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GIS based Spatial Mapping of Bulk Waste Generators in Panaji City, Goa

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Abstract:- The Corporation of the City of Panaji (CCP), despite being a front runner in implementing measures such as source segregation, door-to-door coverage, and material recovery from dry waste, is facing an enormous challenge in handling the biodegradable waste that is generated in the city, especially, waste from bulk generators. *Objective:* The objective of the paper focuses on mapping of bulk waste generators in the 12 different zones of the city of Panaji, using the Geographic Information System (GIS), so the City Corporation of Panaji could devise a route map with suitable planning for waste collection and transportation. *Methods:* A Geographical Information System based methodology, which includes digitization of the bulk waste generators and preparation of map layouts. *Results:* The zone-wise mapping of the bulk waste generators revealed that zone 2, 3, 7, and 8 was highly concentrated with the number of bulk waste generators. *Conclusions:* As demonstrated in this study, the studied GIS methodology can be used for identification of the source of waste generation and further help in optimizing for waste collection and transportation in a city.

Keywords:- *Panaji, Bulk waste generators, Solid waste management, GIS, Optimizing waste collection and transportation.*

I. INTRODUCTION

Rapid population growth coupled with unplanned urbanization has resulted in a multifold increase in waste management and sanitation services in Indian cities. The prevailing system for the collection, segregation, transportation, and disposal of solid waste is under unprecedented pressure. Urbanization is a phenomenon that is being observed in countries around the world. The global waste generated amounts to 2.010 million TPA, and the average waste generated per person per day is 740g (Kaza, Yao, Bhada-Tata, & Woerden, 2018). At present, India's population amounts to 17.5% of the globe (Kumar, et al., 2021). "Urban Settlements" has been observed owing to the transition of the population from a rural setting to cities with better employment, educational or medical facilities. This increased population density has resulted in increased waste generation in urban areas. The urban population of India is 34.43% (MoHWF, 2020). With this much urban population, the country generates around 119g/ day of solid waste (CPCB, 2020). Studies also establish the relation between improved living standards and an increase in MSW production per capita (Kawai & Tasaki, 2015).

Goa is located on the Konkan coast in western India. It has a population of around Goa's population is 1458545 residents and a floating population of almost 302751 tourists (Government of Goa Website, n.d.), (Market Research Division, 2021). Of the total estimated population in 2011, approximately 62.17% is considered an urban population, while 37.83% is a rural population (DPSE, Goa, 2018). The growing phenomenon of urbanization and the consequent changes in lifestyle are key factors that have gradually led to a gradual increase in the total amount of waste generated in the state. According to reports, Panaji generates 21,609 kg of waste per day based on its population of 40,017, but only 42,000 kg of waste is collected each day (GSPCB, 2019). Interestingly, the amount of waste collected is more than the estimated amount of waste generated, indicating that the municipality is collecting waste from bulk waste producers like hotels, shops, markets, and restaurants. The floating population could also affect the collection rate (GSPCB, 2019). To address this issue, the CCP should stop collecting waste from bulk waste generators. To manage waste better, Panaji has recently launched a "Dry Waste Management project" in collaboration with HDFC-United Nations Development Programme, which involves implementing 16-way segregation at source model. This model requires that all bulk waste generators separate their dry waste into 16 distinct categories, including e-waste, cardboard, cloth, ceramic, paper, needles, blades, and others.

Previous research studies, ((Bashir & Goswami, 2016), (Seng, Hirayama, Katayama-Hirayama, Ochiai, & Kaneko, 2013), (Mundhe, Jaybhaye, & Dorik, 2014)) have indicated that bulk waste generators are a significant contributor to wet waste generation. For instance, Bashir & Goswami (2016) found that Pahalgam, a tourist destination in South Kashmir, produces the highest amount of waste from hotels and restaurants (74%), followed by local households (18%) and markets (5%). The study also revealed that waste from the accommodation sector and Yatra have a high potential for composting since they contain 65% and 66% compostable waste, respectively. Similarly, Seng et al. (2013) noted that in Cambodia, commercial establishments (shops) (68.4%), markets (67.4%), households (61.4%), and hotels (38.6%) generate a significant amount of kitchen waste. Mundhe et al. (2014) observed that in Pune, 40% of waste (constituting majorly wet waste) is generated from households, followed by hotels, restaurants, and other commercial establishments.

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Additionally, some researchers ((Raharjo, et al., 2018), (Kum, Sharp, & Harnpornchai, 2005), (Yousuf & Rahman, 2007) have recommended composting as an effective waste management option to reduce the amount of landfill waste. Further, the manure produced from such compost could also be sold to nearby nurseries or farmers, creating an opportunity for generating income from the recycled product.

