Optimal Location and Proximity Distance of Municipal Solid Waste Collection Bin Using GIS: a Case Study of Coimbatore City

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Abstract: A better Municipal Solid Waste (MSW) management plans are required for developing urban cities in India. Further to facilitate MSW management, the enhanced options are to be provided for initial functions of MSW such as collection and transportation. The environmental and cost effectiveness of the functions would be achieved and analysed with adopting scientific technology like Geographical Information System (GIS). Hence, in this study GIS was used for investigating adequate number and positions of existing collection bins in one of the urban ward Sidhapudur, Coimbatore, India. The proposed numbers of collection bins were assessed according to MSW generation in the ward. Then the optimal positions were found with reference to existing bin locations, road network and population density. Moreover, based on the public preferable walking distance to drop the MSW to the collection bin, a model was developed. In this model, the three different proximity distances such as 50m, 75m and 100m around existing and proposed bins were generated and found the optimal distance. As a result, the entire area was covered by 75m distance around the collection bin with 99%. Thus, the proposed model suggested some modifications in existing system and which would recommend best possible collection services.

Key Words: *Municipal Solid Waste (MSW), Collection & Transportation, Collection Bin Number and Locations, Optimal Position, Optimal Distance, Geographical Information System (GIS).*

1 Introduction

The developing country like India the quantity of Municipal Solid Waste (MSW) has increased with improved life styles and social status of the populations in the urban centers [21]. It is estimated that about 1,60,000 MT of MSW is generated daily in India. Per capita waste generation in cities varies from 0.2 kg to 0.6 kg per day depending upon the high living standards, the rapid economic growth and the high level of urbanization. An assessment has been made that per capita waste generation is increasing by about 1.3% per year. With growth of urban population ranging between 3 to 3.5% per annum, the annual increase in overall quantity of MSW is assessed about 5% [22, 29]. However, there are insufficient infrastructure and resources for the MSW management in many urban areas of the

country. Also, suitable services to dispose most of the MSW from households are not up to the satisfactory level. The rapid generation of MSW leads to management issues in addition to environmental impact. [28]. Thus, Bani et al., 2009 suggested that the impacts can be minimized by the proper management with improved technology applications.

In the management system, local administrative positions are more responsible for MSW management services, either directly or indirectly through sub contracting part or all of these services [5]. Especially, MSW collection and transport are provided at the individual municipality level. Currently, collection and transport of commingled MSW is responsible for a large portion of the total waste management costs, in the range of 70-100% [16, 14]. This is considerably higher than the typical values, between 50-75%, reported for modern waste management systems [23] because an adequate amounts is not used for the disposal of MSW due to the unawareness in pretreatment for materials and/or energy recovery and practicing of illegal dumping [5]. Therefore, the cost effective collection system and finding the appropriate number and location of collection bins can be confronted with applying the sophisticated technology like Geographical Information System (GIS) computerized tool.

In this context, the investigation of the related literature reveals that the GIS technology is used to computerize the waste management planning and design of waste collection and transport and disposal. Nowadays integrating GIS technology with MSW management has been recognized as one of the most promising approach to automate the process of planning and better management of MSW [13, 20]. Moreover, the IT related methods based on integrated GIS and multi-criteria techniques are mostly used for selecting appropriate landfill sites to dispose the MSW. For example, Svoray et al., (2005) and Higgs (2006) applied multi-criteria and GIS techniques to investigate the suitability of different land uses for residential, industrial, forest, natural conservation and also to investigate the possibility of public participation in the MSW management. Chang et al., (2008) used multi-criteria and fuzzy model with the help of GIS to find a site for the MSW disposal in southern Texas.

