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REVIEW ON DECISION SUPPORT MODELS FOR SOLID WASTE MANAGEMENT AND CBA OF SWM IN RURAL INDIA

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Abstract:

The convolution involved in municipal solid waste management necessitates development of new tools which will be capable of processing data inputs of varying formats like Decision Support Systems (DSS) which gives expert opinion in multi objective decision making scenario. This paper conducts a literature review of decision support models and tools that are commonly used in the solid waste management area. These decision support models include study of lifecycle assessment, the cost–benefit analysis and the multi-criteria decision-making. In this paper work is focused on the methodology of CBA in solid waste management. Study is carried out on solid waste management of Bidal village in Maharashtra, India.

Key words: cost-benefit analysis, life cycle assessment, DSS, ISWM, municipal solid waste management

1. Introduction:

Now-a-days Municipal solid waste is a main concern issue for many communities throughout the world including India. Increasing MSW generation rates and disposal costs, environmental and health concerns, limited landfill space, legislative changes, political climate, and social attitudes have a significant impact on waste management efforts. Sustainable management of MSW is necessary at all phases of impact from planning to design, to operation, and to decommissioning.

Rather than relying completely on landfills or conventional disposal methods for SWM, ISWM is a new practice which uses several alternative waste management techniques to manage and dispose of the various components comprising the municipal solid waste stream. Moreover, the best practicable options tend more and more to be selected based on a well-established DSS, which may include decision support models. Most of them are based on a variety of methods such as: cost benefit analysis, life cycle assessment, ERA, MCA, and EIA [3].

This paper is a review of the types of waste management models currently applied for integrated municipal solid waste management, which shows their shortcomings and advantages as components of a decision support system. The abbreviations used throughout this paper are presented in the following Table 1.

Table 1: List of abbreviations

CBA	Cost benefit analysis
EIA	Environmental impact assessment
LCA	Life-cycle assessment
MSW	Municipal solid waste
ERA	Environmental risk assessment
MCA	Multi-criteria decision making
DSS	Decision support system
ISWM	Integrated solid waste management
GIS	Geographical Information System
SWM	Solid waste Management
PW	Present worth

2. Literature review of International scenario on decision support systems for solid waste management:

The development of DSS for SWM started in middle ’90s and still remains a topic of interest and analysis worldwide. Various approaches are employed in the event of DSSs for solid waste management. To build an entire model of waste management system, a large data and deep analysis should be done on all aspects together with characteristic of waste, attainable treatment choices, resource conservation, recovery versus disposal cost analysis etc.

Many DSS were proposed for SWM in 1996. Barlishen and Baetz (1996) developed a prototype decision support system to assist the preliminary planning of MSW management. This designing tool combines knowledge-based system parts with computer program, optimization and simulation models for waste forecasting, technology evaluation, recycling and compost design, facility sizing, location and investment timing including waste allocation and municipal solid waste management (MSWM) system analysis.

Chang and Wang (1996a) developed an innovative graphical, interactive, problem-structuring tool for management planning of solid waste collection, recycling and incineration systems in Taiwan. In the same year, they developed another DSS employing a fuzzy goal programming (FGP) approach, supported the concerns of economic and environmental impacts of noise, air pollution, and material recycling within the long term planning program for landfills, incinerators, and transfer stations in a typical solid waste management system. Interactions among the effects of waste generation, source reduction, recycling, collection, transfer, processing, and disposal are tied together within such an analytical framework.

Galante et al. (2010) has addressed the problem of the localization and orienting of transfer stations and determination of how many number of vehicles and sort of vehicles to carry waste from municipalities to the incinerator. He evaluated two conflicting objectives and also evaluated the minimization of total cost and the minimization of environmental impact measured by pollution. To determine the most effective means of compromise, goal programming and fuzzy multi objective techniques were used. The model was applied to the waste management of optimal territorial circle (OTA) of Palermo (Italy).

3. Different models for waste management:

Various classifications of waste management models were carried out, some reviews and analyses have classified them as follows (MacDonald, 1996; Morrissey and Browne, 2004):

- Models based on cost-benefit analysis,
- Models based on life cycle analysis,
- Models based on multi-criteria decision analysis.