Various measures are needed to ensure the efficient ways of solid waste management. Upgrading waste collection and transportation using the novel tools provided by spatial modeling techniques and Geographic Information Systems (GIS) may result in significant cost and time savings. A geographic information system is a computer-based system for capturing, storing, displaying, querying, manipulating, and analyzing geographically referenced data. The use of GIS in conjunction with advanced technologies such as Global Positioning System (GPS) and Remote Sensing (RS) aids in the recording of spatial data and, as a result, the direct use of those data for analysis and other purposes. Several recent studies, including (Balakrishnan, Mohammed, & Al-Kuwari, 2019), (Ghose, Dikshit, & c, 2006), (Sanjeevi & Shahabudeen, 2015), have suggested the use of GIS technology in the waste management sector. By mapping the sources of waste generators, planners can improve waste collection, route planning, and site selection for transfer stations, landfills, and collection bins (Chalkias & Lasardi, 2011). The combination of remote sensing and GIS allows for the identification of the most efficient routes in terms of both distance and travel time, which can reduce the impact of waste on public health and limit air pollution caused during waste transportation (Ramesh & Ramakrishna, 2015).

Digitization is the process of converting an analogue feature such as a map into digital form, with each feature having its own unique locational identity (Faust, 1995). Digitizing the available spatial data (which gives information about the location of buildings, and other sources of waste generation) will help form primary data, which can further help the planners analyze the situation of waste management in the area and develop appropriate waste management plans.

The main aim of this study is to support CCP in “optimizing waste collection and transportation” so that they are not overburdened with the waste collected against the estimated waste generation. Furthermore, this study aims to explore the various benefits of using tool like GIS in the waste management sector. The main objective of this study is to prepare map layout mapping the source of bulk waste generators in the 12 different zones of Panaji using GIS. As the given map layouts mark the sources of different bulk waste generators, the corporation could devise a route map with suitable planning for waste collection and transportation that will save time, money, and which in return will lead to the optimal utilization of the waste management funds.

II. STUDY DATA

Panaji, the capital city ranks very high on the cultural heritage index and is a popular tourist destination. The study area spreads over the latitude of 15º26’54.02’’N to 15º30’16.69’’N and between the longitude of 73º47’40.89’’E to 73º50’16.36’’E. The city covers an area of 7.56 Km^2 and has an estimated resident population of 40,017 (M. Corp) as per the Census 2011 and generates around 50 TPD of MSW (Climate&CleanAirCoalition, 2020). The city has been a “front runner in waste management in terms of source segregation and collection, and reports impressive service figures of 95% coverage of households; 80% collection efficiency; 98% waste segregation; 32% waste recovery; and 80% efficiency in collection of user charges (Corporation of the City of Panaji, 2015).” The city has 30 administrative wards and is further divided into 12 zones for easier management and planning of MSW. It has 115 residential colonies 14,500 households, 350 hotels, and restaurants, and generates around 50 tonnes of waste daily (Climate&CleanAirCoalition, 2020).

The term "Bulk Waste Generator," as used in the “Solid Waste Management Rules 2016”, refers to “buildings occupied by Central and State Government Departments or Undertakings, Local Bodies, Public Sector or Private Companies Undertakings, Hospitals, Nursing Homes, Schools, Colleges, Universities, other Educational Institutions, Hostels, Hotels, Commercial Establishments, Markets, Places of Worship, Stadia and Sports Complexes, and other similar structures that generate waste on average at a rate more than 100 kg per day (of all waste streams put together)” (Ministry of Housing & Urban Affairs, 2017). In a small city like Panaji, Bulk waste generators include hotels, commercial establishments, marriage halls, housing societies, and hospitals, which generate more than 25 kg of waste on a daily basis (Goa Waste Management Corporation , 2022). The stream-wise break up of MSW generated is presented in Table 1.

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Table 1: Stream-wise breakup of the MSW generated in Panaji

S. No.	Waste Stream Generated	TPD
1.	**Wet Waste**	**28.1**
	a) Hotel/ Restaurants	11
	b) Households	8.5
	c) Markets	8.6
2.	**Garden/Horticulture**	**9**
3.	**Dry Waste**	**7**
4.	**Littered**	**6**
	Total	**50**

(TPD: Tonnes Per Day) (Source: Corporation of the City of Panaji (CCP))

III. METHODOLOGY

In this study, 12 zones of Panaji, Goa were selected to retrieve information about the location of the bulk waste generators of the city. Keyhole Markup Language (KML) files containing the location of all the bulk waste generators (shops, markets, schools, colleges, hotels, restaurants, dispensaries and hospitals) in these 12 zones acquired from CCP, served as the primary data for this study. The 12 different zones in Panaji formed the target population.

