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Selection Of Collection Sites And Optimization Of Waste Bins Of Rohtak City, Haryana (India)

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ABSTRACT: Placement of bins is an important aspect of the solid waste management process. Optimization of bin placement results in adequate number of bins as per the waste generation capacity of the locality, ease of access due to proper spatial distribution of the bin by the waste generators as well as waste collectors. In the present study the bin optimization for the city of Rohtak has been done using Geospatial inputs from remote sensing imageries and local solid waste generation survey and census. Solid waste generation was estimated for 488 blocks of the city taking population and socioeconomic conditions of each block in consideration while determining the waste generation. Bins of 3000 Liter volume having a calculated capacity of 990Kg were used as collection depots for deposition of solid waste collected from house to house through rickshaw trolleys. The Centroid of each block was generated using Data Management Tool .The distance of the block Centroid to the nearest road was determined through Analysis Tool. The bins deport of each block was placed on the determined nearest road. Depending upon the waste generation of each block the numbers of bins have been placed. It was ensured that the distance between two bins was not exceeding 500 meters and minimum distance 100 meters. To ensure this bin depots were combined or split. The optimization of bin placement through GIS resulted in ensuring adequate bin waste handling capacity, optimization of the bins distance for ease of waste collection and transportation to dumpsite.

KEY WORDS- Municipal solid waste management, Geographical Information System, buffering, Community Bin Placement, service area.

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I. INTRODUCTION

The secondary storage (SS) is a crucial component of any solid waste management system (Vijay *et.al*., 2008; Gopagani *et.al*., 2014; Krishna *et.al.*, 2014) . Secondary storage capacity should be adequate to handle the waste of the catchment area and at the same time the community bins (CBs) should be easily accessible for the waste generators in terms of distance (Yalan *et al.*, 2008; Kashid *et al.*, 2015; Abdulai *et al.*, 2015). The placement should also ensure that they are easily reachable by waste collection vehicles. For optimization of bins, a spatial perspective is useful. It gives the planner a better understanding of the spatial arrangement of waste generation components, road network and proximity of all the components relevant for the waste management planning (Worrell and Vesilind 2012; Parrot *et al.*, 2009). Bin placement is a basic step for the best management practice (Ghose *et al.*, 2006). As placement of bins should placed in such a manner that it will covers the maximum service area, it easily accessible, and it should follow the rules as per given by Municipal solid waste (Management & Handling) Rules, 2000. Using GIS environment, an optimization of the bins can be achieved in terms of numbers required for a geographical area and their optimized spatial distribution. Location modeling in GIS improves service area and at some time takes care of required constraints and enforces regulations made for bin placement (Senthil *et. al.*, 2012; Kallel *et. al*., 2016; Khan and Samadder 2014; Karadimas *et. al.*, 2008).

II. STUDY AREA-

Rohtak city of Haryana is our study area as shown in Fig.1. Rohtak city lies between longitude $76^0$31'47.764" to $76^0$42'43.071" and Latitude $28^0$49'53.354" to $28^0$56'33.819" (Fig.1) and situated at a mean sea level of 220 meters. As increase in population and urbanization the municipal limits also extended which was 30.96 Km^2 in 2007, this limit was extended in 2012 the municipal corporation included surrounding nine villages due to which limits became 139.4 Km^2 with a population 4.8 lac (Municipal Corporation Rohtak (MCR), 2013). With an objective of increase the efficiency and effectiveness of its waste management activities, the MCR divided the city in 6 MCR zones to collect and transport solid waste (Fig.2) by private contractors. Zone 5 and Zone 6 include 9 villages where as other zones include city area. A survey of the city depicts the following community bins scenario-

1. There are insufficient numbers of community bins to cater to the waste generated in each of the zones.
2. The spatial distribution and placement of bins is haphazard and no criteria have been taken into account. Due to which at some places these are unused bins due which at some places there are too many bins, and at some places bins are placed where there is no use and at some locations there are no bins at all.
3. Some bins were placed in narrow lanes thus causing hindrance to traffic and not easily accessible to the waste collection vehicles.

