Evaluation of collection and transportation of Municipal Solid Waste Management System in JnNURM cities in Gujarat, India: A Case Study of Ahmedabad, Surat, Vadodara and Rajkot

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ABSTRACT *The quantity of MSW has also increased tremendously with improved life style and social status of the populations in urban center (Sharholy, et al., 2007).This paper focuses on the evaluation of Collection and Transportation(C&T) aspect of the four selected cities. Citizen/residents are more concern with collection and transportation, as they are directly affected with C&T system. Once garbage is collected and transported away from their habitats, they are least bother with the treatment and disposal of the solid waste. Ahmedabad, Vadodara, Surat and Rajkot are four cities having population more than one million. All four have received fund under JnNURM for infrastructure upgradation scheme. Comparison of C&T of four cities identifies area of concern for improvement.*

INTRODUCTION

In world there has been a significant increase in generation of solid waste, which is largely due to rapid growth in population, urbanization and industrialization. Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries (Minghua, et al., 2009). The reason behind that is mainly changing lifestyle, food habits and change in the living standard. The quantity of MSW has also increased tremendously with improved life style and social status of the populations in urban center (Sharholy, et al., 2007). Solid waste comprises of household garbage and rubbish, street sweepings, construction debris, sanitation residues etc. Solid waste management (SWM) encompasses planning, engineering, organization, administration, financial and legal aspects of activities associated with generation, collection, storage, transfer and transport, processing and disposal of municipal solid wastes in an environmentally sustainable manner adopting principles of economy, aesthetics and energy.

NEED FOR STUDY

Poor waste management is a major threat to sustainable development of SWM system, since the lack of proper management has negative and serious effect on a number of areas such as health care, environmental quality, water resources, tourism, trade, and food security, etc. The threat arising from poor solid waste management is made worse due to: increases in waste generation caused by economic and population growth, limited availability of suitable land for landfill site, outright refusal of people to allow landfills in their communities (NEERI, 1997).

OBJECTIVES

The basic objective of this study is to compare and analyze Collection and Transportation of solid waste management in Ahmedabad, Surat, Vadodara and Rajkot.

COLLECTION AND TRANSPORTATION SYSTEM OF MSW

The MSW (Management and Handling) Rules, 2000 recommend source-specific waste collection and transportation in addition to appropriate processing and disposal. It has been observed that knowledge of the quantity and characteristics of MSW aids in preparation of a long-term plan for a MSW management (MSWM) system (Kumar, et al., 2008). The community bin collection system is adopted in most of the cities. In a few cities, the waste generated from various sources such as residential, street sweepings, garden, parks, offices, and shopping complexes is collected separately. Waste from slaughterhouses and hospitals are mixed with the MSW at the storage bins. A number of open collection spots exist in many cities, and these cause poor sanitary conditions and pose health hazards to the workers and nearby population (Gupta, 2001). The MSW (Management and Handling) Rules, 2000 suggest the provision of appropriate containers based on waste quantity generation by the nearby population. Assorted types of brick masonry bins/RCC bins, as well as M.S. and PVC containers, are used for collection of waste. It was observed that the size of the bins and their spacing are not based on the quantity of waste contributed by the citizens in the neighbourhoods. Front end loaders are deployed for solid waste loading at storage bins in a few cities (Kumar, et al., 2008).

Image 1 Primary Collection: Door to door collection, Street Sweeping

Image 3 Lifting of Community Bins and Primary Transportation

Image 4 Transportation and Disposal at Transfer Station

EVALUATION OF SWM SYSTEM

Solid waste management system of any city is very complicated system. It involves various types of wastes and various types of operations. It is not only limited with collection, transportation and disposal but segregation, recovery of valuables, waste to energy etc. also plays an important role (Ramachandra, et al., 2007). Each criteria and sub criteria has a different attribute in SWM System. It has its own importance and value in the system. Key performance indicators are identified by literature survey, stack holder consultation, personal discussion with experts etc. AHP can effectively support decision making with regard to complex sustainability issues and can help to recognize and define a problem in detail (Milovanović, et al., 2012). To identify importance of each key performance indicators pairwise comparison is done.

RESEARCH METHODOLOGY:
APPLICATION OF AHP FOR DEVELOPMENT EVALUATION MODEL

Identification of Performance Indicators: Performance evaluation of SWM requires a set of indicators for collection, storage, transportation, treatment & disposal. Identification of performance indicator is accomplished by structured interviews with the experts, a brain storming session was also organized with the distinguished speakers, NGOs, Consultants, City managers, research scholars, and students.

Pairwise comparison of Indicator: The pairwise comparison method was introduced by (Fechner, 1965) in 1860. Based on pairwise comparison, Saaty proposes the analytic hierarchy process (AHP) as a method for multi-criteria decision-making. It provides a way of breaking down the general method into a hierarchy of sub-problems, which are easier to evaluate. The Analytical Hierarchy Process (AHP) Basically a tool that permits explicit presentation of evaluation criteria and possibly improves selection of technology for solid waste management plan (Saaty, 1980).