The complex waste management systems, in particular sitting MSW management and disposal facilities and optimizing waste collection and transportation have been a preferential field of GIS applications from the early onset of the technology [7, 8, 9, 14, 23]. GIS is the most feasible methodology for designing an optimal waste collection routes for the bin to bin collection in Spain [1, 18]. Teixeira et al (2004) applied heuristic techniques to solve a collection model in order to define the geographic zones served by the vehicles, as well as the collection routes for recyclable waste collection of Portugal. Christos Chalkias, Katia Lasaridi (2009) developed a model in ArcGIS Network Analyst in order to improve the efficiency of waste collection and transport in municipality of Nikea, Athens, Greece, via the reallocation of waste collection bins and the optimization of vehicle routing in terms of distance and time travelled. Optimization of waste collection and transportation making use of the novel tools offered by spatial modelling techniques and GIS may provide large economic and environmental savings through the reduction of travel time, distance, fuel consumption and pollutants emissions [3, 6, 12, 15, 19, 26].

Based on the investigation of literature review, the GIS spatial technique is a good decision support tool to implement for locating new bins in one of the main urban area Sidhapudur ward in Coimbatore city, India. The objectives of the study are

i. to review current MSW management practices including waste generation, location of collection bins, type & size of collection bins and collection frequency of MSW removal from the bins

ii. to find and allocate new collection bins based on MSW generation using GIS technique and
iii. to find the optimal proximity distance for the collection bins by generating buffer zone.
Thus, the study helps in analyzing the present MSW collection issues and used as a decision supporting tool for efficient collection of MSW in the ward.

2 Present Scenario of Research Area

The Coimbatore city is situated in south India and it is around 11° North latitude, 77° East longitude and 432.0 m above the mean sea level. The city had 72 administrative wards and recently the corporation boundary has been expanded to 100 wards with an area of 265.36 Km^2. Coimbatore, known, as `The Manchester of South India'. It is the third largest city in Tamil Nadu and houses numerous textile mills and small scale engineering units. The city has urban development and area having potential of rapid industrialization. It has an urban population of 9.31 lakhs as per 2001 census and the provisional population as on 2010 is about 10.59 lakhs (CMC). The city generates an average amount of MSW is about 635 MT per day [11]. The city presently consists of four transfer station from where the wastes are transferred to disposal site which is situated in the place called Vellalore. Source segregation of waste is not properly being practiced. The study is carried out in one of the ward such as Sidhapudur, Coimbatore (ward ino.52, old no.29) which is nearer to one of the transfer station. The ward map is shown in Fig.1.

2.1 Description of the Ward

The ward Sidhapudur comprises of diverse economical group of people and also consists of mixed residential and commercial areas. Large number of hotels, restaurants, city bus stand, offices and shops are located in the ward. This is one of densely populated urban ward in the Coimbatore Corporation (Report on Business Plan for Coimbatore Corporation, Nov, 2006). The population is about 12,689 as on 2006 (CMC).

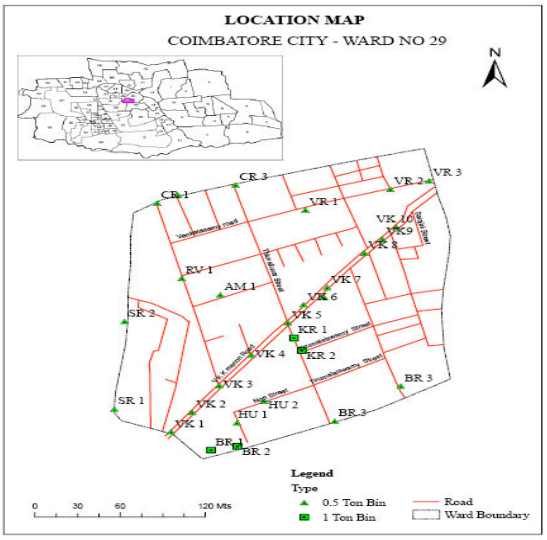

Fig.1 Ward map

2.2 MSW Generation and Collection Methods in the Ward

The MSW generation in the ward is about 8 tonnes per day. Waste collection is carried out mechanically using 1 rear-ends loaded compaction trucks with 2 tonnes average capacity. The crew size is two, a driver and a worker who move and align the bins with the hydraulic lifting mechanism of the truck. No proper segregation of MSW and collection method is practiced. The two collection services such as alley and door to door collections are followed for collecting comingled MSW. The door to door collection services dumps the MSW into the nearby collection bins. Since the collection frequency is varying bin to bin in the alley services, the door to door services find the place to drop. If the road side collection bins are filled completely, the door to door collection dumps the MSW around the bin.