There is requirement to put in place a management model which will overcome the main problems encountered with the present bin placement system. The objective of this management model will be the allocation of sufficient number of bins. Not only in number but placement according to the spatial distribution of the waste and the built up areas so that maximum area is serviced by the bins and no waste is left unaccounted. Proper spatial distribution will also ensure that the door to door collection cycle rickshaws have not to travel too long a distance to the nearest bin. In the present study the bin optimization for the city of Rohtak has been done using Geospatial inputs from remote sensing imageries and local solid waste generation survey and population census. Solid waste generation was estimated for 488 blocks of the city, taking population and socioeconomic conditions of each block in consideration while determining the waste generation. Solid waste collected from house to house through tricycle rickshaws. The optimization of bin placement through GIS resulted in ensuring adequate bin waste handling capacity, optimization of the bins distance for ease of waste collection and transportation to dumpsite.

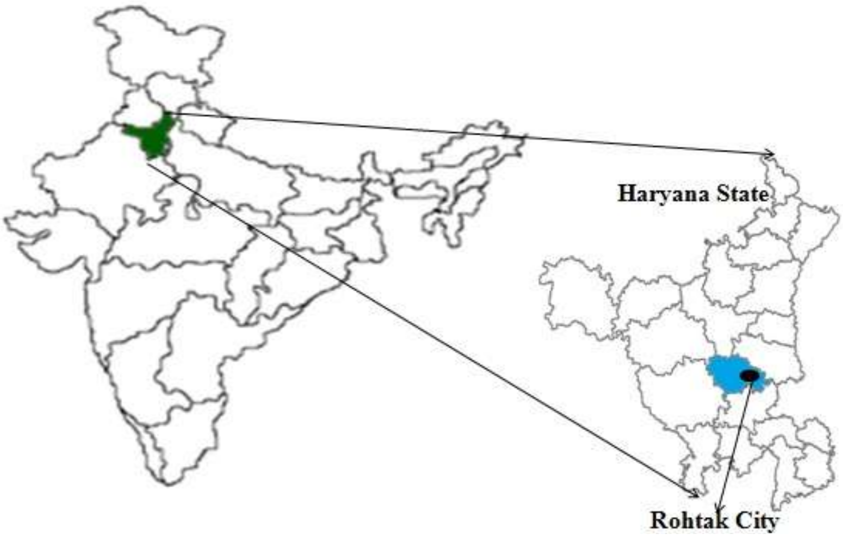


Fig.1 Study area.

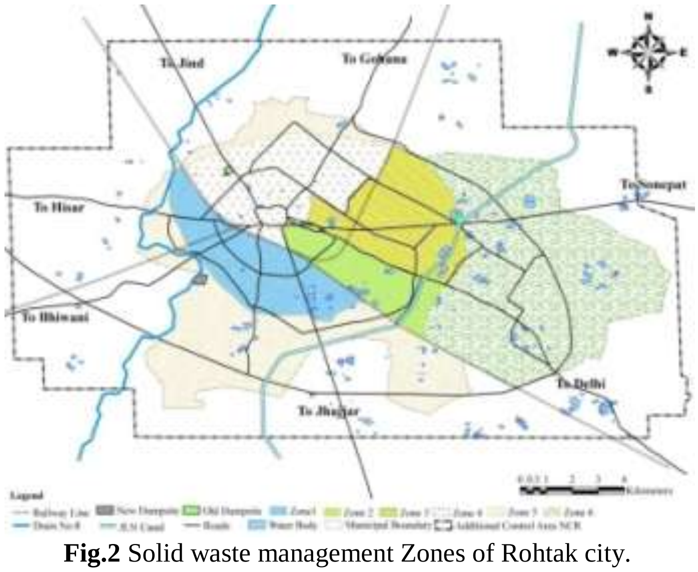


Fig.2 Solid waste management Zones of Rohtak city.

III. METHODOLOGY

Through GIS technique the methodology is constructed in the study which follows the following phases.

