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Optimum Selection of Landfill Site for Small-Scale Town and Village around of Developing Country

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Abstract: *Disposal of MSW is one of the major criteria for proper MSWM. Landfill site are most commonly used technology for disposal of inert waste around the globe. As per regulation of MSWM 2000 municipalities are responsible for MSWM. Nearly 72% of total population resides in small-scale town and villages around. For development of sustainable MSWM for developing country small-scale towns and villages need to studied and developed. Study has been done for development of land fill site for disposal of inert waste of small-scale town and villages around them. Optimization model is develop for selection of landfill considering transportation and site development cost.*

Keywords: *MSW, Landfill, Optimization, Small-scale town, Village*

I. INTRODUCTION

Municipal Solid Waste (MSW) is defined using Chapter 21.3 of Agenda 21 (United Nations Conference on Environment and Development, Rio de Janeiro, June 14, 1992). Solid wastes." include all domestic refuse and non-hazardous wastes such as commercial and institutional wastes, street sweepings and construction debris". MSW primarily comes from households, but also includes wastes from offices, hotels, shopping complexes/shops, schools, institutions, and from municipal services such as street cleaning and maintenance of recreational areas (cited from UNEP IETC). As per MSW Rules 2000 India MSW includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes. Due to urbanization and population, growth there is constant increase in quantity of MSW. According researchers to there is increase of 1- 1.33% per annum in quantity of MSW (Pappu *et al*., 2007; Shekdar, 1999; Bhide and Shekdar, 1998). Constant increase in Improper management and increasing quantity of MSW leads to environmental and health hazards. MSWM that includes collection, transportation, segregation and disposal of MSW needs to plan as per rule governed by the authorities. It requires proper infrastructure, maintenance and upgrade for all activities. Due to continuous increase in MSW management of MSW has becomes very expensive and complex. Generally, dumping of MSW transported for different location at low-lying area contaminates air, and ground water. It can also lead to serious health hazards for population residing of the area.

II. REGULATORY FRAMEWORK FOR MSWM IN INDIA

Municipal Solid Waste (Management and Handling) Rules 2000 (MSWR-2000) given by Government Of India gives all aspects of MSWM for all regulatory bodies. Urban Local Bodies (ULB) are responsible for proper implementation of MSWR in accordance to state government and pollution control board. According to MSWR-2000 disposal of MSW is done in scientific method so as contamination of ground water, surface water and ambient air quality is prevented. Private organization are now included in MSWM by government for better implementation of MSW plans. Disposal of MSW in India includes composting (Vermi composting or microbial composting) and landfill dumping. According to MSWR-2000 landfill is defined disposal of residual solid wastes on land in a facility designed with protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion. Scientific landfill sites should be made for proper disposal of MSW.

III. INTEGRATED SOLID WASTE MANAGEMENT SYSTEM

Literature gives study of MSW and MSWM at metro, large scale and medium scale town at large. While small-scale town and surrounding villages were around 72% of total population of India reside are studies less. Negligence for small-scale town and surrounding villages are due to low population, less budget of municipality, unawareness of people etc. Composition of MSW varies because of urbanization and change in life style. Large quantity of organic matter is found because of major occupation of population is agriculture.

MSWM of area having low quantity of waste becomes more uneconomical thus integrating management of waste for two or more area can give economical and practical solution. Cluster for collection and segregation of solid waste made is more manageable and economical for low quantity of waste.

3.1 Proposed Optimization Model

In the present work, an optimization model is developed to identify suitable disposal site for solid waste from segregation site of cluster in compliance with the regulatory guidelines. The mixed integer nonlinear program model has been proposed to solve cost minimization problem. The installation cost of the site, transportation cost, infrastructure cost is taken into consideration.

To optimize solid waste disposal cost, it is necessary to define cost of land, landfill site installation cost, landfill site operation cost, travel cost from town to landfill site, man power cost at landfill site and vehicle cost. The summation of all these costs becomes the total cost, which needs to be minimized.

3.2 Waste to be disposed:

The amount of waste generated is segregated before transportation to the disposal site. It is found that only 10-25% of the total waste collected at segregation site is to be disposed in the landfill site. Based on this total amount of waste to be disposed from a given city in 25 years is calculated

3.3 Land price:

Depending on the location of the disposal site, the cost of the land changes the actual cost of the site depends on the amount of solid waste to be disposed in that site for 25 years. The height of the land fill is taken as six meters and average density is taken as 0.8 T/m3. for the calculation of area required for the given landfill site. Total amount of waste disposal $\sum_i T(i)$ in the site j depends on the selection of the site to dispose material from the source "i" this is decided based on the decision variable x(i,j). If decision variable is one then only the solid waste will be counted. Similarly the cost of given site j per square meter is p1(j). Land price is INR Lacs calculated

