Indicators for Measuring Performance of Municipal Solid Waste Management in Khartoum State

Hala Misbah Elsadig[1], Kamal ElTayeb[2]

Abstract

Population and urbanization growth caused an increase in the amount of solid waste generated. The 7- cleaning projects responsible for the collection and transport of Solid Waste (SW) for Khartoum State are currently unable to perform their duties to the level expected with the result that the city is unclean and there is considerable impact on the environment and health of the citizens. There is a need to quantify these general observations. This is done by the use of Key Performance Indicators (KPIs). This paper aims to identify a set of KPIs for measuring the performance of Solid Waste Management (SWM) system at the collection and transport level. The study targeted the 7-cleaning projects -in particular, the operation department responsible for collection and transport of SW for each cleaning project together with the operation department at the Supervisory Authority of Cleaning Khartoum (SACKH) which supervises their work. List of 28 potential performance indicators have been identified through the literature review. A survey questionnaire was conducted on a randomly selected sample of the operation departments . The statistical analysis of the collected responses was provided in 11 significant KPIs. It is hoped that the results of this study will become the first step in developing Integrated KPIs for enhancing the performance of SWM of Khartoum state- the capital of Sudan.

Key Words: Solid Waste Management (SWM); Key Performance Indicators (KPIs); Khartoum Cleaning Projects, Khartoum State

مستخلص

ان زيادة السكان والتوسع العمرانى سبب فى زيادة كميات النفايات الصلبة المنتجة بولاية الخرطوم. فى الوقت الحاضر مشاريع النظافة المسؤولة عن نظافة ولاية الخرطوم عاجزة عن تحقيق هذه المهمة بالمستوى المطلوب وهذا أدى إلى عدم نظافة المدينة وأثر سلباً على البيئة وصحة المواطن. لذلك أتت الحوجة لقياس هذه الملاحظات وذلك بإ ستخدام مؤشرات الأداء .إستهدفت الدراسة قسم العمليات بمشاريع النظافة–المسؤولة عن نقل النفايات– والهيئة الاشرافية لنظافة ولاية الخرطوم وهى المشرفة على العمل. تم تعيين 28 مؤشر أداء من البحوث السابقة وتم توزيع إستبيان على عينات من قسم العمليات. أوضح التحليل الأحصائى 11 مؤشر أداء والتى ستساعد فى إدارة النفايات بولاية الخرطوم.

1- Hala Misbah Elsadig, Institute of Engineering Research & Materials Technology- The National Centre for Research, Sudan . email hala.misbah@yahoo.com
2- Kamal ElTayeb, Departement of Chemical Engineering, University of Khartoum,Sudan Email keetyeb@u of K.edu

1.Introduction

1.1 Solid Waste Management (SWM)

Solid Waste is the unwanted solid materials generated from combined residential, industrial and commercial activities in a given area; management of solid waste reduces or eliminates adverse effects on the environment and human health and support economic development and improved quality of life. In general factors affecting solid waste management (SWM) are waste generation, Storage, collection, transport, processing and resource recovery, and final disposal (1).

1.2 Key Performance Indicators for Solid Waste Management

A key Performance Indicator (KPI) is a measure of performance. It is a quantitative measure of whether the system is delivering its service at the desired level (2).

1.3 Solid Waste Management in Khartoum State

In 2010, a survey implemented by Japan International Corporation Agency (JICA) showed that there is significant lack of appropriate waste collection and disposal systems and decided to support capacity development in SWM in Sudan. The house to house collection became the responsibility of the cleaning projects while the Supervisory Authority of Cleaning Khartoum (SACKH) became responsible for the transfer stations and dumping area in addition to supervision of the cleaning projects (3).

1.4 Study area

The study area covers the jurisdiction of Khartoum State, which has an area of 22,122 Km2, and is the capital of Sudan. The state of Khartoum is divided into seven localities. According to SACH, the estimated generation amount of SW is 3,635 tons/day (4).

