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Geographic Information System 'GIS' Role to Manage Urban Household Waste El Khroub City as a Case Study

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Abstract

As all Algerian cities, El Khroub city is suffering from Environmental pollution problems, especially those resulting from the accumulation of urban household waste and such, as a result of the rapid growth brought about the discharge of Constantine's human overpopulation; various economic activities have made it more appealing; the population's high living standards as well as the lack of public awareness of the risks posed by deteriorating hygiene requirements; the city mismanagement; the city's insufficient technical, material and human capabilities, in addition to the absence of the relevant competencies. Hence, the importance of GIS technology, which has become one of the world's most important decision support systems; therefore, it is indispensable in rapid development areas, especially in solving large and complex problems and monitoring the solution and results thereafter .Thus, many computerized and accurate digital maps associated with databases have been created through the application of GIS in this study because they could not be created only with latest technologies. Our findings illustrate the description of the city's existing waste situation, as well as the existing irregularities and issues in its management, highlighting the inefficiency and the uneven distribution of containers in the city in general and the residential neighbourhoods in particular. Based on the recent technique, a model of spatial analysis of the most appropriate geographical distribution of containers and selection of the best paths aligned to population and produced waste quantity, drawing on urban and environmental planning methods and norms that were proposed for the selection of optimal sites.

Keywords: Management, Urban Solid Waste, Geographic Information System 'GIS', El Khroub City

Introduction

Economic, social and technological developments of many cities over the past two decades have contributed to the emergence of new living patterns that have increased and diversified people's requirements within the urban sphere. Among the most significant and serious problems is the solid waste management, which is considered as a National wealth. This latter, if it is properly managed it may become a significant return since it can be recycled and most of its ingredients used. So, indiscriminate disposal wastes potentially economically valuable substances as well as adverse environmental and health impacts.

Urban solid waste is one of the world's leading environmental problems. Today, there is an increasing focus that is given to it by many States. As one of the developing countries, particularly in the context of overpopulation, Algeria is facing the problem of household solid waste, which is becoming more acute as the population grows exponentially. Algeria produces about 10 to 13 tons of waste per year. The waste quantity and quality increase from year to year. Therefore, human health and the surrounding environment were negatively impacted, giving rise to the cultural development distortion (Environment Directorate of Constantine,

2022). Accordingly, examining the phenomenon and the identification of its effects and processing methods have become important and urgent; especially its treatment and disposal require financial, administrative and technical prospects.

Research Problem

Solid waste is one of the major of environmental problems in urban areas, owing to its direct impact on human quality of life and the cultural development, which has serious implications on the overall development.

Like all Algerian cities, El-Khroub, as a member of Constantine's metropolitan, is a model of the proliferation of household solid waste phenomenon and its problems, such as: the rise of all types of pollution. In recent years, there has been rapid urbanization and a significant population increase that was estimated at 270 606 inhabitants, in 2022. (Bosti Sandra, 2021) In addition to the existence of many economic activities made it more attractive (such as the industrial zone of Oued Hamimim, the weekly market, small businesses... etc.), as a result of this, the daily produced quantities of solid waste have increased; therefore, its management is going to be difficult. Consequently, the indiscriminate spread of many trashcans over the city. The latter, is giving rise to the urban environment deterioration. On one hand, the problems of rapid urbanization have known notable growing and aggravate. On the other hand, there has been increased interest on how to get rid of them and how to manage them, but this development has not been matched by actual legal, regulatory and technical actions (Boufnara Fatima, 2009).

Geographic Information Systems, known as GIS, is a computer system for geographical and descriptive data collection, entry, processing, analysis, presentation and output for specific objectives. This definition includes the system's ability to enter geographical data (maps, aerial images, space images), and descriptive data (tabular data, as well as their processing, storage, retrieval. In addition to the spatial and statistical analysis; the analyses display on the computer screen or maps, reports and graphs. Unlike the level paper map, GIS is presenting various data layers (Rakeb Soulef.et al, 2018).