1. Collection of data.
2. Geo-Spatial Database generation.
3. Proposed management model.

Collection of data-

Primary database includes- Bulk density of waste, waste generation rate of Class A and Class B Blocks, number, types and position of collection bins, and Sensitive area (Schools, Hospitals and temples). Survey of city was conducted for the information regarding the per capita income and waste physical and chemical properties. The investigation was carried out repeatedly in the city of Rohtak, for one month. Each sampling the three levels of waste disposal investigated was housing units. Fig.3 presents the procedure adopted for sampling of municipal solid waste management. Colonies were classified into two categories class A (low economy) and Class B (high economy) on the basis of their economic status as shown in Fig.4. Economic status of colony was differentiated on the basis of size of the plots, colony infrastructure, building structure and the type and number of vehicles. Ten representative colonies each, from both the classes were selected and ten housing units from each colony class were randomly selected. The waste samples collected from each housing unit in each colony for the estimation of waste generation per day. For estimating persons per housing unit a questionnaire survey was conducted in the selected colonies. After estimation of waste generation and person per housing unit whole city was divided into Class A and Class B category as shown in Fig.5. through this waste generation per capita was calculated. On the basis of the above classification, the city as a whole has 156 colonies in class A and 54 colonies in class B. The population of the 156 class A colonies is 3, 67,586 whereas the population of class B colonies is 1, 18,446. Total population are 4,86,032. Class A colonies occupy 114.4 km^2 (82%), and the per capita waste generation is 0.45 Kg/day. Class B colonies cover 25 km^2 which is (18%) of the city area and have a per capita waste generation of 0.53 kg/day. The distribution of class A and class B colonies is given in Fig.5.1. From the population and the per capita waste generation of the colonies, the waste generation of class A colonies and class B colonies can be computed. The waste generated in the city given below-

Class A colonies = 163612.8 Kg/day,
Class B colonies = 62864.64 Kg/day,
Total = 226477 Kg/day or approximately 226 tons per day.

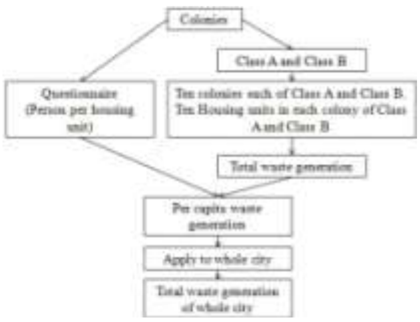
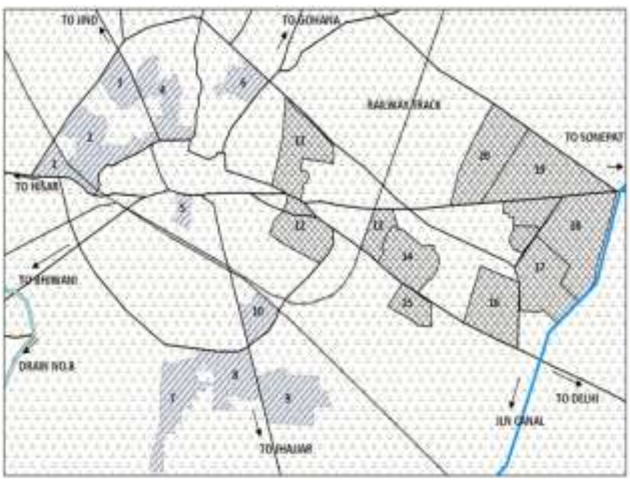


Fig.3 Course of sampling and per capita waste generation of study area.



Legend- 1- Shyam Colony, 2- Indra Colony, 3- Nehru Colony, 4- Kabir Colony, 5- Dairy Mohalla, 6- Hanuman Colony, 7- Amrit Colony, 8- Vijay Nagar, 9- Ekta Colony, 10- Shivaji Colony, 11- Prem Nagar, 12- DLF Colony, 13- Subhash Colony, 14- Modal Town, 15- Dev Colony, 16- Sector-14, 17- Sector-1, 18- Sector-2, 19- Sector-3, 20- Sector-4.
Fig.4 Demarcation of class A (No.-1 to 10) and B (No.-11 to 20) colonies selected for sampling (Source- Municipal Corporation Rohtak)

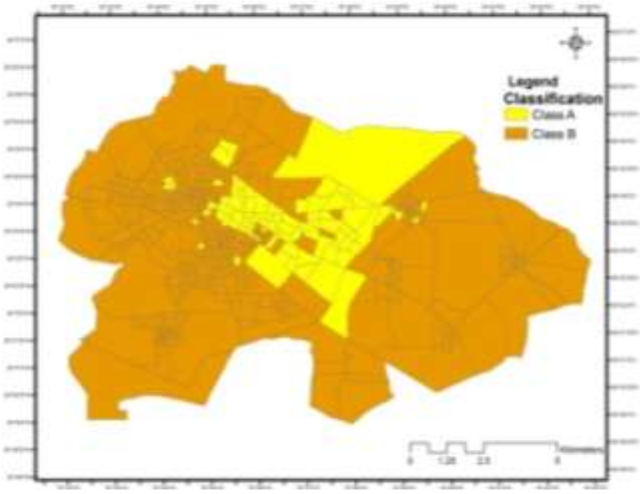


Fig.5 Classification of study area into Class A and Class B.

