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Efficient Waste Collection: A GIS Approach to Route Optimization

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ABSTRACT. Efficient collection and disposal of the collected waste is a prerequisite of effective waste management system. Waste management also includes solving the problem of collection and disposal of solid waste. It also includes the allocation and reallocation of bins and checking for the unsuitability and inconvenience due to waste bin location to the users. The imbalance in the location and inadequacy in the transportation system generates more waste. The optimization of routes for reducing the travel distance and ultimately reducing the overall costs and travel times along with the selection of appropriate site for waste disposal without causing any adverse effects on the environment are the major components of waste management. The selection of suitability of potential dumping sites and location of collection bins and modifications to the existing facilities requires a comprehensive assessment of the existing conditions. This paper addresses the problems associated with the existing waste collection and disposal system in the study area. By optimizing the system, the number of collection points has been reduced from 101 to 50, with increased bin capacity, and two alternative dumping sites have been proposed. From the analysis of distance traveled from collection point to dumping sites using GIS with proposed routes covering the entire city and no waste is left uncollected resulted in reduction of 12.4% travel distance and hence reducing cost incurred in solid waste management of the city.

Keywords: waste, geographic information system, route optimization, dumping sites, sustainability.

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1. Introduction

To improve waste management systems, new technologies have been developed, with Geographic Information System (GIS) being one of the most impactful advancements. GIS has made significant contributions to waste management and society within a short period (Fatima et al. 2023). It enables data manipulation, simulation, and analysis, facilitating the search for alternatives to support effective decision-making. GIS is a system combination of software and hardware, that allows the user to collect, analyze and retrieve volumes of spatially referenced data along with the attribute data collected for the study (Nguyen-Trong and Nguyen 2022, Sanjeevi and Shahabudeen 2016). GIS helps in dealing with many factors that are required to be considered while planning waste management simultaneously.

The manual methods used for the analysis are very lengthy and tedious and during the merging of spatial and non-spatial data there are more possibilities of errors. But in GIS, different layers are used to incorporate the data and to carry out the work, making the system capable of coordinating between spatial and non-spatial data, hence reducing the chances of confusion and errors. GIS can be used as a good decision support tool for the various waste management aspects. Due to its multifunctional approach, there is a good flexibility in spatially relating the data for comparing, evaluating and analyzing the information for its processing. Accessing the location and combining the information with surrounding feature information enables one to take decisions for efficient management. GIS has been used by many researchers for the efficient collection and disposal systems of waste management. GIS in combination with site investigations, GIS with Multi-criteria evaluation (MCE) and GIS with analytical hierarchy process (AHP) have been used for landfill siting. GIS has also been used for route optimization to reduce the overall travel distances and costs (Cheng et al. 2018, Akhtar et al. 2017). GIS has also proven to be an efficient tool in transportation model of solid waste disposal (Abdullah et al. 2021, Nanda and Berruti 2020).

1.1. Study Area

The study area is a city which is the administrative headquarters of a District in Punjab, India situated at Latitude of 30.3398° N and Longitude of 76.3869° E. Founded in 1974 by Baba Ala Singh, a Soldier par excellence on an ancient mound, *"PRASTHALA"*, frequently referred to in the Mahabharata and has long acquired a place of eminence in political, social, religious, music and the fine arts, academic and military spheres. It has long been a centre of trade and commerce, but in recent years the commercial activities and educational institutes have duly increased the population of the city, and it has gradually developed into an industrial town. As per census of 2011 the population of the city was 4451969 with an area of 70.20 sq km. The city is divided into 50 municipal wards with a waste Generation of 260 MT per day as per records of the Municipal Corporation of the city. Generated solid waste is collected at 101 collection points and the disposal site is 3.5 km from the centre of the city. The present infrastructure of the solid waste management of the city is not sufficient to cope with the ever-increasing generation of solid waste by the households. The collection points are not uniformly divided, the few wards do not have any collection points and in few of the wards there are more than required collection points. All the points are merely open dumps and near to the residential areas causing unhygienic conditions in the city. There is neither any container for the collection of waste at any collection point nor any vehicle to transport waste. Due to which the waste is littering on the roads, creating unhealthy conditions in the city. There is no specific collection route and no fixed time for collection and disposal of waste. The existing route followed in the city by the trucks passes through residential areas causing health problems and foul smell. The width of the roads is also not wide therefore traffic jams are also caused. The site meant for dumping waste is within the residential area with no arrangement for waste transport or any treatment.

With the present waste management systems and conditions of the city, most of the area of the city remain un-served and waste collection points and dumping site is not properly located resulting in poor waste management. Therefore, there is an urgent need for the proposal of an ideal site for dumping and for the new route.

2. Data Collection

The database of the study area has been prepared by collecting information from different sources and the collected information is transferred into the GIS database. Maps were collected from the Municipal Corporation and Department of Town and Country Planning Punjab. The maps contained information on the city boundary, wards boundary and important landmarks. Another map of the city contained information about major buildings, Institutes, detailed road networks, water streams, railway station, bus terminal, and landmarks. Both the maps were scanned and later were imported to GIS and joined together. Then the base map raster image of the city was geo-referenced. The map raster image of the city was located on its position on the city map. Finally, the raster images were digitized for inclusion of spatial information in vector form. Point, Polyline and Polygon feature were used to spatially locate the information collected (Hashemi-Amiri et al. 2023, Thomé et al. 2016).

2.1. City Boundary and Ward Boundary Data

The maps collected from the Municipal office contained the city boundary and wards boundary. The city is divided into 50 municipal wards with varying area and population. As there was no availability of population distribution in the maps so the information relating to wards boundary gathered from the maps was incorporated in the database.

2.2. Land Use Data

The areas which are shown in the land use are the residential area, commercial area, industrial area, public/semipublic area, important landmarks, and environmental sensitive areas like forest area, green area, canal area, parks and protected area. The maps being old, some latest information was also updated in the database. There is one natural water stream passing through the city, which is also demarked on the map. Figure 1 shows the land use map of the city and Figure 2 shows the percentage land use area of the city.