It is an analytical spatial tool for handling geographical data needed by city designers and decision makers in waste management process, using an integrated and effective waste management system based on a set of foundations, programmes and techniques to facilitate the management process. Also, it assists researchers and decision makers at all planning stages of solid waste management (Fadi Rahma, 2006), using easy, inexpensive and efficient ways. Despite, facilitating waste- collection and waste-removal; identifying its disposal places; and determining the waste movement paths. In addition to ensuring a database of digital data future waste problem surveillance program, including predicting the waste quantities, its management, and determining the solid waste quality with setting the containers number, quality, sizes and their appropriate locations through GIS to choose the most economical solutions that correspond the legislative and technical variables. These problems can be adapted and radically resolved to be useful for decision makers, interested persons and institutions involved in solid waste management (Fadi Rahma, Ibid,2006).

Therefore, several questions spring to mind on this research study:

- ✓ How can GIS technology be used to examine the best planning and management of urban solid waste El Khroub city?

Proceeding from this main question, the following questions could be raised:

- ✓ What are the most significant sources of household waste in El Khroub city? And what are the waste types?
- ✓ How is the city's solid urban waste gathered, and how can GIS be used to select the best future container location according to available data and norms?
- ✓ What are the significant norms used to plan and manage urban waste using GIS technology? Can we decrease waste production, and protect the urban environment from its aggravation?

Research Hypotheses

After attempting to know the major reasons that led to urban waste mismanagement in El Khroub city that we are studying, the following hypothesis is included to be confirmed through our study.

- ✓ The aggravation of solid waste problem in El Khroub city and its accumulation in the urban environment due to the lack of environmental culture among the population, decision maker and managers, in addition to the administrative, technical and environmental deficits; the lack of appropriate techniques and possibilities; and the absence of a management system.
- ✓ Containers quantitative and qualitative number and their distribution over the study field, is not commensurate with the urban population size and the produced waste amount. This requires the use of Geographic Information Systems (GIS), which will improve household solid waste management, and it will achieve the best and effective management by identifying gathering methods, as well as selecting the best locations for mechanical mechanisms to gather solid waste, using digital map showing the best management of household solid waste.

Research Significance

The current research aims to highlight the magnitude of this problem and its negative effects with the methods needed to process it, using recent techniques and modernizing technology, which uses GIS technology in environmental planning process of household solid waste management. It will be through assessing the geographical distribution of waste containers in the city and planning the best location, as well as choosing the right waste collection trucks locations. This technique has a high potential to provide, manage and analyze data at various levels; therefore, it is beneficial to support the decision and to contribute to recommend solutions to waste problems.

Research Methodology

Our research study is based on analytical descriptive approach and quantitative approach. Also, the spatial analysis approach was used through the application of the appropriate GIS analysis functions in order to identify the different places of waste containers and their proliferation, where the researcher can describe the phenomenon systematically and to more knowledge-based data access about the research study phenomenon. After that, the analysis phase using different tools and finally, the findings codification.

Field Study

The study relied on field-collected data from digitized maps, in addition to their modernization to produce new maps with reconnaissance visits; furthermore, the interviews with institutions' various managers, technicians and employees to identify the household waste deteriorating reality in the study field.

Constructing Geographical Database

In this research paper, we used available spatial analytic tools and methods in GIS, namely: Proximity that includes a number of other functions; the Buffer; Point Distance. Also, Measuring Geographic Distance functions were used, including measurement of phenomenon mediation or centralization; the distribution direction; and the standard distance. This study also has sought to apply identifying or measuring location adequacy model.

Maps Creation

Based on obtained findings from data analysis, a number of maps have been created to localize existing and programmed container places. Also, other maps have been created in the form of containers layers, through research, enquiry and selection.

Concepts and Terminologies

What is Geographic Information Systems?

GIS is a modern information technology system based on the computer use to bring, maintain and store data, and then analyze to be ready to bring out the processed spatial, non-spatial and descriptive data from its sources in order to process them, then to assist in planning and decision-making when needed. Also, this system is based upon capture, analysis, storage and presentation of geographically baseline data. It depends on the use of location-related data (Hafid. HS, all; 2021, Pires. A, Martinho. G, 2010), which helps individuals and institutions better understand patterns and spatial relationships (Fadi Rahma, Ibid, Al Jebri. et al, 2019, Khalaf Hussein Ali Al-Delimi, 2010).

