Quantitative Analysis of Spatial Pattern of Dustbins and its Pollution in Dhaka City--A GIS Based Approach

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***Abstract*--** **Smart waste management in a city is significantly manifested by the optimal distribution of waste collection points (dustbins). Evidently, inadequate number of dustbins coupled with improper management may trigger pollution to a great extent. Waste collection using insufficient street dustbins is a widely used way of solid waste management in Dhaka city. Yet an uncomforting scenario of air pollution is prevailing in different wards of Dhaka. The reasons can be put forth as inadequate and unequal distribution of municipal dustbins, improper management including waste overflow and the lack of awareness in usage among the people. In this context, an attempt has been made in this paper to obtain a quantitative analysis between existing dustbins and their serving population. This study first analyses the spatial distribution of dustbins in some areas of Dhaka city employing average nearest neighbor functions of GIS. Interestingly, the spatial distribution of the existing dustbins has shown to be predominantly in clustered pattern. Next, an optimal number of additional dustbins were calculated. An additional number of 20 and 8 dustbins are required in areas (wards) # 34 and # 35 in Dhaka city. We also examined the extent of pollution caused by the existing dustbins using spatial analyst functions of GIS. It is found that all the dustbins are burst with wastes and causing pollution to the ground surface and air. The results thus obtained would help to understand the present scenario of the waste management of Dhaka city and to optimally place the required number of dustbins to prevent further pollution to environment.**

1. INTRODUCTION

Dhaka, the most densely populated urban area in the world [1], witnessed a very fast growth of urban population in recent times with population above 12 million [2]. Due to imprudent urbanization, the city is confronting many problems; environmental problem is a prominent one and a result of increased solid waste [3]. Urban solid waste in Dhaka City increased from 3,200 tons/day in 2004 to 3,909 tons/day in 2010 and has been predicted to be 4,634 tons/day in 2015 [4]. This increasing rate of solid waste generation has therefore become a complex issue in the city as Dhaka City Corporation (DCC) is having hard time to manage it [5]. However, environmental degradation due to unplanned waste disposal and improper waste management has always been an incognizant issue [6]. Dumping of garbage and waste on busy and important streets and roads is now a common scene in Dhaka [7]. It creates unbearable nuisance for the people of the area [8]. Hence, waste management is required to be the topmost priority in urban planning in DCC area [9].

DCC is responsible for secondary waste collection from street side dustbins in the city's 90 wards, and transport the wastes to final disposal sites [10]. Residents are responsible to carry their waste to certain location of the dustbins. However, the DCC only collects less than half of the solid waste produced [11] which means the wastes remain in the dustbins for at least three consecutive days. Although the number of the dustbins is inadequate, construction of new solid waste management facility is a big challenge in Dhaka because of limited space [12]. The resultants are overflow of dustbins and careless dumping of wastes in the city street along with the consequent odor and ground surface pollution as well as visual contamination [13]. The overall phenomenon has called for a research to find out the existing scenario of the solid waste management facility in Dhaka city. In this backdrop, this research has been conducted to analyze existing distribution pattern of dustbins, to derive the actual demand of dustbins and to examine the environmental pollution occurred from dustbins.

This study also facilitates to understand the overall environmental pollution in Dhaka City engendered by dustbins. Apart from that, Geographic Information System (GIS), a good decision support tool for waste management planning is used to examine spatial distribution of dustbin location in the study area in order to identify whether the dustbins are uniformly distributed throughout the study area or not. GIS is used also to derive pollution areas of dustbins. The research results will optimistically help to understand the present scenario of the waste management of Dhaka city and to determine the required number of dustbins and their distribution with a very simple and thorough analysis.

