Urban Solid Waste Management using Geographic Information Systems (GIS): A Case Study in Doha, Qatar

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Abstract Qatar is one of the rapidly developing countries in the world due to its surging economy. This has led to a boost in the population size and thus influencing the country's waste management system on a large scale. Management of waste is the foremost task of a country as it can lead to outspread of diseases, illness and can harm the environment if kept unmanaged. According to Qatar national vision 2030, the key role of Qatar is to plan and create solutions that are sustainable for management of waste. The major outflow of domestic waste in Qatar is from the homes, shops, hotels and restaurants. The method followed in Qatar for domestic waste disposal is collecting waste from the bins by the trucks, loaded in the transfer stations and then taken to landfills. This study is focused on the waste management in a small urban area of Qatar. Waste management in the sense, to make the waste collection sustainable by providing or reallocating the bins according to waste generation and population density utilizing GIS application. The results acquired after analysis shows that there is notable minimization or saving of time after re-distributing the bins.

Keywords Buffer; GIS; Hotspot analysis; Network analysis; Qatar; Waste management

1. Introduction

Qatar has been developing very fast in recent years and the country is continuing to grow. Solid waste management seems to be the most highly challenging task due to the high population growth, industrialization and urbanization. According to a report published by Ministry of Development Planning and Statistics (MDPS), 2017, Qatar Environment Day 2017, Qatar generates a per capita waste of 1.23 kg per day as of 2015. Qatar's production of domestic solid waste is more than 2.5 million tons per year. Solid portion of the waste mostly comprises of organic substances (~60 %) and the remaining portion comprises of the recyclables, which consists of paper, glass, plastics and metal (Zafar, 2016). Qatar, due to the lifestyle and continuously growing population has increasing amount of waste generation. Therefore, in order to cope up with the generated waste in a sustainable way, there needs to be a solution. The management of waste can be started from small scale, which then can be expanded to other areas. This research will enhance the idea about the waste management system in Qatar and how it can be managed in an efficient way using GIS. Qatar is one of the rapidly growing economies worldwide. Qatar needs to improve its waste management system to keep up the standard
level of living. One of the visions for Qatar 2030 is to create sustainable solutions for managing the solid waste. This study will provide information about the management of waste in urban areas, as there is a lack of research in those areas. This research also shows that there is a need for sustainability in managing waste as it makes the task more efficient, saving cost and time.

In any country, its population, geographical conditions, seasonality, and socio-cultural properties are the major components that effect the rate of production and composition of domestic solid waste (Akinci et al., 2012; Chandrappa et al., 2012; Khatib, 2011; Magrinho et al., 2006). As claimed by Khatib (2011), waste generation is dependent on the population growth of developed and developing countries, if the population growth increases, the waste generation tends to increase. The disposal of municipal waste from restaurants, hotels, and households, can create danger for public health and environment, if the wastes are not managed in a proper way. The economic status of the country determines the quantity of waste generated, however, the components of waste are almost similar to some degree among the countries. Research done by Chandrappa and Brown (2012), states that in low-income countries, the rate of waste generation is between 0.3-0.9 kg/capita/day, and in high-income countries, the rate of waste generation is between 1.4-2.0 kg/capita/day. Apart from the quantity of waste, the component that determines the generation rate of municipal solid waste (MSW) is the percentage composition of MSW constituents. In case of low-income countries, people’s way of living produces organic waste that shows about 50% of the total MSW generated. And for the case of high-income countries, people’s ways of living are a bit different, which is mostly ordering the food rather than cooking the food at home, and this will minimize the organic waste, which shows less than 30% and there might be an increase in inorganic materials like packaging materials (Khatib, 2011) that might increase the generation rate. The fundamental aspect of public health and environmental management is the management of solid waste. During the past times, solid waste generated were mostly natural and food waste. At those times, the problems with waste management were little, but due to the increase in population and rapid increase in urbanization and expansion in technology, the issues of managing solid waste became more problematic and as the generation of waste kept on increasing with the time passing on, the condition of solid waste management (SWM) got more daunting.

Management of waste includes the process of managing all the waste from its origin until the final scrapping. Waste generation can be from any sector of the society including industries and societies, and its management impacts households and health care. The management process of different wastes differs from country to country and place to place. The waste quantity can be differentiable in different sectors of a country. Where there are ongoing human activities, different sources contribute to the municipal or household wastes. Some studies have shown that the households generate much of the municipal waste (55%-80%) in the developing countries, and then comes the market or commercial outlets (10%-30%) having different quantities coming from the streets, industries and distinct establishments (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2012).