1.5 Objective

The research objective is to identify the most important KPIs that can be used to evaluate the performance of the operation department in Khartoum- State cleaning projects. This will be the first step in developing integrated KPIs for SWM in Khartoum State.

2.Research Methodology

To determine and analyze the set of perceived KPIs , the operation departments for the 7 cleaning project and SACKH were targeted and a representative sample of this population was determined.

The potential KPIs that can be used to evaluate the performance of the operation departments were identified from the literature review. These KPIs formed the basis of a questionnaire, which was used to sample the opinions of experienced personnel involved in solid waste collection and transport on the degree of importance of the KPIs. In analyzing and ranking the results, the relative importance index was used (5, 6). The detailed research approach is thoroughly introduced in the following sections.

2.1 Performance indicators and questionnaire design

A set of 28 raw KPIs were obtained from literature review. These indicators were classified under 10 performance groups which are illustrated in table (1).

Table (1) Summary of Performance Indicators at Collection & Transport Level.

No.	Performance Indicators	Groups
1	Coverage	Collection &Transport
2	Frequency of collection	
3	Complaints (from odor, flies, attitudes of workers…)	
4	Flies Density	Env. & area cleaning
5	Diseases due to flies	
6	Overall area cleaning	
7	Incineration & smoke	
8	Demographic Information	Generation
9	Quantities	
10	Number	Physical resources
11	Readiness	
12	Type	
13	Efficiency	
14	Average downtime	
15	Number	Human resources
16	Wages & fringe benefits	
17	Awareness & training programs	Education, awareness & training
18	Behavior of individuals	
19	Development & implementation of transfer stations	Processing & resource recovery
20	Separation from source	
21	Separation & treatment from source	hazardous medical waste
22	Density	Waste characteristics
23	Moisture	
24	No. of communal containers	Storage
25	Type of communal containers	
26	No. of individual containers	
27	Type of individual containers	
28	Household containers	

The classified 28 KPIs formed the basis of a questionnaire survey. The questionnaire was developed in accordance with the objective of the research which was to identify the significant KPIs. It is divided into two major parts; the first part contained questions that seek to identify the level of experience of the respondents and whether they are using KPIs in their work. In the second part , the SW personnel were asked to rate each KPI based on their professional judgment. Ordinal scale used in this study was adopted from Enshassi et al (7) (where1= not important, 2= low importance, 3= medium importance, 4= high importance, and 5= very high importance). In addition, there were group discussions with the respondents concerning problems of SWM in Khartoum-State.

Prior to data collection work, a preliminary study was carried out by conducting discussions with 3 experienced persons who are involved in SWM. This was done to validate the contents of the questionnaires for the relevancy with Sudanese SWM sector. Data were collected using a developed structured questionnaire.

2.2 Sample size

The target population of the study are the operation departments of the 7 cleaning projects covering the 7 localities of Khartoum state and SACKH which supervises their work. The responsibility of the operation department at the cleaning project is the house to house collection of solid waste using a scheduled collection frequency. The SW is then transported to the transfer station.

Waste Management Flow chart in Khartoum State is shown below

Fig. (1): The Waste Management Flow Chart in Khartoum State

The operation department at each cleaning project is divided into service sectors covering each locality .Each sector is responsible for the following: House to house waste collection (including hospitals and clinics waste but not hazardous medical waste), Markets waste collection, Open areas cleaning, and Streets sweeping and drain cleaning.

The total number of sectors in the 7 cleaning projects is 37. These number of sectors are increased from time to time for administrative reasons. These number of sectors together with the operation department at (SACKH) made a total population of 38. The sample size that would represent this population was calculated based on the following formula (8) :

$$n = n' / [1 + (n' / N)]$$

Where $n' = p\{1 - p\} / v^2$

Where n= the required sample size, n' = the first estimate of the sample size, N = the population size , p = the proportion of the characteristic being measured in the target population, and v = standard error of sampling population. For the purpose of getting the maximum sample size, the value of p was taken as 0.5. According to Al-Mahasheer (9), the standard error used in determining the sample size was set equal to 10 % which represents the maximum standard error allowed giving a minimum response rate of 39.5%. Total of 38 questionnaires were distributed to the health officers who are managing the service sectors.