Secondary data includes- zone wise population and waste generation were collected from MCR. Road network, limits of blocks, Sensitive areas (water bodies) were digitized using the digital maps from MCR and satellite image of the ward. The existing location of the collection bins were derived from on-site capturing with the use of Global Positioning System (GPS) technology.

Geo-Spatial Database generation- The geospatial database was formed in ArcGIS for the allocation and analysis of collection bins, the data was derived through the sources such as Digital maps from MCR, attribution data from government authorities and online capturing with the use of GPS technology. The description of the database is given in the Table 1.

Table.1 Description of Geo spatial database

Spatial	Type	Attributes	Geometry
Road Network	Vector	-	Line
Collection bin location	Vector	-	Point
Road Network attribute	Tabular	Road length	-
Collection bin attribute	Tabular	Dimension, capacity, longitude, latitude, type.	-
Satellite imagery of area of interest	Raster	-	-
Blocks	Vector and tabular	Population, waste generation, area covered.	Polygon
Sensitive area	Vector and Tabular	Longitude, latitude, schools, hospitals, and water bodies.	polygon

Proposed management model- The primary and secondary data was integrated in GIS domain in the form of theme layers. The various layers were road network, sensitive area (schools, hospitals, water bodies), blocks, present bin location and open dumps. The road network taken for this study excludes the narrow streets and only those roads are considered where waste collection vehicles can easily go and collect waste from the bin without much hindrance to the traffic. Conceptual flow of model shown in Fig.6. Taking the municipal block layer the centroid of each block was generated using the data management tool (Feature to point). 300 m buffer was created around centroid of each block. The purpose of creating the 300 m buffer is for the selection of service road for the placement of bins catering to the waste generation of the block. The centroid point is moved to a suitable road within the 300 meter buffer. The same process was repeated for each block. Keeping into account that if available bins of 2 or 3 blocks should be kept on the same road to facilitate the bin collection and transportation to the dumpsite. The above methodology has been adopted to ensure optimum spacing of bins as per the waste generated in the different localities. The numbers of bins to be placed per block were calculated using the block waste generation attributional data and the formula given in Equation 1. If the waste generation of a block was less than the capacity of one bin then the waste from two or three blocks was combined till it become sufficient for the bin capacity. However it was ensured that bin distance criteria was followed. If bins are too close to each other than a number of bin were placed at one location to form a bin depot. While placing the bins care is taken to avoid placing bin in the restriction buffer zones of sensitive areas.

a. Assumptions for the Model-

- Bins are of 1000 kg type (3.1 m^3 volume) taken for the model.
- Waste is collected from house to house through tricycle rickshaws
- The collection frequency is twice a day.

  In the second step bins are shifted in order to comply with certain buffer rules set by CPHEEO.
- Individual bins should not be closer than 100 m.
- Bins should not be farther than 500 m.
- Bins should not be closer than 20 m to designated structure such as water bodies, schools, hospitals, religious places and educational institutes.
- Bins should not place in private colonies such as Sun City and Omax city.
- Bins should not place near unsuitable sites like water logged areas.

In order to comply with these rules bins are shifted to new locations. Finally in third step a 250 m buffer is created around each bin. And bins are again shifted to ensure maximum coverage of the waste generation of the command area (within the 250 meter buffer) by the bins.

b. Calculations

Formula for estimation of number of bins in each zone is given in Equation 1 (Nithya et al. 2012; Chalkies and Lasaridi 2009) -

$$N = \frac{W}{D \times S \times \varepsilon} \qquad (1)$$

N = Number of collection bins

W = Total quantity of waste generated per day in Kg

D = Density of waste in 320 Kg/m^3

S = Size of bins in 3.1 m^3

ε = Coefficient of filling the bin (Generally 75%)

The obtained numbers of bins (Table 2) were allocated at locations based on the following criteria:

1. With reference to existing bins – Bins in place in the existing management scheme were kept.
2. The road network- The road chosen for placing of bin is not narrow and should have suitable space for the bin.
3. Waste generation capacity- The waste generation of the block
4. Unserved area- New bins are placed to provide service in unserved areas.

