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Optimization Model for Integrated Solid Waste Management in Gurugram

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Abstract: ***Gurugram, amongst the largest metropolitan city in India, generates 500-600 tons of waste per day. It is the responsibility of the Municipal Corporation of Gurugram and private players to provide Municipal Solid Waste (MSW) management services; however, increase in waste is becoming beyond their ability. As a result of which waste litters all over the places giving rise to health and environmental problems. Hence, there is an urgent need to involve larger contribution from private sector and community participation in waste management. Solid Waste Management (SWM) is a set of consistent and systematic regulations related to control generation, storage, collection, processing and land filling of wastes according to the best public health principles, economy, preservation of resources, aesthetics, other environmental requirements and what the public attends to. Many countries are continuously facing problems in managing solid waste and need comprehensive and practical solutions. Therefore, the optimization conditions for sustainable approach to SWM are a key factor for managers and planners. Currently, the planners and decision-makers in the area of integrated solid waste management are confronting increased complexity uncertainty and multi-objectivity of this issue. At the beginning, the process of decision-making on SWM was simple. It is because of the decisions were made only through simple comparison of some options out of the available options.***

Keywords: Optimization, Linear Programming, Transportation Cost

1. Introduction

One of the major factors that have contributed to poor waste collection and management in India is very limited public participation. The limited participation has budded from co-ordination and collaboration problems that exist among the three stakeholders in solid waste management- the communities, the public (government) and the private sectors. This study seeks to optimize the solid waste collection system and explore public participation in solid waste management in Gurugram city in Haryana in India.

Particularly ***w***aste quantity has increased in urban areas due to the growing urban population and concentration of industries and consumption of residents and inadequate finance and facilities to manage waste. This state of affairs has led to the volume of solid waste generated to go beyond what the available facilities can accommodate. New consumption patterns and social linkages are emerging. India, will have more than 40 percent, i.e. over 450 million people clustered in cities over the next thirty years. Modern living brings on the problem of waste management, which increases in quantity, and changes in composition with each passing day.

Urban labour groups, planners, environmental regulators, municipal agencies and**.**NGO need to develop a variety of responses which are rooted in local dynamics, rather than borrow non-contextual solutions from elsewhere.

New consumption patterns and social linkages are emerging. India, will have more than 40 per cent, i.e. over 450 million people clustered in cities over the next thirty years. Modern living brings on the problem of waste management, which increases in quantity, and changes in composition with each passing day.

There is a widespread literature on optimization of solid waste management. Few of the names are Sarika[1], Muztoba[2], Sanhita[3], Dawa Zam[4], Tashmeer[5], Tilaye[6], Mohsen[7],Rajkumar[8]

[1] developed mathematical model for Mumbai and also done a comparative analysis from shifting to different method of disposal and cost benefit analysis of the same. The study concludes that installation of decentralized solid waste processing units in metropolitan cities/towns and development of formal recycling industry sector is the need of the hour in developing countries like India. [5]States the proper management and treatment of MSW of Indore .The determination and the type of MSW and treating with respective method is the best way to manage MSW, so that it does not create pollution and harm our society.

[3] Rapid urbanization along with increases in population has led to the deterioration of physical environment in Gurugram. Effective Solid Waste Management is one of the major challenges faced by the local authorities. High volumes of waste generation, inefficient collection and transportation system and limited disposal options are continuously impacting the health, environment and quality of life in the area.[7] A linear mathematical programming model has been designed for integrated SWM. Using Lingo software and required data from Tehran, the proposed model has been applied for Tehran SWM system as a case study.[2] Optimization means using resources and existing technology at the best possible way. Better planning and its execution results in optimization of many problems. Quantitative

models and mathematical tools such as linear programming allows for better result. We can use modern computing equipment for this purpose. Nowadays various problems of operational planning are solved by mathematical methods.[4] Due to the lack of segregation practices, all types of waste produced are mixed and disposed in single bins leading to the filling up of provided bins within a short period of time. Collection vehicles are sent to collect wastes from different areas in a random manner making it ineffective.[8] The study concludes that installation of decentralized solid waste processing units in metropolitan cities/towns and development of formal recycling industry sector is the need of the hour in developing countries like India.
[6] Privatization of urban services focuses often on the involvement of foreign enterprises. This contribution deals with micro-privatization, the partial transfer of government responsibility for solid waste collection to micro-enterprises.