Formulating the decision problem in the form of the hierarchy framework is the first step of AHP, with the top level representing overall objectives or goal, the middle levels representing criteria and sub-criteria, and the decision alternatives at the lowest level.

Pairwise comparisons sheets were sent to Municipal engineers, policy makers, NGOs, Consultants, City managers, research

scholars, academician etc. related to SWM services. Responses from 30 experts were analyzed iterations. To determine the validity of the software some manual calculations were also carried out which matched with the software results. Matrix for each respondent for main criteria is generated. To finalize weight from 30 respondents 'Geometric mean' of the 30 respondents is calculated and results in terms of weight of each indicators are shown Table 1.

Table 1: Weight of Main Criteria

Criteria	Weight after 6th iteration
1. Coverage	17.19%
2. Transportation	12.92%
3. Disposal	15.00%
4. Consumer's Complaints	9.18%
5. Unit Cost	7.20%
6. Outcome	8.41%
7. Segregation, Recover, Recycle	16.16%
8. Environmental Aspect	13.94%
Total	100%

Weight of each main criteria and subcriteria indicators useful for evaluation of SWM system is calculated and thus model for performance evaluation SWM system is prepared. Weight of each sub criteria of Collection and transportation derived using AHP is tabulated in Table 4.

Table 2: Sub Criteria wise Weight Distribution

	Coverage	Weight of Sub Criteria
C1	%Area covered under waste collection	2.54
C2	Separate system for collection of waste other than domestic waste (Biomedical waste, C & D waste, Hotel waste, Market waste, Dead animal disposal)	1.87
C3	Staff deployed per Lac pop.	1.14
C4	No. of sweeper per supervisor	1.46
C5	Average attendance (%)	2.26
C6	Beats left unattended (%)	2.08
C7	No. of waste storage site per lac pop.	2.80
C8	Collection effectiveness ration (%)	3.04
	Total	17.19
	Transportation	
T1	Vehicles deployed for transporting waste per 100 MT	1.22
T2	Average number of trips to landfills per vehicle per day	1.64
T3	Efficiency in carrying garbage = garbage carried/ Rated capacity of vehicle	2.25
T4	Staff deployed for transportation of waste/ 100 MT	1.09
T5	Attendance level of drivers	1.85
T6	Average trips per driver per day	2.17
T7	Average diesel consumption per MT **per Km** of garbage transported	1.37
T8	% of spare vehicle	1.32
	Total	12.92

A scale is required to evaluate each performance indicator for such varied data. This scale will have distribution of data within range. To decide range of scale, questionnaire was prepared to get opinion of filed expert. The survey questionnaire was sent to various professionals, experts of SWM field via email attachment and invitation through weblink hosted on www.surveymonkey.com. Respondents were given choice of entering data directly online on www.surveymonkey.com, entering data in writable pdf form or entering data on physical form (printout of pdf form).Input from experts in form of maximum and minimum service level is used to decide a range of scale. Scale to evaluate performance of collection and transportation indicators are described in Table 3.

Table 3: Scale for performance measurement

Scale for measurement of performance in Coverage and Transportation					
Distribution of weight	0.2	0.4	0.6	0.8	1
	Minimum performance level				Max. Expected performance

For application of above model; Solid Waste Management System of four cities i.e. Ahmedabad, , Surat, Vadodara and Rajkot have been studied. The selection of these cities is based on their inclusion as JnNURM cities(population more than one million).

SWM SYSTEM OF AHMEDABAD, SURAT, VADODARA AND RAJKOT

In India, JnNURM is the biggest central government scheme for upgrading infrastructure in 65 identified cities. In Gujarat, Ahmedabad, Surat, Vadodara and Rajkot are identified for funding under JnNURM. These four cities have received grant under JnNURM fund, for up gradation of their Solid Waste Management System.

PROFILES OF CITIES

India comes under developing and low income category as per CPHEEO. Surat is 4th, Ahmedabad is 73rd and Vadodara is 86th fastest growing city in world (City Mayor, 2011).

Door to Door collection plays major role in solid waste management system. Table 4, Shows that Surat is more efficient with 100% coverage, Ahmedabad with 93% coverage, Vadodara with 95% coverage and Rajkot city is covering 91% of the population of city.

Table 4: SWM Collection Data of Four Cities

Key Parameter for Comparison					
	Coverage	Ahmedabad	Surat	Va-dodara	Ra-jkot
C1	%Area covered under waste collection	93%	100%	95%	91%
C2	Separate system for collection of waste other than domestic waste (Biomedical waste, C & D waste, Hotel waste, Market waste, Dead animal disposal)	5	5	4	5
C3	Staff deployed per Lac pop.	167	136	142	187
C4	No. of sweeper per supervisor	21	24	23	21
C5	Average attendance (%)	88	86	90	88
C6	Beats left unattended (%)	11	10	14	15
C7	No. of waste storage site per lac population (community bins)	25	26	21	23
C8	Collection effectiveness ration (%)	93	91	90	95

Transportation system of cities when compared, all four municipals have sufficient vehicles. In Surat compaction of waste

is carried out at six transfer station using stationary compactor system. While in Ahmedabad compaction of waste is done during collection using mobile compactor. Surat, Vadodara and Rajkot has adopted Door to door to transfer station and to disposal type transportation system, While Ahmedabad has adopted Door to door to Direct dumping type transportation system.