2.3. Waste Collection Points Data

Collection point information was collected from the Municipal office. The actual location of collection points that can be used in database was collected using handheld GPS. The information of 101 collection points has been used in the database.

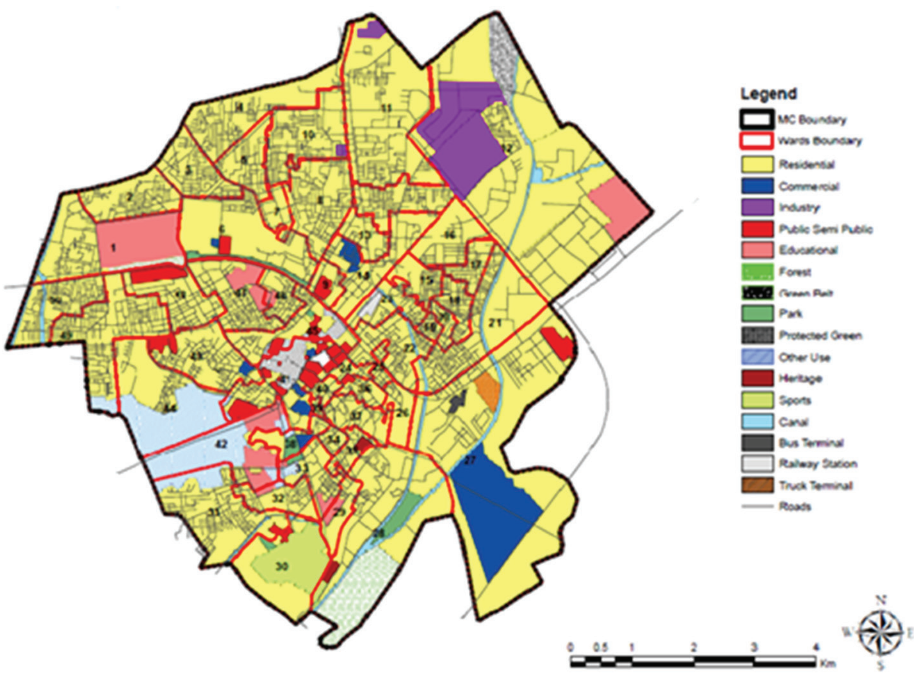

Figure 1. *Land Use Map of the City.*

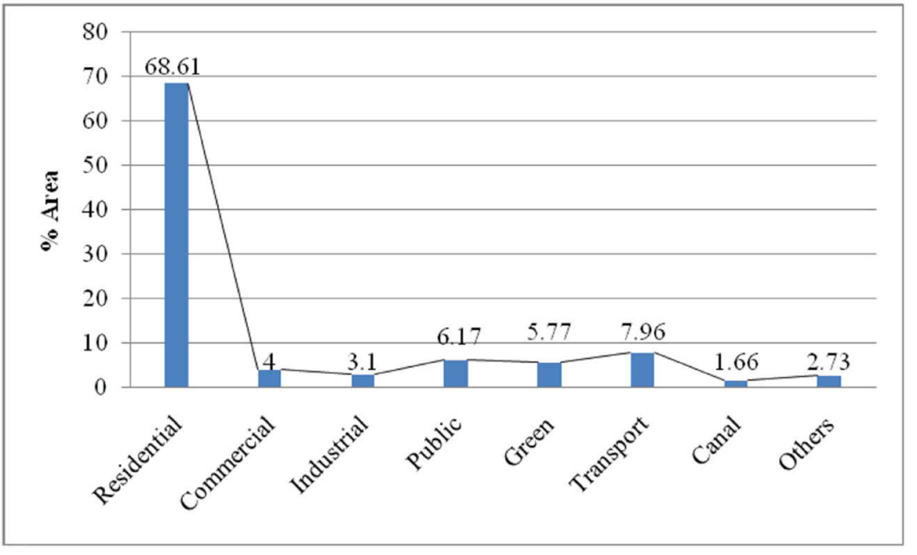

Figure 2. *Percentage Land use area of the city.*

2.4. Dumping Site Data

Information about the dumping site was collected from the Municipal office. The actual location of the site was collected using handheld GPS. It was a complex job to collect detailed information about the area of the dumping site as no boundaries are specified for the dumping site and the municipal office had only location data of the site. Hence, dumping site is represented by a point in the database.

2.5. Routing Data

There is no specific collection route and no fixed time for collection and disposal of waste. So, data regarding the routes was collected by physical interactions with the municipal workers and the drivers. Based on information collected the routes have been incorporated into the database.

2.6. Limitations of The Data

In the GIS database, efforts have been made to incorporate the collected detailed data information but there were some limitations in the data. The maps available from the Municipal office were old and were not updated with the information about the latest dates and changes. The collection points and dumping site data is available in a point feature. The point feature depicts only location by point but does not provide exact area information. There is no availability of detailed information on population density or distribution, so the quantity of waste generation cannot be related to the area density. Although population density data was not available in spatial format within the base maps, ward-level population statistics were obtained from municipal records and used for waste generation calculations.

3. GIS Workflow Model

The designed model can be used for proposing a system that will reconsider the existing collection point and dumping site locations in the city and provide some better alternatives for allocating and relocating the existing facilities (Wang et al. 2019, Sah et al. 2021, Singh and Sharma 2018). The proposed modifications in the system would increase the efficiency of collection and disposal of waste thereby reducing the adverse effects of the environment and reduce travel distances ultimately reducing the time and cost. Figure 3 shows the proposed GIS workflow model that has four components i.e. primary data, analysis, function and finally the results.

