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Original research article

Optimization Model for Collection and Transportation of Municipal Solid Waste in Jaipur City

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ABSTRACT

We are living in that era when economic growth rapidly increases the amount of solid waste. The process of solid waste collection involves door to door collection of solid waste and transporting it to depot, after segregation process at the depot it will be transferred to the landfill. Due to shortage of disposable land to fix the solid waste, most of the Indian cities have landfill outside the city within 15-50 km radius. The facilities given by the government not up to the mark so they offer private partners to handle the situation. The road map of the collection route is not fixed and the traffic intensity and insufficient resources also plays a vital role to handle this situation. In this paper, optimization model is proposed for collection and dispose the solid waste. With the help of ArcGIS we are gathering the information of all major collection sites in all zones and best possible routes with low intensity traffic. Our aim is to handle the situation using vehicle routing problem. We are taking Jaipur (India) as case study to implement our mathematical model.

Keywords: Cross-docking; Environmental modeling; Solid waste management; Route optimization; Vehicle routing problem

1. Introduction

This populace of India is expanding quickly; most recent information [1] shows that in 2019, it is around 1.372 billion approx. In India individuals moved to urban areas for looking through open positions which increment the populace metropolitan regions. It is provoking errand for each civil partnership to appropriately deal with the MSW inside their spending plan. So an enhancement model is expected to give viability just as better administration.

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Being capital of Rajasthan, Jaipur is the monetary center point and the celebrated vacationer location. In Jaipur, the populace in 2019 is 3.812 million [2] approx. Age of waste is expanding step by step. Each administration attempts to improve the administration of strong waste. In any case, because of multifaceted nature in administration, this issue is constantly picked by specialists. Our work in this paper is mostly centered on the transportation of strong waste.

Jaipur's everyday creation of strong waste is right around 1700-1800 MT/day [3]. Out of which around 250-350 MT actually stays in the city and streets, that implies lifting productivity is around 80%. The per capita strong waste age every day is around 500 gm [3], which with a family size of just about five, brings about 2.5 kg/day.

The organization of various squanders continues to differ from season to prepare. In the midyear there is more biodegradable waste delivered in light of more vegetation. The creation of plastic in waste has most likely been diminishing because of the restriction on plastic packs in Rajasthan from starting August 2010 [3]. It has been seen that Jaipur Municipal Corporationhas utilized privately owned business BVG [3] for assortment and transportation of the strong waste. Moreover, JMC hires permanent and private contractor's that clears the streets and other normal zones physically. The sweepers place the loss from the street in a wheeled cart and afterward move the loss to trash bins or assortment focuses.

Generally, waste collection, storage and transport are important components of any SWM framework. Squander collection is the responsibility of the metropolitan organizations in India, and regularly, biodegradable and idle waste is collected in canisters [3]. The waste collected in India is normally a blend of biodegradable and latent waste, with open consumption often taking place. Improvements to the waste collection and transportation system will generate employments, enhance health, and expand the travel industry. The nearby bodies spend about Rs. 1500 on SWM per ton, with 70% of this amount spent on assortment and 20% on vehicle maintenance [3].

The current state of waste management in India is poor because the best and most appropriate methods from squander collection to disposal are not being used. There is no training in waste management and qualified waste management experts are not easily accessible. Additionally, there is a lack of responsibility in SWM frameworks in India [7]. Civil specialists are responsible for overseeing MSW in India, however their budget plans do not reflect the costs involved with creating lawful waste collection, stockpiling, treatment and removal. SWM in India faces significant obstacles due to the absence of MSW plans, waste separation and isolation, and a government funding system [8].

In this paper, the creator will talk about his viewpoints on the absolute most significant methodology and proposals to challenges looked by the strong waste administration area. The given methodology, by and large, will be separated into those looked by the business all in all on various boundaries which influence the strong waste industry [7]. The current examination writes about the current strong waste administration rehearses in four significant urban communities of Himachal Pradesh (Sunder Nagar, Mandi, Baddi and Solan) in India, and recommends answers for better administration of the MSW produced at these areas [8]. This special investigation utilized inbuilt enhancement procedures and self-changed calculations of the organization expert device in the foundation of Geographical Information System (GIS) to propose the advanced ways for civil strong waste (MSW) assortments at Kanpur, India [9].