Fig. 1: KML files containing the 12 zones of Panaji with the bulk waste generators mapped

Open source GIS software called QGIS 3.16.2 was used for preparing the map layout of the bulk waste generators located in the study area. A study demonstrating the spatial prediction of bulk waste generators in the city of Panaji is novel to the city. QGIS is a GIS program that allows users to create and export graphical maps as well as analyze and update spatial data. This enabled us to get the sources of the bulk waste and this will help CCP identify the bulk waste generators and refrain them from collecting waste from bulk waste generators.

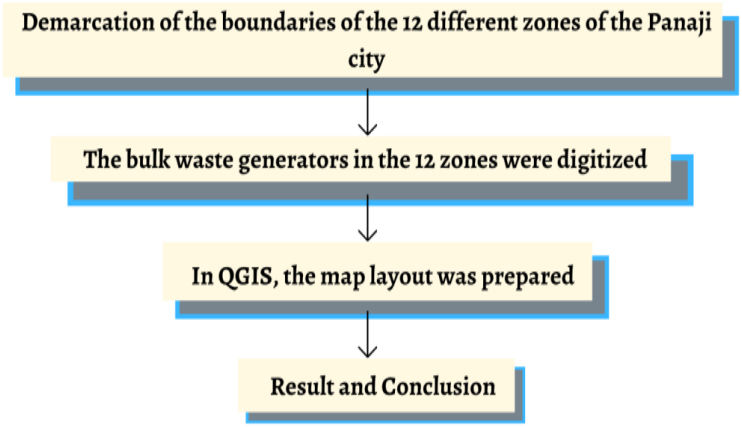

Fig. 2: Flowchart for the Present study

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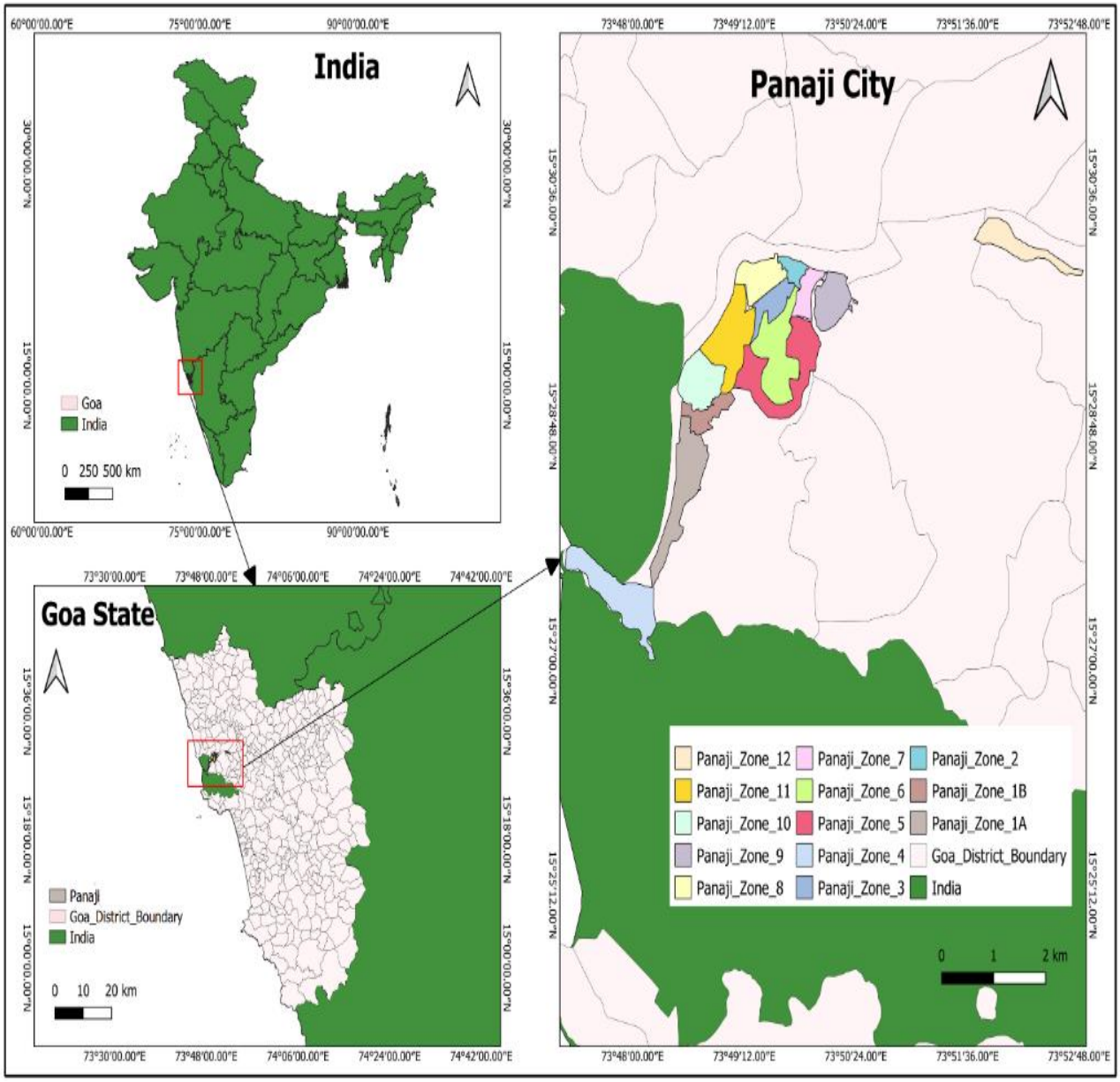