4. Results and Discussions

The primary data comprises of various map layers of the study area. The layers being, boundaries, collection point's locations, dump site location, land use, road network, environmentally sensitive areas, and important landmarks. The city boundaries, ward boundaries and land use areas including environmentally sensitive areas like parks are represented by a polygon, the collection points and dumping site locations are marked by point and the road network and natural water stream have been represented using line feature. On the basis of availability of primary data different analyses have been covered by the model for the improvement in the existing waste collection and disposal efficiency of the study area. The results of the analysis will serve as decision support in the relocation of the collection points and the dumping site along with the proposal for new routes. These analyses are discussed below.

4.1. Ward-Wise Coverage of Collection Points

There are 50 municipal wards in the city that need to be covered by all collection points. So, this factor has been analyzed for the existing collection points and will serve as a guideline for the proposal to relocate them. For this, collection points have been compared with the ward boundaries of the city. This would provide information regarding the ward areas that are not being covered by the existing collection points.

4.2. Proximity of Dumping Site from Residential Areas

The residential areas are to be kept away from the dumping sites. In the case study area dumping site is in a close proximity of the residential area. So, this factor is analyzed for particular area.

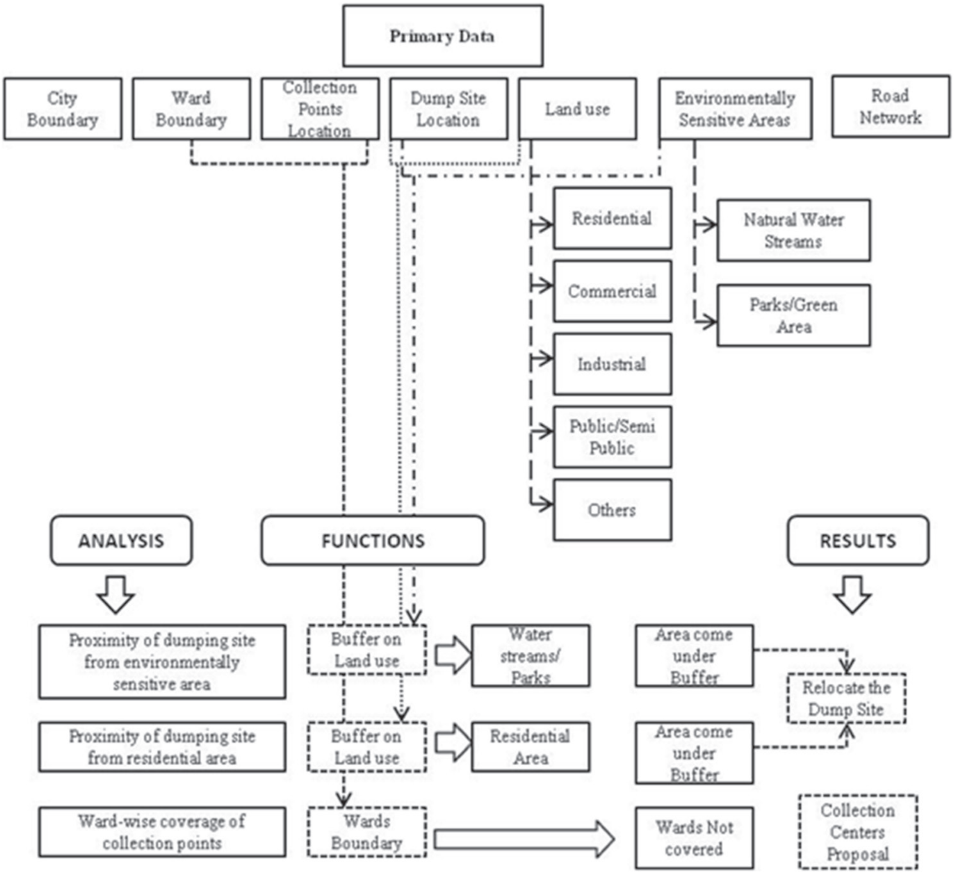

Figure 3. *Proposed GIS workflow Model.*

For this buffer analysis has been carried out around the dumping site. A buffer of 1000 meters is applied around the site based on literature recommendations and urban planning standards, which suggest this minimum distance to protect residential and environmentally sensitive areas from potential health and environmental hazards (Cheng et al. 2018, Sah et al. 2021). This will highlight the residential area which is in proximity to 1000 meters. As residential areas cannot be moved, the existing dump site will be relocated.

4.3. Proximity of Dumping Site from Environmental Sensitive Areas

In this case, one natural water stream is passing through the study area. The dumping site is in a close proximity to the water stream polluting the natural water stream. Also, there is a Park area near to the dumping site. For this buffer analysis has been carried out around the dumping site. A buffer of 1000 meters is applied around the site. This will highlight the environmentally sensitive areas which are in proximity of 1000 meters. As natural streams and parks need to be protected from pollution so the existing dump site will be relocated. Based on the analysis of maps, observations were made from solid waste management point of view. The following are the observations from the analysis:

1. There are 50 municipal wards in the city with varying population density and an area with total 107 waste collection points, out of which only 101 points are practically available.
2. The collection points are not uniformly divided, few wards have as high as 10 collection points whereas there is no collection point in few of the wards. All the points are very closely placed, causing unhygienic conditions in the city. Figure 4 Ward-wise number of collection points and Figure 5 shows a map of city with existing collection points.
3. The site for dumping waste is within the residential area without any arrangement for waste transport or any treatment. And it is also near to the Environmental sensitive areas like water bodies and Parks. Figure 6 shows existing dump site with buffer (1000 meter).
4. The widths of the roads approaching the dumping site are also not wide therefore traffic jams are also caused. The existing route followed in the city by the trucks passes through the residential areas causing health problems and bad odours.