2. Linear Programming

Linear programming or linear optimization is a mathematical method for determining a way to achieve the best outcome (minimize) in a given mathematical model for some list of requirements represented as linear relationships. Linear programming is a specific case of mathematical programming (mathematical optimization).
Linear programs are problems that can be expressed in canonical form:

$$\text{Minimize } c^T x$$
$$\text{subject to } Ax \le b$$
$$\text{and } x \ge 0$$

More formally, linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints

Where, x represents the vector of variables (to be determined), c and b are vectors of (known) coefficients, A is a. (known) matrix of coefficients, and $(.)^T$ is the matrix transpose. The expression to be minimized is called the objective function ($c^T x$ in this case). The inequalities $Ax \le b$ are the constraints which specify a convex polytope over which the objective function is to be optimized. In this context, two vectors are comparable when they have the same dimensions. If every entry in the first is less-than or equal-to the corresponding entry in the second then we can say the first vector is less-than or equal-to.the second vector. The problem is to determine the optimal waste to be transferred from collection stations to transfer station order to obtain the minimum transportation cost. The transfer station which receive waste from different waste container locations, so if linear programming is applied to determine the optimal quantity of waste transferred from different locations to transfer stations it will be able to minimize the transportation cost significantly, which will result in increased profitability. For my scope of study I have taken 4 transfer stations, and located the collection bin stations.contributing.to respective transfer stations. It is also necessary to determine the approximate waste collected, for this interview was carried to calculate approx weight generated at each location.

3. Mathematical Model Formulation

For the given problem, we formulate a mathematical description called a mathematical model to represent the situation. The model consists of following components:

Decision Variables: - These variables represent unknown quantities (number of items to produce amounts of money to invest in and so on)

Objective Function: -The objective of the problem is expressed as a mathematical expression in decision variables.

The objective may be maximizing the profit, minimizing the cost, distance, time, etc. Consider waste container location as i. The total outgoing waste from waste container is the sum $x_{i1} + x_{i2} + \cdot\cdot\cdot + x_{in}$. In summation notation, this is written as

$$\text{more} \sum_{j=1}^{n} x_{ij}$$

Since the total supply from container location is a_i, the total quantity of outgoing waste cannot exceed a_i. That is, we must require

$$\sum_{j=1}^{n} x_{ij} \le a_i \text{ for } i = 1,2,3\ldots.,n$$

Consider transfer station as j. The total incoming waste at this outet is the sum of $x_{i1} + x_{i2} + \cdot\cdot\cdot + x_{in}$. In summation notation, this is written as $c_{ij}x_{ij}$. Since the demand at outlet j is b_j, the total incoming waste should not be less than b_j.

$$\sum_{j=1}^{n} c_{ij} \le b_j \text{ for } j = 1,2,3\ldots.,m$$

This result in a set of m + n functional constraints. Of course, as physical shipments, the x_{ij} should be non negative. Waste goes from container location i to transfer station j. For any i and any j, the cost parameter is c_{ij} ; and the size of the shipment is x_{ij} . Since we assume that the cost function is linear, the total cost in terms of distance is given by $c_{ij}x_{ij}$.

Formulate a mathematical description called a mathematical model to represent the situation. In summary, we have arrived at the following formulation. Summing over all I and j now

$$\text{Minimize} \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}x_{ij}$$

Subjct to

$$\sum_{j=1}^{n} x_{ij} \le a_i \text{ for } i = 1,2,3\ldots.,n$$

$$\sum_{j=1}^{n} c_{ij} \le b_j \text{ for } j = 1,2,3\ldots.,m$$

$$x_{ij \ge 0} \text{for } i=1,2,3\ldots.,m \text{ and } j=1,2,3\ldots..n.$$

This is a linear program with m × n decision variables, m + n functional constraints, and m × n nonnegative constraints.

