

Assessment of Spatial Distribution of Waste Bins in Karachi Through GIS Techniques

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Abstract: Karachi has been facing various issues of municipal solid waste management. In the early 1960s, Karachi was the centre of leisure, now it has stretched out due to its increasing population. However, due to insufficient facilities and ineffective strategies, issues related to waste management are also increasing. For the problems related to waste management, the fundamental units available are municipal trash bins. In this study, 409 GPS point data of collection points of waste have been assembled from various areas of Karachi for assessment of the spatial distribution of waste bins. A spatial variation of distance between the trash bins is also identified through ArcGIS 10.3.1 cartography tool of generalization, which aggregates the points of trash bins by making polygon shape of the same distance. Globally, Geospatial techniques are used for changing the system of waste management. This is the first study that assessed the suitable distance of bins placement in the area under focus. The results revealed that there are no principles acquired by the government for the placement of trash bins with appropriate distance. In many towns of Karachi like Landhi and Korangi, bins are absent which impels people to throw their trash anywhere in the city.

Keywords: Aggregate point; bins placement distance, geospatial techniques, kernel density, municipal solid waste, container size.

Introduction

Karachi is a city of 16.1 million people. It is the highest revenue-generating city and people belonging to different cultures living here made it known as mini Pakistan (Sohoo et al., 2021). Due to its urban sprawl, many issues have arisen like unavailability of clean drinking water, electricity shortage, deteriorating law and order situation and most prominently the improper disposal of waste management. The main issue that is badly affecting almost all state administration and urban agencies is the lack of proper dumping of solid waste (Ajadi and Tunde 2010). Globally, a geographic information system (GIS) is equipped with a very smart tool in the latest research studies. It offers the analysis of different layers of data set easily and smoothly. Since waste bins are the fundamental units to control the waste management system of an area, so in this study assessment of the spatial distribution of waste, bins have been done through various GIS techniques.

The environment of the city describes the quality of life. The process through which solid waste is collected and transferred is the core of the waste management system. The placement of hauled containers is suggested in the industrial area, which experiences a huge volume of waste, and the stationary container system to be placed in the surrounding areas of the neighbourhood for commercial and residential areas (Wekisa and Majale, 2020).

Furthermore, Kallel et al. (2016) stated that the utilization of GIS one of the most beneficial methods to evaluate the complicated spatial situation.

Consumption of GIS in location modeling is the well-organized path to ameliorate service coverage and effectuality in the solid waste management system (Aremu et al. 2011). Besides, Pon and Becherucci (2012) stated that a relationship is found between the abundance of urban waste and the three anthropogenic variables which are pedestrians, parked vehicles, and trash bins. Moreover, a variety of ways are available to resolve the issue of solid waste; while various researchers sorted out different models to resolve the grave issue. Pardini et al. (2019) revealed the internet of things-based reference model through which the urban issue of waste is resolved in a well-organized way. Deciding on the placement of bins and their quantity is a very difficult task, due to its impact on service coverage and public satisfaction Aremu et al. (2012).

Subsequently, Popoola, et al. (2016) found that the nonappearance of bins from the city promotes the dumping of refusals along the median and collector roads, while the placement of a sufficient number of bins improves environmental conditions. An inefficient waste management system badly impacts the economy and environment of society. Such poor solid waste management never allows the issue to be resolved in developing countries, which results in the piling up of waste (Olapiriyakul et al., 2019). However, the technique of waste segregation could reduce the issues related to the solid waste management system. To help improve the waste collection and its segregation; different types of trash containers of various designs could be used deciding the colors of trash bins that could also contribute to the proper system of waste collection and segregation. For instance, lignocellulose waste could be used for making cost-effective biofuel

and value-added products (An et al. 2021; Leeabai et al. 2021). As observed by Ali et al. (2020) that the migration of people towards big cities and the absence of a smart technology system in managing waste makes this issue even more challenging to be fixed. In the present era of advanced technology and swift communication through machines, a well-organized solid waste management system is still missing, though it is a need of time to introduce a smart waste management system (Zeb et al., 2019).

The main purpose of this work was to assess the spatial distribution of waste bins in the mega city Karachi, since waste bins are the fundamental units to control the municipal solid waste situation in an area. The proper placement of bins may reduce problems related to municipal solid waste. Currently, people are facing several MSW problems, which is due to three reasons, a) the improper number of bins has encouraged people to throw their trash in open plots, nalas (streams), and parks, b) uncontrolled dumping sites are a source of methane and CO₂ because waste pickers burn all waste for collecting metals, and c) piles of waste are also a source of various diseases for residents in the vicinity.

