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Improving the Location of Recycling Stations in Shiraz Metropolitan Areas Using Landscape Geographic Information Systems Software and Landsat Images

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Abstract

Solid waste production has been a major problem in human societies in recent decades. Changes in consumption patterns have imposed great problems and costs on large cities to dispose the waste. Today, the geographic information system is considered due to the possibility of analyzing a huge volume of information layers, which has been used in this study to investigate the current stations and improve them. National and international experiences, three layers of the population, land use and access route have been selected. The hierarchical analysis method has been used to weigh the criteria and Landsat images of Shiraz have been used to locate the stations. According to experts, the covered population with the weight of 0.540 has the highest value, land use with 0.297has the next priority and access route with 0.163 is used to improve the collection stations for home recycling materials in Shiraz, based on the population in 1396. Assuming that 50% of the city's population delivered their recycled materials to the stations, 61 stations were located using Landsat images, of which 16 stations with a short distance (300 meters) from the current station were shown. Twenty-one medium-distance stations (300-700 meters) and 24 long-distance stations (more than 700 meters) were identified. In areas with long-distance stations, it is necessary to build and add drop-off centers, collecting recycled materials.

Keywords: hierarchical analysis, Geographic Information System, recycling, Landsat, drop-off centers, Shiraz

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1. Introduction

One of the main and important problems of human societies is the production of solid waste in different amounts and qualities and their proper disposal (Fattahi and Al-Sheikh, 2009). In large cities, solid waste disposal, in addition to the high costs of collecting, transporting and burying it in cities, poses serious environmental risks, and important concerns about the continuation of this situation should be addressed to all segments of the society, especially the managers. Urban decision-makers are forced to take solutions to deal with these problems (Saeidnia, 2003). For solving these problems, it seems necessary to use the studies and experiences of other countries or successful methods in other cities of the country. Urban waste can cause a variety of health problems as well as a poor living environment, if not disposed properly and safely. These materials are all solid or semi-solid urban materials that do not worth maintaining (Abdoli, 1993). "There are different ways to manage waste, including recycling, landfilling, incineration, etc. but the choice of technology depends on the type and the amount of the material" (Asadi et al., 1997). The main criterion for discussing segregation at the source is initiated by the proverb of "prevention is better than cure" which means proper management and design and using methods for separating dry waste from wet and then dry waste into paper, cardboard, glass, metal, etc.. With classification and separation, it is easy to transfer the waste to the processing centers or factories and save time and money (Bozorgmehr et al., 2014).

Many researchers, both international and even national, have studied the location of drop-off centers for collecting recycled materials and landfills. In 1995, Diaz used the Geographic Information Systems (GIS) software to design recycling warehouses for a community of 22,000 people. Shopping malls and municipal car parks were nominated to become recycling warehouses in two models. Alistair et al. (2001) in a joint project in Ireland and Portugal on the decision-making and process of hierarchical analysis in locating the appropriate location for solid waste landfills according to the rail network and routes and weighting each indicator, used and chose the best option. In 2008, Yang et al. used three indicators of spatial access, population density, and integration efficiency in Tai Chung, Taiwan, and optimized the area to locate and complete new recycling warehouses with Arc GIS software and C ++ programming. Three different scenarios were considered in this city for locating recycling warehouses. In 2018, Xenia et al. examined the challenges of recycling food waste in high-rise buildings in Hong Kong. His findings showed that there are three potential challenges for recycling waste in crowded buildings: 1. limited space, 2. health issues, and 3. execution and management.

Ghazanfari (2016) in his research has studied various containers and waste storage tanks in Shiraz, according to the location and the use of these containers in tasteful places and away from engineering calculations and scientific analysis, while examining the current situation in Shiraz, especially the current storage and location, with the help of new and scientific methods and Arc GIS software, the exact location of storage containers in the whole city of Shiraz for two types of wet and dry waste according to scientific standards and criteria was identified. Due to the distance and the volume of the reservoirs, several different executive modes for the project have been presented in the form of executive plans, as well as statistics and the number of reservoirs for all 10 regions of Shiraz.