Table 3.1: Transfer stations (Decision Variables)

Transfer Station	*Code*
Sheetla Mata Road	A1
Kadipur Chowk	A2
Saraswati Kunj	A3
Atul Kataria Chowk	A4

Objective function: The objective function contains costs associated with each of the variables. It is a minimization problem. Waste container location BX(X=1….33)

4. Modeling the problem using excel solver

This section will demonstrate, how to use excel solver to find the optimum transportation cost. First step would be to organize the spreadsheet to represent the model. Once the model is implemented in a spreadsheet, next step is to use the solver to find the solution. In the solver, we need to identify the locations (cells) of objective function (minimize) and constraints.

Step by step solution of the problem using Excel Solver is given below:-

Step 1:

L	M	N	O	P	Q
	TO				
CONTAINER LOCATIONS	Sheetla Mata Road (A1)	Kadipur Chowk(A2)	Saraswati Kunj(A3)	Atul Kataria chowk (A4)	
B1	0.5	0	4	5.2	
B2	1.1	0.9	4.2	5.5	
B3	1.3	1.7	4.7	5.7	
B4	1.4	1.2	5	6	
B5	1.9	2.4	6.2	6.5	
B6	1.7	3.2	7	7.5	
B7	2	3.5	7.6	8.2	
B8	2.2	3.8	8	8.5	
B9	1.5	0.5	0.3	4.2	
B10	2	0.9	1.3	4.5	
B11	1.5	1.3	1.2	4.4	
B12	2.4	1.7	2.5	5	
B13	3.1	2	3	5.5	
B14	2.9	1.8	3.2	6	
B15	3.4	3.4	4.1	4.4	
B16	3	1.9	4	4	
B17	4	3.2	0.3	0.4	
B18	3.9	3.4	0.5	0.6	
B19	4.5	3.7	0.9	1.2	
B20	5.5	3.5	1	1.4	
B21	5.3	4	1.3	1.1	
B22	5.7	4.4	1.6	1.2	
B23	6	4.2	1.7	2.3	
B24	5.9	3.9	2	1.9	
B25	5.7	4.2	1.8	1.5	
B26	6.1	3.9	1.2	1.5	
B27	5.2	0.7	0.7	1	
B28	6.3	4.6	1.5	1.5	
B29	6.9	4.5	3	1	
B30	7.5	5	3.1	1.3	
B31	8	5.5	3.3	1.4	
B32	7.2	5.4	3.6	1.7	
B33	9.2	5.9	2	2	

Figure 4.1: Input Table Representing distance in kilometer of container location from 4 transfer stations.

At first we will construct a table in excel that will contain cost parameter (distance) between each constraint.

Here in this excel sheet, container at different locations are given name B1 to B33 indicating 33 waste container locations, and there distance (in Kilo metre) to transfer stations is calculated using Google map.

This table corresponds to input data which represents distance between container locations and 4 transfer stations.

Step 2:- Creating output table with constraints in it. It gives solid waste in metric tons that goes from source to destination.

This output table which is to be determined shows that given waste container BX(X=1 TO 33) it has 4 different options where it can be transferred.

	A	B	C	D	E	F	G	H	I
1		TO				Objective value		0	
2	CONTAINER LOCATIONS	Sheetla Mata Road (A1)	Kadipur Chowk(A2)	Saraswati Kunj(A3	Atul Kataria chowk (A4)				Waste Generated(In MT)
3	B1					0			1.5
4	B2					0			1.3
5	B3					0			1.4
6	B4					0			1.5
7	B5					0			1.3
8	B6					0			1.2
9	B7					0			1.1
10	B8					0			2
11	B9					0			2.2
12	B10					0			1.3
13	B11					0			1.3
14	B12					0			1.6
15	B13					0			1.2
16	B14					0			2
17	B15					0			1.5
18	B16					0			1.3
19	B17					0			1.7
20	B18					0			1.4
21	B19					0			1.5
22	B20					0			1.3
23	B21					0			1.3
24	B22					0			1.2
25	B23					0			1.3
26	B24					0			1.4
27	B25					0			1.9
28	B26					0			1.7
29	B27					0			2.2
30	B28					0			2
31	B29					0			1.7
32	B30					0			1.4
33	B31					0			1.3
34	B32					0			1.3
35	B33					0			1.2
36		0	0	0	0				
37		<=	<=	<=	<=				
38	Capacity of trasfer station (in MT)	20	20	25	25				
39									

Figure 4.2: Output Table to be determined

On I column in figure 3.2 extreme right, it indicates the waste received daily at that particular BX(X varies from 1 to 33) container location, hence there is a limit that waste transfers form BX (X varies from 1 to 33) will be equal to the waste produced at that particular location.