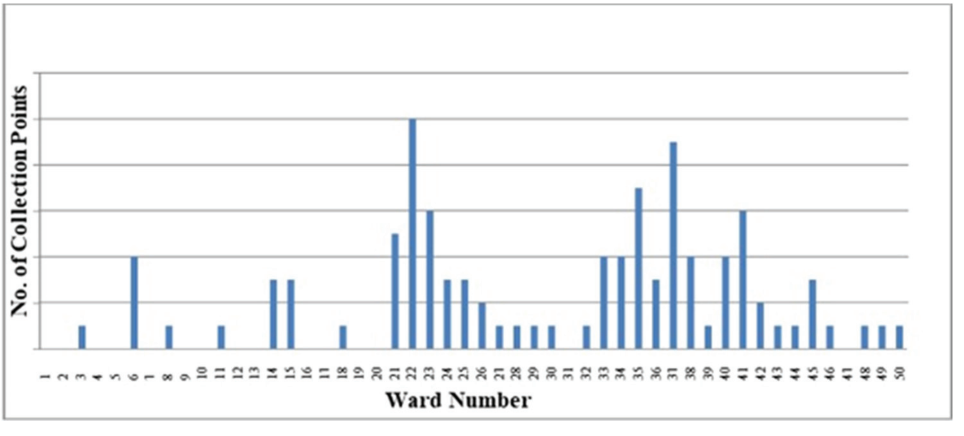

Figure 4. *Numbers of Collection Points (Ward-Wise).*

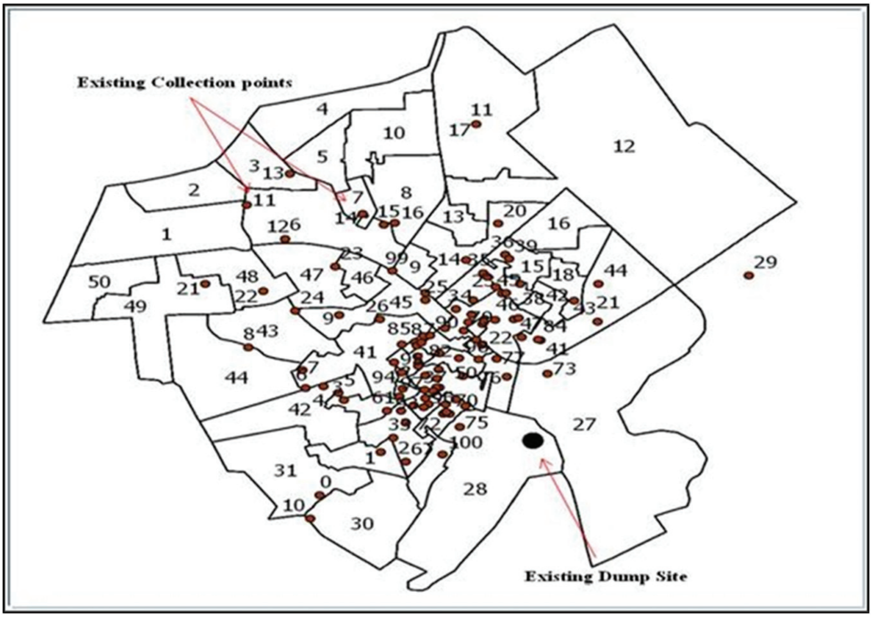

Figure 5. *Ward-Wise Map (Existing Collection Points).*

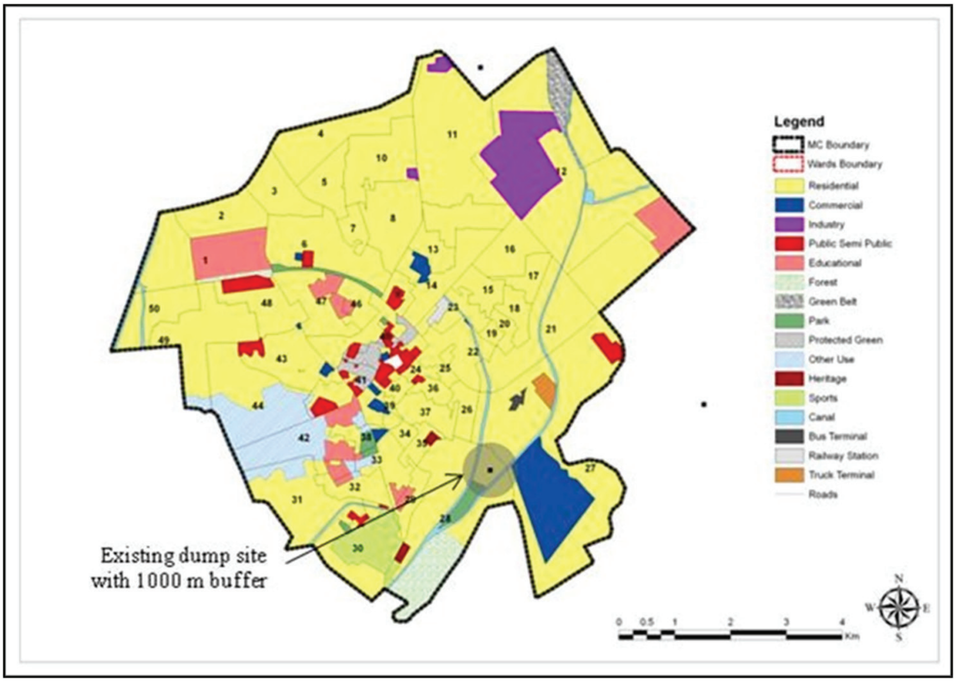

Figure 6. *Existing Dumping Site with Buffer.*

5. Proposal of Collection Centres and Alternate Dumping Site

The collection centers are the storage places where the solid waste is collected and stored and then transferred to the dumping site. Dumping site is the place where collected waste from all the collection centers is dumped.