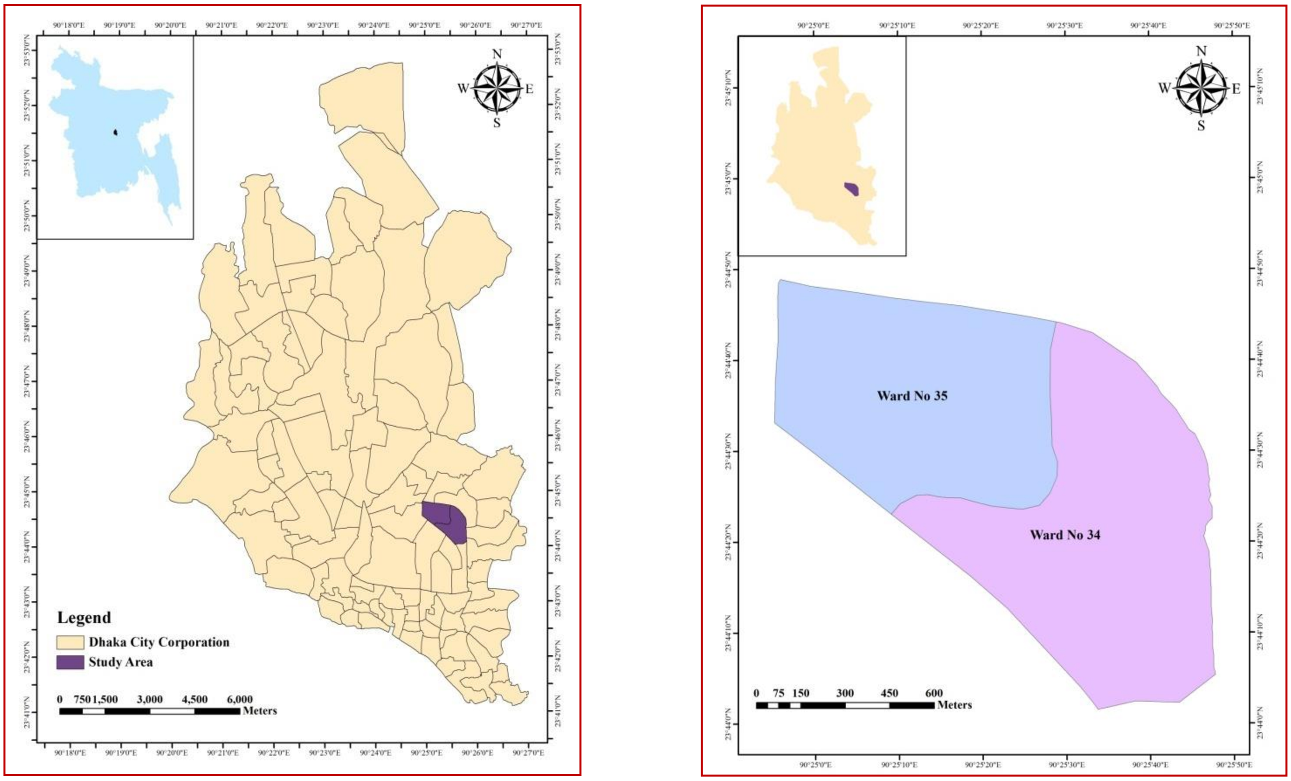
2. STUDY AREA

Ward no 34 and 35 of Zone 4 under south part of DCC has been selected as study area for the research. The area and population of ward 34 and ward 35 are given in Table I and the entire study area is shown in Figure 1.

Table I
Study area information

Ward Number	Area in (sq. m)	Population
34	730016.85	59,999
35	593334.69	51,067

Source: BBS 2011



(a) (b)

Fig. 1. (a) Study area within Dhaka City Corporation; (b) Study area

3. METHODOLOGY

3.1 Data Collection

Both primary and secondary data were required to carry out the study. Secondary data mainly includes the shape file (.shp) of ward boundary and the building structures of DCC. Other secondary data used in the study mostly are population census data and relevant standards which were collected from Bangladesh Bureau of Statistics and different reports. Primary data of the study were collected through field survey. Identification of dustbin's location was a prerequisite to conduct the study. To accomplish this task, location of the dustbins is identified through GPS (Global Positioning System) survey. GPS device is capable of creating shape files (.shp) of a location using particular geographic coordinate system. GPS records data on World Geodetic System (WGS 84). In this coordinate system, a particular location is recorded in terms of latitude and longitude. The coordinate system of identified location was then transformed to 'Everest Bangladesh 1937' geographic coordinate system and subsequent projection was done using BTM (Bangladesh Transverse Mercator) projection system. Geocentric Translation was performed to transform the WGS 84 to Everest Bangladesh 1937 geographic coordinate system using following parameters-