One of the significant administration issues in solid waste management is developing techniques for data interpretation (Tinmaz et al., 2006). The issue of waste is not only because of increased quantities but also largely because of inadequate management system. One of the largest oil producers globally is the kingdom of Saudi Arabia; yet, Management of solid waste in the country is done in the simplest way. The simplest way being the collection of waste and dumping it in open dumping ground (Ouda et al., 2013). After an increase in awareness of many problems faced due to the increased generation of about 14 Mt/year of MSW, the Government of Saudi made new rulings to aid the management of MSW in the early 2015.

A report “What a Waste: A Global Review of Solid Waste Management”, published by the World Bank in 2012, conveyed numerical information associated with generation of waste, and demonstrated that the measure of waste produced had expanded from 0.64 kg/capita/day in 2002, with a population of
2.9 billion, to 1.2 kg/capita/day in 2012, with a population of 3 billion individuals. The increase in rate of waste generation was obviously the outcome of growing populace. The increasing amount of waste generation day by day is grasping the attention of the governments and stakeholders responsible for the country’s waste management. Management of waste is a mandatory process to keep the environment tidy, which will help in minimizing the risk of negative effects that can deteriorate the health of all living beings.

1.2. Waste Management in Qatar and Gulf Co-Operation Council (GCC) Countries

Despite the fact that the Gulf co-operation council (GCC) countries are reviewed by their advanced development and richness, they do not have proper research with respect to the was management and they utilize the extensive regions of deserts as landfills. The report published in 2008 by the Arab Forum for Environment and Development (Tolba et al., 2008) stated that GCC countries had the highest rate of construction waste followed by municipal waste, consisting mostly of organic materials. One of the main goals in Qatar national vision 2030 is to save the environment by promoting recycling and minimizing the generation of waste in all the public and private sectors. In any case, findings show that there is still much to improvement in the manage of solid waste in Qatar. Only few studies have been done in Qatar related to this topic, and this might be due to lack of information and methodologies to understand the issues identified with municipal solid waste generation. It is known from the previous studies that the quantity of waste generation depends on the population of the country. Qatar due to its rapid development of economy has seen an increase in rate of population and that contributes to multiplying the waste generation Table 1.

There are currently four waste transfer stations situated in South Doha, West Doha, Mesaimeer, and Dukhan, to which all the Qatar's urban waste from all its seven municipalities are brought. The wastes are then compacted from those transfer stations and transferred to the domestic solid waste management center or landfill situated in Mesaieed through transfer trailers. Q-Kleen is the private company under the administration of Ministry of municipality and environment that is in-charge for the transfer of waste from waste bins to transfer stations (Ahmad, 2016). As stated by the statistics for domestic solid waste generation 2013-2014, a sum of 7,569 tons of solid waste was generated out of which domestic waste comprised 2,700 tons. Domestic waste includes the waste from all sectors except for waste from hospitals and construction sites (Ahmad, 2016).

Table 1: Daily generation of waste by type (metric ton/day)

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic waste</th>
<th>Construction waste</th>
<th>Bulky waste</th>
<th>Tires</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2,320</td>
<td>25,215</td>
<td>4,792</td>
<td>51</td>
<td>14</td>
<td>32,391</td>
</tr>
<tr>
<td>2011</td>
<td>2,234</td>
<td>26,219</td>
<td>4,798</td>
<td>59</td>
<td>16</td>
<td>33,325</td>
</tr>
<tr>
<td>2012</td>
<td>2,388</td>
<td>26,594</td>
<td>4,507</td>
<td>67</td>
<td>15</td>
<td>33,571</td>
</tr>
<tr>
<td>2013</td>
<td>2,550</td>
<td>25,629</td>
<td>4,922</td>
<td>70</td>
<td>28</td>
<td>33,197</td>
</tr>
<tr>
<td>2014</td>
<td>2,871</td>
<td>19,332</td>
<td>4,788</td>
<td>87</td>
<td>34</td>
<td>27,113</td>
</tr>
<tr>
<td>2015</td>
<td>3,002</td>
<td>11,716</td>
<td>5,614</td>
<td>125</td>
<td>594</td>
<td>21,051</td>
</tr>
</tbody>
</table>