Based on analysis of the primary data, fifty (50) collection centers keeping one collection centre in each municipal ward in place of existing 101 collection points and two dumping sites i.e. site-1 and site-2 have been proposed. The reduction from 101 to 50 collection points was based on the need to eliminate redundancy and optimize collection. Each of the 50 proposed points corresponds to a municipal ward, ensuring equitable distribution and increased efficiency with upgraded bin capacity. Although the number of collection points has been reduced, the spatial distribution now ensures one point per ward, improving accessibility in previously underserved areas. The strategic placement of higher-capacity bins mitigates the risk of reduced convenience. Figure 7 shows the location of proposed collection centers and the proposed dump sites, and Figure 8 shows the proposed site-1 and site-2 with 1000 m buffer. The proposed collection centers will serve most of the un-served areas of the wards and proposed dumpsites fulfill the criteria discussed in the analysis (Table 1). The waste from all the ward houses will be collected at respective collection centers and from here it will be taken to the selected dump site. The amount of waste collected at each collection center is calculated based on the population of the ward.

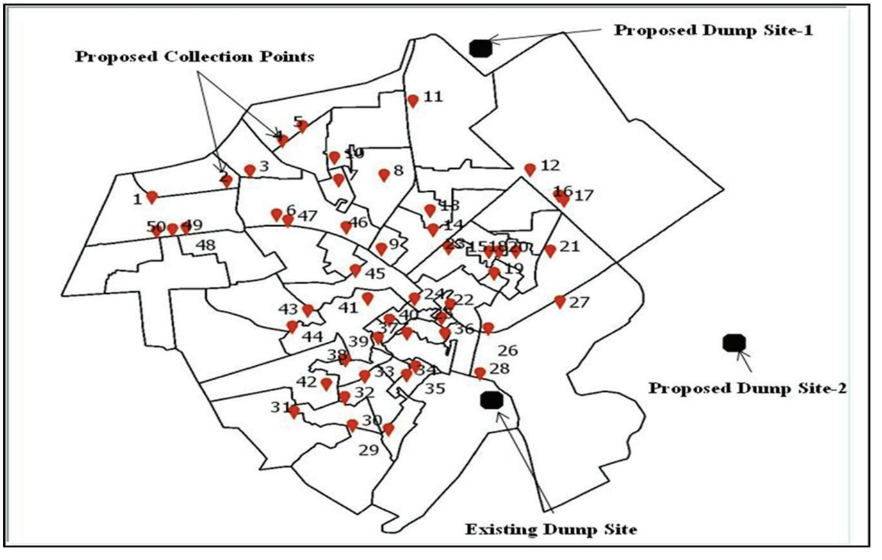

Figure 7. *Ward-Wise Map showing Proposed Collection Centers.*

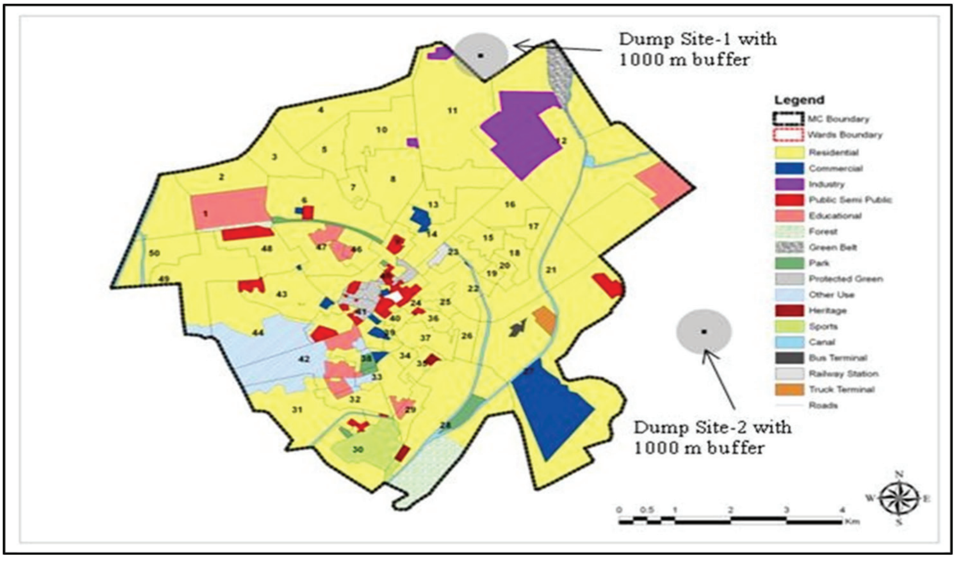

Figure 8. *Dumping Site-1 and 2 with Buffer.*

Table 1. *Analyses of Existing and Proposed Disposal Sites.*

Criteria	Existing Site	Site-1	Site-2
Distance from residential area (1000 meters)	×	✓	✓
Proximity to water user (1000 meters)	×	✓	✓
Proximity to water body (1000 meters)	×	✓	✓
Proximity to Eco Sensitive Area (1000 meters)	×	✓	✓
Wide roads	×	✓	✓

5.1. Site Selection and Proposed Routes

Site selection and routing require careful examination and evaluation of all the components that can potentially result in adverse effects on the environment and increase in travel distance and ultimately time and cost of the system (Kumar et al. 2022, Okot and Abandu 2024, Gilardino et al. 2017, Zaveri 2016). For the selection of ideal site and optimized route for the efficient collection and disposal of solid waste each of the 50 collection points was assigned a waste quantity based on ward-wise population figures collected from municipal data, applying a standard waste generation rate of 0.61 kg/capita/day and the following points have been considered while doing analysis and calculations:

- The amount of total waste generated in the city that is to be collected at 50 collection centers is 273.86 MT/day (0.61 kg/capita/day).

- The number of collection points is 50 (one center in each ward) accommodating waste quantity according to the population of the ward.
- Each truck used for carrying waste from collection center to dumping site can cater up to 5MT of waste.

Site selection has been made on the basis of the minimum distance from the proposed collection centers and the routes have been decided accordingly. The route distances of the existing dumping site from the existing collection points and proposed route distances from the proposed dumping sites to the collection centers have been calculated using network analyst tool of the GIS. While making calculations of the shortest route distances of collection center from dumping sites, the collection centers falling on the route have also been accounted for depending upon the truck capacity. For example, while calculating the shortest route distances of collection center-1 from dumping site-1 collecting 3MT of waste, collection center-2 collecting 2 MT of waste is falling on the route. Then the waste from both the collection centers can be picked in one go and the distance of collection center –1 will be used for calculations.