$\Delta X = -283.729$ $\Delta Y = -735.942$ $\Delta Z = -261.143$

Besides, two specific data are obtained from the field survey. One of them is the dimension of all type of dustbin and the other is the average radius of pollution area caused by the dustbins. Radius is identified with respect to visible ground surface pollution surrounding the dustbins and the air pollution recognized by emitted smell.

3.2 Data analysis

3.2.1 Determination of required dustbin number

Firstly, from the field survey data on dustbin volume is calculated. From the standard rate of solid waste generation, total amount of waste generation in the ward is determined. Then using the bulk density of waste and total volume of dustbin in the ward, present capacity of all the dustbins is calculated. Lastly, the extra amount of waste, which requires additional dustbins, is determined by subtracting present capacity of dustbins from the total amount of wastes.

3.2.2 Distribution pattern of dustbins

The spatial distribution of dustbins in the ward is explored in order to observe whether the distribution is uniform throughout the ward or not. Spatial statistic tool of ArcGIS is used to find out the distribution pattern of dustbins. The location of dustbins, identified by GPS device, is analyzed by Average Nearest Neighbor tool of ArcGIS. By comparing the determined Nearest Neighbor ratio with standard index value, spatial distribution pattern of dustbins in the ward is identified.

4. Results and Discussion

4.1 Required dustbin number in study area

Table II shows that, in ward 34 and 35, there are 7 15 dustbins respectively. The location of these dustbins, as identified by GPS, is shown by Figure 2.

Table II
Number of dustbins in study area

Ward Number	Number of Dustbins
34	7
35	15

Source: Field Survey 2013

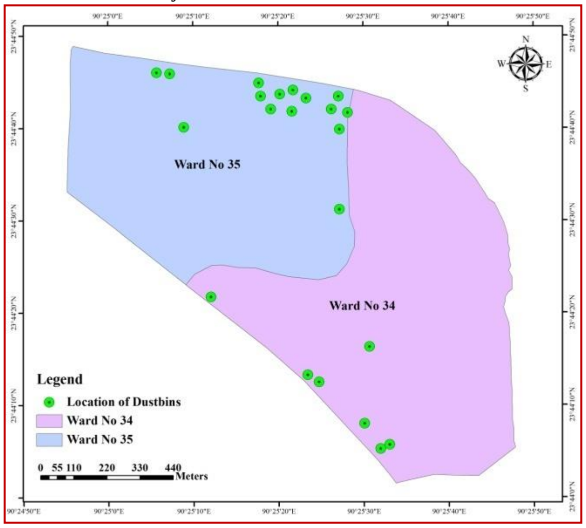


Fig. 2. Location of dustbins in study area

From field survey it was found that, volume of each dustbin is 10.67 m^3. Therefore, by adding the volume of all dustbins in a ward, accumulated volume of the dustbins was determined. The accumulated volume of dustbins in ward 34 and ward 35 was calculated as 74.69 m^3 and 160.05 m^3 respectively (Table III).

Table III
Accumulated volume of dustbins in study area

Ward Number	Number of Dustbins × Volume of Dustbin (m^3)	Accumulated Volume (m^3)
34	(7 × 10.67)	74.69
35	(15 × 10.67)	160.05

The accumulated volume of all dustbins in study area was then multiplied with the waste storage capacity by each dustbin to find out the present storage capacity of the dustbins in study area. Bulk density of waste is considered to find out the storage capacity per dustbin. Density is a critical criterion for the estimation of storage, collection, transportation as well as landfilling of waste. In this research the average bulk density is considered to be 0.235 ton/m^3 or 213.19 kg/m^3, which is the average of dry and wet season (Table IV).