In a study, Maryam Ilanloo et al. (2016) studied the location of Kelardasht urban waste recycling station, which has obtained 4 suitable sites for this purpose with the help of GIS software and the use of Analytical Hierarchy process (AHP). In this study, 5 criteria of distance from residential areas, distance from urban thoroughfares, distance from the river, distance from the hospital and educational centers, and distance from hotels and banks were considered and finally, the best points were located through the field survey.

According to the above findings, it is important to optimize and adapt existing stations to collect recycled materials in the city of Shiraz as the sixth metropolis of the country. This study hypothesize that the current 46 stations for collecting recycled materials in Shiraz with a population of one and a half million people are very small and limited, the same number is located without scientific support and only according to experts and managers. It is planned to review and optimize the locations of these stations to help the use of GIS software and Landsat images for this purpose. In this study, considering the 3 criteria of covered population, land use, and access route for the first time, the combination of these three criteria has been used, assuming that 50% of the people deliver their recycled materials to the stations. Cases can have an effective role in achieving the right results in terms of the number of required stations, the appropriate location for the construction of the station, and the optimization of the current stations. In this research, first the current stations are placed on the map, then the demographic coverage of each station in Shiraz city is evaluated and the per capita production of recycled materials in different areas of Shiraz is evaluated. Waste collection stations in Shiraz city have been done by Arc GIS software according to the current stations and the proposed locations for these stations have been determined.

2. Materials and Methods

2.1 Methodology

In this study, the following steps have been considered to conduct the study. At first, the information was collected about the existing stations, population and density of the city according to the 2013 census. Then, the information on the amount of waste produced, recycled materials in Shiraz and per capita according to the latest estimates and available information was collected. The criteria used in this study were then selected based on international experience and innovation in this study, as well as the 50% scenario of delivery of recycled materials to stations by people to determine the volume and size of stations. The layers were then classified based on the value of the Analytical Hierarchy process (AHP) method and then the weighting of the layers. At this stage, by combining all the information layers in Arc GIS software, the final maps were prepared and then the current stations were located with the help of Landsat images, which finally led to the evaluation and comparison of the stations located with the current stations in Shiraz. The following figure shows the research method (*Figure 1*).