Table 2 shows the calculation of route distances for the existing collection points from existing dumping site and Table 3 and Table 4 shows the calculation of route distances for the proposed collection centers from proposed dumping site-1 and dumping site-2 respectively. Table 5 and Table 6 show the comparison of the route distances and comparison of existing and proposed routes respectively.

From the calculations of route distances Site-1 is the ideal site as there is a reduction of total travel distance by 12.4% as compared to the existing practices and it earmarks the selection criteria for the dump site. The reduction in travel distance was calculated using the GIS Network Analyst tool based on shortest path algorithms. The total distance of all existing routes was compared with those of the proposed routes, and site-1 showed a 12.4% reduction in cumulative travel distance. Figure 9, Figure 10 and Figure 11 shows sample examples of routes adopted for Optimized route from Collection Point No. 13 to Existing Dump Site, Optimized route from Proposed Collection Centre No. 31 to Dump Site-1, and Optimized route from Proposed Collection Centre No. 50 to Dump Site-2 respectively.

Table 2. *Route Distance Calculation for Existing System.*

Collection Point Number		Number of Trips	Distance from Existing Site (km)	Multiplying factor for round trip	Total travel Distance (km)
Start Point	Points Covered				
0	-	2	4.381	2	17.524
1	-	1	3.955	2	7.91
3	3,71,70	1	3.772	2	7.544
4	-	1	4.324	2	8.648
5	-	1	4.017	2	8.034
6	-	1	4.625	2	9.25
7	-	1	4.604	2	9.208
8	-	2	5.422	2	21.688
9	-	1	4.72	2	9.44
10	-	2	4.94	2	19.76
11	11,12	1	7.66	2	15.32
13	-	1	7.805	2	15.61
14	24,19	1	6.281	2	12.562
15	-	1	5.85	2	11.7
16	-	2	5.787	2	23.148
17	-	2	7.783	2	31.132
18	-	1	5.502	2	11.004
20	-	1	6.028	2	12.056
21	21,99	2	8.85	2	35.4
22	-	1	7.295	2	14.59
23	-	1	5.57	2	11.14
24	-	1	6.359	2	12.718
25	-	1	4.88	2	9.76
26	26,83,55,91,92	1	4.137	2	8.274
27	27,28	1	4.06	2	8.12
29	-	1	5.898	2	11.796
30	-	1	3.66	2	7.32
31	-	1	3.557	2	7.114
32	-	1	4.251	2	8.502
33	-	1	4.417	2	8.834
35	35,34	1	4.525	2	9.05
36	36,37,47	1	4.538	2	9.076
38	38,45	1	4.518	2	9.036
39	-	1	4.422	2	8.844

42	-	1	4.738	2	9.476
44	44,43	1	4.56	2	9.12
46	46,40	1	3.217	2	6.434
50	-	1	3.538	2	7.076
51	51,49,59,48,60	1	3.042	2	6.084
52	-	1	2.267	2	4.534
53	-	1	2.645	2	5.29
54	-	1	2.598	2	5.196
56	-	1	2.781	2	5.562
57	57,2,67	1	4.166	2	8.332
58	-	1	2.783	2	5.566
61	-	1	4.609	2	9.218
62	-	1	3.854	2	7.708
63	-	1	3.484	2	6.968
65	-	1	2.079	2	4.158
68	68,64,66,72	1	2.479	2	4.958
73	-	2	3.054	2	12.216
74	-	1	2.91	2	5.82
75	-	1	1.699	2	3.398
76	-	1	2.277	2	4.554
77	-	1	2.775	2	5.55
78	-	1	3.135	2	6.27
79	79,80	1	3.392	2	6.784
84	84,41	1	3.306	2	6.612
85	85,82,81	1	4.367	2	8.734
86	-	1	4.334	2	8.668
87	-	1	4.235	2	8.47
88	-	1	4.243	2	8.486
89	-	1	3.815	2	7.63
90	-	1	4.057	2	8.114
91	91,93	1	2.989	2	5.978
94	94,2,67	1	5.212	2	10.424
95	95,69	1	3.369	2	6.738
96	-	1	2.529	2	5.058
97	-	1	2.967	2	5.934
98	-	1	2.759	2	5.518
99	-	1	4.881	2	9.762
100	-	1	2.035	2	4.07

Table 3. *Route Distance Calculation for Proposed System (Site-1).*

Collection Centre Number		Number of Trips	Distance from Site-1 (km)	Multiplying factor for round trip	Total travel Distance (km)
Start Point	Points Covered				
1	4	1	7.44	2	14.88
1	-	1	7.44	2	14.88
4	-	1	4.382	2	8.764
2	-	1	6.09	2	12.18
2	3	1	6.09	2	12.18
5	-	2	4.023	2	16.092
6	-	2	6.759	2	27.036
7	-	1	4.58	2	9.16
7	11	1	4.58	2	9.16
11	-	1	1.978	2	3.956
8	-	2	3.824	2	15.296
9	-	1	5.262	2	10.524
10	-	2	4.749	2	18.996
14	-	1	4.708	2	9.416
14	13	1	4.708	2	9.416
13	-	1	4.369	2	8.738
15	-	1	7.454	2	14.908
15	23	1	7.454	2	14.908
16	-	1	5.23	2	10.46
18	-	1	7.115	2	14.23
19	-	1	7.812	2	15.624
19	12	1	7.812	2	15.624
12	-	1	4.548	2	9.096
20	17	1	7.377	2	14.754
17	-	1	5.359	2	10.718
21	-	2	6.532	2	26.128
22	-	1	6.832	2	13.664
24	-	1	6.703	2	13.406
25	-	1	7.242	2	14.484
26	-	1	7.64	2	15.28
27	-	2	8.06	2	32.24
28	-	1	8.591	2	17.182
29	-	1	9.635	2	19.27
30	-	2	9.499	2	37.996
31	-	2	9.765	2	39.06