3.1. Models based on multi-criteria decision analysis

MCA is included in the category of compromising methods considered in waste management modelling. It is used to evaluate environmental problems by developing a complete set of alternatives on the basis of several criteria. In models based on the MCA the type of the chosen criteria depends on the objectives of the model. Several types of MCA models were developed to help in detecting the best compromising alternative. For example, Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE).

Other particulars methods based on MCA are as follows: Multi criteria Decision Aiding Hybrid Algorithm (THOR), Analytical Hierarchical Process (AHP), MAUT, SMART, UTA, TOPSIS, ELECTRE, ORESTE, QUALIFLEX.

3.2 Models based on Life Cycle Assessment:

It is an objective method used to evaluate the environmental impacts associated with a product, system or process, through whole life cycle, from raw materials acquisition, passing through manufacture, distribution, use, possible reuse/recycling to final disposal.

According to the ISO standard (14040:1997) a complete LCA study comprises of four major stages which are shown in (Fig. 1):

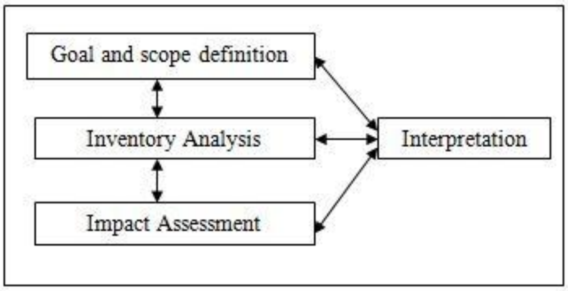


Fig.1. Phases of LCA

In next step, inputs and outputs for each activity are identified and the flows of material, energy and emissions are calculated. The results from life cycle inventory are used for the evaluation of the impact categories in the life cycle impact assessment, which includes four steps:

1. Selection of impact categories and classification
2. Characterization
3. Normalization
4. Valuation

According to standard methodologies, interpretation of results is the last phase of LCA study. Interpretation can include: identification of key environmental issues, verification, conclusions and recommendations.

3.2.1 Examples of LCA models:

The most applied particular models developed based on LCA are: Organic Waste Research (ORWARE), the Waste Analysis Software Tool for Environmental Decisions (WASTED), the Environmental Assessment of Solid Waste Systems and Technologies (EASEWASTE).

3.3 Models based on Cost Benefit Analysis:

Hansjurgens (2004) define and comments [10] CBA as follows: "CBA is an economic way of choosing among a number of alternatives (say policies and programmes); the advantages i.e. benefits and disadvantages i.e. cost of a certain project, investment are weighted up against each other and the project with the highest net value is recommended for adoption". Hence benefit and costs are essential foundations of CBA. According to Hansjurgens [10] CBA contains eight stages (Fig. 2):

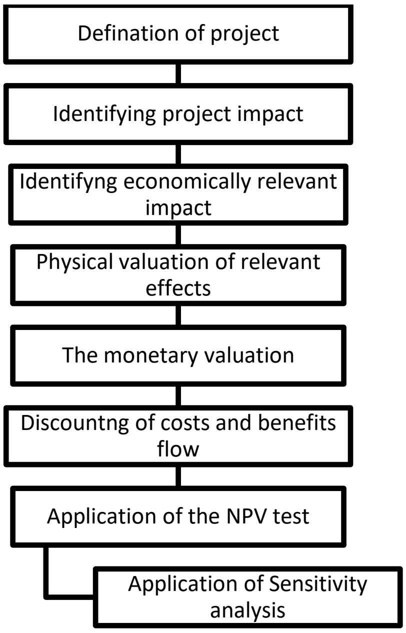


Fig. 2. Stages of CBA (Hansjurgens, 2004)

These stages provide guidance for the evaluation of health and environmental effects of certain activities and enables decision-makers to choose what scenarios are more efficient (Hansjurgens, 2004; Morrissey and Browne, 2004). The determinant key of decisions and choices in waste management technologies and practices is represented by costs because more often the costs for implementing a waste management alternative are taken into account more than the possible benefits that the municipality can gain from the project implementation.