Table IV
Apparent bulk density of waste

Survey Time	Source Category	Average Bulk Density (ton/m^3)
Dry season	Domestic, business and street waste	0.24
Wet Season	Domestic, business and street waste	0.23

Source: JICA 2005

Therefore, the total bulk density of the present dustbins in ward 34 and 35 ward was computed as 15776.06 kg and 34121.06 kg respectively. This calculation is shown in Table V.

Table V
Total bulk density of dustbins in study area

Ward Number	Accumulated Volume × Average Bulk Density	Total bulk density (kg)
34	(74 m^3 × 213.19 kg/m^3)	15776.06
35	(160.05 m^3) × 213.19 kg/m^3)	34121.06

To find out the total amount of wastes generated in study area, the average solid waste generation rate from domestic sources of 0.34 kg/person/day [4] was considered. This rate is the average of domestic waste generation rate of different income levels in both dry and wet season as shown in Table VI.

Table VI
Waste generation rate in Dhaka

Sources	Rate (kg/person/day)		
	Dry	Wet	Average
Domestic waste			
High income group	0.588	0.438	0.513
Middle income group	0.371	0.428	0.4
Middle-low income group	0.279	0.346	0.313
Low income group	0.326	0.345	0.336
Lowest income group	0.314	0.205	0.26
Weighted Average		**0.34**	

Source: JICA 2005

Therefore, total amount of waste generated in ward 34 and ward 35 was computed as 20399.66 kg/day and 17362.78 kg/day. Apparently these figures are not that uncomforting as compared to the calculated total bulk density. However, from Japan International Cooperation Agency (JICA) report it is found that, in Dhaka city waste collection rate is 37% [14]. In other words, the waste collection frequency is 2.7 days or 3 days. Therefore, the accumulated wastes of all dustbins in ward 34 and ward 35 in 3 consecutive days becomes 61198.98 kg and 52088.34 kg respectively. Whole calculation is shown in Table VII

Table VII
Accumulated wastes in three consecutive days in study area

Ward Number	Waste Generation rate × Total Population	Total Waste Generation per Day (a)	a × 3	Accumulated Wastes in 3 Consecutive Days (kg)
34	(0.34 kg/person/day × 59999)	20399.66 kg	(3 × 20399.66)	61198.98
35	(0.34 kg/person/day × 51,067)	17362.78 kg	(3 × 17362.78)	52088.34

Using the data of Table IV and Table VI the amount of the extra waste beyond the dustbin capacity in study area was computed. The extra waste in ward 34 and ward 35 is 45422.92 kg and 17967.28 kg respectively.

Therefore, the additional amount of dustbins required in ward 34 and ward 35 is 20 and 8 respectively. The calculation is shown in Table VIII.

Table VIII
Additional dustbin number required in study area

Ward Number	Accumulated Waste – Total Bulk Density	Extra Waste beyond Dustbin Capacity (a)	(a) ÷ (213.19 kg/m^3 × 10.67 m^3)	Required Number of extra Dustbins
34	(61198.98 – 15776.06) kg	45422.92 kg	45422.92 kg ÷ (213.19 kg/m^3 × 10.67 m^3)	20
35	(52088.34 – 34121.06) kg	17967.28 kg	17967.28 kg ÷ (213.19 kg/m^3 × 10.67 m^3)	8

However, required number of the dustbins, as determined from the analyses, should be distributed in study area with respect to the present distribution pattern of existing dustbins. Therefore, the distribution pattern of existing dustbins in ward 34 and ward 35 was explored.