32	-	1	8.882	2	17.764
33	-	1	8.414	2	16.828
34	-	1	9.043	2	18.086
35	-	1	9.262	2	18.524
36	-	2	7.852	2	31.408
37	-	1	7.64	2	15.28
38	-	1	8.07	2	16.14
39	-	1	7.649	2	15.298
40	-	1	7.333	2	14.666
41	-	1	6.56	2	13.12
42	-	2	8.824	2	35.296
43	-	1	7.068	2	14.136
44	-	2	7.538	2	30.152
45	-	1	5.866	2	11.732
47	-	1	6.609	2	13.218
47	46	1	6.609	2	13.218
48	-	1	7.779	2	15.558
49	-	2	8.029	2	32.116
50	-	1	8.378	2	16.756

Table 4. *Route Distance Calculation for Proposed System (Site-2).*

Collection Centre Number		**Number of Trips**	**Distance from Site-1 (km)**	**Multiplying factor for round trip**	**Total travel Distance (km)**
Start Point	**Points Covered**				
1	-	1	12.711	2	25.422
1	6	1	12.711	2	25.422
6	-	1	9.954	2	19.908
6	46	1	9.954	2	19.908
2	-	2	11.399	2	45.596
3	-	1	11.483	2	22.966
4	-	1	11.385	2	22.77
4	12	1	11.385	2	22.77
12	-	1	6.284	2	12.568
5	-	2	10.961	2	43.844
7	-	2	10.655	2	42.62
8	-	2	10.223	2	40.892
9	-	1	8	2	16
10	-	2	10.875	2	43.5

11	-	1	8.954	2	17.908
11	17	1	8.954	2	17.908
17	-	1	5.417	2	10.834
13	-	1	8.888	2	17.776
14	-	1	8.48	2	16.96
15	-	1	6.457	2	12.914
15	20	1	6.457	2	12.914
16	-	1	6.547	2	13.094
18	-	1	6.017	2	12.034
19	-	2	5.715	2	22.86
21	-	2	5.376	2	21.504
22	-	1	6.358	2	12.716
23	-	1	7.968	2	15.936
24	-	1	7.178	2	14.356
25	-	1	6.826	2	13.652
26	-	1	5.661	2	11.322
27	-	2	4.334	2	17.336
28	-	1	6.591	2	13.182
29	-	1	8.785	2	17.57
30	-	2	9.499	2	37.996
31	-	2	10.752	2	43.008
32	-	1	9.791	2	19.582
33	-	1	9.88	2	19.76
34	-	1	8.458	2	16.916
35	-	1	7.221	2	14.442
36	-	2	6.683	2	26.732
37	-	1	7.691	2	15.382
38	-	1	9.647	2	19.294
39	-	1	8.456	2	16.912
40	-	1	7.724	2	15.448
41	-	1	8.2	2	16.4
42	-	2	10.39	2	41.56
43	-	1	9.799	2	19.598
44	-	2	10.215	2	40.86
45	-	1	8.605	2	17.21
48	47	1	11.349	2	22.698
47	-	1	9.622	2	19.244
49	-	2	11.562	2	46.248
50	-	1	11.782	2	23.564

Table 5. *Comparison of Existing and Proposed Route Distance.*

	Existing Site	**Proposed Site-1**	**Proposed Site-2**
Calculated Route Distance (km)	691.58	909.002	1207.595
Waste Collected (MT)	186.71	273.76	273.76
Area Covered (%)	70	100	100
Factor for 100% Collection	1.5	1	1
Equivalent Route Distance for 100% Collection (km)	1037.37	909.002	1207.595
Reduction is Distance	-	**128.368**	-
% Distance Reduction	**12.40%**		

Table 6. *Comparison of routes for collection and disposal at Existing dump site with proposed.*

Existing Route	**Proposed Route**
The area is not fully served.	The area is served fully.
The road approaching the dump site does not have enough widths.	Enough road width is available near the dumping site.
The route passes through the residential areas of the city.	The route passes through the main road of the city without causing disturbance to residential areas.
It causes traffic congestion problems.	Does not cause traffic congestion.
Increased travel distance, time of travel and cost.	Reduced travel distance, time and cost.