Optimization of municipal solid waste transportation by integrating GIS analysis, equation-based, and agent-based model was discussed in [10]. Many Other researchers discussed the Optimization in solid waste management [11-14].

Strong waste administration was chosen as the subject of this investigation since it is a noticeable ecological supportability issue that India is defying, since Jaipur is a quickly creating city, powerful waste administration rehearses is particularly required. The target of the investigation was to streamline the strong waste assortment and transportation measure. In our methodology, we are utilizing traditional blended number vehicle steering issue.

This paper is separated into 6 segments. In second segment, arrangement of strong waste assortment and transportation is talked about. Numerical detailing is examined in the third part. Contextual analysis of Jaipur city for the MSW transportation and assortment is examined in the following segment. Toward the finish of the article result and conclusion part is talked about.

2. MSW Collection & Transportation System

In general, the collection and transport of municipal solid waste (MSW) can be divided into 3 stages, as shown in Fig. 1. Firstly, the MSW, generated by different sources(S) (households, markets, Institutes, offices and so on) is collected and conveyed to the nearest collection point(C) or collected solid waste from sources (S) directly transferred to the depot (D). Each collection centre (C) is made up of a number of bins having the same capacity (in m^3). Then, vehicles departing from Depot (D) pass via the Collection Centres following a scheduled route, it collects municipal waste, returns it to the depot for further separation processes, and transports the remaining waste (by cross-docking) to landfills (L) for composting and landfill processes.

The distance between the terminal and the landfill are around 15-50 Km. Accordingly, we assume the accompanying suppositions for our framework:

a) The all out volume of waste in a gathering visit is not exactly or equivalent to the limit of the vehicle. So that, our concern can be changed into an old style VRP. Truth is told, for the perplexing case with more vehicles and the all out volume of waste more noteworthy of the complete limit, we can change into numerous old style VRPs.
b) Way for house to house assortment is as of now known.
c) The good ways from various stations to the landfills are as of now known.
d) The position and the amount (the quantity of canisters) of every assortment place are known.
e) The arrangement of assortment of every vehicle is accessible. It implies groupings of the assortment community that the vehicles should go through.
f) The distance between hubs is known.
g) The waste age rate is known. This sign is introduced by the proportion of the waste assortment into a receptacle. So that, the volume of waste at a middle relies upon the quantity of canister and this proportion. For straightforwardness, all assortment habitats have an equivalent proportion.

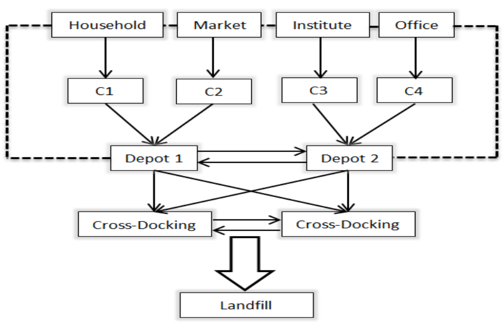

Fig. 1. Solid waste management process.

3.Mathematical Formulation

3.1 Mathematically formulate

For this model [10], we apply the traditional vehicle directing issue utilizing blended whole number straight programming to recognize the advanced arrangement. Let $G=(V,A)$ be the diagram that presents the course of a vehicle in which, $V=\{v_0,v_1,...,v_n\}$ is a vertex set, where:

- Consider the depot to be located at v_0.
- Let $V'=V\setminus\{v_0\}$ be used as the set of n collection centers, v_n is the landfill.
- Arc set, $A=\{(v_i,v_j)\mid v_i,v_j\in V;i\neq j\}$.
- C-matrix of non-negative costs (distances) c_{ij}-distance between collection centers v_i and v_j.
- Here m indicates the number of vehicles.
- Here S denotes the set of routes, which is satisfying all associated constraints of the objectives.
- $X=$ matrix of $(0,1)$ where:
  $y_{ij}=1$, the path goes from hubi to hub j
  0, otherwise.