Fig. 2: Study area map.

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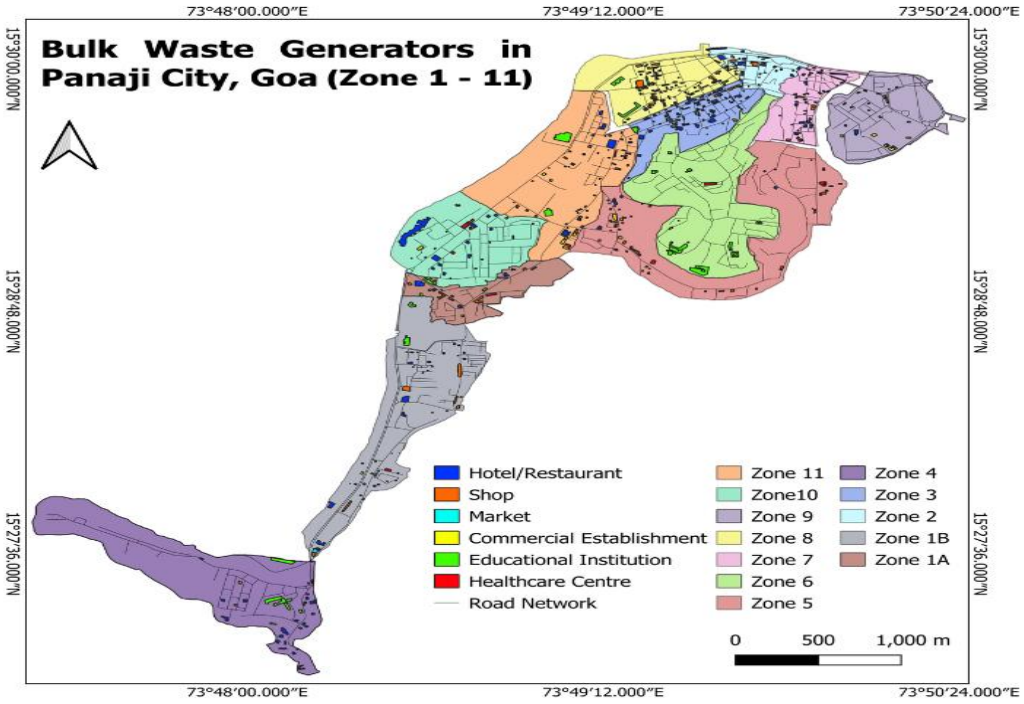