Source: MDPS, 2017

According to one research (Ahmad, 2016) conducted for the quantification of domestic solid waste among 84 houses from different municipalities, it was revealed that the average quantity of waste was about 1.135 kg/capita/day. From the constituents of wastes, organic waste was found to be the most with 60.98%, and then plastics with 8.85%, followed by clean paper with 8.46%, and lastly ceramic scrap and glass with 6.10%. As of 2015, Qatar generates a per capita waste of 1.23 kg/day, according to MDPS (Figure 1).
Qatar is almost surrounded by water from all the sides except the southern part of the country that has a land border with the Kingdom of Saudi Arabia. As of 2016, Qatar has a population of about 2,545,603. Due to Qatar’s fast-growing economy, population rates increased by 67.6% from 2010 to 2015. A small area in Qatar named Bin Mahmoud was used as a case study in this research.

According to ministry of development planning and statistics, the population of Bin Mahmoud is 34,028, as of 2015. Bin Mahmoud falls under the Doha municipality and under zones 22 and 23.

We initiated this study to get a factual idea about the management of waste in Qatar’s small residential/commercial area using GIS based application. In this study, GIS enabled us to get a realistic idea about the production and management of wastes in different locations of the study area and helped us in manipulating the data to perceive the mechanism of management of waste broadly. ArcGIS software was used to analyse the waste generation and capacity of bins allocated in each block of the study area. ArcGIS was also used to reallocate the bins according to proximity analysis and population density ensuring that all the places are covered. The objectives of the research were:

1. To review current solid waste management (SWM) practices including waste generation, location, type & size of waste bins.
2. To find and allocate new collection bins based on solid waste generation using GIS technique.
3. To solve the irregular distribution of bins and redistribute the waste bins of study area to complete the collection process at less cost and save time.
4. To find the optimal proximity distance for the collection bins by generating buffer zone.
5. To analyse the hotspots and cold spots of the waste bins in the study area.

Thus, the study was expected to help in analysing the present SWM collection issues and thus can be used as a decision-supporting tool for efficient collection and SWM in the study area.

2. Materials and Methods

Based on the proposals from the past studies, the objective was accomplished utilizing ArcGIS. The methodology of GIS techniques to be applied in the research area followed five phases:

1. Data collection
2. Development of GIS database
3. Analysis of present solid waste collection in the study area
4. The optimal allocation of collection bins for the proposed model based on road network, population density and;
5. Analysis of optimal proximity by creating buffer zone of the existing and proposed models.
2.1. Study Area

Qatar is a peninsula as it is mostly surrounded by water extending northwards covering an area of 11606.8 km² and shares a land border with the Kingdom of Saudi Arabia along the southern region. Qatar is divided into 7 municipalities consisting of 94 zones, and 755 districts. The population of Qatar is about 2,545,603 as on February 28, 2016 (MDPS). Due to the exports of natural resources like petroleum and gas, Qatar has had a rapid developing economy, which aided in rapid increase in population rate. The study area is a residential area in Qatar, located in the country’s east side covering an area of 1.8 km², known as “Bin Mahmoud”. Bin Mahmoud area was chosen out of all the other areas in Qatar due to the reason that it is one of the oldest cities in Qatar, and contains all types of buildings, apartments, schools, mosques, open space, parks and other commercial outlets. Figure 2 presents the location of this area.

![Figure 2: Location of Bin-Mahmoud – Zones 22 and 23](image)

**Figure 3: Methodology and analysis steps**

- **Data Collection**: Maps, Field data (bins), road network
- **GIS Conception**: ArcGIS
- **GIS Analysis**: IDW, Buffer, Network analyst and Hotspot Analysis
- **Evaluation**: Comparison Benefits/gains /Savings
- **Proposed scenario**: Reallocation of Bins, Change of waste collection
- **Optimised Route**:
2.2. Field Data Collection and Database Creation

The methodology includes the collection of data about the management of waste in Bin Mahmoud area of Qatar. The first step was going to the study area and noting down all the required data; location, number of bins and the capacity of each bin. This information collected was used in creating database for further analysis as shown in Figure 3.

Following are the ways in which the field-data collection was done:

- Locating the waste bins with GPS and marking on the map.
- Recording the number of waste bins in the study area.
- Monitoring the quantity of waste generated in different places.
- Creating a map that locates the bins and the distance between them.
- Recording how the waste is collected from the bins.
- Monitoring what type of vehicle and equipment are used for waste collection.
- Identifying if there are areas with the display of hoarding for the bins.
- Different numbers are allocated to the locations of bins to identify them easily.