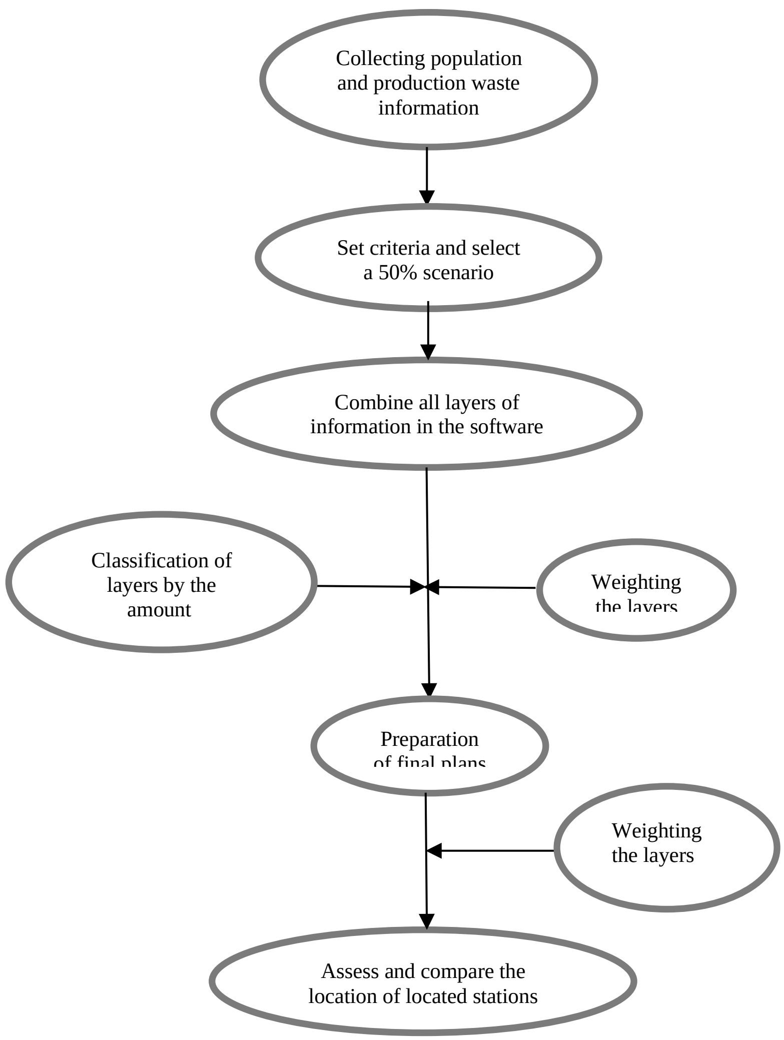

Figure 1. Stages of the research

In this research, the field method with questionnaire design has also been used alongside using descriptive and analytical methods. Thus, the questionnaire was distributed among 80 students of related fields, university professors, and experts of the Waste Management Organization and the following results are a combination of location criteria of drop-off centers for collecting recycled materials in Table 1.

Table 1. Investigating and Optimizing the Location of Existing Stations for Collecting Recycled Materials in Shiraz

Land use
Covered population (person)
Access path

2.2 Introducing the Metropolis of Shiraz

Shiraz is one of the major cities of Iran and one of the metropolises of this country and the center of the Fars province. The population of Shiraz in 1396 SH was 1547130 persons and by calculating the population living in the suburbs, it reached 1869001 persons. Shiraz is the fifth largest and most populous city in Iran. Shiraz city, according to urban zoning in 1396, includes 600 municipal districts and the numbers of currently drop-off centers in each region are shown in Table 2.

Table 2. Number of Fixed Stations for Collecting Recycled Materials in Each of the Areas of Shiraz Municipality (Waste Management Organization of Shiraz Municipality, 2017)

Number of area centers	Area number	Number of area centers	Area number
5	6	5	1
3	7	4	2
1	8	5	3
6	9	9	4
6	10	2	5

2.3 Identify the Main Criteria and Standardize the Maps

First, the main criteria for locating and optimizing the drop-off centers of recycled materials have been determined. Based on this, during the specialized interviews and the completion of the questionnaire by 80 experts, the main criteria of the study are proximity to areas (which in this research it is referred to the land use, which means to which areas or uses are closest to the station), the covered population (meaning how many people should be covered by each station) and the access route (meaning in which direction should the stations be located).

Due to the non-uniformity of the scale of the maps, it is necessary to standardize the location of fixed maps of recycled maps after entering the software in order to locate and optimize the location of drop-off centers so that the software can be compared with each other. This research has used a phased method to standardize the maps. In the qualitative criteria, by converting the vector layers to the raster, the maps were standardized, which will be explained below.

2.4 Phased Maps of Proximity to Areas, Access route, and Covered Population (Qualitative)

In this layer, according to the completion of the relevant questionnaire by experts and based on the standardized and phased map, the points related to land use (proximity to areas) in Shiraz were thus evaluated and shown in Table 3.

Table 3. Determined Value for Each User on the Map

Rate	points
Value=1	Residential, educational, commercial (shopping centers) uses
Value=-0/8	Office applications and fruit and vegetable fields
Value=-0/7	Recreational uses
Value=-0.6	Therapeutic uses
Value=-0.5	Other uses

Also, in standardizing and phasing the maps related to the access route in Shiraz, the value of streets and some boulevards for locating drop-off centers collecting recycled materials (value =1) and the rest of the access roads (value =0) for locating drop-off centers collecting recycled materials were considered. Regarding the standardization of the covered population and based on the 50% forecast of the delivery of recycled materials (50% collection by machinery at home and 50% delivery to the drop-off centers by the people) of the *Relation 1* is mentioned in the Population Economics book (Tavakoli, 2016) and population forecast in 1396 was done as follows:

$$n\ (1 + r)\ P = P0 \quad (1)$$

Population in 1396: P

Population in 1392: P0

12 = n

044/0 = r

2.5 Population Covered by Each Station (50% Scenario)

Considering that the capacity of each collection station (18-meter canopy) per day, 1 ton, and these stations are active 6 days a week and the per capita production of recyclable materials per person in Shiraz is 140 grams (1396 statistics). These populations under the coverage of each station according to this scenario in 1396 are calculated 12244 people (*Figure 2*).