Fig. 4(a): Bulk waste generators in Panaji city (from zone 1 to 11),

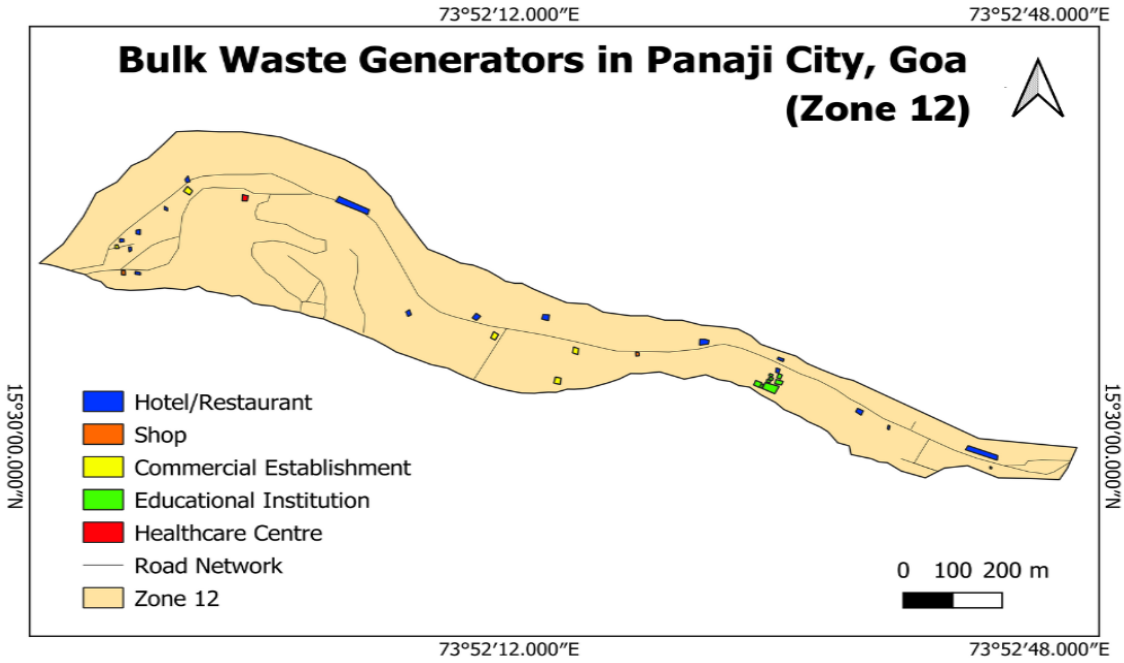

Fig. 4(b): Bulk waste generators in Panaji city (Zone 12)

IV. RESULT AND DISCUSSION

Panaji city is demarcated into 12 zones for easy management and planning of MSW. The GIS-based spatial mapping was prepared for locating the bulk waste generators within the distributed zones using the QGIS platform (Figure 4-8). The zone-wise mapping of the bulk waste generators revealed that zone 2, 3, 7, and 8 was highly concentrated with the number of bulk waste generators (Figure 5-8). The waste generators in Zone 2 (Figure 5) and Zone 7 (Figure 7) were mostly related hotels/restaurants and shops whereas the numbers of shops were found majorly localized in zone 3 (Figure 6). Likewise, the shops were also higher in zone 8 (Figure 8).

As it is observed that in the city of Panaji, the waste collection is higher than the estimated waste generation; which indicates that the corporation is collecting waste from bulk waste generators. Hence, the bulk waste generators should come up with solutions to reduce their contribution to waste generation. From the table 1, it can be seen that the wet waste along with garden/horticulture waste accounts for

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almost 74% of the total waste generated in Panaji. As per the "Solid Waste Management Rules, 2016" if the bulk waste generators could manage their own waste by composting their waste instead of throwing them out, or come up with a community-based Bio-methanation plant, it will reduce their contribution towards waste generation. Further, the manure prepared from such compost could be sold to the nearby nurseries or farmers creating an opportunity of income generation from the recycled product.

Being said that, there is a need to place emphasis on GIS based research as it helps in "optimizing for waste collection and transportation". Several studies ((Mundhe, Jaybhaye, & Dorik, 2014), (Balakrishnan, Mohammed, & Al-Kuwari, 2019), (Verma & Bhonde, 2014), (Khanh Nguyen-Trong, 2016), (Sanjeevi & Shahabudeen, 2015)) have proved that modern technologies like GIS help in proper planning of waste collection and transportation in a city. GIS based research provides an ideal environment for conducting spatial research, allowing the researcher to visualize and analyze data on a map. The visualization of geographic data familiarizes waste management planners with the investigational area and helps devise a proper route map which will help in optimizing waste collection and transportation.