Sometimes this dumped MSW around the bins may not clear even during transferring into vehicle as shown in the Fig.2. And also stays the door to door collection push carts with M

SW until collection time as shown in Fig.3. As a result, during non collection period the MSW brim over the collection bins. This is due to the inadequate number of supply of collection bins by the management and the restriction of residence to place the bins in front of their house, thereby only limited number of bins are located in the ward. Owing to the inadequate number of collection bins, there is no proper segregation is carried out and also overflowing of waste during non collection and festival periods. This shows the accumulation of waste on the road side. Hence, the study aims to propose new collection bins and their optimal locations with considering existing bins, road network and population settlement by using GIS technique. The proposed location of bins would reduce the present MSW collection service difficulties.

Fig.2 MSW around the bin

Fig.3 Overflowing of MSW in Door to door collection service

2.3 Need for the Study

The entire quantity of generated MSW in the ward is planned to deliver to the transfer station located in Sathy road. Though the transfer station is located within the ward boundary, partial amount of MSW is cleared. This is due to the insufficient vehicle fleet, traffic congestion in the city and operation delay in the transfer station. And also, due to the insufficient number of collection bins, the collected MSW by door to door collection is dumped around road side bins. This service is provided only during week days and non traffic time. Consequently, the people tend to dispose the MSW into nearby drains. The numbers of obsolete individual houses have become apartments in the ward. Moreover, the recent expansion of the CMC boundary, the MSW management confronting problems for the proper functioning of the system due to inadequacy of conservancy workers (The Hindu News Paper, 2011). This reveals that, a proper collection service of MSW is necessary in the ward.

3 Methodology

The methodology is established by GIS technique in the research area by following three phases. The conceptual flow of the work is shown in Fig. 4.0

i.Data collection

ii.Development of geo spatial database

iii.Present analysis of MSW collection in the ward

iv.The optimal allocation of collection bins for the proposed model based on road network, population density etc., and

v. Analysis of optimal proximity distance by creating buffer zone of the existing and proposed model.

3.1. Data Collection

In co-operation with the Coimbatore Municipal Corporation (CMC), the following primary and secondary database of MSW management has been collected: population, population density; waste generation rate for mixed waste; number, type and positions of collection bins; the road network; truck capacities and their characteristics; and the geographic borders and characteristics of the waste collection sectors. The main sources of developed database were derived using the digital maps from CMC 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.

3.2 Development of Geo Spatial Database

The geospatial database was framed in Arc GIS for the allocation and analysis of collection bins. The database was derived through the sources such as digital maps from CMC, interview with government authorities and online capturing with the use of GPS technology. The description of the database is presented in the Table.1.

3.3 Existing Model for MSW Collection in the Ward

The present collection services are followed as partly alley and door to door collection. In alley collection service, 26 numbers of collection bins (either green or white colour) with the capacity of 0.5 tonne and 4 numbers (only 2 locations) of 1 tonne capacity collection bins is positioned on the road side. The existing bins are not evenly distributed for entire collection of MSW. There is no scientific method followed to allocate the bin. Due to the uneven distribution, there is an inconvenience for the residents to drop their MSW in the collection bin in the ward. This ultimately leads to more dumping of MSW in the drainage.

In remaining part of the area, the door to door collection is carried out using 12 numbers of push carts containing bins with the capacity of 10 Kg each- green bins (3 nos.) and white bins (3 nos.) This collection is done only in early hours of week days. This service facilitates MSW collection during non traffic time. The collected MSW is dumped in to nearby road side bins. If there is any delay in the collection and no synchronization between two collection services, leads overflowing of MSW around the collection bins.

In order to overcome the shortfalls present in the existing system, an appropriate technology like GIS is needed to find the adequate number, size and optimal location of the bins. For this, initially the existing bin locations were analysed based on the service area of each bin by creating a buffer zone around the bin. According to WHO recommendation and Shaikh Moiz Ahmed (2006), Illeperuma.I.A.K.S et al (2010) statement, the preferable walking distance of the people to drop their MSW to the collection bin is less than or equal to 100m.