![Image: Location of existing bins in Zones 22 and 23]

Primary data about the solid waste of the study area was collected through Global Positioning System (GPS) survey throughout the study area. The two hundred sixty bin locations were recorded with different bin types (Figure 4). The exact location of the solid waste bins, containers and illegal waste disposal sites was collected by using GPS device. Spatial data was generated using collected GPS data and Google Earth Images. An amount of secondary data about other relevant information associated with solid waste management like population, economic data, were collected from Government organizations. The different types and forms of information was converted into the GIS database. GIS software (ArcGIS 10.3) with its network analyst extension was used to recommend reallocation of waste bins, containers location, routes for collection and preparation of final maps.
2.3. Geostatistical Interpolation (Inverse Distance Weighted (IDW))

An interpolation model can be constructed and evaluated using the geostatistical analyst function. Selection made in one of the sites decides which options will be available in the next, and the way you manipulate the data aids in constructing a satisfactory model. The interpolation of inverse distance weighting evaluates the values that are not known by specifying the closest points, search distance, power setting and barriers (ESRI, 2015).

2.4. Buffer Analysis

A buffer zone can be defined as an area surrounding any mapped attribute, and that area is estimated in units of distance. It is utilized in the analysis of proximity (ESRI, 2015).

2.5. Hotspot Analysis

The hotspot analysis helps us to determine if the attribute is significant or not. It calculates the Getis-Ord Gi* statistic for each component in a dataset. This statistic results in z-scores, p-values and confidence level of bins which highlights high (hot spot) or low (cold spot) values clustering spatially. A statistically significant hotspot area is where the attributes have higher values with other high values surrounding them. A high value of z-score and low value of p-values means that the spatial cluster is formed of high values representing a hotspot area. A confidence level of 99 percent of statistical significance is given when the feature falls in the +/-3 bins. A confidence level of 95 percent of statistical significance is given when the feature falls in the +/-2 bins. A confidence level of 90 percent of statistical significance is given when the feature falls in the +/-1 bin. No confidence level is given when the feature falls in bin zero, as it is not statistically significant (ESRI, 2015).

2.6. Network Analysis

Network analysis in GIS aids in finding the efficient routes or creating routes to travel from one point location to another considering distance, time and cost on an existing attribute class or attribute layer. It helps in reducing the time and cost by determining the best course for travelling and reaching the destination (ESRI, 2015).

3. Results and Discussion

This section will discuss about the results obtained from all types of analysis and models created in ArcGIS software. The major findings in this research will demonstrate the need for bin allocations according to population density, waste generation, concentration of bins regardless of their capacity, and re-routing of collection trucks to reduce the time and cost.

3.1. Types of Bins

There were five types of bins found in the study area (Table 2).

<table>
<thead>
<tr>
<th>Type of bin</th>
<th>Number of bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100 Liter</td>
<td>364</td>
</tr>
<tr>
<td>360 Liter</td>
<td>9</td>
</tr>
<tr>
<td>240 Liter</td>
<td>38</td>
</tr>
<tr>
<td>18 Cubic Meters (18000 Liter)</td>
<td>1</td>
</tr>
<tr>
<td>7 Cubic Yard (5351 Liter)</td>
<td>6</td>
</tr>
</tbody>
</table>
The 1100-Liter bins were distributed the most around the area with other types of bins distributed in very less places. After creating the corrected new bin locations with corrected new bin capacities, the distribution of the type of bins and their numbers are listed in the Table 3.

**Table 3: Distribution of re-allocated bins**

<table>
<thead>
<tr>
<th>Type of bin</th>
<th>Number of bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100 Liter</td>
<td>393</td>
</tr>
<tr>
<td>360 Liter</td>
<td>6</td>
</tr>
<tr>
<td>7 Cubic Yard</td>
<td>6</td>
</tr>
</tbody>
</table>

The 1100-liter bins were increased, and the 240-liter bins were removed. The larger bins were distributed in more places as they would consume less place by adding just one or two instead of four or five of the small bins and more over large bins can contain more waste. The 7 cubic yard waste drums were placed in places where they threw large materials like cupboards and house appliances.

### 3.2. Land Use Map - Zones 22 and 23

![Land use - Zones 22 and 23](image)

Figure 5: Land use – Zones 22 and 23

Seven types of land uses were present in Bin Mahmoud area (Figure 5). The data were collected from Qatar GISNet. Seven land uses included commercial frontage, commercial office, mosques, multifamily residential buildings, park/recreation/open space, and public institutions.