Our focus is to limit the complete cost associated with a visit, which includes the length of the visit and the fixed expenses arising from the visit to the hub. Although our concern is similar to the OVRP [15-17], we see a specific imperative: the vehicle should end at the landfill (the expense to transport from the landfill to the station is consistent; we believe the vehicle should end at the landfill).

3.2 Mathematical model of the problem

Mathematical model of the problem is presented in the subsequent manner [10]:

$$\min\sum_{i=0}^{n}\sum_{j=0,i\neq j}^{n} f_{ij}y_{ij}, \tag{3.1}$$

subject to

$$\sum_{i=0,i\neq j}^{n} y_{ij}=1, i=1,2,...,n, \tag{3.2}$$

$$\sum_{j=0,i\neq j}^{n} y_{ij}=1, j=1,2,...,n, \tag{3.3}$$

$$\sum_{i=0}^{n} y_{i,0}=m, \tag{3.4}$$

$$\sum_{j=0}^{n} y_{j,0}=m, \tag{3.5}$$

$$\sum_{i\notin S}^{n}\sum_{i\in S}^{n} y_{ij}>r(S),\forall(S)\in V\setminus\{0\},S\neq 0, \tag{3.6}$$

$$y_{ij}\in\{0,1\},\forall(i,j)\in A. \tag{3.7}$$

The second and third constraints relate to the classical evaluation limitation that every source in the set $\{v_1,v_2,...,v_n\}$ must be precisely visited by one vehicle. According to constraints (3.4) and (3.6), the number of vehicles leaving the stop equals the number entering. In constraint (3.6), there is a capacity cut, which forces courses to be associated and interest on routes not to exceed the vehicle limit. In Constraint (3.7), the choice factors are intelligently depicted in terms of the standard task limitations.

3.3 Cross docking

The concept of cross docking refers to a logistics process where goods and materials are unloaded from one inbound source (truck, railcar, etc.) and then immediately transferred to another source of outbound transportation with a small amount of stockpiling time. This is attractive in light of the fact that the more extended items sit in a distribution center or other stockpiling area, the less generally esteem they give.

4. Case Study

Jaipur is situated at the scope 26°55' N and longitude 75°49' E. The municipal corporation of Jaipur is isolated into 8 zones for the purpose of collection and storage of wastes. The zonal commissioner is liable for the tidiness of each zone, whose wellbeing official and a chief sanitary inspector help. With the cleaning point, these 8 zones again separated into 91 wards (Fig. 2). In each ward, the duty of cleaning is finished by the sub inspector, who gives the Jamadar, supervisor and sanitary worker uphold identified with that ward.

The cleaning work in Jaipur Municipal Corporation depends on three-level framework. The leady cleaner clears her in the fixed zone and the male specialists work to clean the nallia. After that the trash is gathered with the assistance of hand-driven trains. The woman cleaning specialist makes the landfill of the trash with the assistance of a brush and the landfill of trash is gathered by the male cleaning laborer. The cleaning of little and enormous channels is finished by male cleaning laborers. The cleaning laborers convey trash by hand to the assortment terminals of each ward. Those spots are called trash assortment stops.

Fixed compartments have never been introduced in the city by the Jaipur Municipal Corporation; consistently mobile containers have been utilized. Prior the quantity of trash warehouses in the city was 2700, which is currently just 150 in year 2019 (preceding acquainting BVG India's door-to-door garbage collection). The door-to-door garbage collection in Jaipur city was begun on May 8, 2017 by Mayor Ashok Lohoti. Little trucks have been set up by the organization for conveying trash. These little trucks handily come into sakri paths which encourages taking trash in the sakri paths. The limit of a little carriage is to raise around 700 Kg of trash, which gets trash from 250 to 300 houses in approximately one trip. The quantity of vehicles utilized by the BVG Company to lift the trash from 8 zones of the city is appeared in table 1.