Materials and Methods

The spatial distribution of waste bins for which a survey was conducted among various towns of Karachi and 409 GPS facts have been collected via mobile GPS map camera throughout the ex-situ assessment. Moreover, the current work was carried out based on the cartography tool of generalization (Aggregate point). The high resolution geo-referenced image of spot 2.5m has been used, taken from the GIS lab of the Department of Geography, the University of Karachi. Digitization has been done in Arc GIS 10.3.1 for making shapefiles of roads, collection points, and town boundaries. The data management tool of raster processing, clip tool for the exploration of AOI was used. The spatial analytical tool of kernel density was also used for risk analysis of open dumping sites. However, Correia et al.(2021) stated that kernel density is a more accurate tool for the analysis of urban area data.

Karachi is a multicultural city that supports the economy of Pakistan. It is located along the Arabian Sea in the south of Pakistan in the province of Sindh, having latitude of 24°54'20.16"N and longitude as 67°4'55.92"E. Furthermore, it has been divided into seven districts and six cantonments which are Karachi East, Karachi West, Karachi Central, Karachi South, Malir, Korangi, and Kemari District. The seven districts of Karachi are further divided into 18 towns namely Orangi, Lyari, Saddar, Site, Kemari, Jamshed, Baldia, Landhi, Shah-Faisal, New Karachi, Korangi, Gulberg, Gulshan, Malir, Bin Qasim, Liaquatabad, Gadap, and North Nazimabad. Kemari district was formed in 2020 by approval of the Sindh cabinet; it was formed by splitting of Karachi west (Fig. 1).

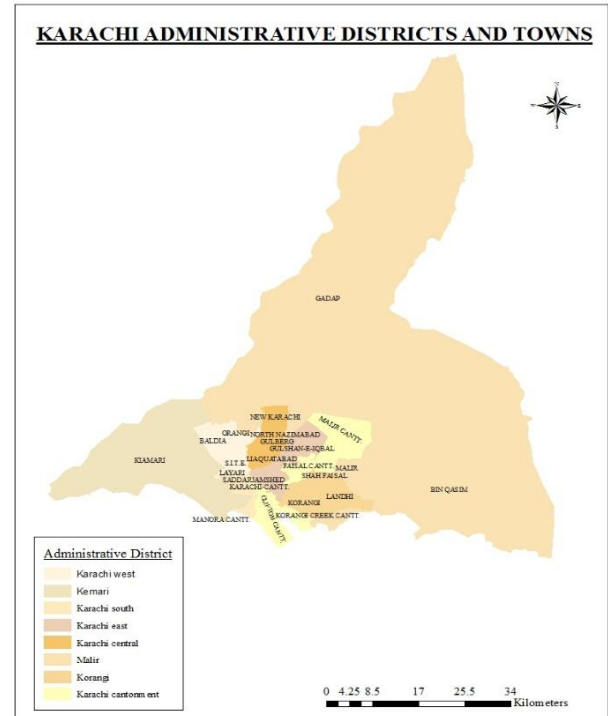


Fig. 1 Karachi administrative districts and towns, source: Author.

Results and Discussion

Types of Bins

Waste bins or trash bins are fundamental units and play a vital role in controlling solid waste in an urban area. Waste segregation is an essential aspect in the primary collection where the color and design of bins also affect the segregation with efficiency. In the current study, 3 categories of manually movable containers were examined, which are a) small-sized container, b) medium-sized container, and c) big-sized container in different towns of Karachi (Table 1).

Table 1. The holding capacity of containers.

Types of containers and their capability	
Type	Capacity
Small size container	240.0 Litre
Medium size container	620.0 Litre
Big size container	6.0 Tons

Spatial Distribution of Dustbin Types in Karachi

Karachi is the highest revenue-generating city in Pakistan, yet it is facing an issue of solid waste disposal. Various factors make this issue vulnerable. To draw the attention of the authorities towards this critical issue, an attempt has been made for the first time in Karachi to assess the spatial distribution of waste bin through RS and GIS techniques. Globally GIS and remote sensing techniques are used in a

variety of fields for monitoring and resolving the issues where containers are the essential component for handling the MSW situation in any polluted area. Therefore, in this study 409 GPS point data were collected by conducting surveys in different towns of Karachi. The results revealed that big sized containers are placed in the areas like North Nazimabad, Site, Liguatabad, Saddar, Gulshan-e-Iqbal, whereas the large numbers of small-sized containers are placed in Saddar, Karachi Cantt, and Gulshan-e-Iqbal town. The medium-sized containers were observed in the particular areas of Clifton cantonment and Jamshed town. The data presented in Fig.2, indicate the spatial distribution of container types in Karachi at the town level in 2019.