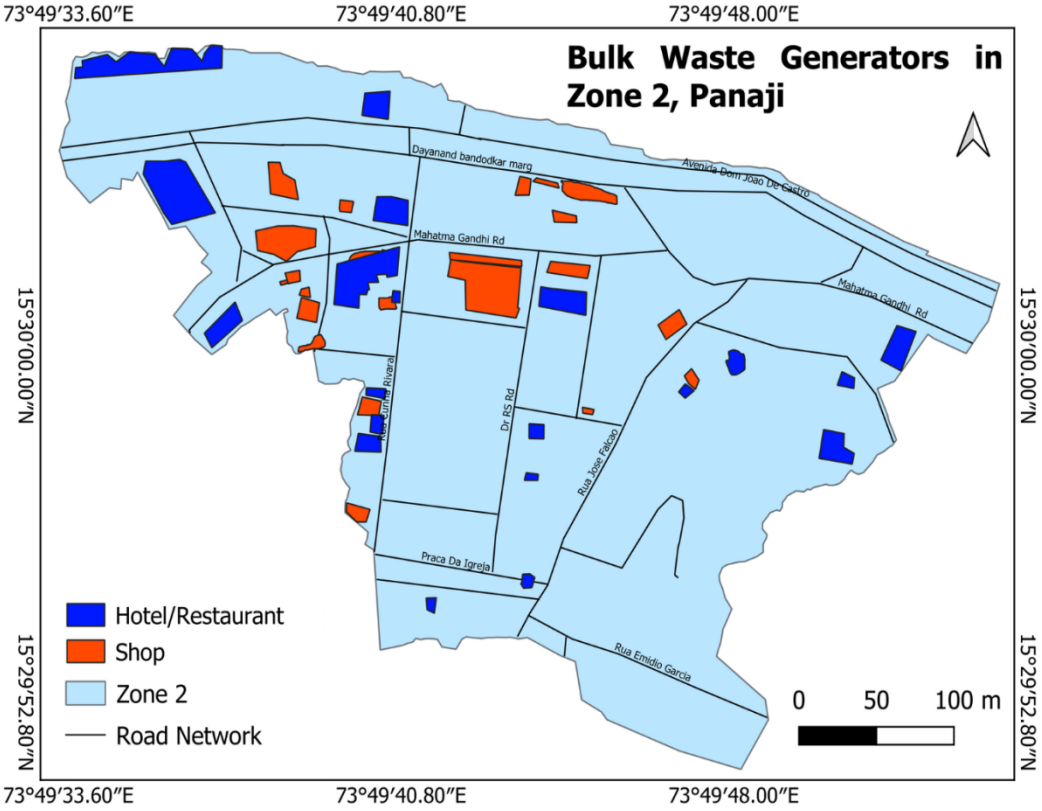

Fig. 3: Bulk waste generators in Zone 2, Panaji

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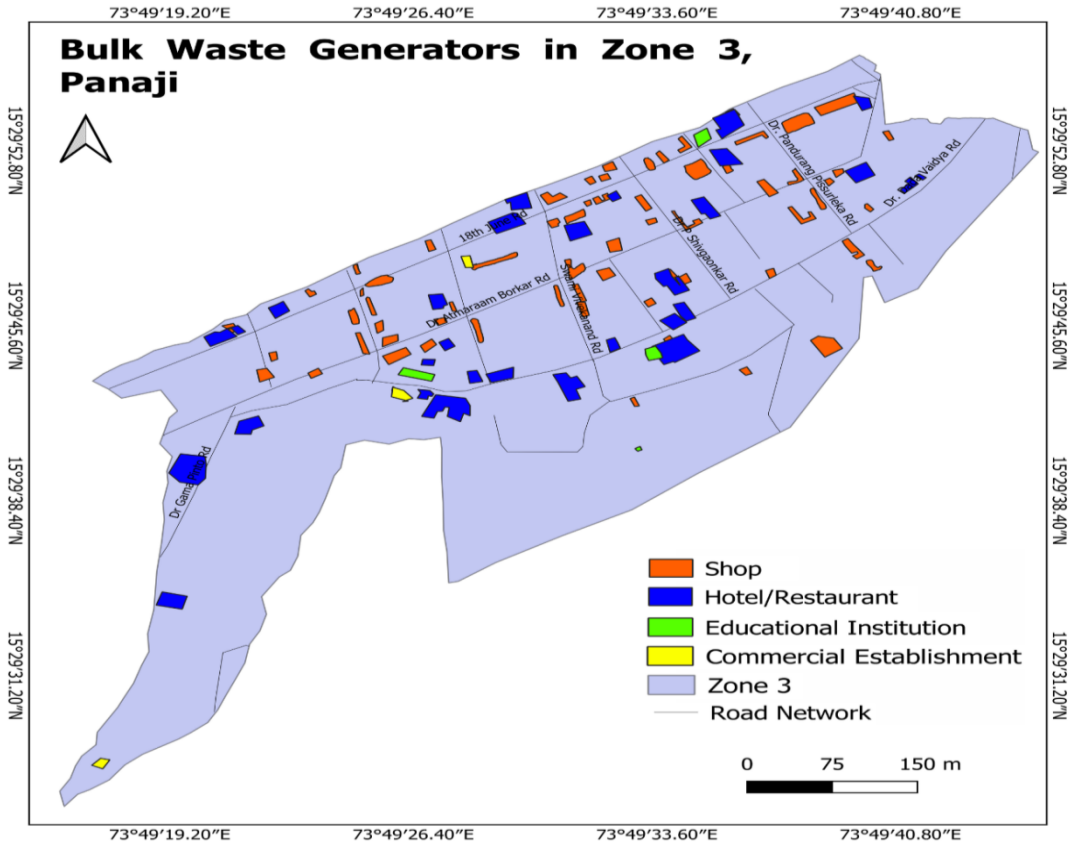