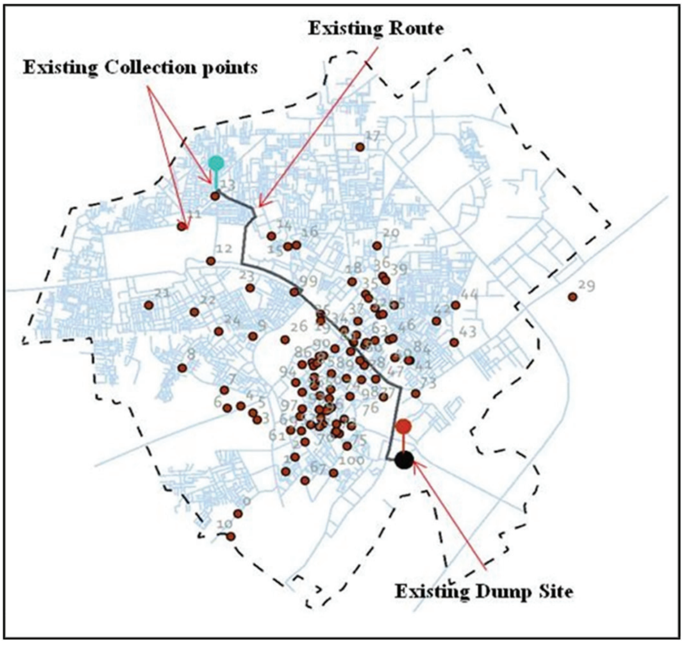

Figure 9. *Optimized route from Collection Point No. 13 to Existing Dump Site.*

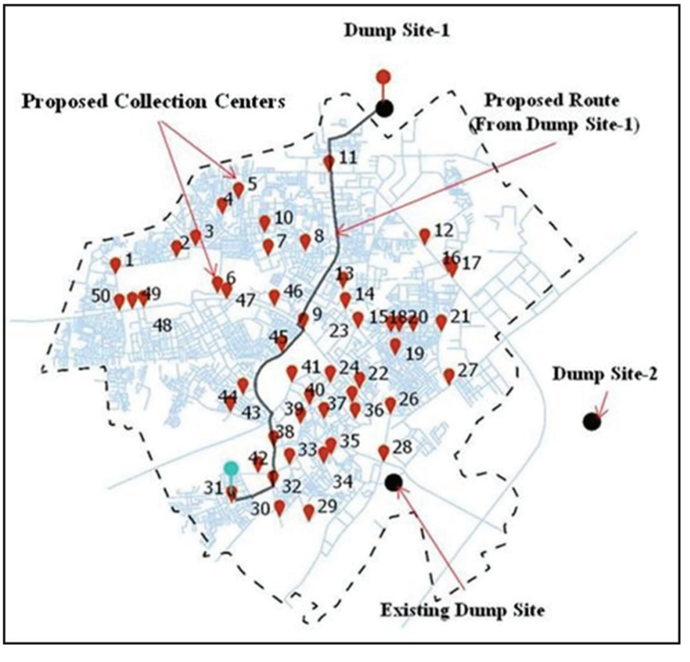

Figure 10. *Optimized route from Proposed Collection Centre No. 31 to Dump Site-1.*

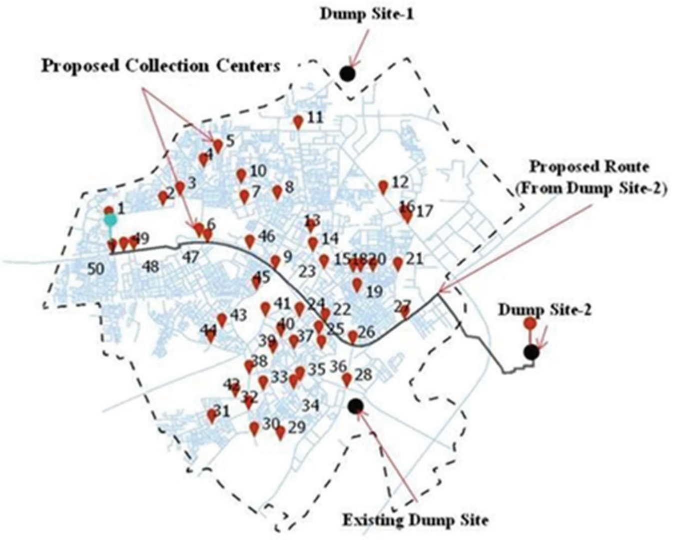

Figure 11. *Optimized route from Proposed Collection Centre No. 50 to Dump Site-2.*

6. Conclusion

The amount of waste collected in the existing system is only 186.76 MT/day whereas total production in the city is 273.86 MT/day. The current route followed for the collection of waste is also not properly designed therefore it causes traffic congestion problems as well as the waste collection and disposal vehicles pass through the residential areas. The collection of the waste is insufficient, untimely, and inefficient. The poor practice of waste management leads to increased time of travel and cost of the collection. Thus, there is a need for additional collection points and proper management of the waste.

To overcome the above problems the number of collection points have been reduced from 101 to 50 with increased capacity and ensuring one collection point in each ward. The current dumping site has been proposed to shift to two alternative dumping sites. From the analysis of distance travelled from collection point to dumping site, it is seen that site-1 is ideal as there is a reduction of 12.4% travel distance. The proposed route covers all the parts of the city, and no waste is left uncollected. These routes were tested using GIS-based simulation. The model incorporates realistic parameters such as road network geometry, travel distances, and truck capacity, ensuring dependable optimization results. This will result in efficient waste collection and minimize travel distance as well as time of travel. Hence, reducing cost incurred in solid waste management of the city. Implementation under real-world conditions forms part of the future scope of this work.

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Učinkovito prikupljanje otpada: GIS metoda optimizacije rute

SAŽETAK. Učinkovito prikupljanje i zbrinjavanje prikupljenog otpada preduvjet je učinkovitog sustava gospodarenja otpadom. Gospodarenje otpadom također uključuje rješavanje problema prikupljanja i zbrinjavanja krutog otpada. Ono također obuhvaća dodjelu i preraspodjelu spremnika te provjeru neprikladnosti i smetnji za korisnike vezano uz lokaciju spremnika za otpad. Neuravnoteženost lokacije i neadekvatnost transportnog sustava stvara više otpada. Optimizacija ruta u svrhu skraćivanja duljine putovanja te konačno smanjenje ukupnih troškova i vremena putovanja zajedno s odabirom odgovarajućeg mjesta za odlaganje otpada bez izazivanja štetnih učinaka za okoliš glavne su komponente gospodarenja otpadom. Odabir prikladnosti potencijalnih odlagališta i lokacija spremnika za sakupljanje te modifikacija postojećih objekata zahtijeva sveobuhvatnu procjenu postojećih uvjeta. Ovaj rad bavi se problemima povezanima s postojećim sustavom prikupljanja i odlaganja otpada na području istraživanja. Optimizacijom sustava broj sabirnih točaka smanjen je sa 101 na 50, uz povećanje kapaciteta spremnika, a predložena su i dva alternativna odlagališta. Analiza prijeđene udaljenosti od sabirnog mjesta do odlagališta korištenjem GIS-a s predloženim rutama koje pokrivaju cijeli grad s time da niti jedan otpad nije ostao neprikupljen, rezultirala je smanjenjem udaljenosti putovanja za 12,4%, a time i smanjenjem troškova koji nastaju u gospodarenju krutim otpadom u gradu.

Ključne riječi: *otpad, geografski informacijski sustav, optimizacija rute, odlagališta otpada, održivost.*

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