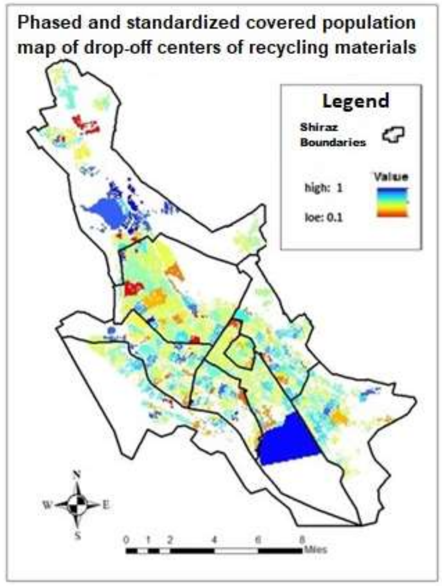

Figure 2. Determining the weight of the criteria in locating the station using Expert choice software

The next step in standardizing the maps is to weigh each of the related layers in the software. In this study, a pairwise comparison of layers was used to determine the weight of each layer in the questionnaire (AHP Analytical Hierarchy process) and the output of all experts' opinions was entered into the Expert choice program and the obtained results are shown in Table 4.

Table 4. The Final Weight of the Effective Criteria in Locating the Drop-off Centers of Recycling Materials in Shiraz in 1396

Calculated weight	Criteria	Row
0.540	Covered population	1
0.297	Proximity to areas	2
0.197	Access path	3

2.6 Applying Weights of Each Layer in Arc Map Software

After determining the weight of each layer, in order to show the importance of each criterion in locating Drop-off Centers (DOC), it is necessary to multiply the weight of each criterion in the relevant standard layer in Arc Map software and draw weighted maps for each of the criteria in the software environment. The weighted maps are shown in *Figures 3, 4,* and *5*.

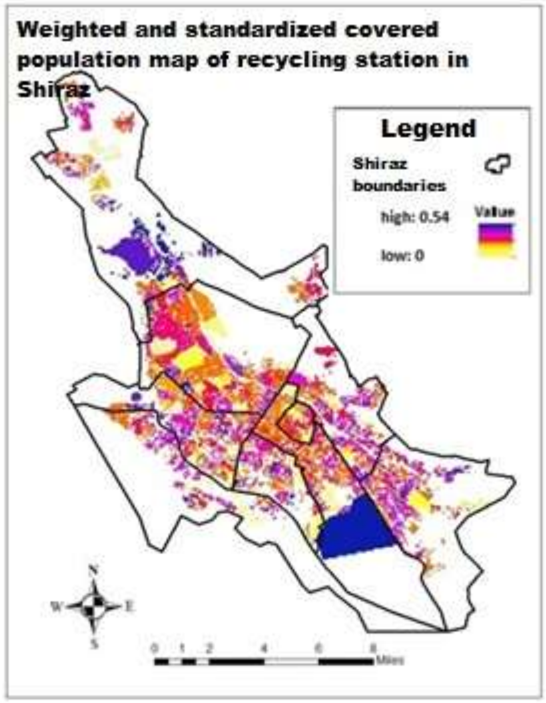

Figure 3. Weighted map of the covered population by different regions of Shiraz (based on the projected population in 1396)