### 3.3. Block Level Population - Zones 22 and 23

The population map shows that the population is generally distributed between 133-313 people per block with highest population of 1011-1671 people in blocks of large apartment areas (Figure 6).
3.4. Existing Bin Location and Capacity

Existing bin capacities as distributed by the municipality are shown in Figure 7.

Figure 6: Population 2015 – Zones 22 and 23

Figure 7: Existing bin capacity in liters
3.5. Waste Generation

Figure 8 was created for the waste generated per capita taken from Ministry of Development Planning and Statistics, which is 1.23 kg/person/day as of 2015. The highest generation of waste is from the areas with high population. Majority of the area produces a maximum of 300 kg/day with increasing waste generation of up to 2000 kg/day in areas of commercial outlets and high population living mostly in large apartments.

![Figure 8: Waste generation](image1)

3.6. Re-allocation of Bin Location and Capacity

![Figure 9: Re-allocated bin capacities](image2)
186 bin locations were allocated by suggesting different sizes of bins at different locations depending on the population and waste generations. Bin capacities were re-allocated and distributed depending on the population and waste generation after the analysis of the data using GIS (Figure 9).

### 3.7. Existing Bin Location - Buffer Zone

![Existing Bin Buffer Zone](image)

**Figure 10: Buffer zone map**

Figure 10 displays 50 m buffer from each of the bin locations. 50 m is the optimum distance for the residences. Some of the places were found to be vacant which were filled by adding or relocating the bins.

### 3.8. Re-allocation of Bin Location and its Buffer Zone

Figure 11 was created after the addition and reallocation of new bins according to the population distribution. Some of the vacant places that fell out of the buffer zone were covered by the buffer zone in this map, but still there were some more vacant places. These vacant places were found to be due to empty lands or empty apartments or the area was under construction.
3.9. Hotspot Analysis for Existing Bin Location

Figure 11: Re-allocated bin buffer zone map

Figure 12: Existing bin location - significance of hotspots
It is well demonstrated in Figure 12 where the number of bins are concentrated more. These bins are the ones placed by the municipality. The red area in the map shows more concentration of bins, and it is classified into three categories of confidence level. The highest confidence level is 99%, which indicates the darkest red color, followed by lighter ones that are of confidence level 95% and 90%. The yellow area indicates that the bins in those areas are not of any significance. The areas that show the lowest significant values are the places that have very low number of bins and these form the cold spots.

3.10. Hotspot Analysis for Re-allocation of Bin Location

Figure 13: Re-allocated bin location - significance of hotspots

Figure 13 was created after new bin locations were added. As explained in the previous map the hotspot area is the area with more significant values or in other words more concentration of number of bins. Just the difference in this map is that the hotspot area has shifted a bit to the center of the map after relocation of the bins. Moreover, this is reasonable because of the high number of villas and small apartments in those areas. The tall buildings or apartments usually keep less number of bins with large capacity, so the hotspot does not fall in those areas. As for the cold spots, they have also shifted from the previous areas, due to the redistribution of bin locations in those areas.

3.11. Route Optimization for Existing Bin Location

The routing for the collection of existing bins from their locations were identified and interpolated using the network analyst. 219 stops were made for 260 bin locations. It is not that 260-bin locations only
had 260 bins; each bin location had one or more than one bins. The stops were made according to the hotspot of the bin locations. If there were bins nearby in one of the locations, only one stop was made for the convenience of collection (Figure 14).

**Figure 14: Route map for existing bin locations**

Zone 1 - colored red as shown in the above figure 14 has 89 stops that has a routing distance of 6.5 miles and by following the speed limit given, it takes 20 minutes to cover that distance. Zone 1 also produces 20192 kg or about 20 tons of waste. The garbage truck collecting the garbage wastes can compact up to 20 tons. After checking the time, the waste trucks take at each stop, the average time taken was found out to be two minutes. The actual time taken to collect all the waste from Zone 1 is calculated by using the below formula:

\[
\text{Real time} = (\text{Number of stops} \times \text{Time taken at each stops}) + \text{calculated time for Routing distance}
\]

\[
\text{Real time} = (89 \times 2) + 20 \text{ min} = 198 \text{ minutes} = 3.3 \text{ Hours.}
\]

Therefore, the total time taken to collect all the waste from zone 1 is 3.3 hours and it needs only one truck to complete the collection of waste.
Zone 2 - colored green has 65 stops that has a routing distance of 4.3 miles and takes 12 minutes to complete the route length. Zone 2 produces about 11891 kg or about 11.89 tons. So, the actual time taken to collect all the waste from zone 2 by stopping at all the stops is calculated as:

Real time = (65*2) + 12 min = 142 minutes = 2.37 Hours.