Bulk density-

The bulk density was obtained by dividing the weight of the sample by volume of the container containing sample after compacting using equation 2. Bulk density of municipal solid waste was 320 Kg/m^3.

$$\gamma = \frac{W_2 - W_1}{V} \qquad (2)$$

γ= bulk density (gm/cm^3), W_1= Wt. of empty container in gm, W_2= Wt. of the container with the sample in g, V= Volume of container up to which the sample is present in the cylinder after compaction.

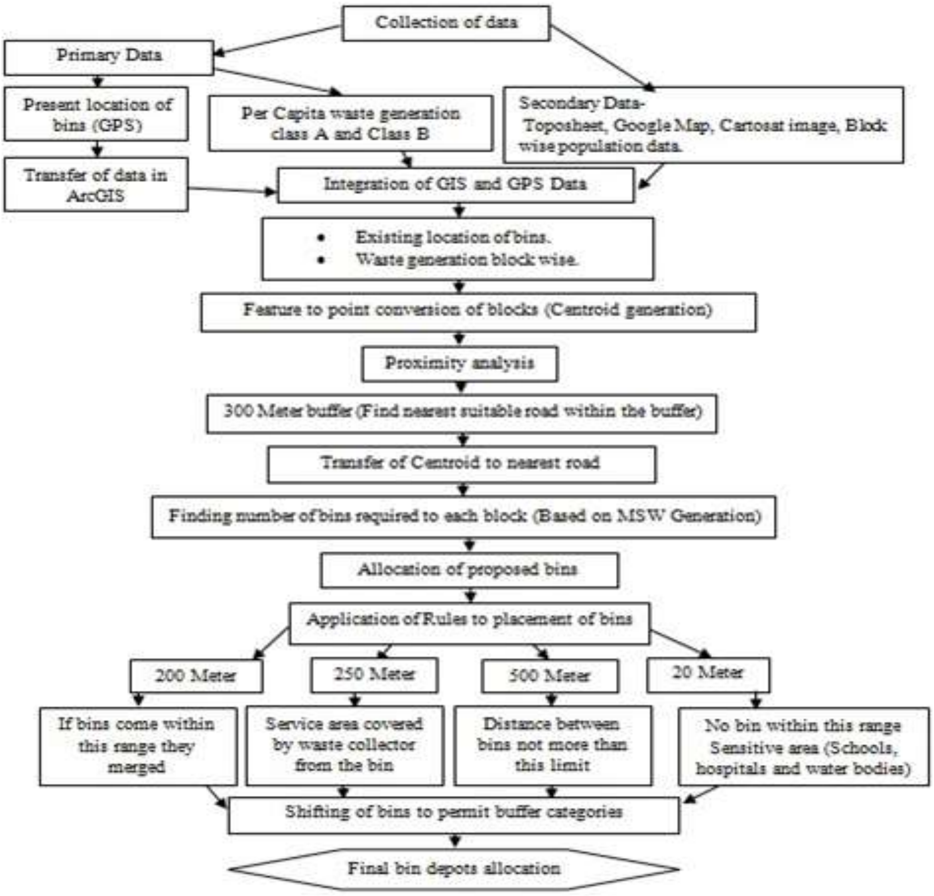


Fig. 6. Conceptual flow of the placement of community bins.

Table.2 Zone wise number of bins required for solid waste management.

Name of Zone	**Area of zone (Municipality Km^2)**	**Population**	**Waste generation (kg/day)**	**Built up area km^2**	**Number of dust bin (collection twice a day)**
1	14	113014	52470.23	4.3	35
2	9	69486	32447.35	2.1	25
3	16	81479	37964.77	5.3	33
4	18	168398	77946.87	4.5	53
5	36	20094	9726.85	1.2	6
6	46	33561	15921.85	2.9	11
Total	**139**	**486032**	**226477.92**	**20.3**	**163**

IV. RESULTS AND DISCUSSION

There are a total 72 community bins present in the six zones. The waste carrying capacity of these bins is 51 MT. The spatial distribution of these bins is shown in Fig.7. Two types of community bins are in use. Smaller bins with a specified capacity of 500 Kg, however, the actual capacity was found to be 336 kg and larger bins with a specified capacity of 1000 Kg bins having an actual capacity of 990 Kg. (Fig. 7). Due to an inadequate number of community bins a substantial quantity of waste is deposited in a large number of small and large open dumps.