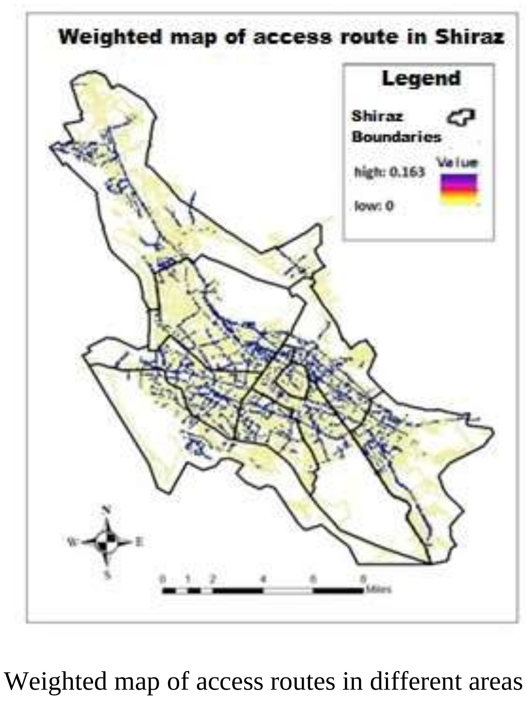

***Figure 4*.** Weighted map of access routes in different areas of Shiraz

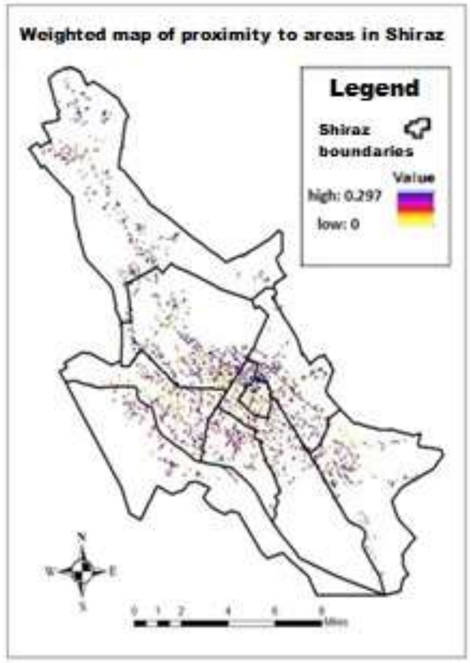

Figure 5. The final location of the drop-off centers for collecting recycled materials in Shiraz (according to the projected population in 1396)

2.7 Map Overlap and Final Output

At this stage, the software provides a suitable model for combining maps according to the characteristics of the parameters and the effect they have on each other. Maps are designed to be able to enter the original model. After selecting the appropriate model and method, combining and putting the information layers together using classification classes for the entire study area, the final map is prepared.

Considering the population in 1396 and assuming that 50% of the people deliver their recycled materials to the stations and proceed to locate and optimize the location of the drop-off centers to collect recycled materials in Shiraz based on all overlapping criteria and preparing the final map of the location of stations, it can be said that in all 10 municipal districts of Shiraz, places can be allocated for the construction of a drop-off center for collecting recycled materials in Shiraz are 6 and 4 Shiraz Municipality which are the most suitable places and district 8 is the least suitable place to build and add a drop-off center for collecting recycled materials in Shiraz. According to the 50% scenario and the population of 1396, 61 suitable points were pinpointed in Shiraz to be allocated to the drop-off centers for collecting recycled materials in Shiraz (*Figure 6*). *Figure 7* shows a map of existing centers and new locations.

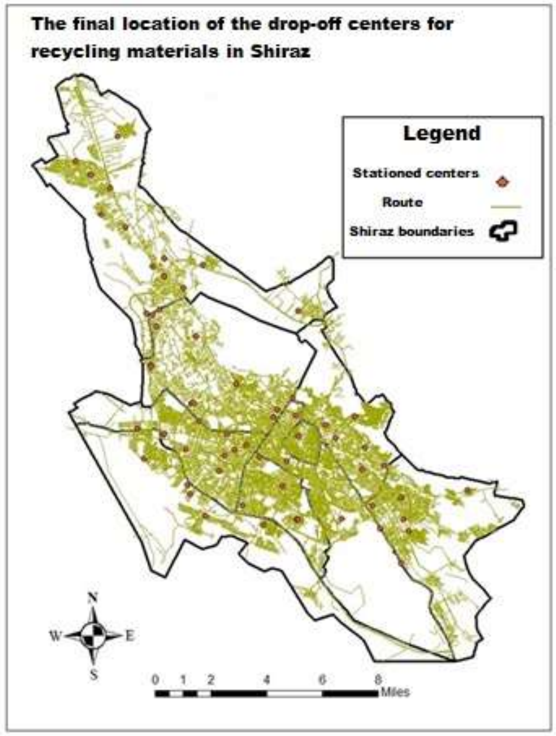

Figure 6. The final location of the drop-off centers for recycling materials in Shiraz (based on the population in 2017)