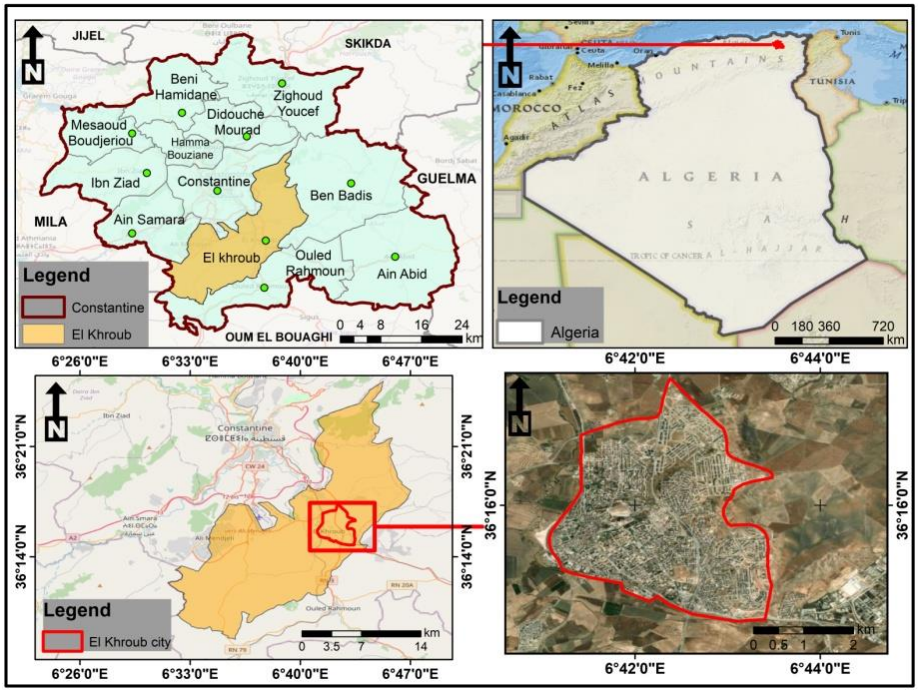
Solid Waste

Solid waste is solid-state materials caused by human activities in various life areas that no longer need it. It may result direct or indirect effect on human life or the environment, if not cleared up peacefully. WHO confirmed the solid waste definition, which meant to garbage and no longer required things that have become irrelevant or worthless somewhere and anywhere (Soulef Rakab, 2018). According to the World Health Organization (WHO), garbage is any worthless material that is disposed by their owners since he wants to throw it away or he is obliged to do it".

The Research Study Fields

El Khroub City is located in the south-eastern part of Constantine. On the north side, it is bordered by Constantine Municipality and Aïn Smara Municipality from the west, while from the east it is bordered by Ibn Badis Municipality and Ouled Rahmon from the south. According to 1984 division, El Khroub was upgraded from municipal center to a district (Saadoun Khaled, 2008). This city has a strategic location as key gateway to eastern Algeria between Constantine's high plains and Tel Atlas, where transportation routes, traffic and

exchanges routes are gathered. It is situated in no more than 770 m high, exactly on the national road axis No. 03 that links it to the northern side of Constantine (16 km away), and Batna from the south. There are also two National Routes, No. 20 and No. 10 heading towards Guelma and Oum El Bouaghi, respectively.



Map 01: *Geographical and Administrative Location of El-Khroub City*

Urban Solid Waste Reality (El-Khroub)

Produced Waste Quantity Increase in El-Khroub City

In recent decades, El-Khroub city has known a significant demographic development in the urban environment, which has led to high demand for basic services, as well as solid waste collection aggravation problem and its disposal. According to the National Waste Agency, solid waste national average is 0.5 kg/day/inhabitant, and according to the Environment Directorate of El-Khroub city (2022), it was estimated at 0.96 kg/day/inhabitant, equivalent to 2,8765.56 tons/year 2022 (Figure 01).

