Decision Support Framework for Effective Disposal of Municipal Wastes for Indian Cities

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Abstract

Due to rapid urbanization and increased population density as well as per capita income, domestic and industrial waste generation has increased extremely. A number of research activities are being pursued on environmental impact of waste and conversion of waste to wealth keeping the futuristic trends in picture. Nevertheless, equally important aspect is the waste disposal management which is affecting the people's health and better living presently. The study is aimed to explore three major aspects associated with the waste disposal system: a) Region wise waste prediction b) Cost and time optimization of logistics and transport functions c) effective implementation of segregation strategy .The major finding of the study is that there is urgent need for an 'end to end' decision support system for waste disposal management. Decision Support Framework (DSF) has to be specifically designed and developed for Indian cities taking into account all the socio-technical-commercial - aspects of waste management. The DSF will help government bodies' policy makers, health Agencies, private firms, citizens and state bodies that are associated with Waste Management (WM).

Key Words: Decision Support Framework (DSF), Waste Management, Optimization

1. INTRODUCTION

Waste management (WM) is one of the services that local municipal bodies have to provide for all city dwellers. A city that fails to provide WM services also fails to provide other vital service like health care, basic education and transportation ;this is because waste management is inter related to many other aspects of city life. In India if generation of waste continuous to increase in the same pace, then it is estimated that by the end of 2047 there would be about to 260 million tons of waste generated annually. Unscientific management of waste will demand landfills that will be costlier option. A report published by European Business and Technology Centre predicts that India will need more than 1,400 km^2 of land, which is equivalent to the size of city of Delhi for landfills by 2047. Other implications like degradation of ground water, soil, generation of greenhouse gases will affect the overall quality of human life. Here, is the list of challenges faced by developing countries like China, India in managing solid can be categories under functional elements of Waste Disposal Management (WDM).

i. Collection: Collection rates range from a low of 41% in low-income countries to a high of 98% in high-income countries [1]
ii. Segregation: Mixed up wastes makes composting very difficult and uneconomical
iii. Transportation: Over and underutilization of transportation vehicles (due to unscientific planning and coordination.
iv. Recycling: Lack of high end technologies in developing countries prevents automated separation of solid waste for recycling [2].

2. LITERATURE REVIEW

Literature review is carried out to identify the gaps and challenges in waste management. Current and future cities demand robust tools and techniques that help to take better decisions and effectively manage wastes. Integrated multi objective decision making tools are required since the variables and priorities are diverse and also to effectively address environmental compliance, operational cost, retrieval and delivery efficiency etc.., Many researcher and study groups are actively involved in research activities in waste management . Most of the developed Decision Support Framework (DSF) for waste management has addressed either one or two functional elements (transportation, collection, management etc.,) in the waste disposal stream. The future cities will be in need of a comprehensive DSF that can assist in all functional areas of waste disposal management [1].

Researchers have focused on many aspects of waste management like generation, segregation, collection, transportation, and disposal, waste to energy, and 3Rs that is Reduce, Reuse and Recycle. In developing countries like India and China unorganized micro enterprises are involved in recycling activity. Optimization tools are used for root optimization and reduction of overall transportation cost, regression models are used in strategies of WM, different Solid WM models are studied and the authors concludes that local municipal bodies have to develop area specific strategies for effective WM. There are commercial software to help generate daily truck scheduling, compute billing, generate job maps for transporters etc. Meanwhile none of the software packages provide DSF support for the functional elements in the waste management stream.

There were several attempts to develop DSF for waste management and study the characteristics of various waste disposal management approaches/framework was carried out by literature reviews.