As of now, squander assortment is being finished by BVG India at the accompanying spots (depots).

Table 1. BVG INDIA LTD zone wise vehicle list [3].

S. N.	Package	Zone	Tata Ace	RC	E - Rickshaw	Try Cycle	Dumper /Hyva	JCB	Tractor Trolley/ Loader	Total
1	I	HMW	38	0	0	12	3	2	34	89
2	I	VDZ	165	0	0	0	20	14	4	203
3	I	AMER	28	3	0	0	5	2	10	48
4	II	CLZ	119	2	8	0	17	11	6	163
5	II	MNS	79	0	7	2	14	5	8	115
6	III	HME	62	0	0	2	5	3	20	92
7	III	MDZ	68	2	1	0	14	5	20	110
8	III	SNG	79	3	0	0	13	8	13	116
Total Ward Vehicles			638	10	12	16	91	50	115	932
Spare			40	4	13	11	4	1	0	71
Total Vehicles			678	14	25	27	95	51	115	1003

Transfer and transport of MSW

The depots are not utilized, and a similar vehicle, which gathers squander from singular compartments, sends them to the treatment or removal site. Metropolitan strong waste gathered in trash bins and assortment focuses is shipped to treatment or removal locales utilizing an assortment of vehicles. In small towns (rural) semitrailers, tricycles and so forth. They are principally utilized for the transport of municipal solid waste. Light motor vehicles and trucks are by and large utilized in the primary urban communities or towns for the vehicle of civil strong waste. The trucks used to move MSW are for the most part open-body type and by and large stay revealed; along these lines, during transport, the waste will in general spread out and about, which brings about unhygienic cleanliness conditions. In certain urban communities, current water driven vehicles are being presented continuously.

Table 2. BVG INDIA LTD transportation list [3].

<table>
<tr><th colspan="4">List of Transfer Station Point</th></tr>
<tr><th>S.No.</th><th>Zone</th><th>Transfer Station Name</th><th>Dumping Station Name</th></tr>
<tr><td>1</td><td rowspan="3">VDZ</td><td>Badhana Puliya</td><td rowspan="3">Sevapura</td></tr>
<tr><td>2</td><td>Swarn Jayanti Park</td></tr>
<tr><td>3</td><td>Kalward Road</td></tr>
<tr><td>4</td><td>HMW</td><td>LalDungri</td><td>Mathuradaspura</td></tr>
<tr><td>5</td><td>AMER</td><td>Jal Mahal Pal</td><td>Mathuradaspura</td></tr>
<tr><td>6</td><td rowspan="2">MNZ</td><td>V.T. Road</td><td rowspan="2">Sevapura</td></tr>
<tr><td>7</td><td>Jhulelal</td></tr>
<tr><td>8</td><td rowspan="7">CLZ</td><td>Kalward Road</td><td rowspan="7">Sevapura</td></tr>
<tr><td>9</td><td>Civil Line Fatak</td></tr>
<tr><td>10</td><td>Darbaar School</td></tr>
<tr><td>11</td><td>V.T. Road</td></tr>
<tr><td>12</td><td>Karni Vihar Police Station</td></tr>
<tr><td>13</td><td>Railway Station</td></tr>
<tr><td>14</td><td>Lal Kothi SubziMandi</td></tr>
<tr><td>15</td><td rowspan="4">SNZ</td><td>Muhana Mandi</td><td>Mathuradaspura / Langrayeewas</td></tr>
<tr><td>16</td><td>Bambala Puliya</td><td>Mathuradaspura</td></tr>
<tr><td>17</td><td>Ghodha Circle</td><td>Mathuradaspura / Langrayeewas</td></tr>
<tr><td>18</td><td>Khaniya Bandha</td><td>Mathuradaspura</td></tr>
<tr><td>19</td><td rowspan="4">MDZ</td><td>Goal Market</td><td>Langrayeewas</td></tr>
<tr><td>20</td><td>Jhalana</td><td rowspan="3">Mathuradaspura /Langrayeewas</td></tr>
<tr><td>21</td><td>MurdhaGhar</td></tr>
<tr><td>22</td><td>Gautam Nagar</td></tr>
<tr><td>23</td><td>HME</td><td>LalDungri</td><td>Mathuradaspura</td></tr>
</table>