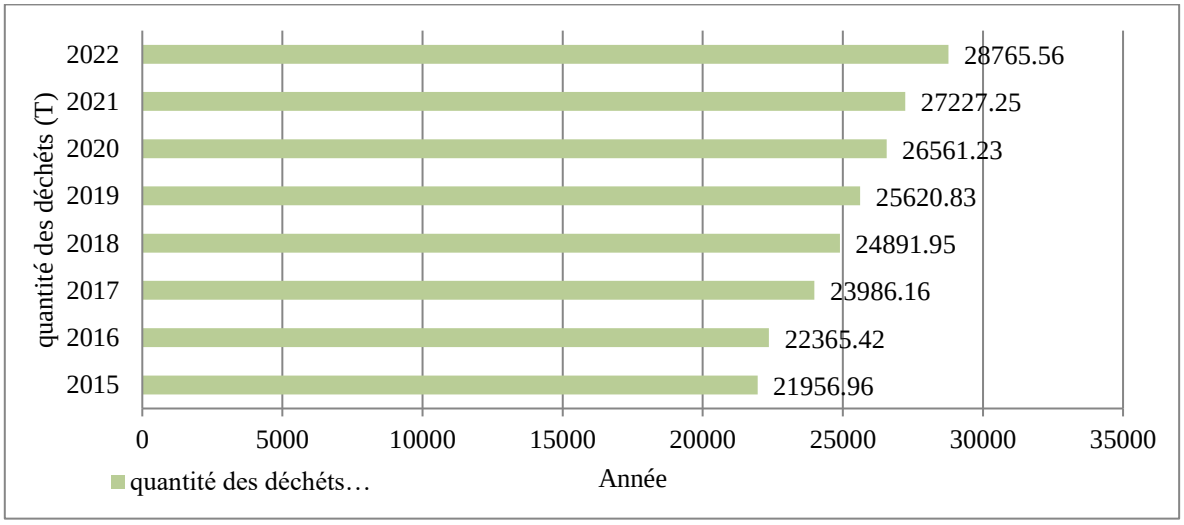


Figure01: *Estimating Produced Solid Waste Quantity in El-Khroub City (ton/year)*

However the existed waste quantity is not the right one, in which there is a noted high waste quantity that is thrown since 2015, because what we have observed is that there are significant waste quantity that have not been counted because there are indiscriminate excreta and places where the waste is thrown, either by population or by some institutions, together with limited number of containers with no places to throw them. Furthermore, the waste relies on traditional structure during its collection process (Chart No. 2).