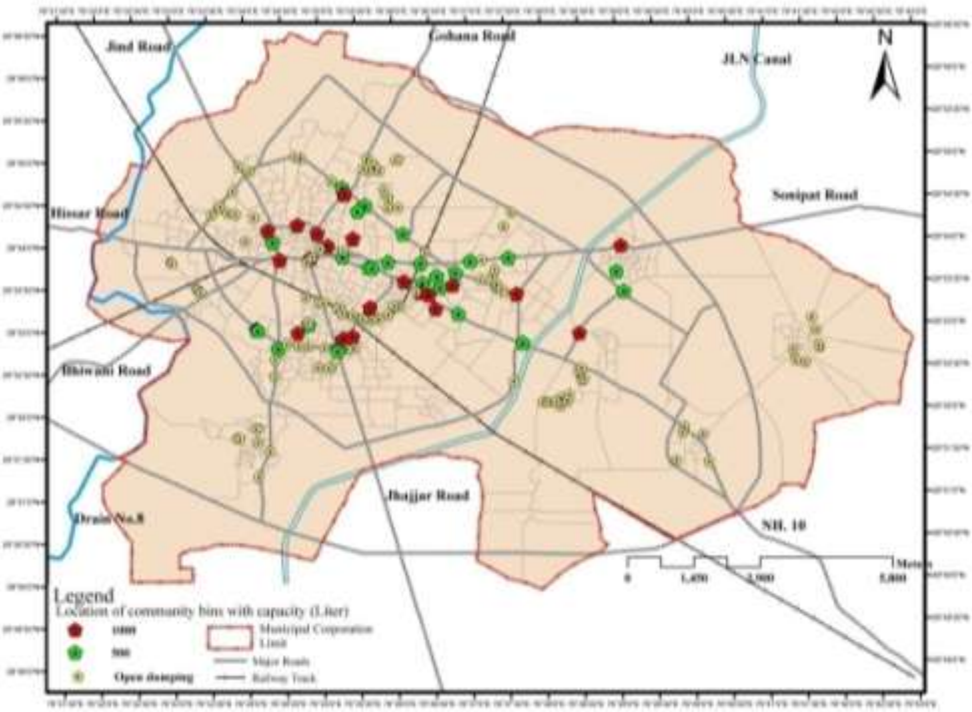


Fig. 7 Location map of Community Bins and open dumps.

There are 172 sensitive area's present in study area which includes schools, hospitals and temples. Zone 3 covered the largest built up area which is 5.3 Km^2 whereas, the smallest zone is zone 5 with 1.2 Km^2. Built up area is more important as compared to area of zone because only built up area is the source of waste generation and placement of community bins is as per its distribution. The total area of these zones are 139 Km^2 whereas, the built up area of these zones is 20.3 Km^2. 4.86 lakh of population resides in these zones and generates 226 tone of the waste per day. The existing number of community bins were 72 but the required number of bins to cater the 100% of waste are 163 if the collection frequency is twice a day. In Z1, Z2, Z3, Z4, Z5, and Z6 there are 14, 6, 29, 20, 0 and 3 bins were located. In zone 5 there was no bin found. Service area covered by these bins were Z1 22%, Z2 8%, Z3 30%, Z4 33% and Z6 16%. These CBs caters waste only 20% in Z1, 13% in Z2, 35% in Z3, 18% in Z4 and 12% in Z6. As per model applied 35 CBs in Z1, 25 in Z2, 33 in Z3, 53 in Z4, 6 in Z5 and 11 in Z6 are required which caters waste, 127% in Z1and Z3, 128% in Z2, 124% in Z4, 120% in Z5, and 129% in Z6. Service area increased by 67% in Z1, 71% in Z2, 40% in Z3, 73% in Z4, 100% in Z5, and 48% in Z6. Due to the increase of number and placement at suitable site the percentage of service area increase as compared to presently located CBs. A higher percentage of service area coverage means that the waste generated in the bin coverage area will need to be transported for shorter distance to the bin. This encourages the residents to deposit the waste in the bins instead of open dumping due to ideal distance to bin. The number of bins and their spatial distribution has been optimized as the number of bins and their location is commensurate with the waste production of the blocks and the placement with the built up area of the zones. Spatial distribution and service area covered by existing and proposed community bins are shown in fig. 8. The comparison between present and proposed model for the CBs placement is shown in Table 3.

Table 3 Service area covered by existing bins and bins proposed in new management model.