In row 38 in figure 3.2, shows the capacity of particular transfer station in metric ton. Hence there is a limit that waste received at particular transfer station will not exceed its capacity.

Step 3:- Now we will create a cell that will automatically calculate objective value.

F	G	H
Objective value		0

Figure 4.3: Objective Value

To calculate total cost we need the function SUMPRODUCT. This will automatically sum all the product of unit and cost per unit.

i.e Total Cost =sumproduct(B3:E35,M3:P35)

Step 4:- In this step we will setup Excel Solver according to this problem. First we will open Solver from Data tab and locate the Total Minimum Cost cell in to ‘Set Objective’ in solver (i.e. H1). As we want to minimize the function we will choose ‘Min’.

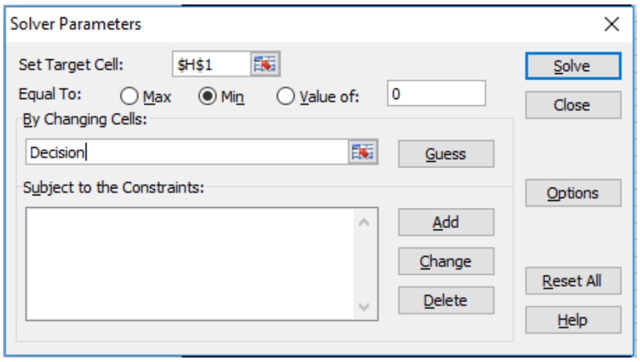

Figure 4.4: Solver Parameters

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Step 5:- Now we will add constrains of this problem in Solver. As previously discussed, there are two constrains in this problem.

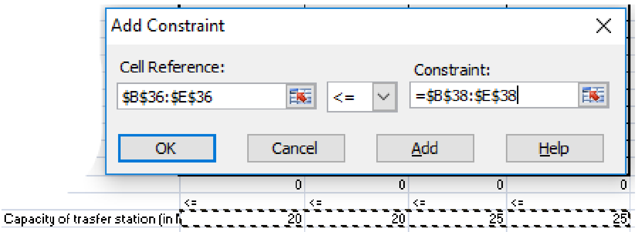


Figure 4.5: Constraint 1st

Constraints 1st:- Sum total solid waste received at each transfer station should be less than or equal to its capacity

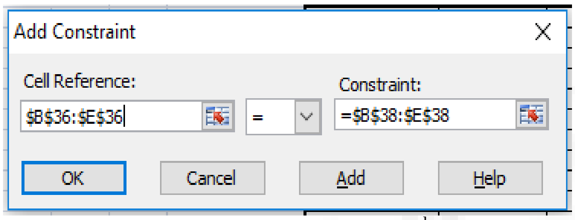


Figure 4.6: Constraint 2nd

Constraint 2nd:- Sum of the solid waste transported from each waste container would be equal to waste generated at that location.