4.2 Distribution pattern of existing dustbins in study area

The dustbins should be distributed uniformly in an area so that people from all part of the area get access to the locations. In this research, the distribution pattern of existing dustbins in ward 34 and ward 35 is identified using spatial statistic tool of ArcGIS. In this regard, Average Nearest Neighbor was used to explore the spatial distribution of dustbins. To do that locations of the dustbins in ward 34 and ward 35, identified by GPS device, are used as input feature in Average Nearest Neighbor. The area of the selected wards is inputted in the area parameter option to increase the efficiency of the computation. The Average Nearest Neighbor tool returns five values these are Observed Mean Distance, Expected Mean Distance, Nearest Neighbor Index, z-score, and p-value. The Nearest Neighbor Index or NN ratio is expressed as the ratio of the Observed Mean Distance to the Expected Mean Distance. The expected distance is the average distance between neighbors in a hypothetical random distribution. The index value has specific interpretation which is given in Table 9

Table IX
Interpretation of Nearest Neighbor index

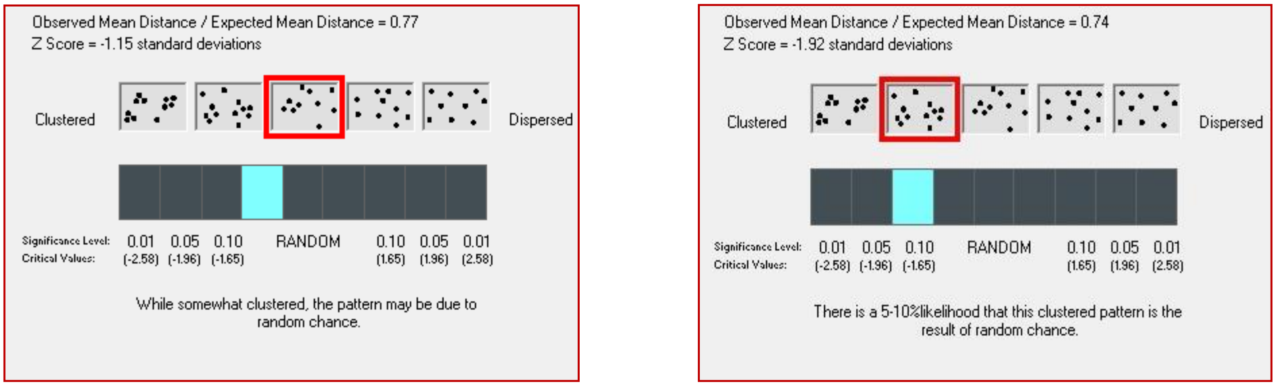
Index Value	Interpretation
Less than 1	Distribution pattern exhibits clustering
Greater than 1	Distribution pattern exhibits dispersed

The results of Average Nearest Neighbor analysis of the spatial distribution of dustbins in ward 34 and ward 35 are given in Table X.

Table X
Result of Average Nearest Neighbor analysis of dustbin location in study area

Ward Number	NN Index	Z Score	P Value
34	0.772109	-1.153473	0.248716
35	0.741372	-1.916248	0.055334

Table X shows that NN index for ward 34 and ward 35 is 0.772109 and 0.741372. Therefore, in both wards the distribution pattern of dustbins is clustered i.e. the dustbins are not uniformly distributed throughout the wards rather these are concentrated in particular location. For ward 34, the z-score falls between -1.65 and +1.65 and the p-value is larger than 0.10 which indicates that, the pattern exhibited could very likely be the result of random spatial processes (Figure 3(a)). Similarly for ward 35, the z-score falls between -1.96 and +1.96 and the p-value is larger than



(a) (b)

Fig. 3. The result of Average Nearest Neighbor for (a) ward 34 and (b) ward 35

0.05 which indicates that, there is 5-10% likelihood that the pattern exhibited could very likely be the result of spatial randomness. The result of the Average Nearest Neighbor analysis for ward 34 and 35 is shown in Figure 3(b).