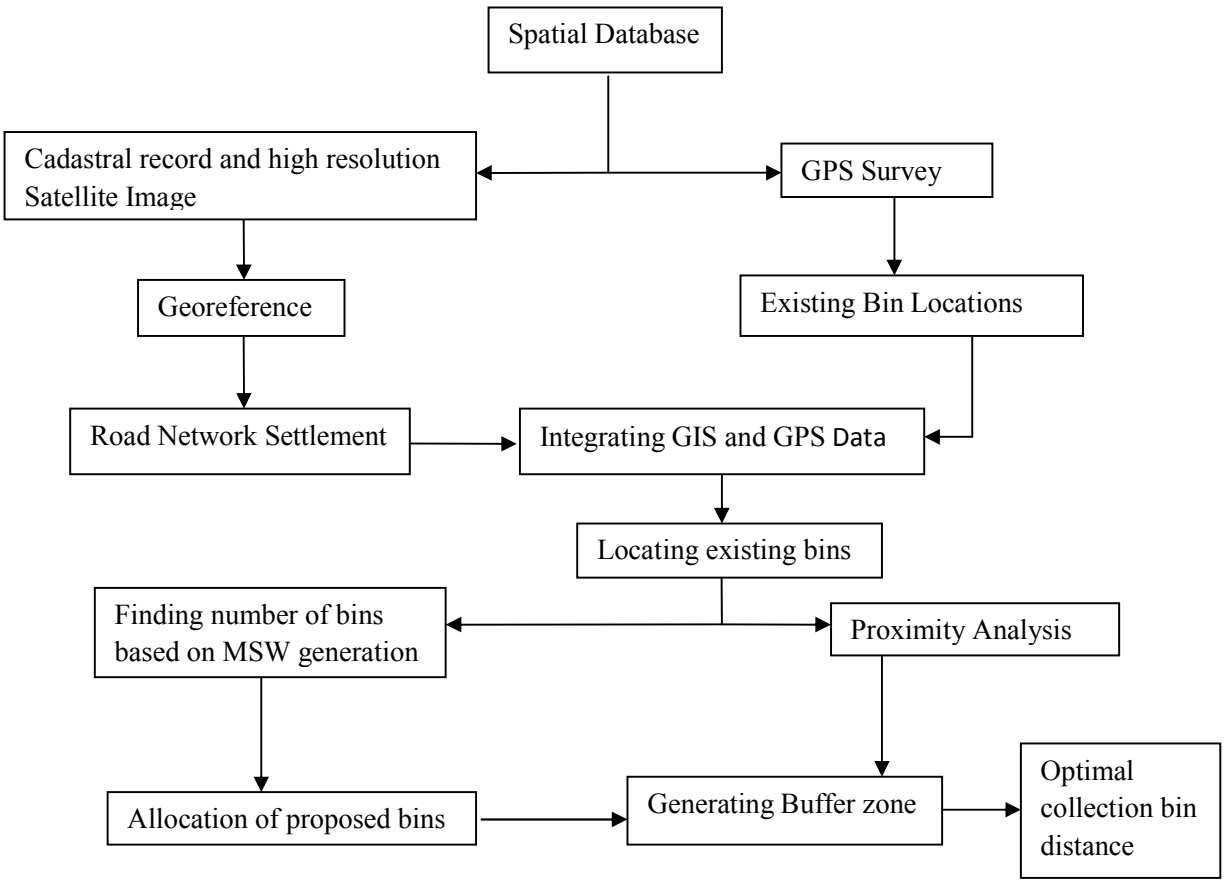

Fig.4 Conceptual Flow of the work

Spatial Data	Type	Attributes	Geometry
Road Network	Vector	-	Line
Collection bin location	Vector	-	Point
Road Network attributes	Tabular	Road Length	-
Collection bin attributes	Tabular	Longitude, Latitude, type and size of collection bins	-
Satellite image of the research area	Raster	-	-

Table.1Description of Geo Spatial database

So that, the study analyses the service area covered by the existing bins with following three cases.