The most noteworthy problem in cost benefit analysis is valuation of the costs and benefits, discounting and aggregation or comparison [2]. Impacts must be valued in common units for evaluation. Discounting is a part in CBA, which is carried out to compare future costs/benefits with present costs/benefits [10]. Hanley and Spash, (1993) recommended a relationship for calculus of the present value of a cost or benefit (Eq. 1):

$PV(X_t) = X_t\,[(1+i)^{-t}]$............. (1)

Where *PV* is present value, *X* is cost or benefit, *t* is time and *i* is rate of interest.

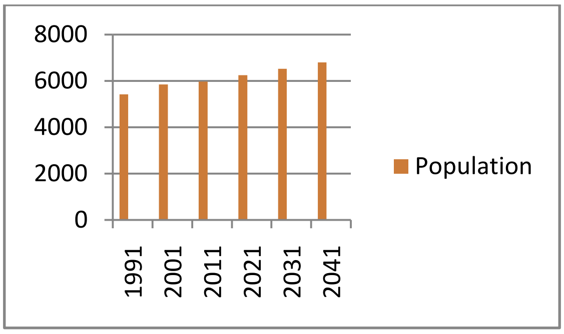
The net effects determined by CBA reflect how much the benefits exceed costs Net benefit can be expressed by Eq. (2)

$NB = TB\text{-}TC$...................... (2)

Where *NB* is the net benefits, *TB* the total benefits and *TC* is the total costs.

4. Case study: Bidal Village

Bidal is a village situated in Satara district of Maharashtra, India. Village does not have any well organized system of Solid Waste Management due to apathy of the Grampanchayat and lack of funds. Grampanchayat workers dump solid waste directly into dry rivulet. However no formal solid waste treatment and processing facilities are provided and hence it leads to environmental pollution as well as health risks. Current population of village is around 6000 and population forecasting data is shown in following graph:



Graph 1: Population data of Bidal

Information regarding solid waste composition was obtained from field sampling data and it is provided in Table 3.

4.1 Current scenario of SWM in Bidal:

Current SWM operations in Bidal village are based on the stationary container system (common bins). For this system, residents place their waste in bins that are located at central points throughout the village. There are only 4 such bins provided in village. Current deficiency in the number of bins distributed in village resulted in waste filling the bins and accumulating around on streets.

Waste generation rate in village is around 0.25kg/capita/day. Based on waste generation rate, amount of daily and yearly generated waste rate is given in Table 2.

Table 2: Waste generation data

Waste generation rate (Kg/captia/day)	0.2-0.3
Considered Fig (Kg/captia/day)	0.25
Waste generation / day	1650
Avg. Annual waste generation (Kg/year)	602,250

Based on table 3, percentage of materials which are considered to be recyclable or compostable is significant. This large percentage of recyclable/compostable material in the waste stream provides optimism that large-scale recycling and composting will be feasible and significantly reduce the volume of solid waste transferred to landfill.

Table 3: Composition of solid waste as percentage of weight

Waste components	Average (%)
Biodegradables	67
Paper	9.6
Plastics and rubber	15
Metal	1.9
Glass	2.5
Others	4

Bidal has designated waste disposal area which is located outside the village. However, this site is not built, operated, or managed to any acceptable standards and hence it can be classified as open dumpsite.

4.2 Development of Scenarios:

In this study, the scenarios shown in Figure 3 have been developed for the management of solid waste generated in Bidal village keeping in mind next 20 years time horizon. The current solid waste collection and disposal in open dumping is considered as the baseline scenario (Scenario 0) for comparison. All scenarios use the same method, equipment, and human labour for waste collection and transportation.