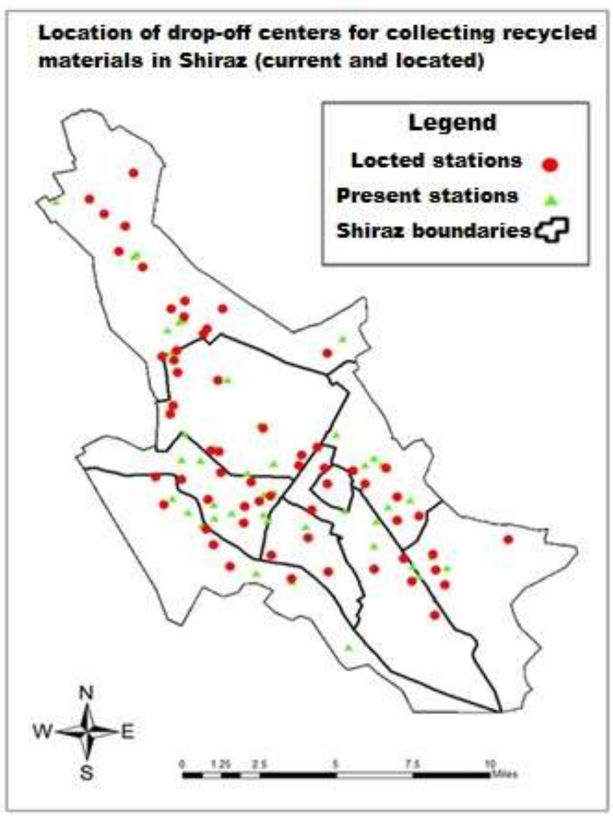

Figure 7. Current location of drop-off centers of recycling materials and newly located stations in Shiraz

2.8 Spatial Improvement of Existing Stations Collecting Recycled Materials

In the final stage, by using the Landsat images of Shiraz, the current stations were located and by inserting the final layer of 61 stationed locations, which can be seen in *Figure 8*, the location of the existing stations was studied and improved. Moreover, by using software features and using Landsat images to facilitate evaluation, the current stations are divided into three groups of less than 200 meters, less than 700 meters, and more than 700 meters distance from the located stations (Table 5). The places that did not have a station were also identified. Therefore, as mentioned in the hypothesis, the current 46 stations are small for the metropolis of Shiraz and the current 16 stations are less than 200 meters away from the stations that the location software has located, which can be considered acceptable, and the rest of the stations are not acceptable in terms of location and 15 new stations are required.

Table 5. Investigation of the Current Status of Recycling Stations in Shiraz with Localized Stations

Condition	**Number of stations**	**The distance between the existing stations to the nearest stationed station**
Acceptable station	16	**Less than 200 meters**
Station with removable location	21	**Between 300 and 700 meters**
Unacceptable stations	24	**More than 700 meters**