3. MATHEMATICAL MODEL AND SOFTWARE DEVELOPMENT

Unscientific waste management of solid waste will not only increase the cost of transportation but has health implications. The study conducted [3] in the well-known city of Madurai, have reported that improper solid waste management has made the ground water un-potable up to 32%. Non dynamic or fixed routing of transportation vehicles either over/under utilizes resource there by effecting entire waste chain. [4] conclude that use of geo-informatics for route optimization in of solid waste transportation and management could reduce the transport expenses up to 50%. There are several factors that are considered for route optimization like population density, waste generation capacity, road network, storage bins and collection vehicles etc. The studied and emphasized on the use of Geo-informatics for efficient management of solid wastes, load balancing within vehicles, fuel usage and also provides daily schedules. This kind of approach tries to eliminate the intuition based and or fixed routing transportation [5]. Zhu and Huang [6] studied the application stochastic linear fractional programming (SLFP) method in sustainable waste management. Here, authors demonstrate how SLFP can be used to generate sustainable schemes/plans having maximized system efficiency in the background of various constraints – violation risks.

Predictive tools/ techniques that are used to generate daily scheduled based on several inputs like waste creation rate, patterns, location , routing options etc., of solid waste will bring down both time and cost of transportation. The users need to enter the basic information about the locale wastes and the mathematical model will provide rioting schedules, predict daily cost, help in resource planning and also improves resource utilization. This will help to take objective decisions on resource allocation and utilization.

3.1. Optimization of Cost and Time

Davide Anghinolfi e.tal propose a dynamic optimization model for solid waste recycling , considering state variables related to quantity of waste per bin per day , routings etc., The main objective of the study was to minimize the sum of cost minus the benefits . This model when combined with GIS based decision support systems resulted in 2.5 times in net benefits when compared with the existing systems at pilot area of Cogoleto municipality, Italy. This type of model are proving their worthiness at the pilot area and be tried to for the mega cities and towns as pilot [7].

Tumpa Hazr and Sudha Goel [8] have reported that more than 70% of the waste management budget of Kolkata Municipal Corporation goes for collection of waste yet waste litters in many places and gives raise to health implications.

Sarika Rathi [9] uses linear programming model as an optimization model to derive schemes for waste management for the city of Mumbai. Various factors like Generation node, mechanical aerobic composting community compost plant and sanitary landfills are used input variables for model building and to evolve waste management strategy considering Cost of land and amount of waste in tons.

Tomasz Stypka [10] discusses three important models for waste management; mathematical models, computer simulation models and models of sustainable development. Tomasz STYPKA concludes that solution to the linear programming software can be used to derive cheapest solutions. The issues with uncertainty or probability can be better handled by using fuzzy sets and grey number theories. The later, approach has not made things complicated and less practical. The author has an opinion that each case or city has to define and solve the problems and obtained results cannot be used to other cities.

The city waste disposal systems has many modules or elements that have to work in synchrony so that effective disposal and processing can be realized. Both central and state governments are coming with rule and regulations for waste management. In the year 2000, rules for municipal solid waste management was made by ministry of environment and forest (MOEF) of the government of India. In India urban municipal solid waste consists of 60% organic fraction and 10% paper [11].

In order to optimize the operating costs of collection and transportation cost various optimizations techniques are being developed and used across cities in developed countries. In Indian more than 80% of the waste disposal budget is being utilized for transportation expenditure. Predictive tools are used to predict for next decade based on optimization of routes, distance, time frame, frequent of travel, amount of waste generation and geographical information system (GIS) with realistic data.

4. DEVELOPMENT OF DECISION SUPPORT FRAMEWORK (DSF)

The major gaps and motivation for the study comes from the thorough literature review and key journal paper [1]. The authors present the chronology of studies related to developing Decision Support System (DSS) for waste management system. It becomes evident that a there is a need to develop a decision support system/framework to help growing cities of India in three important aspects:

Absence of region wise predictive tool/s for municipal waste generation

Lack of suggestive tool/s for waste disposal processes methods: cost and environmental factors.

Absence of integrated support system to coordinate all the stages in waste disposal stream and provide intelligent suggestions to improve resource utilization.

The current proposal aims to develop an computer based integrated mathematical model that can used to take logical and practical decisions in stages of waste disposal management like collection, segregation, transportation, general management etc. The proposed conceptual DSF systems will be developed and is shown in Fig.1.