2.3 Data Analysis

The participating respondents have provided numerical scoring expressing their opinions on the degree of importance of each KPI. The relative importance of the KPIs was identified using the relative importance index(RII).

$$RII = \frac{\sum_{i=1}^{5} Wi\,Xi}{A \times n}$$

Where Wi = the weight given to the ith response: i=1,2,3,4,5, Xi = frequency of the ith response, A = the highest weight (5 in this study), and n = the number of respondents

3. Results and Discussion

3.1 Results

3.1.1 Response Rate

The questionnaire survey was carried out by distributing a total of 38 questionnaires to the targeted population. A total of 23 questionnaires were completed and returned, resulting in a 60.5% response rate, which is greater than the minimum required response rate of 39.5%.

3.1.2 Characteristics of respondents

The respondents were asked to provide the number of years of experience in SWM. The majority of the respondents have more than 7 years of experience. This experience in SWM should give a high reliability for the results of the study.

3.1.3 Extent of applications of KPIs

The operation departments at the 7-cleaning projects identified 2 KPIs ;

amount of waste collected and density of flies to evaluate their performance on a regular basis. For monitoring the work of the cleaning projects, SACH identified 5KPIs; Frequency of collection truck, degree of satisfaction of service, insects breeding, illegal dumping and degree of cleanliness (streets, open areas ,drains , communal containers). The respondents agreed on the importance of other indicators.

3.1.4 Ranking of performance indicators

The main purpose of this step is to identify the appropriate KPIs that can be used to measure the performance of the operation department in SWM. The following Table (2) shows the mean value, standard deviation and Relative Importance index (RII) of 28 indicators. Standard deviation of each indicator was relatively small.

Normally, the organizational performance is measured in terms of KPIs. According to Swan and Kyng (10), the application of any KPI system will become very difficult if there are too many measures, so the number of indicators must be limited to about 8-12.

Table (2) Ranking of Performance Indicators

No.	group	Performance indicator	Mean	Standard deviation	RII %
1	Collection & transport	Coverage	4.91	0.29	98.3
2	Env. & area cleaning	Flies density	4.87	0.34	97.4
3	Generation	Demographic information	4.78	0.42	95.6
4	Physical resources	number	4.78	0.42	95.6
5	Physical resources	readiness	4.78	0.51	95.6
6	Education, awareness & training	Awareness & training programs	4.78	0.51	95.6
7	Education, awareness & training	Behavior of individuals	4.78	0.51	95.6
8	Collection & transport	frequency	4.69	0.55	93.9
9	Human resources	number	2.83	0.72	91.3
10	Env. & area cleaning	Diseases due to flies	4.56	0.72	91.3
11	Human resources	Wages, fringe benefits	4.52	0.78	90.4
12	Generation	quantities	4.48	1.03	89.6
13	Physical resources	Type	4.48	0.72	89.6
14	Processing & resource recovery	Development & implementation of transfer stations	4.43	1.07	88.7
15	Env. & area cleaning	Overall area cleaning	4.39	0.98	87.8
16	Hazardous medical waste	Separation & treatment at source	4.26	1.54	85.2
17	Waste characteristic	density	4.04	0.92	80.9
18	Human & physical resources	efficiency	4.00	1.20	80
19	Processing & resource recovery	Separation at source	3.96	1.39	79.1
20	Collection & transport	complaints	3.87	1.32	77.4
21	Storage	No. of communal containers	3.82	1.29	76.5
22	Storage	Type of communal container	3.83	1.33	76.5
23	Physical resources	Average downtime	3.74	1.44	74.8
24	Storage	No. of individual container(found in main streets & parks)	3.65	1.36	73
25	Storage	Household containers	3.56	1.61	71.3
26	Environment & area cleaning	Incineration & smoke	3.52	1.58	70.4
27	Waste characteristic	Moisture	3.48	1.31	69.6
28	Storage	Type of individual container	3.17	1.45	63.5

3.2 Discussion of Study Results

The complexity of managing solid waste requires that managers be able to view performance in several areas simultaneously.