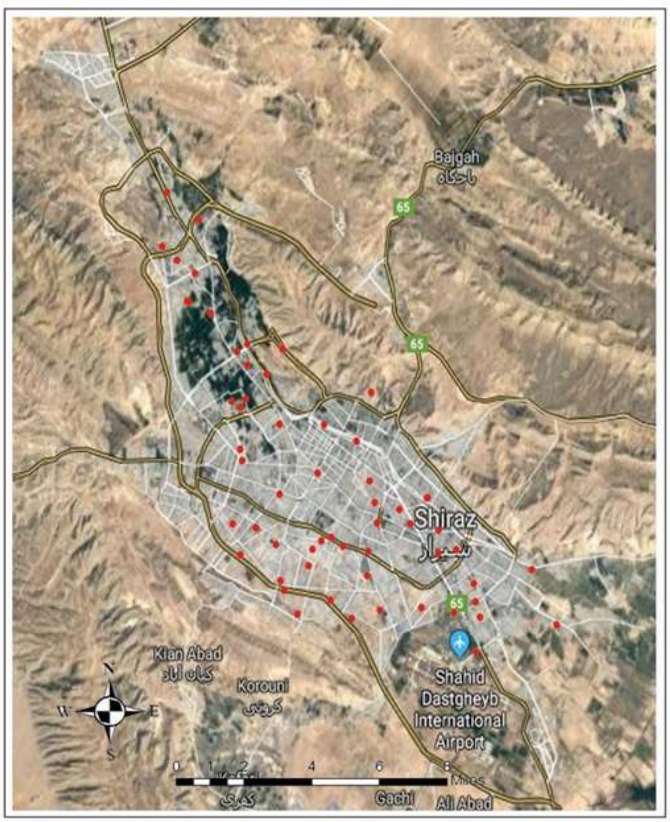

Figure 8. Investigation of the location of the stationed stations of recycled materials in Shiraz (based on the population of 1396)

3. Discussion and Results

3.1 Comparison of Achievements with Previous Research

In this study, Arc GIS software and Landsat images of Shiraz could be used while locating the required stations for collecting recycled materials (61 stations) for the metropolis of Shiraz, whereas the current stations are not based on scientific theory and evidence. The opinions of the managers and experts of the relevant organization about the stations are reviewed and optimized. Innovations of this research, which in comparison with national examples such as the location of Kelardasht urban recycling and also the study of storage methods and location of solid waste storage tanks in urban passages, can be used utilizing 3 criteria: population coverage, land use and the access path which were named for the first time and at the same time, using Landscape images of the city, which were very useful in the accuracy of the operation. It is also possible to consider the logical hypothesis of delivering recycled materials by 50% of the city's population to collection centers.

4. Conclusion

The purpose of this study is to investigate the spatial status of existing drop-off centers collecting recycled materials and located stations using a Analytical Hierarchy process by the Geographic Information System (Arc Gis) according to the population in1396 and a 50% forecast of participation of people delivering recycled materials to the stations. Analytical Hierarchy process and Expert choice software were used to weigh the criteria. The results of the hierarchical analysis showed that the criterion of the population covered with the calculated weight of 0.0540 has the highest importance (the first priority) in locating the drop-off centers of recycled materials and then, proximity to the areas (calculated weight 0.2977). The access route (calculated weight 0.163) is in the next priorities of the location of the drop-off centers for collecting recycled materials in Shiraz according to the population in 1396. Finally, 61 stations were identified using ArcGIS software and placed on the output of maps and Landsat images of Shiraz metropolis, of which 16 stations with a short distance (100-200 meters) compared to the current stations. Twenty-one medium-distance stations (300-700 meters) and 24 long-distance stations (more than 700 meters) were identified. A fixed collection of recycled materials seems essential. Meanwhile, areas 6 and 4 have the most suitable places and areas 9, 8, and 1 have the least suitable places and need to build a fixed station to collect recycled materials in Shiraz. The innovation of Landsat images to compare stations with each other and proposing to relocate existing stations with drop-off centers are the things that have not been done in previous international research. Moreover, the realistic prediction of 50% of people's participation is one of the cases that was not seen in national and international research, and in some cases, all the people of the city participated in the proposed research plan. The results of the study confirmed the hypothesis that the number of recycling stations was insufficient and that their location was inappropriate.

4.1 Suggestions for Further Study

Using other main criteria for decision making (per capita production-role of education, etc.)
Use other scenarios to make decisions (100% or 75% or 25%)
Decision making based on the division of municipal areas according to the per capita area
Use of user map based on places applicable by Shiraz Municipality
Using other decision-making methods (ANP, TOPSIS, Vikor, etc.) in locating the drop-off centers for collecting recycled materials in Shiraz and comparing it with the Analytical Hierarchy process and making the final decision based on comparing the results of the above methods.

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