Assortment and transportation exercises represent around 80-95% of MSWM's total budget; in this way, it is a critical component in deciding the economy of the whole MSWM framework. Civil organizations utilize their own vehicles to ship MSW, albeit in certain urban communities they are employed by private project workers. MSW assortment is the obligation of the organizations/districts. The overwhelming assortment framework in many urban areas is through mutual compartments situated at different areas along the streets, which once in a while prompts the formation of unapproved open assortment focuses. With the help of non-governmental organizations, house to house collection is beginning in numerous megacities, such as Delhi, Mumbai, Bangalore, Madras and Hyderabad. It has been observed that numerous districts have contracts with private workers for hire for optional vehicle transportation to and from common compartments or from assembly centers to removal destinations. Others have utilized NGO's and resident advisory groups to screen isolation and assortment from the wellspring of creation to assortment focuses at middle focuses among sources and landfills. Also, social help affiliations coordinate explicit month to month assortments in certain metropolitan territories. Sweepers are assigned a certain zone to sweep (about 250 m^2) in order to clear the streets physically. Sweepers collect trash from the streets and then transport it to trash cans or collection points.

Three regions have been chosen out of the city for removal of trash by the Jaipur Municipal Corporation is Sevapura, Langariyawas and Mathuradaspura (Table 2). This is the three spots where the trash of the entire city is gotten. The absolute region of these three is 859 bigha. The distance from the city of these three zones and their description is shown I in table 3.

Table 3. Places of garbage disposal in Jaipur city [3].

Place	Area	Distance from city
Mathuradaspura	176 bigha	17 km
Sevapura	200 bigha	20 km
Langariyawas	483 bigha	21 km

According to the figures of the year 2019, the average amount of garbage brought from the city of Jaipur in Mathuradaspura, Sevapura, Langariyawas is shown in Table 4.

Table 4. Garbage disposal of the year 2019 per day [3].

Place	Garbage
Mathuradaspura	700-800 MT/day
Sevapura	250-300 MT/day
Langariyawas	350-450 MT/day

Table 5. Waste Generation Rate (Kg/C/Day).

S. No.	Year	Waste generation rate (kg/day) per person	Source
1	2001	0.48	JMC, 2001
2	2004	0.39	CPCB, 2004
3	2010	0.44	JMC, 2011
4	2014	0.478	JMC, 2014
5	2019	0.530	JMC, 2019

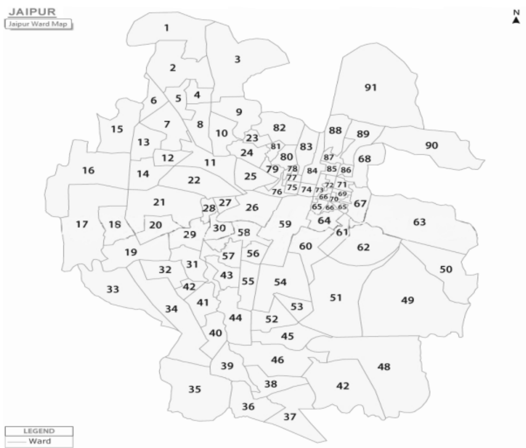

Fig. 2. Ward map of Jaipur city [3].

The population density in Jaipur city is increasing annually and as a result the measure of strong waste age is increasing every day. Strong waste is a mixture of different sorts of strong waste, including biodegradable food waste, and strong waste like paper, glass, metal things, clothes, and so on, which are called refuse. The trash incorporates a wide range of putrescible natural waste got from kitchens, inns, eateries, and so forth All waste food articles, vegetable peelings, organic product peelings, and so on, are accordingly remembers for this term. Since these wastes are organic in nature, they can quickly decompose and cause foul odors and health hazards. The density of trash normally differs between 450 to 900 kg/m^3.