The collection and transport group include two measures that received high ranking by the respondents, namely, coverage and collection frequency . The total amount of waste collected is used regularly by the operation department as a coverage indicator and it is measured as follows; the sum of the total number of journeys made by each truck to the transfer station × volume of each truck. According to the respondents, this measurement is not accurate because trucks are not usually totally filled with SW. Frequency of collection (in terms of the number of times in a week or a month that waste is collected) is a fundamental parameter of any waste collection system (11) and it is considered important in studies such as Pacific Region Infrastructure Facility (12) and Egypt National Cleaner Production Centre (13). According to the respondents, the scheduled collection frequency is affected by many factors including; fleet defects, crowd in transfer stations and bad roads during the rainy season.

Physical resources included two measures that received high ranking by the respondents; readiness and number . They are considered as important indicators in many studies such as Ministry of local government (14) and David (15). Human resources were ranked 9th and 11th. The respondents see that the success of their work depends on physical and human resources; in particular sufficient number of workers with appropriate wages and fringe benefits and provided with ready and sufficient number of equipments (trucks, collection bins/baskets, brooms…). The high cost of spare parts affects the fleet readiness.

According to the respondents, flies density is generally looked upon as a parameter to measure the performance though sophisticated equipment for measuring flies density are not available. Dumped waste containing decomposing food waste that is moist but not wet is the perfect site for laying eggs of houseflies -which spread diseases- and its breeding cycle is much faster at high temperature (Sudan is a hot country), and so the waste should be collected more frequently to control the number of insects (16) . The dumps not only serve as breeding grounds for flies but they are invaded by waste pickers and animals which scatters the waste.

Demographic information (service area, population in service area, , length of streets that need sweeping and drains that need cleaning……) is ranked third among the 28 indicators. Generation indicators are considered as important indicators in many studies such as that of Ministry of National De-

velopment (17)
Awareness and training programs (Seminars, workshops, meetings, advertisements,…….) and behavior of individuals are ranked sixth and seventh respectively among the 28 indicators and many studies like Janwani pune(18), Hishashi (19) and Eltaher (20) agreed on its importance. Behavior of individuals is a major problem for the respondents; about 50 % of the households do not store their SW in appropriate containers, many households do not respond to the instructions of bringing out their SW in a fixed time, and in markets waste is scattered because of the negative behavior of sellers and buyers.

The study revealed that performance indicators under the groups Processing and resource recovery, got less importance by the respondents. According to respondents; households are not prepared at all for the segregation of solid waste. For some respondents , the transfer station affects negatively their average downtime because it is always crowded for two main reasons: Its area is small, and there are always defects in the trucks which transport SW to landfill. Since transfer stations are the responsibility of SACKH, they cannot control these problems. Another problem is the traffic jam and some prefer to transport the SW directly to the landfill site.

The hazardous medical waste indicator got less importance by the respondents because it is not their responsibility. Medical waste is supposed to be collected by Ministry of Health, though collection workers sometimes find medical waste mixed with non hazardous waste from hospitals.

Waste characteristics indicators received lower ranks. The operation departments have no means to measure them.

Storage indicators are the lowest ranked. According to some respondents, storage containers can be of benefit only if behavior of individuals changed, while others see that the availability of individual containers- which are distributed by the municipalities in main streets and parks-change positively the behavior of individuals.

4.Conclusion

The following results were obtained:

* The statistical analysis of the collected responses regarding the degree of importance of the 28 performance indicators is provided using 11 most significant KPIs which include, coverage, flies density, demographic information, number of physical resources, readiness of physical resources, awareness and training programs, behavior of individuals, frequency of collection, diseases due to flies, number of workers and wages and fringe benefits.
* Characteristics of waste and storage indicators are the lowest

ranked indicators for measuring performance of the operation departments.

* The 11 indicators can be considered as a first step in developing integrated KPIs to measure the performance of SWM system in Khartoum state.

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