The decisions support framework has modular functions. The expected functions are executed from respective modules of the framework. The framework has five major modules they are:

i. Data Input Module (DIM)
ii. Data processing Module (DPM)
iii. Optimization Module (OM)

iv. Reports Module (RM)

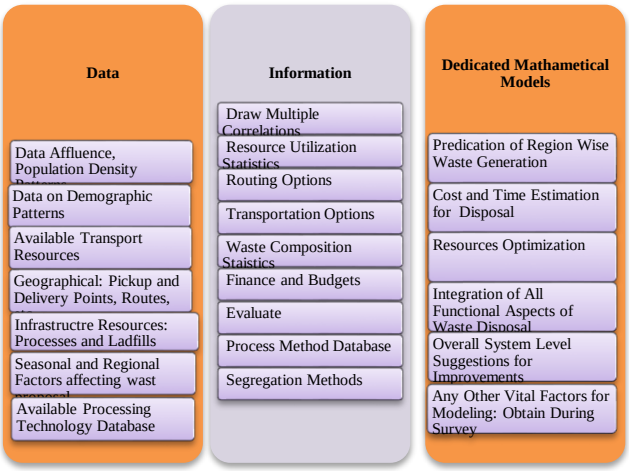

Fig. 1 Proposed conceptual Model of DSF for waste management in Indian cities

4.1 Data Input Module

The main function of data input module is to consolidate data from different sources and stakeholders on real time basis, following are data sources as shown in Fig. 2.

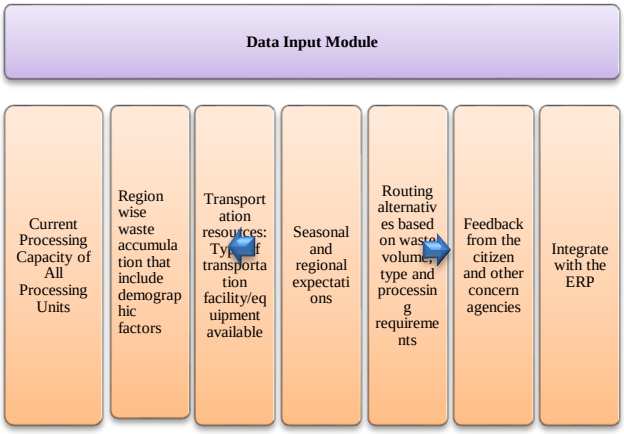

Fig. 2 Data Module from different data sources

4.2 Data Processing Module

The main function data processing module is to data processing. Data from data input module will be processed to generate multiple correlation maps that will help to understand the relationship between waste generation and affecting parameters like region, time period in a year, special occasion like festivals and functions and its effect on volume of waste generation etc. Based on the input data module, well-defined algorithms are used to generate operational Key performance Index (KPI) and are displayed in the dash board; this information is having accesses control and can accessed based on organizational hierarchy. The following are the indicative KPIs that are expected from DPM as shown in Fig. 3.

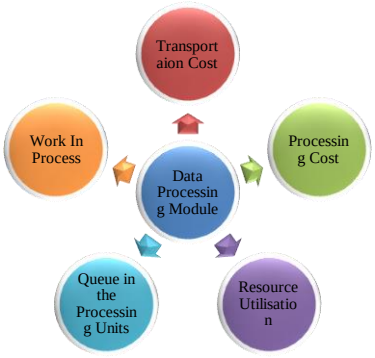

Fig. 3 Expected Outcome from Data Processing Module (DPM)

4.3 Optimization Module

Optimization module is used to generate different alternate solutions for changing requirement of the waste management operations. This module will help to try different what if conditions and generate report on the cost and service level KPIs. This module is the brain of the DSF as it must consider all the functions in the account and experiment different what if conditions beforehand. Thus making it an more capable of handling the operation; for example if any one of the processing units halts its operations then segregation and transportation plans must change dynamically without affect the overall operations of waste management. This module can have dedicated sub module for each applications under recourse, predictive analytic, cost, integration and region specific requirement as shown in Fig. 4.