E_1: Proximity distance of 50m for existing collection bin
E_2: Proximity distance of 75m for existing collection bin
E_3: Proximity distance of 100m for existing collection bin

3.4 Proposed Model for the optimal allocation of Collection Bins

In order to enhance the current MSW collection services in the ward, the present work investigated the inadequacy of existing collection bins and their service areas. Thus, initially the number of bins required was calculated on the basis of per capita MSW generation and population. It is given in following equation.

$$N = W/(D * S * F1 * CF) - - - - - 1$$

Where
N = Number of collection bins
W = Total quantity of waste generated per day in Kg
D = Density of waste in Kg/m^3
S = Size of bins in m^3
F_1 = Average filling rate of bin. (Generally 80 %)
CF = Collection Frequency
Then obtained numbers of bins were allocated at new locations based on the following criteria:

i. With reference to existing bin location
ii. The road network and population density
iii. Unserved area

The land use pattern of the proposed collection bins was also analysed with creating buffer zone around the collection bins by following three cases

P_1: Proximity distance of 50m for existing and proposed collection bin
P_2: Proximity distance of 75m for existing and proposed collection bin
P_3: Proximity distance of 100m for existing and proposed collection bin

4 Results and Discussion

In order to facilitate the MSW collection efficiency system, the current study proposed new collection bin locations and also analysed optimal proximity distance of the collection bin by Arc GIS.

4.1 Analysis of Existing Model in the Ward

With the purpose of analyzing the existing locations, the buffer zones were created around the bins with various cases of people preferable distances. From the Fig. 6, Fig.7 and Fig.8, the total service area covered by each buffer zone distance of 50m, 75m and 100m was 32%, 38.6% and 58% respectively. This implies the alley collection services are to be improved by providing sufficient number of collection bins at optimal locations in the research area. So, the study was conducted to analyse the existing location of the bins through proper continuous monitoring of the system.

At present, totally 30 numbers of collection bins are located in the ward with two capacities (0.5 tonne and 1 tonne) as shown in Fig.5. About 37 % of the bins are located closer to each other in V.K.K menon road, because of existence of more number of the small hotels, central bus stand, schools and residents. In some area, bins are placed closely. Thus, more number of bins is serving same area. In addition, the location of some bins is not based on the MSW generation rates and population density in the V.K.K menon road. Hence, there is a necessity for relocation of the bins on the road.

The part of southern side, northern side and eastern side, the door to door collection service is followed. The roads are wider in northern and southern side whereas narrower in the eastern side. Hence, it is recommended to adopt the door to door collection service in the eastern side of the ward where collection vehicle may not access through the roads for the collection of MSW. Hence in this study, the ward the collection bins were not located in the eastern side of ward.

4.2 Analysis of Proposed Model

Based on the present analysis, the existing study recommended a model to diminish the above mentioned issues. This proposed model helps to ensure efficient collection of MSW in the ward. Hence, it is a necessary of finding the optimal locations of the MSW collection bins which helps to managing the local level issues for the collection of MSW. The quick analysis in the decision making can be performed by the advanced technology like GIS. The GIS technology can find a quicker and rational solution for defining a service area for a particular service, with network measurements (Syed Anwar, 2009). Hence, in this study GIS was used to locate the proposed bins and their collection service area coverage for the entire ward with optimal proximity distance to the collection bins.

4.2.1 Number of Collection Bins

Initially, the total quantity of MSW generated was assessed based on per capita MSW generation and population. The population growth rate of the ward was projected 4 % annually. The percapita MSW generation is about 0.6 Kg (CMC, 2010).

From the equation 1, it was found that 46 numbers of collection bins were required for the collection of MSW in the ward for the present analysis. This reveals that there is 33 % shortage of bins in the ward. Thus, additional proposed number bins were located optimally in the ward and shown in the Fig. 9.

4.2.2 Identifying Optimal Location and Proximity Distance

In the field survey, existing location of bins, road network (intersection), population density and unserved area of the ward were identified. Based on the above study, the road width was considered as prime importance during the analysis of the optimal location of the bins in the ward.