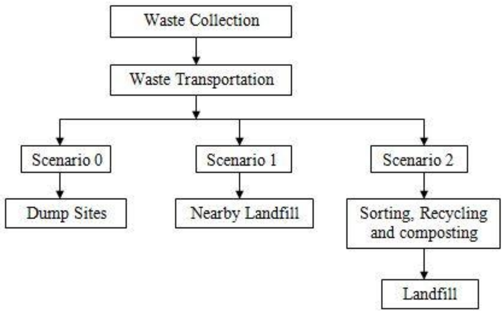


Figure 3: Scenarios considered during study

The other three scenarios are as follows:

Scenario 1: Waste is collected from collection bins, transported in a vehicle and then disposed in a current dumping site.

Scenario 2: Landfill site allocated for waste disposal which is located outside the limits of village.

Scenario 3: Waste collected from village is transported to integrated treatment and disposal facility (ITDF). The facility is designed to receive solid waste, where recyclable materials are separated manually and made ready for either bale & sell, or recycled in new plants in the future phases of the project for reuse in safe industries and then land filling is followed for remaining waste.

Waste material data for proposed scenarios in given in Table 4. Values in table 4 are calculated by considering SWM composition values from Table 3.

Table 4: Waste material data for proposed SWM scenarios

Scenario	Recycling (Kg/year)	Composting (Kg/yr)	Disposal	
			Current dumpsite (Kg/year)	Sanitary landfill (Kg/year)
0	-	-	602,250	-
1	-	-	-	602,250
2	1,44,540	4,03,508	-	54, 202

4.3 CBA for SWM in Bidal village: Cost estimation for the SWM scenarios will include capital costs and operation and maintenance (O&M) costs. The capital cost consists of the addition of civil works cost and mechanical equipment cost. Operation cost includes the annual expenditure for fuel and labour. Maintenance cost is considered as a percentage of the capital cost. Minimum cost is always one of the criteria to select the most economical scenario.

4.3.1 Calculation of PW for the scenarios:

1. LCC analysis is applied to find out least cost scenario. Some assumptions were made to calculate present worth of capital cost and operating and maintenance cost. One of the assumptions is Capital and O&M costs are discounted at a constant interest rate of 10%.

2. Total cost consists of total discounted capital cost and total discounted O&M cost.

3. PW calculations are carried out using formulae given in equations 1 and 2 of this paper. Result is tabulated in following table (Table 5).While doing calculations, population in year 2031 is considered.

4. Since the waste generation rate is less compared to cities, for wet/ biodegradable waste method of vermicomposting and windrow composting is considered for calculation. Recyclable waste is either reused or if found hazardous then sent for further processing at district level plants.

Table 5: PW of costs based on scenarios

Present worth	Scenario 0 (in RS)	Scenario 1 (in RS)	Scenario 2 (in RS)
Capital cost	10,000	7,14,000	8,45,000
O & M cost		50,000	1,00,000
Subtotal	10,000	7,64,000	9,45,000

4.3.2 Results and Discussion:

1. This analysis considers social, economical and environmental aspects to possible extents.

2. As mentioned above currently there is no SWM system in Bidal village. Hence in case of scenario 0, 10,000 minimum cost is considered because at present there are expenses of transportation of waste, labour charges and vehicle maintenance only.

3. For scenario 1, landfill design is proposed whose cost in mentioned in Table 5.

4. Though scenario2 is costing more than 1 still it is the scenario that has added value as benefits from marketing the produced recyclables and compost in the treatment facility. For this case, some waste will be undergoing recycling and composting while remaining will be sent for landfill. Therefore, benefits have been estimated for scenario 2, assuming that the produced compost will be sold in market and revenue will be generated.

5. Conclusions:

1. Literature of various DSS models like LCA, CBA and MCA along with their applications is studied in this paper.

2. Application of these models to rural SWM using CBA method is presented in this study.

3. Current open dumping practice is considered as the baseline scenario. Additional two scenarios are compared namely direct waste disposal into a sanitary land fill and sorting, recycling and composting followed by landfill disposal.

4. The benefits from the revenues of selling the produced recyclables and compost suggests scenario 2 as best option in economical, social and environmental point of view despite the fact that always minimum cost option is chosen as the best option.

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