Therefore, it takes 2.37 hours to collect all the wastes from zone 2. Only one truck is enough to collect the waste from zone 2.

Zone 3 - colored yellow has 65 stops that has a routing distance of 4.7 miles and takes 13 minutes to complete the route length. Zone 3 produces 9772 Kg or about 9.7 tons of waste. So, the actual time taken to collect all the waste from zone 3 by stopping at all stops is calculated as:

Real time = (65*2) + 13 min = 143 minutes = 2.38 Hours.

Therefore, it takes 2.38 hours to collect all the wastes from zone 3. Only one truck is enough to collect the waste from zone 3.

To sum up, it took about 8.05 hours and a total of three trucks of 20 tons compacting capacity to collect the total waste of 41855 kg or about 41.85 tons generated from all the three zones.

3.12. New Route after Re-allocation of Bin Location

![New Route](image)

**Figure 15:** Re-allocated bin locations - new routing map
This new route was created after the new bin locations were added. There were 186 bin locations and 182 stops to be made. The stops and the number of bin locations are almost same due to the reason that the bin locations were added in such a way that it is not crowded in one place while the other place is empty. This has helped in reducing the time and cost.

The new route summary covers 17 miles and takes 49 minutes to complete the route length as derived from figure 15. There is an increase in distance due to the addition of bin location in places where no bins existed earlier. As per previous collection process, two minutes were taken into account for each stop. Therefore, in this new route for the new bin locations there are 182 stops in total. So, using the previous formula for calculation of real time taken after stopping at each location,

\[\text{The real time} = (182 \times 2) + 49 \text{ minutes} = 413 \text{ minutes or approximately 6.88 hours.}\]

As one trucks has capacity to compact 20 tons, three trucks should be enough to collect all the wastes in the study area. Therefore, if the 6.88-hour job is divided in to three trucks, each truck will need different time in three different zones:

Zone 1: Time taken = (76*2) + 21 minutes = 173 minutes = 2.88 hours.

Zone 2: Time taken = (61*2) + 14 minutes = 136 minutes = 2.27 hours.

Zone 3: Time taken = (45*2) + 14 minutes = 104 minutes = 1.73 hours.

It is noticed that there is a huge reduction of time after redistributing the bins and rerouting, reducing the man power, saving cost and time. After new bin locations were created the collection time decreased from 483 minutes to 413 minutes, which saved around 1 hour and 10 minutes in total each day.

4. Conclusion

A short and brief description about management of solid waste and the advantages of using GIS in the process of managing this solid waste has started this case study. To use GIS in the process of solid waste management was the main aim of this case study. Through various field works in the study area and contextual findings, this research has shown the advantage of utilizing GIS in the fields related to solid waste management. Different case studies have shown that with GIS agencies and organizations running different waste management issues, it was possible to diminish the work stress, save time and reduce cost and enhance the serviceability.

The main approach used in this case study done in Qatar's Bin Mahmoud area was to use GIS to locate waste bins that are inappropriately placed and to relocate those waste bins and stabilize the amount of work done. Collection of the waste is the costliest part of waste management and is not an easy task. The main aim was to make the waste collection more efficient using GIS. The result was obtained by relocating the bins in such a way that they are distributed according to population and waste generation and in addition, optimizing the routes using GIS-based network analysis tool. The utilization of GIS can help in reducing the time and cost in a significant way.

The result obtained from this case study can help the municipality of Qatar in creating a more self-sufficient waste management strategy. This case study has proven that with GIS it is possible to reduce the workload and save time. As discussed in the previous section earlier the time taken to collect all the waste in the existing routes with its existing bin locations was 483 minutes and the new route made after re-allocating the bins needed only 413 minutes, reducing the time by 1 hour and 10 minutes from the existing collection time.
The utilization of GIS in the process of waste management in Qatar, starting from waste source to the dumping ground will help in analyzing, demonstrating, and solving all the complex problems. This will make the management system more efficient, which in turn will be saving a lot of time and cost and help also in making the management of waste sustainable in future.

This research project provides a general idea about the waste management in Qatar and about the Bin Mahmoud area’s waste management in particular. The provided information in this case study could help in the future planning of waste management in Qatar.

References