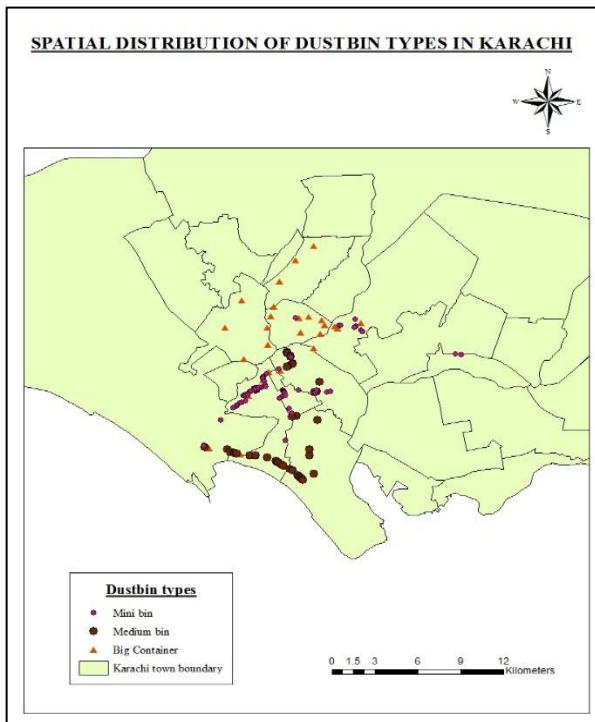


Fig. 2 Spatial distribution of container types in Karachi at the town level during 2019.

Spatial Variation of Placement Distance of Bins

The hypothesis proposed in this study is proved with the help of cartography and the aggregate point tool. Through this tool, we made polygon of the same distance locations, which was very supportive in understanding the dissimilarity of the distant location of the containers. Waste bins are the fundamental units for managing solid waste conditions in any area. However, the usual distance observed in the placement of containers did not appear in selected areas i.e. Landhi, Korangi. On the other hand, people throw their trash in open plots or parks because there are no community containers positioned. Figure 3 reveals the spatial difference of location of small, medium, and big size containers.

Parrot et al. (2009) reported that only 37.4% of people dump their waste in waste bins if the average distance

between the nearest bin is long. Murray, (2010) found that the application of GIS supports data management, helps in visualization, resolve issues, and provides theoretical advances. Boskovic and Jovicic (2015) performed a study ArcGIS 10.1 software and gives a methodology to improve waste collection and the reduction of fuel consumption. This study highlighted the spatial distribution of dustbin types in Karachi at the town level, the subject holds great importance to manage the solid waste situation and proper placement of waste containers for better services. Purkayastha et al. (2015) stated that, if waste bin placement is improved while open dumping areas are reduced and recycled, it would be an important step to initiate a clean world. Hatamleh et al. (2020) found a reduction in container placement distance by 2880.2 m in each round and the percentage of abandoned containers reduced from 25% to zero.