Table 5: SWM Transportation Data of Four Cities

	Transportation	Ahmedabad	Su-rat	Va-dodara	Rajkot
T1	Vehicles deployed for transporting waste per 100 MT	35	32	26	42
T2	Average number of trips to landfills per vehicle per day	2	2	1.5	1.5
T3	Efficiency in carrying garbage = garbage carried/ Rated capacity of vehicle	12	13	11	12
T4	Staff deployed for transportation of waste/ 100 MT	83	88	82	74
T5	Attendance level of drivers	89	87	82	95
T6	Average trips per driver per day	2	2	2	1.5
T7	Average diesel consumption per MT **per Km** of garbage transported				
T8	% of spare vehicle	10%	9%	10%	10%

Municipal solid waste collection system of all four cities have been studied and evaluated using weight of each criteria mentioned in Table 2 and using scale mentioned in Table 3. Performance score of each criteria/indicator is calculated and noted in Table 6.

Table 6: Collection Score of Four Cities

Key Parameter for Comparison						
	Collection	Weight of Sub Criteria	Score of Ahmedabad	Score of Surat	Score of Vadodara	Score of Rajkot
C1	%Area covered under waste collection	2.54	2.54	2.54	2.54	2.54
C2	Separate system for collection of waste other than domestic waste (Biomedical waste, C & D waste, Hotel waste, Market waste, Dead animal disposal)	1.87	1.87	1.87	1.50	1.12
C3	Staff deployed per Lac pop.	1.14	1.14	0.69	0.91	1.14
C4	No. of sweeper per supervisor	1.46	1.17	1.17	1.17	1.17
C5	Average attendance (%)	2.26	1.81	1.81	1.81	1.81
C6	Beats left unattended (%)	2.08	1.66	1.66	1.66	1.25
C7	No. of waste storage site per lac pop.	2.80	2.80	2.80	2.24	2.24
C8	Collection effectiveness ration (%)	3.04	3.04	3.04	3.04	3.04
C	Total	17.19	16.0	15.58	14.88	14.31

Performances of each indicator in collection head mentioned in Table 6 shows that, Ahmedabad is on top with 16.0 point in managing collection of waste followed by Surat, Vadodara and Rajkot. Ahmedabad and Surat have separate Biomedical waste, C & D waste, Hotel waste, Market waste, Dead animal disposal

system. Overall performance in waste collection of all four cities is more than 80%.

Table 7: Transportation Score of Four Cities

	Transportation	Weight of Sub Criteria	Score of Ahmedabad	Score of Surat	Score of Vadodara	Score of Rajkot
T1	Vehicles deployed for transporting waste per 100 MT	1.22	0.73	0.73	0.98	0.24
T2	Average number of trips to landfills per vehicle per day	1.64	1.64	1.64	1.31	1.31
T3	Efficiency in carrying garbage = garbage carried/ Rated capacity of vehicle	2.25	1.80	1.80	1.80	1.80
T4	Staff deployed for transportation of waste/ 100 MT	1.09	0.87	0.87	0.87	0.65
T5	Attendance level of drivers	1.85	1.85	1.85	1.85	1.85
T6	Average trips per driver per day	2.17	2.17	2.17	2.17	1.74
T7	Average diesel consumption per MT **per Km** of garbage transported	1.37	0.82	0.82	0.82	0.82
T8	% of spare vehicle	1.32	0.79	0.79	0.79	0.79
T	Total	12.92	10.67	10.67	10.59	9.20
	Total of Collection and Transportation	30.11	26.67	26.25	25.47	23.51

In Transportation criteria, all four cities have achieved almost equal score with an average performance. Ahmedabad and Surat are at 10.67 out of 12.92. Followed by them Vadodara (10.59) and Rajkot (9.20) are slightly behind of Ahmedabad and Surat. Vehicle deployed for transportation 100 MT waste is similar for Ahmedabad, Surat and Vadodara, Rajkot is having lesser score.

DISCUSSION:
In final verdicts, collection and transportation criteria are very essential part of solid waste management system. All four cities are using nearly similar man power and machinery to achieve more than 90% of city area covered under waste collection system with collection effectiveness ratio more than 90% i.e. all most all waste generated in city is lifted by municipal corporation and remaining 10% is expected to be collected by rag pickers. Score achieved by all i.e. Ahmedabad-26.67, Surat-26.25, Vadodara-25.47, Rajkot-23.51 shows that bigger cities have performed better in solid waste management.

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