Zone	Number of bins existing	Percentage of waste cater (existing)	% of service area covered	Number of bins proposed	Percentage of waste cater (Proposed)	% of service area covered by new bins
Z1	14	20	22	35	127	67
Z2	6	13	8	25	128	71
Z3	29	35	30	33	127	40
Z4	20	18	33	53	124	73
Z5	-	-	-	6	120	100
Z6	3	12	16	11	129	48

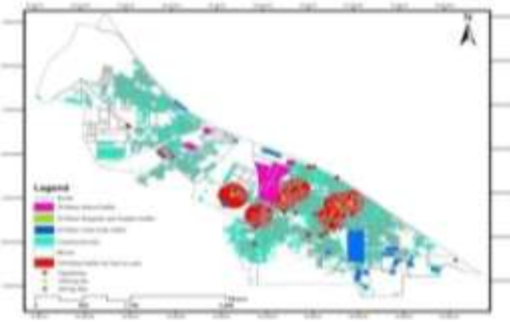
Table 4 Service area covered by Existing bins and bins proposed in new management model.

Zone	Built up area (km^2)	Service area covered by present bins (km^2)	Service area covered by proposed bins (km^2)
Z1	4.3	0.96	2.9

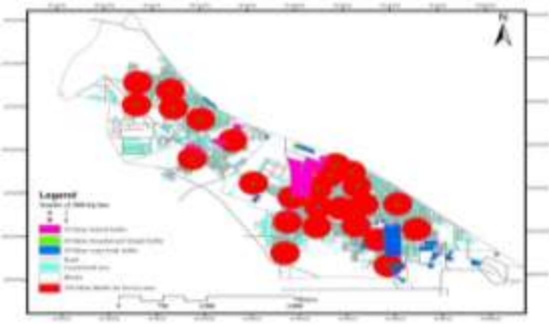
Z2	2.1	0.16	1.5
Z3	5.3	1.6	2.1
Z4	4.5	1.5	3.3
Z5	1.2	-	1.2
Z6	2.9	0.45	1.4

Zone-1

Present

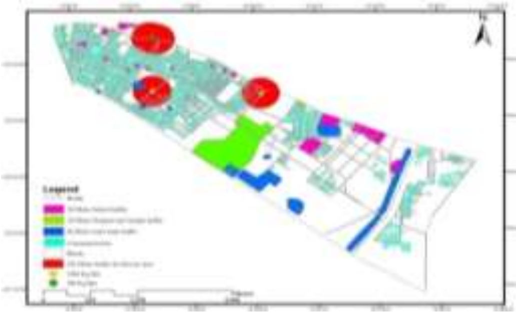


Proposed



Zone 2

Present



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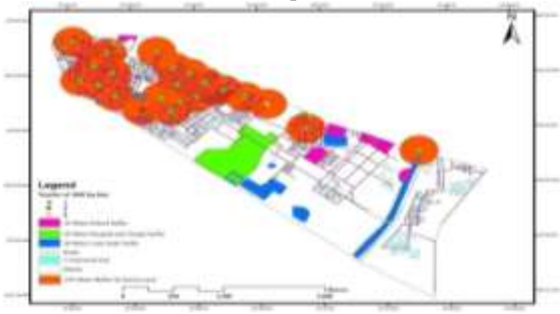
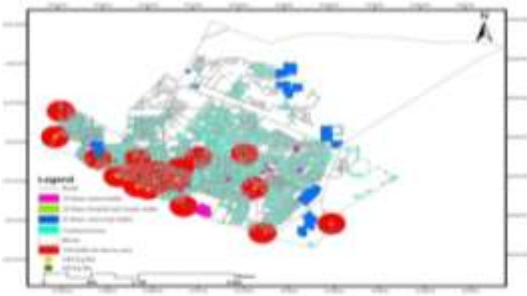


Zone 3

Present



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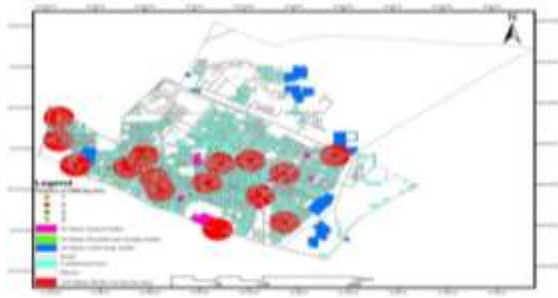
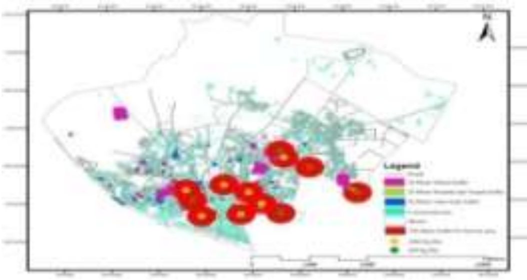