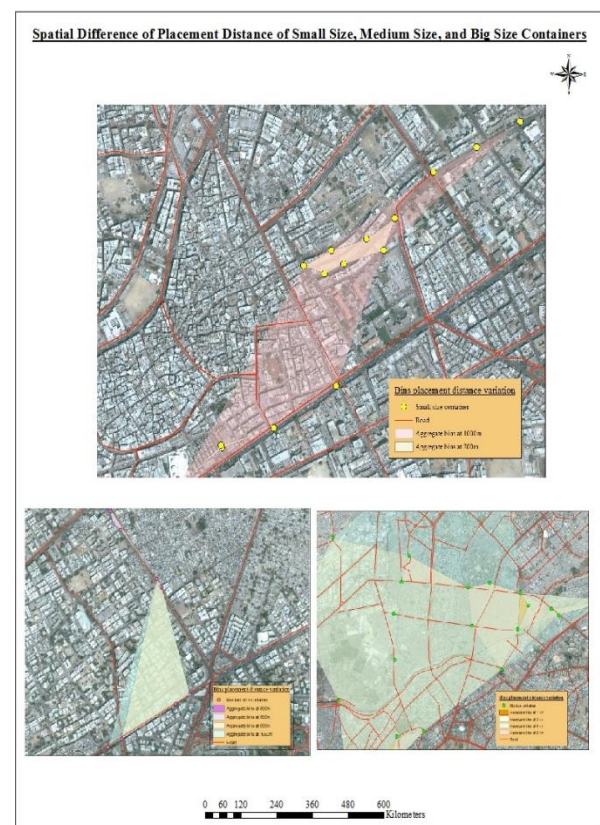


Fig. 3 Spatial difference of placement distance of small, medium, and big size containers.

Spatial Analysis of Open Dumping Sites

For spatial analysis, the Kernel mass tool was used to estimate the density of point topographies in the area. Around each point where the efficiently arched superficial was in close-fitting; the superficial value was uppermost at the positions of points and reduces when the distance between the points increases (ArcGIS Pro). In this study 409 GPS points for the collection of waste have been collected for assessment of the spatial distribution of waste containers in Karachi. During the survey, a large number of unofficial dumping sites have been documented. In the

current study, a spatial analysis tool of Kernel density has been used for risk analysis of open dumping sites. The result shows that some areas of the site like Liaquatabad, Orangi, and North Nazimabad are at high risk (Fig.4). Kondracka et al. (2021) observed that the electrical resistivity tomography (ERT) pinpoints the exact site of the stored waste, notable among the types of waste, and recognizes the soil cover. Gujre et al. (2021) reported that the MSW dumping place has resulted in significant ecological and wellbeing risk, furthermore, the higher human health risks are linked with Cd and Ni, because of misplanning and incomprehensive adaptive management practices for MSW.

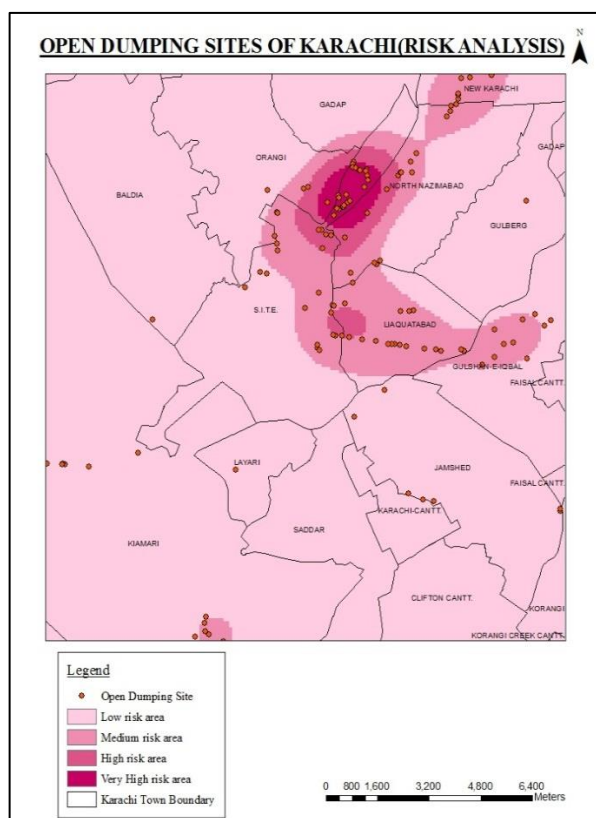


Fig. 4 Spatial risk analysis of open dumping sites in Karachi.

Conclusion

It is concluded that the existing solid waste management is facing a serious issue of the large number of open dumping sites in the megacity of Karachi, which is due to improper placement or absence of waste bins in various areas. Bins are the fundamental units to control the solid waste situation in an urban centre because improper distancing, placement and the absence of bins encourage people to throw solid waste in the open areas, parking sites, roadside, and dumping in nalas (streams). This is the first time in Karachi that spatial investigation of waste containers has been done via Arc GIS 10.3.1 and the results revealed that no proper criteria are followed for the placement of containers. Big sized containers are positioned in North Nazimabad, Site, Liqutabad, Saddar, Gulshan-e-Iqbal while the dense quantity of

small size containers is located in Saddar, Karachi Cantt, and Gulshan-e-Iqbal town, and the medium-sized containers are found in zones of Clifton cantonment and Jamshed town.

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