Fig. 6: Bulk waste generators in Zone 3, Panaji

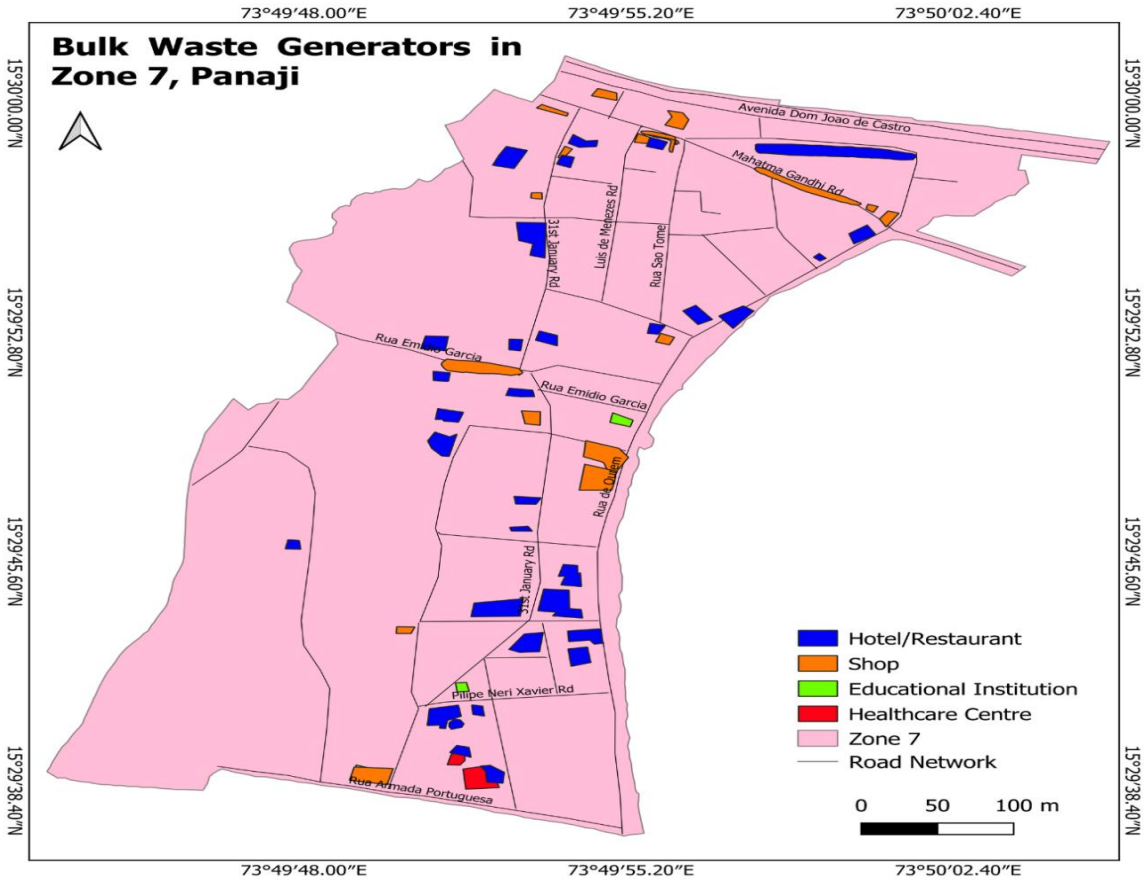

Fig. 7: Bulk waste generators in Zone 7, Panaji

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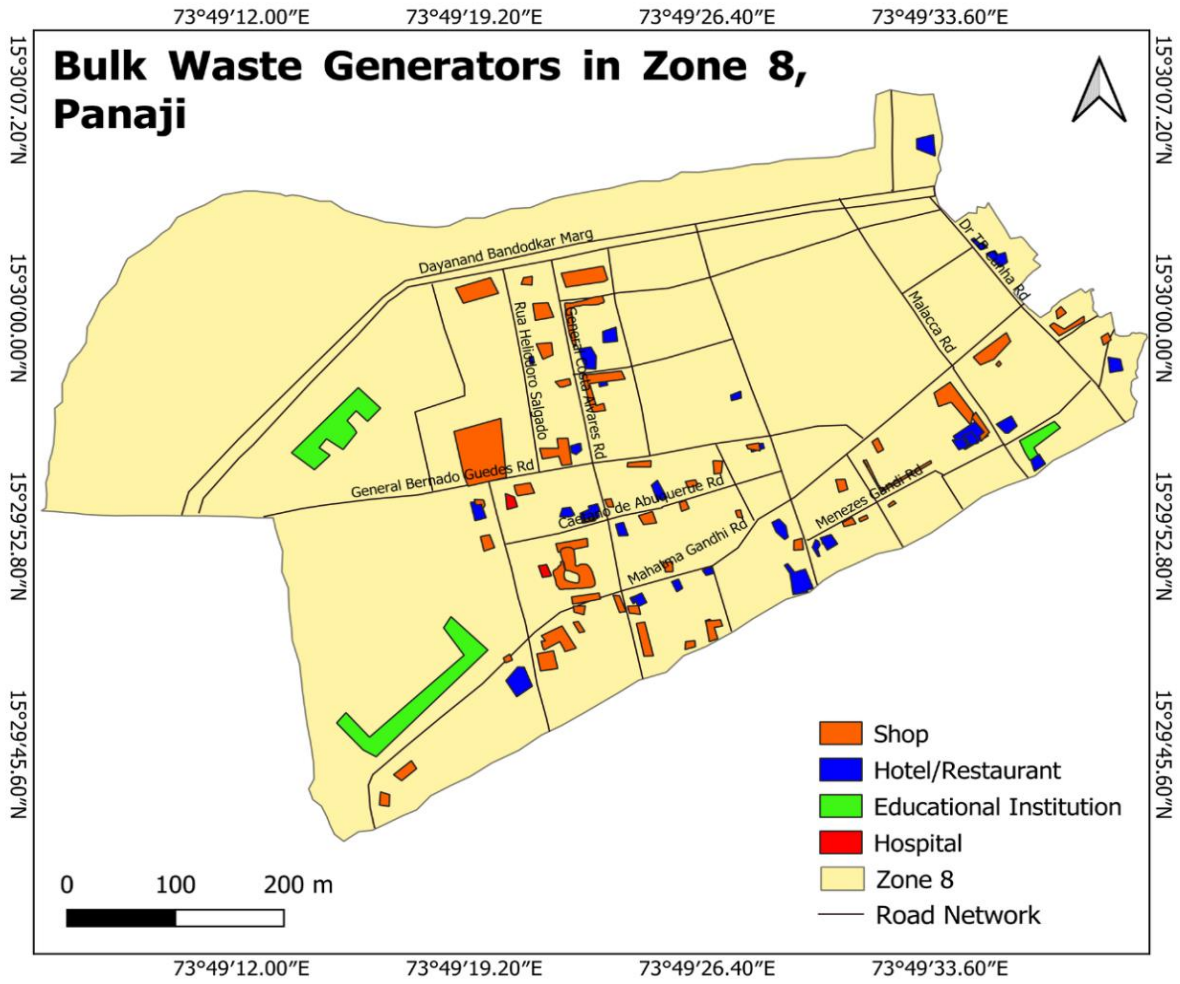

Fig. 4: Bulk waste generators in Zone 8, Panaji

V. CONCLUSION

In this study bulk waste generators of the city Panaji were located through GIS-based spatial mapping. The conclusion of the study marked that out of the 12 zones, zone 2, 3, 7, and 8 has a high density of bulk waste generators.

A study demonstrating the spatial prediction of bulk waste generators in the city of Panaji is novel to the city. As it is observed that in the city the waste collection is higher than the estimated waste generation, and which manifests that the corporation is collecting waste from bulk waste generators; the map layouts prepared as part of this study will help planners to identify the sources of these bulk waste generators and facilitate in terms of route planning for waste collection and transportation. If the bulk waste generators could manage their own waste by composting their own waste instead of throwing them out, or come up with a community-based Bio methanation plant, it will reduce their contribution towards waste generation. The bulk waste generators could also partner with Non-governmental/private players to reduce the waste generated.

The resulting mapping of the locations has highlighted the potential of GIS as a modeling and analysis tool for spatial data, as well as a cartographer and visualization tool. With GIS planning of routes for waste collection and transportation, and selecting sites for waste disposal facilities can be achieved that will save both time and cost, and the optimal utilization of the waste management funds.

The Corporation of the City of Panaji can use these map layouts to support their decision-making process for efficient waste management, planning routes for waste collection and transportation (refraining collection from bulk waste generators), and eventually preparing a proper work schedule for their workforce and reduce the workload. This research is a step towards further improving the waste management system in Panaji city.

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CONFLICT OF INTEREST

The authors declare that they have no financial, personal, or professional conflicts of interest that could influence the research, analysis, or presentation of the findings in this paper.

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