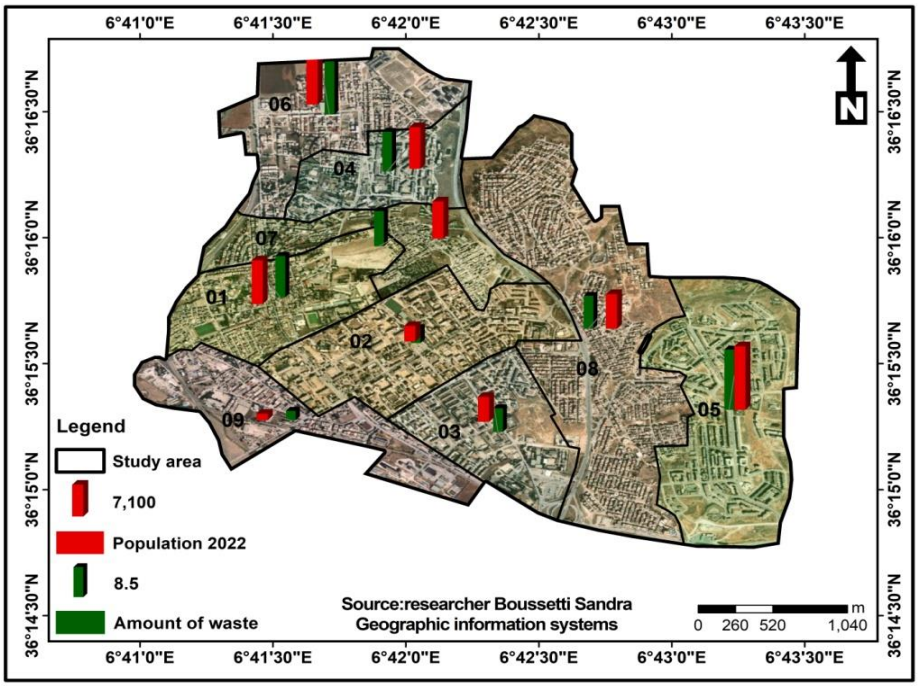


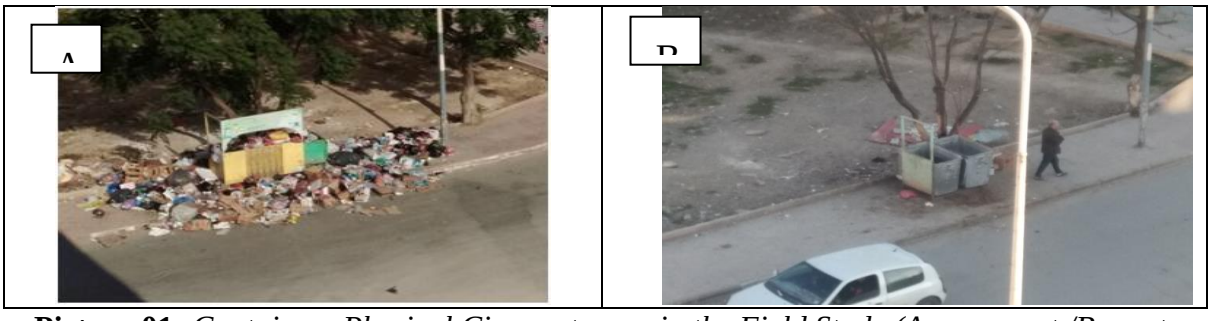
Chart 02: *Waste and Population Distribution in urban environment (El-Khroub City)*

Containers Number-Disparity on Almost Every City Areas

Through the field study of El-Khroub City, the available containers were small according to the population, that is why they through waste in vacant spaces. Consequently, a large spread of insects and an awful district view. The size of the majority of available containers around all districts (approximately 61%) is 01 m^3, especially in large population density residences, followed by indiscriminate places that contain 23% of the city's total containers.

Containers Circumstances

The field study of the containers physical circumstance shows that about 51% of them are in very bad situation; therefore, they need maintenance. Thus, the aforementioned cause is the major cause of waste spread in the city. Whereas, good circumstance containers are about 32%, and the remaining 17% are in acceptable situation, which needs an improvement.



Picture 01: *Containers Physical Circumstances in the Field Study (A: pre-reset /B: post-reset)*

Geographical Distribution of the City's Waste Containers

Studying containers geographical distribution is one of the most important means of demonstrating services proliferation, including solid waste collection. On December 31st, 2022, the number of El Khroub city's containers has reached more than 182 locations (81.25%), where waste is collected. These containers are distributed to city's districts where waste is collected through containers and over the city's corners that adopt collecting waste through door-to-door collection system; while approximately 18.85% is the portion of indiscriminate places where wastes are thrown (Chart 3).