Step 6:-

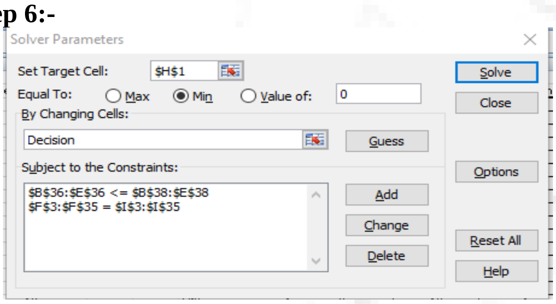
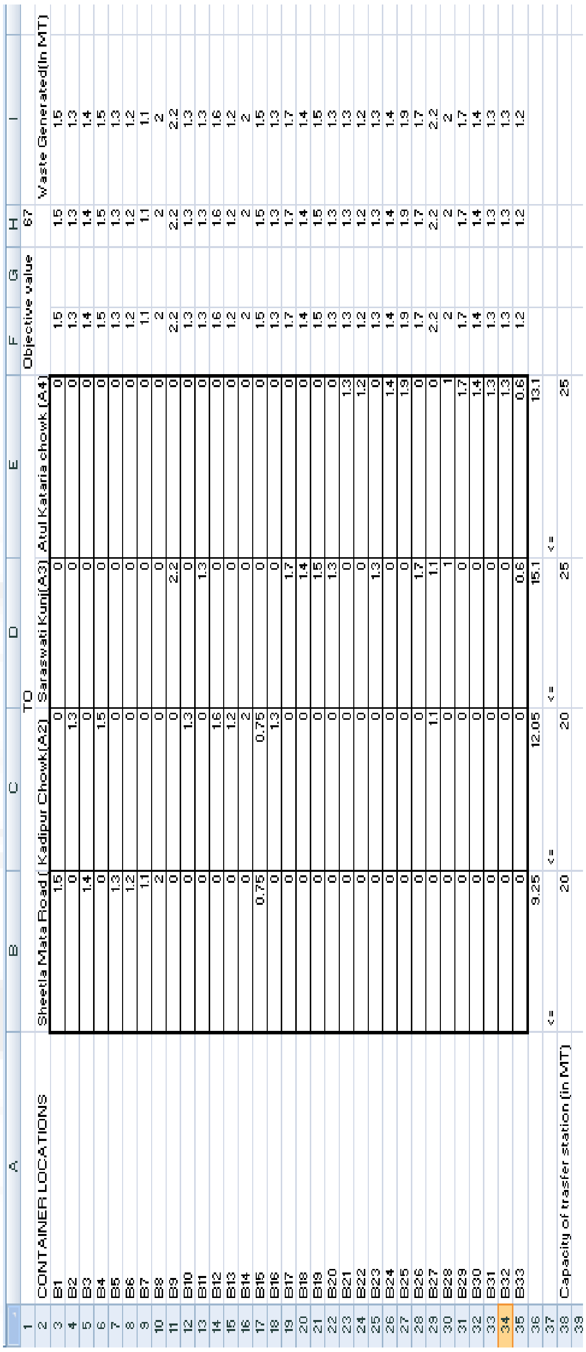


Figure 4.7: Solver

Constraints are added in solver, now we are done with the setup, all that is left is to click on 'Solve' button. This way we will find the following solution from solver.

5. Results and Discussions



	A	B	C	D	E	F	G	H	I
1		TO				Objective value		67	
2	CONTAINER LOCATIONS	Sheetla Mata Road (	Kadipur Chowk(A2)	Saraswati Kunj(A3)	Atul Kataria chowk (A4)				Waste Generated(In MT)
3	B1	1.5	0	0	0	1.5		1.5	1.5
4	B2	0	1.3	0	0	1.3		1.3	1.3
5	B3	1.4	0	0	0	1.4		1.4	1.4
6	B4	0	1.5	0	0	1.5		1.5	1.5
7	B5	1.3	0	0	0	1.3		1.3	1.3
8	B6	1.2	0	0	0	1.2		1.2	1.2
9	B7	1.1	0	0	0	1.1		1.1	1.1
10	B8	2	0	0	0	2		2	2
11	B9	0	0	2.2	0	2.2		2.2	2.2
12	B10	0	1.3	0	0	1.3		1.3	1.3
13	B11	0	0	1.3	0	1.3		1.3	1.3
14	B12	0	1.6	0	0	1.6		1.6	1.6
15	B13	0	1.2	0	0	1.2		1.2	1.2
16	B14	0	2	0	0	2		2	2
17	B15	0.75	0.75	0	0	1.5		1.5	1.5
18	B16	0	1.3	0	0	1.3		1.3	1.3
19	B17	0	0	1.7	0	1.7		1.7	1.7
20	B18	0	0	1.4	0	1.4		1.4	1.4
21	B19	0	0	1.5	0	1.5		1.5	1.5
22	B20	0	0	1.3	0	1.3		1.3	1.3
23	B21	0	0	0	1.3	1.3		1.3	1.3
24	B22	0	0	0	1.2	1.2		1.2	1.2
25	B23	0	0	1.3	0	1.3		1.3	1.3
26	B24	0	0	0	1.4	1.4		1.4	1.4
27	B25	0	0	0	1.9	1.9		1.9	1.9
28	B26	0	0	1.7	0	1.7		1.7	1.7
29	B27	0	1.1	1.1	0	2.2		2.2	2.2
30	B28	0	0	1	1	2		2	2
31	B29	0	0	0	1.7	1.7		1.7	1.7
32	B30	0	0	0	1.4	1.4		1.4	1.4
33	B31	0	0	0	1.3	1.3		1.3	1.3
34	B32	0	0	0	1.3	1.3		1.3	1.3
35	B33	0	0	0.6	0.6	1.2		1.2	1.2
36		9.25	12.05	15.1	13.1				
37		<=	<=	<=	<=				
38	Capacity of trasfer station (in MT)	20	20	25	25				
39									