4.3 Pollution from the Dustbins

The research analyses show that, in the study area the number of the dustbins is inadequate and the existing dustbins are not distributed uniformly. People from all part of the study area are therefore limited to dump solid wastes into those particular dustbins. Therefore, all the dustbins are burst with wastes and causing pollution to the ground surface and environing air. Since, refuse stored in the dustbins are collected after 3 consecutive days, the situation becomes more appalling. From field survey, the area of visible ground surface pollution and the approximate affected area of odor pollution are identified. The area of ground surface might be small for a single dustbin but the accumulated area of surface pollution of all dustbins in study area undoubtedly engenders a great concern. The area affected by odor emitted from the dustbins is identified by the radius up to which the odor can easily be smelt. The area of ground surface and odor pollution caused by the existing dustbins in ward 34 and 35 is shown in Table XI and Table XII respectively.

Table XI
Pollution caused by dustbins in ward 34

Dustbin no	Radius of visible ground surface pollution (m)	Radius up to which odor can be smelt (m)
1	2.00	16.65
2	1.03	11.65
3	2.67	20
4	1.00	11
5	1.57	11.65
6	0.67	10
7	4.00	25

Source: Field Survey 2013

Total area of ground surface pollution in study area is 259.33 m^2 and the total area affected by emitted odor in the study area is 19172.06 m^2 (Table XI-XII).

Table XII
Pollution caused by dustbins in ward 35

Dustbin no	Radius of visible ground surface pollution (m)	Radius up to which odor can be smelt (m)
1	0.69	14.8
2	1.22	16.1
3	1.81	10.9
4	2.00	23.35
5	1.00	20
6	1.89	19.9
7	2.33	11.65
8	1.67	18.8
9	2.68	13.4
10	2.44	17.2
11	1.91	15.95
12	1.75	12.85
13	0.84	17.4
14	2.26	23.1
15	1.66	16.8

Source: Field Survey 2013

GIS analysis reveals that, the number of buildings affected entirely or partially by the odor emitted from dustbins in ward 34 and ward 35 is 11 and 130 respectively as shown in Table 13 and 14. It was the number of buildings that was lying under the area affected by emitted odor from dustbins. The area affected by odor from dustbins and the affected buildings in ward 34 and 35 are shown in Figure 4.