3.4 Site installation cost:

Once landfill site selected it is required to prepare it for solid waste disposal by making excavation, earthen bands, laying tarpaulin for preventing latchet as well as construction of infrastructure for its operations. Different capacities of cells are constructed phase wise. Site installation cost depends on the capacity of site, normally it very from INR 300 To INR1100. In the present study installation cost is taken as 1 per cubic meter of SW. Site installation cost by assuming that the site will be operational for 25 years

$$Sc = \sum_j \sum_i T(i) * x(i,j) \frac{s1}{100000} \quad \ldots\ldots (1)$$

3.5 Minimum cost for Vehicles:

Vehicles which are involved in transporting SW from town to landfill site have minimum cost involved irrespective of how much SW is transferred by it. It is linked with trip. This cost is towards fix expenditure like driver wages when it is off road, maintenance of vehicle, insurance, depreciation etc. In general specially designed trucks are used for transportation of MSW. Capacity of truck may vary depending on its make; accordingly this fix minimum cost may be changed. An assumption of each truck can carry 2 ton of SW only is made in the present study. Moreover it is assumed that minimum cost for vehicle per trip is constant and is denoted by s4 i.e. INR 370 per trip. The cost (vmc) expressed in Lacks of INR can be evaluated using equation (4). Where ceil rounds of the value towards its nearest integer.

$$vmc = \sum_i ceil\left(\frac{T(i)}{2}\right) * \frac{s4}{100000} \quad \forall\, i \in I \ \ldots\ldots (2)$$

3.6 Travel cost:

Travel cost is of summation of minimum cost of vehicle and the cost for operating vehicle from town to landfill site. Cost for operating vehicle includes the fuel cost, rut in maintenance cost and remuneration to the driver. Operating cost depends on fuel prices. The transportation cost is calculated as the total distance travelled by the trucks between the selected source town (i) and disposal site (j). The number of trips are calculated based on amount of SW generated from the site and with an assumption of each truck can carry 2 ton of SW only. Moreover, it is assumed that cost for transportation per kilometre is constant and is denoted by s3. The cost (Trc) expressed in Lacs of INR can be evaluated as

3.7 Manpower cost:

Manpower cost consists of manpower required during transferring solid waste from town to landfill site with vehicle as well as at land filled site. It depends on trips from source town per day. The numbers of trips are calculated based on amount of SW generated from the site and with an assumption of each truck carries 2 ton of SW only and three persons are required per trip. Moreover it is assumed that remuneration for persons who are engaged in this work is constant and is INR120. The cost (mc) expressed in Lacs of INR

3.8 Operating cost at landfill site:

Operating cost of landfill site includes the machinery and man power cost to levelling the waste at landfill site, covering the waste through sand or clay, watering for proper settlement. It also includes the cost of sampling and testing of waste and leach ate. For this one should provide the infrastructure for at least 25 years. The manpower is calculated based on amount of SW handled at the landfill site and with an assumption of 10 ton solid waste handle per person and remuneration is INR120. Machinery also needed for spreading and levelling of solid waste which is brought from different towns. Covering the waste through sand or clay, watering for proper settlement also needs special type of machinery. It is assumed that INR18 per cubic metre of solid waste for machinery operation and maintenance cost. The cost (olc) expressed in Lacs of INR

3. Total cost:

Total cost for each land filled site consist of land price of the landfill site, landfill site installation cost, man power cost, travel cost and operation cost of landfill site. Landfill site selection should be such that total cost should be minimal for disposing solid waste from the town to the landfill site. It can be evaluated as

$$total\_\cos t = \left(\sum_{j} Lp(j) \right) + Sc + mc + tc + olc \qquad \text{…………………… (3)}$$

3.10 Mixed integer non linear programming solution:

The objective function presented in equation (14) along with constraints forms a Mixed Integer Nonlinear Programme (MINLP) problem for minimization of total. This MINLP can be solved using suitable commercial software. In the present work GAMS® solver has been used for simulation. The solver compiles the proposed optimisation model using DICOPT solver of MINLP type.

IV. CASE STUDY: GUJARAT STATE

As per study done by authors composition of waste for small-scale town is found to be 48% decomposable, 30% recyclable and 22% inert while for village the composition of waste is found as 73% decomposable, 20% recyclable and 7% inert. These area have large quantity of compostable waste which can be decomposed (vermin compost / microbial compost). Recycle waste about 20-30% of total waste generated consist of paper, plastic bags and containers and metal in small quantity. Paper segregated should be given to industries like recycle paper manufacturer, cardboard making etc which utilizes paper as raw material. As per directive given by GPCP to cement manufacturing industries MSW should be included as alternate fuel plastic from MSW can be send to cement industry. Local vendors take away metal available from MSW. Inert waste about 10- 25% is to landfill, which requires a proper landfill site.

Due to small quantity, it becomes uneconomical to have segregation and landfill site at each town and village. Integrated municipal solid waste can give most economical and feasible approach to these small-scale town and surrounding villages. We have studied formation of cluster for segregation site is by optimization model. It is found that having such cluster reduces cost of segregation to 30-70% as cost of construction of segregation site reduces for each town and village. Inert waste obtain from segregation site is to be given to land fill site.