Figure 5.1: Optimized Results (in Metric Tons)

This is the result from excel solver, which indicates which transfer station should receive solid waste in (metric tons) from which container location in order to minimize the cost. Here cost parameter is distance. Hence it shows that an optimal network of waste collection system can be built using this optimization. The waste received at each transfer station is less than its capacity means it is built with keeping future requirements also.

But there is a need of optimization at container locations because waste generated is not uniform, as there are certain locations where waste collected is more and at some location less waste is being received. The capacity of transfer station A1 and A2 is 20 metric tons and tat of A3 and A4 is 25 metric tons and waste received at these locations after optimizing is 9.25, 12.05, 15.1 and 13.1 metric tons from different locations.

6. Conclusion

The results from optimization indicated that requirement of analysis of size of bins to be kept at each location as there is variation in waste collected at each location. The capacity at transfer station is appropriate and is more than current requirement, as these are developed areas; increase in solid waste due to future expansion is less. Increase in solid waste would probably because of increase in living standards. There will be some real life constrains, which we won't be able to solve with any model. In those cases, we will have to depend on our intuition and experience.

Waste reduction through waste reuse is a primary function of the public at the stage of waste generation. Gurugram Municipal Corporation can use this model as decision support tool for efficient management of moving the solid waste, fuel consumption. Optimization problems could be solved more easily with linear programming approach if one should be able to formulate the problem using linear equation for both the objective function and the binding constraints or restrictions. The major proportion of the wastes emanates from the residential sectors and recycling is not currently practiced formally in the metropolis. The consequences of the poor waste management are manifested in environmental degradation, road encroachment, air pollution, residential land encroachment and loss of aesthetic view of the metropolis. From face to face interview came to know that there is need of creating awareness amongst people about waste management.

References

[1] Sarika Rathi, Optimization solid waste model for Mumbai, India, *International Research Institute for Climate and Society* (2007).
[2] Muztoba Ahmad Khan Cost Optimization using Linear Programming, *International Confrence on Mechanical, Industrial and Energy Engineering* , Volume 2(2014).
[3] Sanhita Bandyopadhyay (2002), Solid Waste Management, an Environmental Challnege in Millenium Cyber City in India, Gurgaon, MCG Gurgaon (2013)
[4] DawaZam, Optimization of solid waste collection and transportation route in Phuentsholing city using GIS, Waste Management and Research 9(6): 495–509.(2007).
[5] Tashmeer Khan, Municipal Solid Waste Mangement Of Indore, Indore Institute of Science and Technology, Indore(2016)
[6] M Tilaye, Private sector participation in solid waste collection in Addis Ababa by involving micro-enterprises, Waste Manage Res.2014 Jan;32(1):79-87.
[7] Mohsen AkbarpourShirazil, Mathematical modelling in municipal solid waste management in Tehran, JEnviron Heath Sci Eng, 2016 May.
[8] Rajkumar Joshi, Sirajuddin Ahmed, Status and challenges of municipal solid waste management in India, Cogent Environmental Science(2016), Volume 2.

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