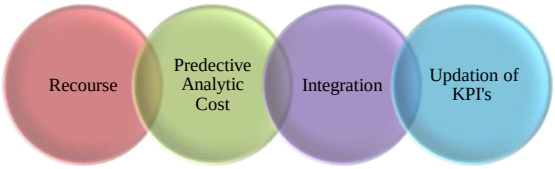

Fig. 4 Optimization Module

4.4 Reports Module

The central function of report module is generate report and communicate to team members. Once optimization solution is generated from the previous module, instructions and guidelines must be seamlessly communicated to member so that timely actions can be taken. The report module acts as post man within the DSF. Each report generated has access control and can be viewed based in the organizational hierarchy as shown in Fig. 5. The report module must also monitors performance of stakeholder groups and generate report for higher management for suitable actions. In total this DSF must be end to end solution provider for waste management for current and future requirements of a typical Indian city.

Fig. 4 Reports Module

5. SUMMARY

This paper tries to develop a much needed DSF for waste management for Indian cities. The literature gaps can addressed by the proposed DSF. The DSF has be improved by incorporating optimization and report module when compared to the key paper of (Ohri, A and Singh 2010). Real time data capture from Information and Communication Technologies (ICT) will help to take better and practical decisions using DSF. In order to use this kind of DSF there are few prerequisites that muse be in place they:

i. Waste management must be operated on a Public Private Partnership (PPP) model
ii. Encouraging state policies for waste management
iii. Tender based waste management proposal
iv. Access to state of the art ICT
v. Soft measures like: Awareness programs for citizens
vi. Hard measures like: Reward and Penalty schemes

The DSF is the first step to scientifically manage and process waste for Indian cities, there is ample scope to refine the DSF and customize for industrial, construction, forestry and other different types of waste.

REFERENCES

[1] Ohri, A. and Singh, P.K. (2010) Development of Decision Support System for Municipal Solid Waste Management in India, International Journal of Environmental Sciences, Volume 1.

[2] Mufeed Sharholy, Kafeel Ahmad, Gauhar Mahmood, R.C. Trivedi, (2008)

[3] Saravanan. P, Arun Prasad. K, Sudha. G, Ilangovan. P (2011) an assessment of environmental degradation: Case study of Avaniyapuram town panchayat, Madurai, International Journal of Environmental Sciences, Volume 1, No 7.

[4] Samidha Siddam, Isha Khadikar, Anil Chitade, (2012) Route Optimisation for Solid Waste Management Using Geo-Informatics, Journal of Mechanical and Civil Engineering, PP 78-83.

[5] Dan Hoornweg e tal, (2005) Waste Management in China: Issues and Recommendations, paper was prepared by the East Asia and Pacific Urban Development Sector Unit, (EASUR). Urban Development Working Papers East Asia Infrastructure Department, World Bank, article retrieved on 14/12/2012.

[6] H. Zhu, G.H. Huang (2011) A stochastic linear fractional programming approach for sustainable waste management, journal of waste management, Elsevier Ltd, 2612–2619.

[7] Davide Anghinolfi , Davide Anghinolfi , Massimo Paolucci , Michela Robba , Angela Celeste Taramasso (2012) A dynamic optimization model for solid waste recycling, Elsevier Ltd , retrieved on 17/11/2012.

[8] Tumpa Hazra, Sudha Goel, (2009) Solid waste management in Kolkata, India: Practices and challenges, journal of waste management, Elsevier Ltd PP 470-478.

[9] Sarika rathi, (2007) Optimization model for integrated municipal solid waste management in Mumbai, India, article, Environment and Development Economics Cambridge University Press, retrieved on 17/11/2012.

[10] Tomasz stypkac, Critical review of municipal solid waste management models, article, Institute of Thermal Processes and Air Protection, Cracow University of Technology, ul. Warszawska 24, 31-155 Kraków, retrieved on 09/11/2012.

[11] Ranjith Kharvel Annepu, (2012) Sustainable Solid Waste Management in India, Waste-to-Energy Research and Technology Council (WTERT), Columbia University.

[12] International Review of Waste Management Policy: Summary Report, Eunomia Research and Consulting Ltd 62 Queen Square Bristol BS1 4JZ, article retrieved on 14/12/2012.

[13] Ashtashil Vrushket Bhambulkar, (2011), Municipal Solid Waste.

[14] Municipal solid waste management in Indian cities – A review, Elsevier Ltd, 459–46.