Table XIII
Buildings affected by the odor emitted from dustbins in ward 34

Dustbins	Affected Building Structures
1	1
2	3
3	3
4	–
5	1
6	–
7	3
Total	**11**

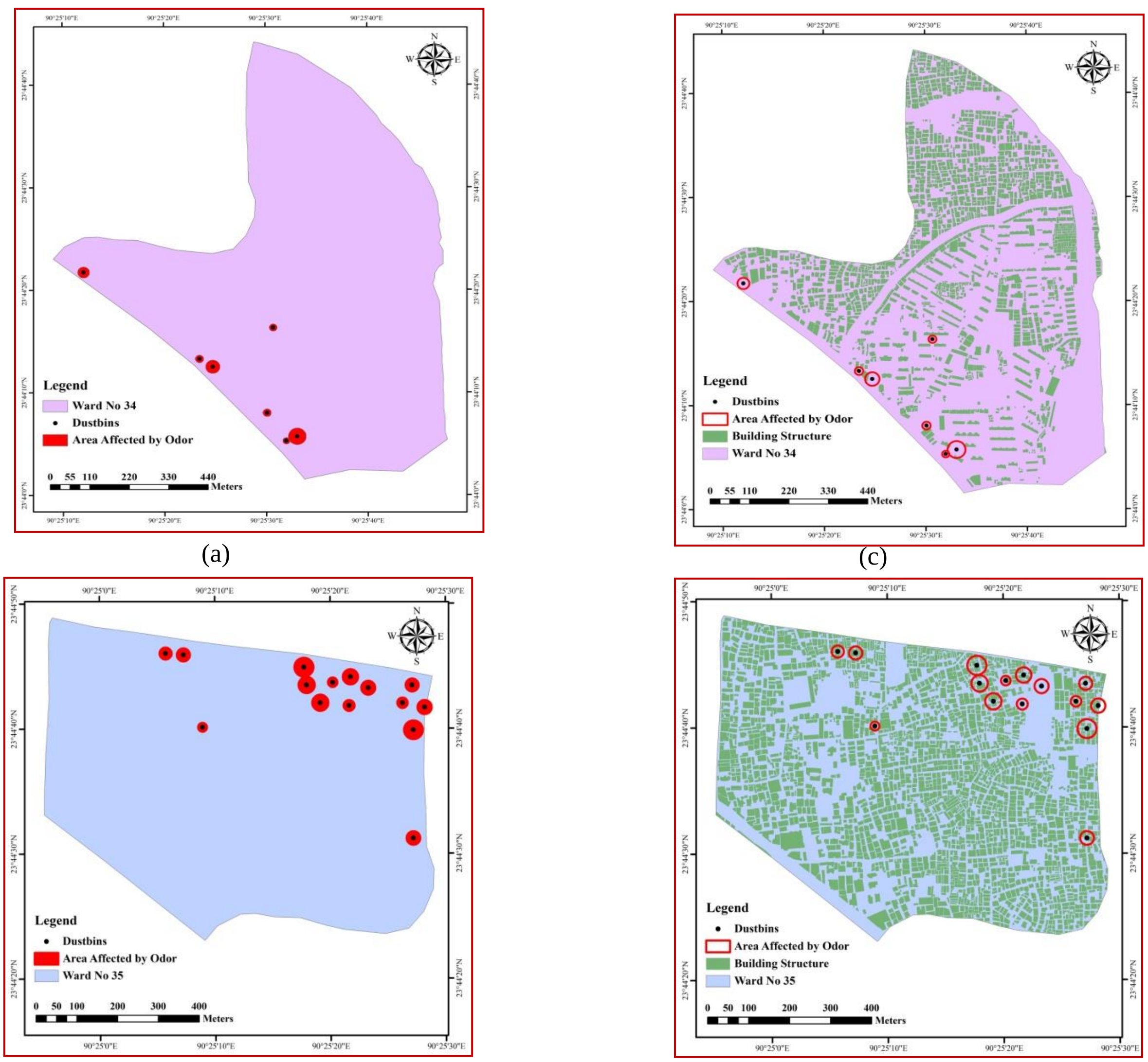
Table XIV
Buildings affected by the odor emitted from dustbins in ward 35

Dustbins	Affected Building Structures
1	9
2	8
3	3
4	18
5	11
6	10
7	2
8	14
9	1
10	–
11	12
12	9
13	7
14	17
15	9
Total	**130**

Following analysis of existing dustbins for waste management, the first and foremost need is to provide the additional number of required dustbins in ward 34 and 35. In addition, the location of the existing dustbins should be reset and the additional dustbins should be distributed in such way that, they altogether are uniformly distributed throughout the entire wards. It is also necessary to increase the municipal waste collection frequency maintaining certain route-wise collection system. Apart from this, stringent rules and regulations must be applied on the management related activities and the level of public awareness should be increased.

5. CONCLUSIONS

We have successfully implemented GIS-based analysis to obtain optimal number of dustbins in Dhaka city. It is shown that the number of existing dustbins is insufficient in the study area and additional 20 and 8 dustbins are required in wards # 34 and # 35



(a) (b) (c) (d)

Fig. 4. Area affected by odor pollution in (a) ward 34 and (b) ward 35; buildings affected by the odor emitted from dustbins in (c) ward 34 and (d) ward 35

respectively. Applying spatial statistic analysis, it is found that the existing dustbins are not uniformly distributed. Proximity analysis of GIS also revealed that the overflowing dustbins are causing ground surface pollution of a total area of 19431.39 sq. meter and affecting a total number of 141 buildings by odor pollution in the study areas. As municipal solid waste is rising alarmingly in mega city Dhaka, it has become a priority issue. Residents are equally oblivious but unhappy about the current situation. Even, Dhaka City Corporation (DCC) is confronting difficulties to offer the desired level of services with the existing capacity and waste management. The results thus obtained can help the decision makers to check the capacity of dustbins routinely and thoroughly as well as to facilitate distribution of dustbins thereby improving waste management system significantly.

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