum value of 100 and the minimum value of 0. The classification of the final index interpretation as given on table 8.

Table 8. Final Index Interpretation

No	Value	Performance
1	80-100	Excellent
2	60 - <80	Good
3	40 - <60	Fair
4	20 - <40	Marginal
5	0 - <20	Poor

Five categories of the final index interpretation were identified based on comparison of these existing indices (i.e. CQWI, SFWQI and WJWSI). Furthermore, the categories of the index interpretation are considered to be more detailed to assess the MSWM LoS.

4. Conclusion
This paper focussed on developing the framework of the MSWM LoS. This was done by exploring the most important components, indicators and sub-indicators for measuring MSWM performance and to formulate an index for decision-making. Some result are expected to be presented here for five components, twenty-six indicators and twenty-one sub-indicators were identified. Subjective weighting was used to weight and prioritize component, indicators and sub-indicators so that objectives and targets

are set to address MSWM issues. The interpretation of the final index was done based on 5 categories of 0-100 scale. The developed index can help to rigorously assess MSWM performance which can help to based evidences for the decision-making to support system in the area of MSWM.

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