Table 6. Distance chart form each ward depot to landfill,

Ward No	Distance	Optimize distance
1	15.3	14
2	15.5	12.1
3	14.6	14.1
4	15.2	13.5
5	15.4	12.3
6	15.5	14.8
7	15.7	13.2
8	15.7	13.8
9	15.7	13
10	15.8	15
11	16	14.6
12	16.2	16
13	16	13.7
14	16.3	15.1
15	27	15.2
16	28.3	26.1
17	29.5	29
18	30	26.4
19	28.5	27
20	29.3	26.1
21	27.9	25.8
22	32.2	29.4
23	15.5	14.9
24	15.5	14.9
25	15.6	14.1
26	28.1	25.2
27	27.5	27.5
28	28.7	26.2
29	32.2	30.5
30	29.6	28.5
31	33.1	29.3
32	33.4	32.4
33	33.6	31.7
34	34	33.6

35	43.5	42.1
36	45.2	43.5
37	43.5	41
38	47.3	44.2
39	44.6	40.6
40	35.3	34.9
41	36	32.1
42	35.2	31.6
43	36.3	34.5
44	37.7	38
45	47.3	44.8
46	48	47.5
47	47.8	42.9
48	44.5	41.5
49	44	40.3
50	42.4	42
51	26.7	23.8
52	46.7	40.2
53	28	27.5
54	27.2	23.9
55	35.9	32.5
56	28.7	29
57	28.1	24.2
58	29.6	23.8
59	26.2	25.1
60	26.9	21.7
61	25.4	24.2
62	26	24.1
63	24.3	20.5
64	24.1	23.4
65	25.2	24.3
66	17.1	16.5
67	17.2	16.5
68	23.2	21.2
69	23.5	21.5
70	23	20.3
71	22.5	22
72	24.6	24
73	23.7	21.4
74	25.3	25.7
75	26	22.6
76	24.6	21.9
77	25	24.2
78	26.4	21.5
79	15.5	14.8
80	15.5	15
81	15.5	14.7
82	15.6	13
83	26.7	23.4
84	26.2	25
85	23.7	22.4
86	24.5	21.7
87	28.4	24.9
88	29.5	29
89	27.1	25.2
90	29.3	28.1
91	28.5	25.6

5. Results and Discussion

After applying the model, we optimize the distances from depot to landfill by 7.75%. Benefit in distances is actually benefited in fuel as well as money.

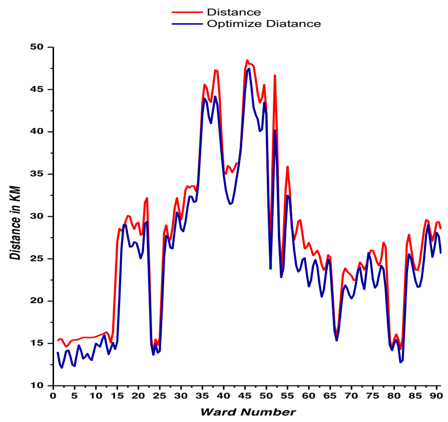

Fig. 3. Optimize distance chart from depot to landfill (Table 6).

6. Conclusion

In this paper, the travel distance from stop to landfill is 7.75% (Fig. 3) optimize by us by using traditional VRP. The proposed approach shows that it will be extremely powerful and furthermore featuring that the current intermittent strong waste assortment and transportation can be improved by streamlined assortment arranging. Future improvements respect the augmentation of VRP to catch the situation where the all out volume of waste in an assortment visit is more that the limit of the vehicle. Split Delivery or group Vehicle Routing Problem can assist us with settling the issue. We likewise require another calculation to cover the novel formalization with group VRP issue joining with cross docking. At long last, in future examination movement, we need coordinate a model to figure the fuel utilization in each progression.

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