Research done by Vatsal Patel has located 19 landfill site for Gujarat state considering GIS and economical aspect along with geographical location of the area. These landfill site are selected for small scale town and village around considering 83 such town in state of Gujarat. Authors have worked in area in small-scale town and surrounding village. Distance between segregation site and proposed disposal site is measured and distance matrix is prepared for use in optimization model. Optimization model done by us have given 83 segregation site for small-scale town and surrounding village of Gujarat state.

4.1 Mixed Integer Non-Linear Programming solution:

The equation of the objective function consisting of minimizing total cost with given constraints representing a MINLP program. This mixed integer nonlinear programme can be solved using suitable commercial software. In the present work, GAMS software has been used for simulation. The detailed program starts with definition of indices, sets, parameters, variables, tables and equations in the required syntax. The software then compiles the model developed using DICOPT solver of MINLP type.

4.2 Results and discussion:

MINLP based optimization problem is solved and it considers not only transportation cost but also land cost, site development cost, transportation cost, Labor cost etc. Figure 1 shows sites 18 selected for development of landfill site for disposal MSW generated from each town under consideration.

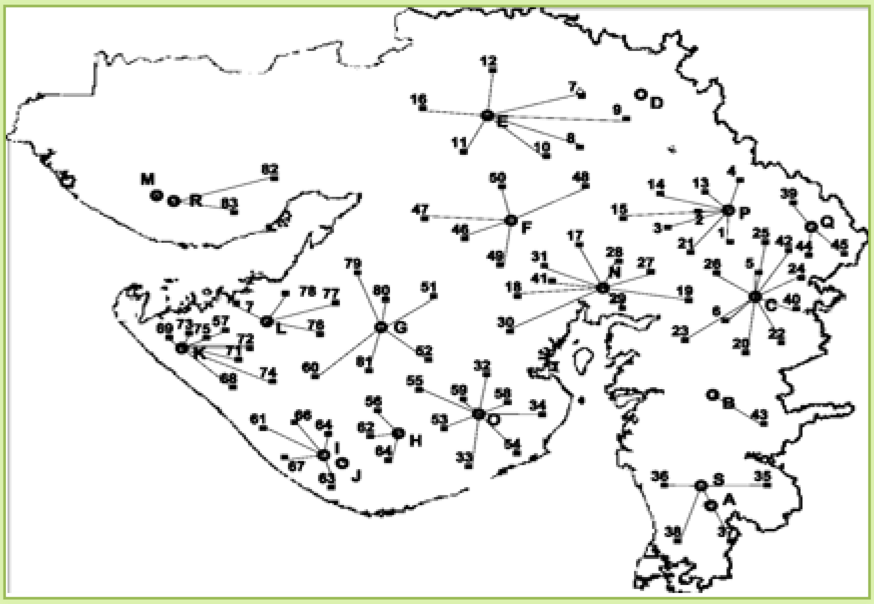

***Figure 1**: Identification of landfill sites for study towns.*

Segregation of MSW before it is disposed in landfill sites is done. The quantity of disposable waste depends on various factors like population, climatic condition etc. Literature for composition of waste shows that approximately 10-25% of total waste quantity is inert waste and it needs to be disposed off on landfill site. Researchers have studied composition of waste by weight for small-scale town and surrounding village. Distance of segregation site and cost of disposal site selection of optimal location of landfill site is considered. Organic waste segregated is results obtained for optimization of four cases are presented in Table 1. It is noted from Table 1 that segregation at the source is the best possible option. Overall it is observed that, the transportation cost is the governing parameter for model to calculate economically optimum location for disposal of solid waste generated from each town.

From Table 1 it can be seen that total cost changes marginally by 2.45% and 0.62% when maximum and average quantities are considered. The variation is marginal as segregation is assumed to done at the landfill site. On the other hand if segregation is done at the source, there is approximately 41% reduction in overall cost of MSWM over a period of 25 years. It is to be noted that approximate cost of MSWM per person per year is estimated to be approximately 400 INR that is less than 7 US dollars per person per year.

***Table 1:** Comparison of cost incurred in Lacs for disposal of MSW under various heads*

% of total waste disposed	As per literature (35)	Approximate Average (25)	Actual quantity (Varies between 15 to 35)	Segregation done at source
Land Price for land fill site	271390.00	194440.00	209990.00	208500.00
Installation cost of landfill site	148990.00	106420.00	114540.00	114540.00
Operation cost of landfill site	1489.89	1064.26	1145.45	1145.45
Landfill site total cost	421869.89	301924.26	325675.45	324185
Transportation cost	3500000.00	3500000.00	3500000.00	1247800.00
Total cost	3921869.89	3801924.26	3825675.45	1572000
% Deviation with respect to Actual	2.45	-0.62		-41.09

V. CONCLUSIONS

Geographical Information System based method for identification of potential land filling sites is proposed. Total 18 potential landfill sites are identified for the study area. An optimization model is proposed for selection of the most economical landfill site for disposal of MSW generated from each source town. Total cost of MSW disposal when waste segregated at land fill site and segregated at source are estimated to be INR 3825675**.**45lacs and 1572000 lacs respectively. The analysis of results has shown that it is advisable to consider source segregation. Approximate per capita cost of MSWM per year is estimated to be approximately 400 INR that is less than 7 US dollars per year.

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