Zone 4

Present



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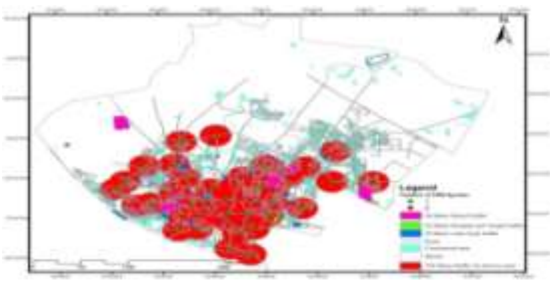
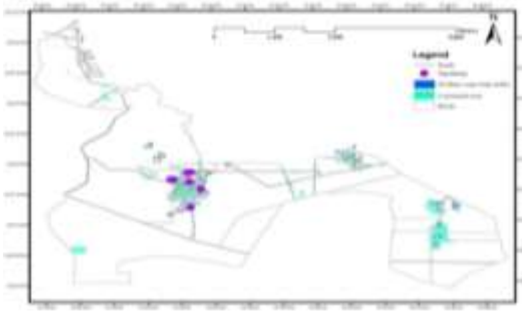


Zone 5

Present



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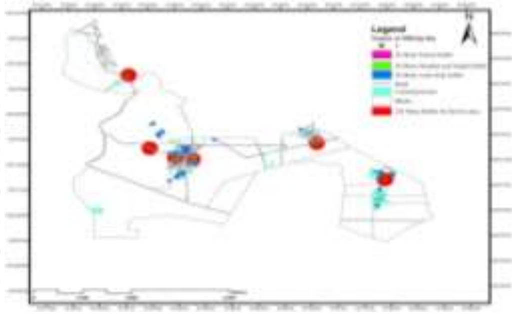
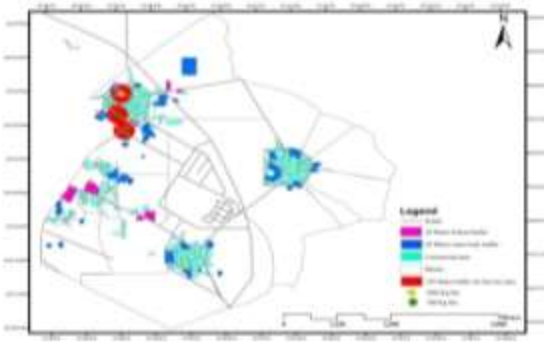


Zone 6

Present



Proposed

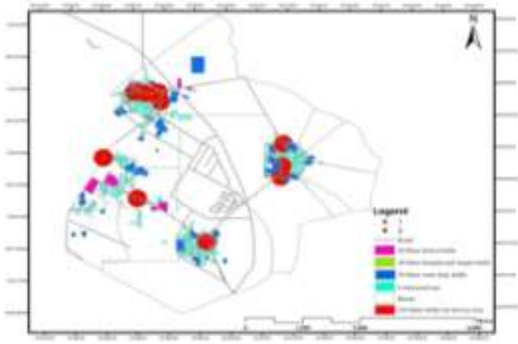


Fig 8. Service area covered by present and proposed community bins of six zones of MCR.

V. CONCLUSION

The study analysis the present issues associated to MSW collection services. The present location of CBs was analyzed for its catering capacity and service area coverage. Spatial distribution for proper collection of waste using GIS. To ensure the entire quantity of MSW generated and its service area coverage from the zones a new model was proposed with optimal number and location of CBs. Findings shows that in present system percentage of service area coverage is in between 8% to 33% whereas after model application coverage area increased in between 40% to 100%. The increase in service area is due to increase in number of bins, due to which the accessibility for waste collector and waste generator becomes better. Waste catering capacity at present is between 12%-35% which becomes greater than 100 % as per new model. Hence, the study recommends the option such as the modification in the placement of collection bin for efficient collection of sources sorted MSW. Proposed CBs placement do not violate the any rules regarding sensitive area which resulting in less chance of water pollution, better hygienic environment and aesthetic quality.

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