In order to check the collection bin proximity distance by the residents in the ward, the different buffer zones such as 50m, 75m and 100m were analysed and shown in Fig.10, Fig.11 and Fig.12 The percentage of area covered by the existing bins with buffer zone of 50m 75m and 100m was 32, 38.6 and 58 respectively . The total area covered by existing bins and proposed bins with buffer of 50m, 75m and 100m were 60 %, 99% and 147%. The optimal proximity distance was found in the Fig.13 which shows the difference in percentage of the total area covered by the collection bins for the existing and proposed model. From the analysis, the 100m distance for existing bins and proposed bins was overlapped in many areas. Hence, 100m buffer zone was not considered as feasible. By comparing 50m buffer zone, it covered only 32% in existing model and 60% in proposed model. Whereas the buffer zone of 75m covered 38.6% in existing model and 99% in the proposed model. Since the 75m buffer zone covered entire study area and it may be optimal primate distance by the residents in the ward.

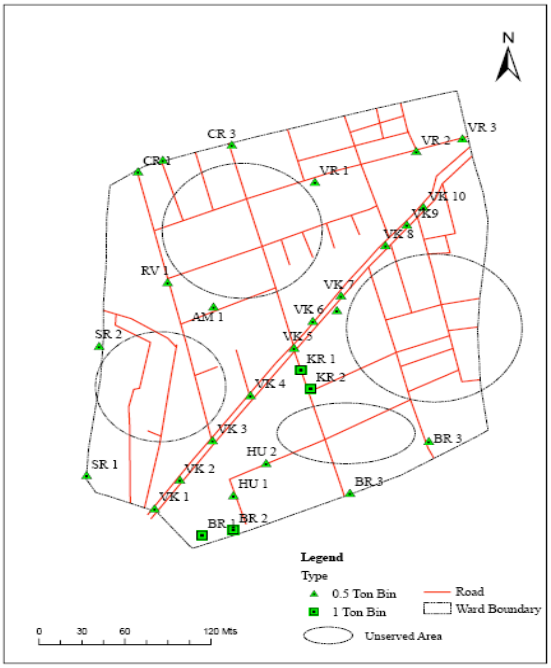

Fig.5 Existing Location of Collection Bins

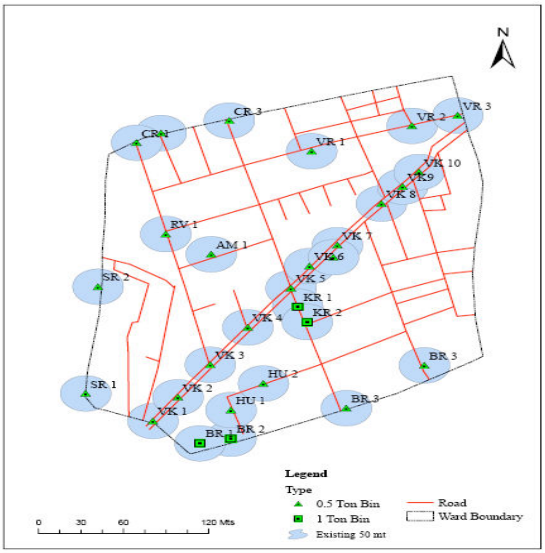

Fig.6 Existing Collection Bins with 50m Buffer Zone

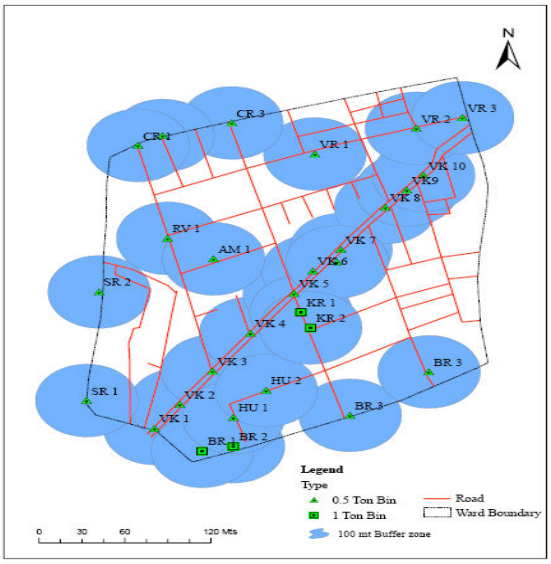

Fig.8 Existing Collection Bins with 100m Buffer Zone

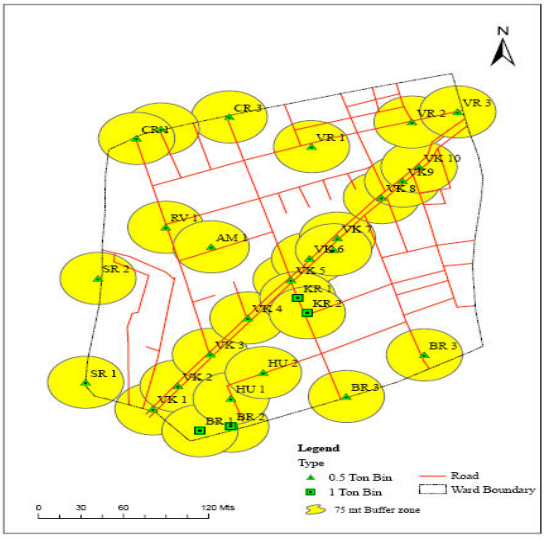

Fig.7 Existing Collection Bins with 75m Buffer Zone

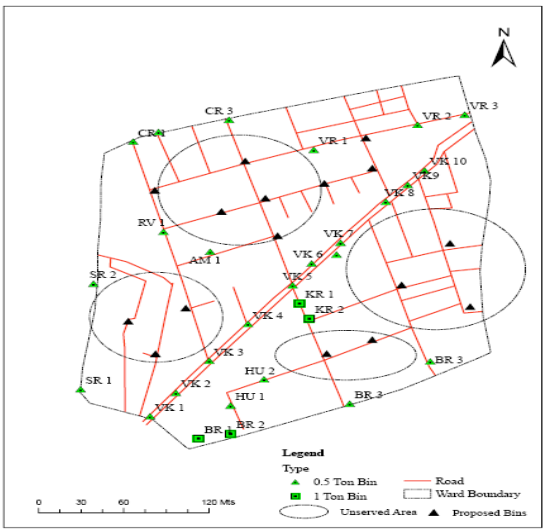

Fig.9 Proposed Locations of bins Buffer Zone

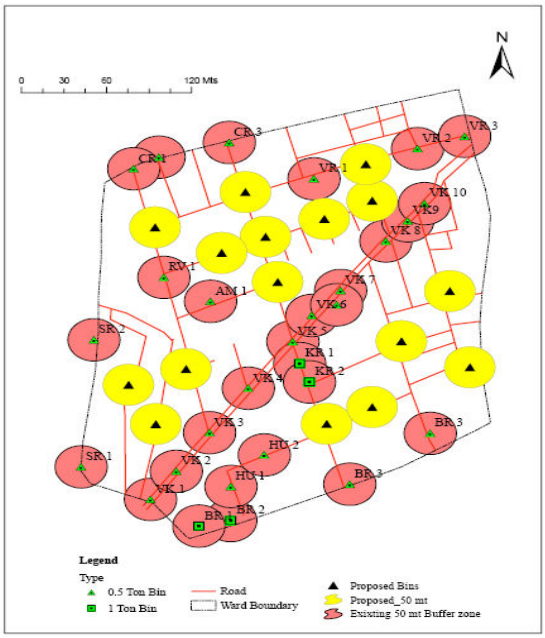

Fig.10 Proposed Locations with 50 m Buffer Zone

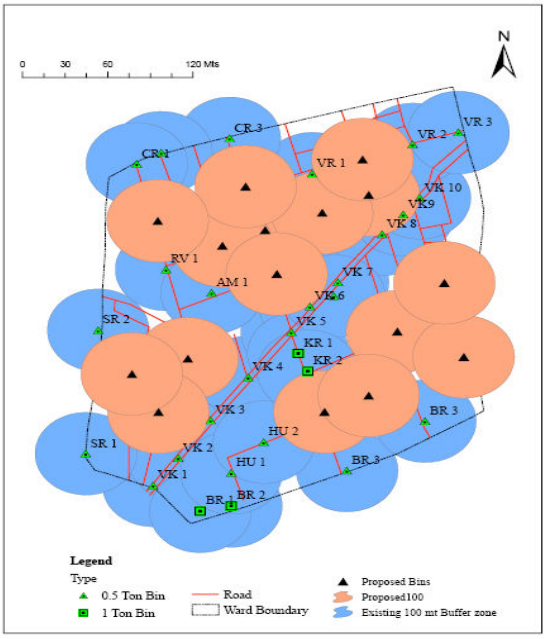

Fig.12 Proposed Locations with 100 m Buffer Zone

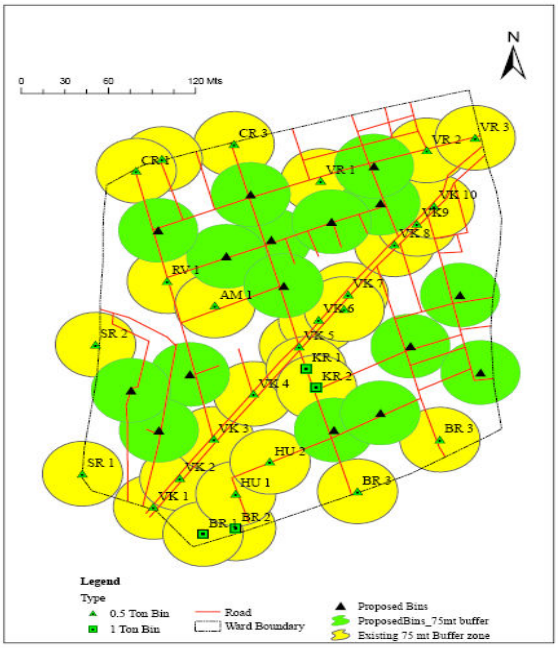

Fig.11 Proposed Locations with 75 m

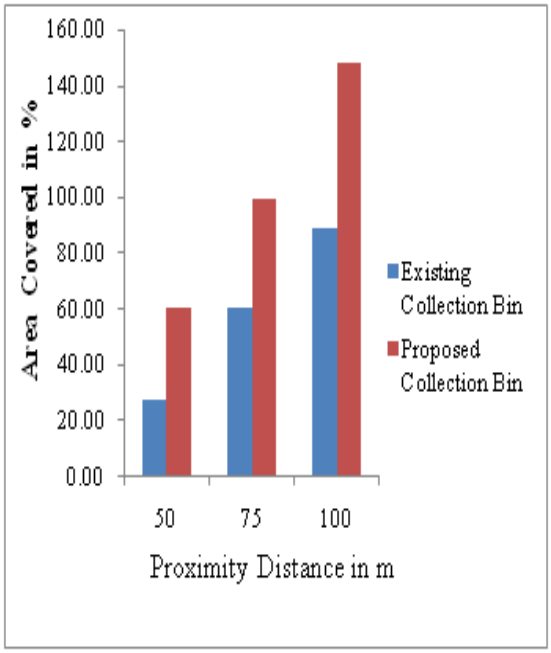

Fig.13 Optimal Proximity Distance

5 Conclusions

The study analyses the present issues associated to MSW collection services. The present location of the collection bins were analysed for the different proximity distances in the ward Sidhapudur using GIS. To ensure the entire quantity of generated MSW from the ward a new model was proposed with optimal number and location of bins. 33 % of bins were increased and located according to the requirement based on the population density and accessibility of the collection vehicle. It was found that the proximity distance of 75m by the residents ensures the complete collection of MSW in the ward. The proposed model also helps the municipal authorities in decision making process in the management of MSW. The CMC is planned for source sorted – degradable and recyclable waste and for the easy disposal. Also, the quantity of degradable waste is much higher (94 %) than the recyclable waste. Hence, the study recommends the option such as the modification in the design of collection bin for efficient collection of source sorted MSW.

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