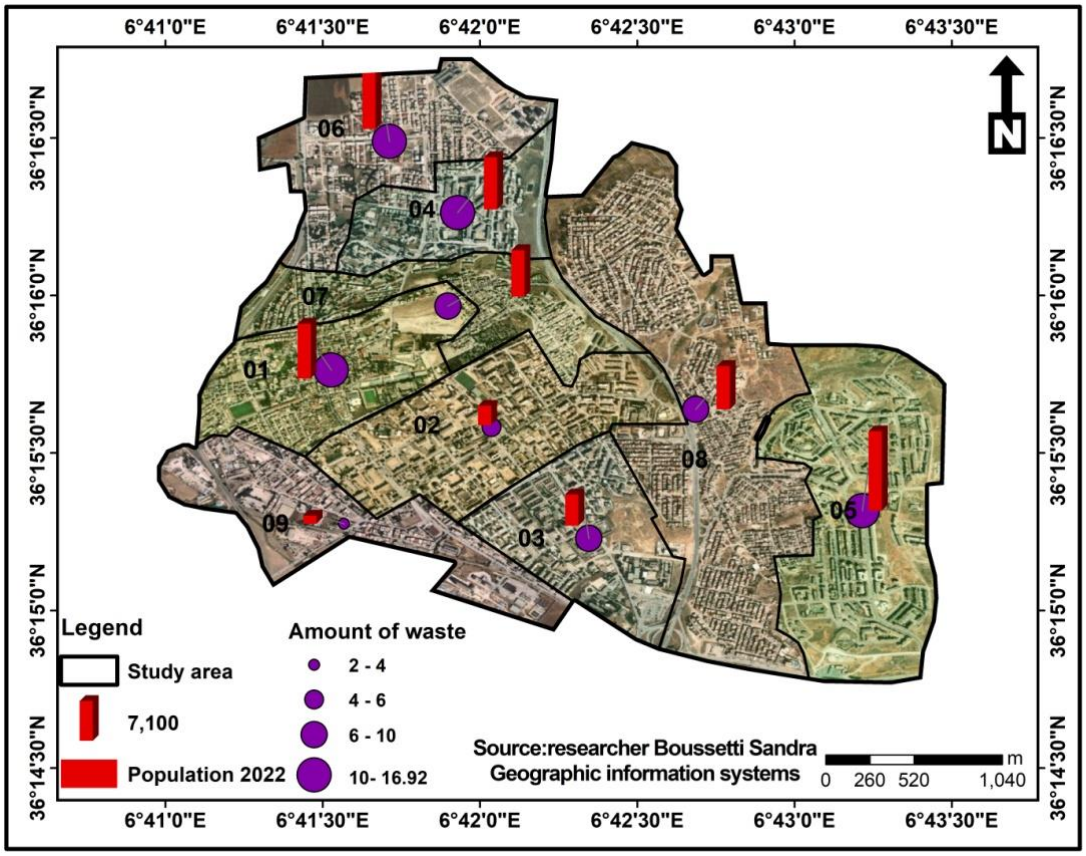


Chart 03: *Geographical Distribution of Household Waste Containers in El Khroub*

The Discussion

Norms and Standards of Selecting and Identifying Waste Containers Locations

Selecting and identifying waste containers locations is regulated by number of different external norms and factors. Choosing the right containers location depends upon their performance, function and role in the community and district that play a great role in planning and managing within the urban area (Al-Jabri, 2019, Ibid), because the selecting the location appropriately contributes to the achievement of officials and designers objectives, in terms of equitable containers distribution and choosing the appropriate close space to throw waste, while providing security and safety to the population and the surrounding area.

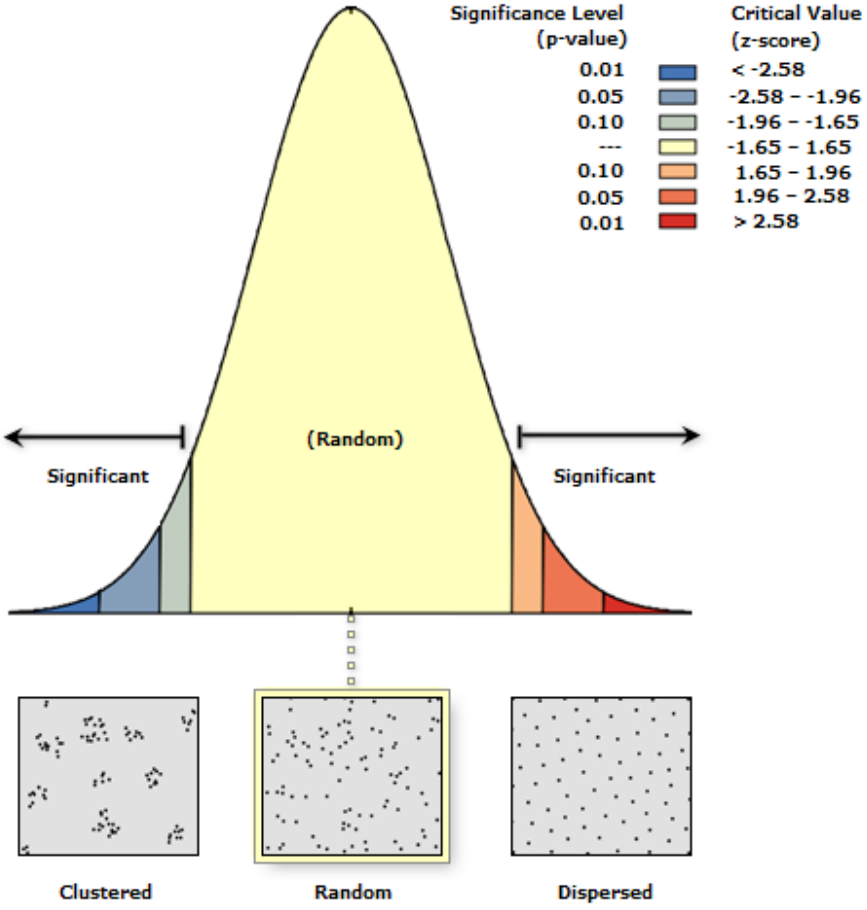
Use of GIS spatial analysis functions

GIS depends on the availability of many analytical functions that rely on spatial and non-spatial data. So, containers services distribution pattern is affected by distance factors, i.e. The distance between the phenomenon itself and where it spreads; therefore, they are significant to use, measure, and analyze the nearest neighbor factor.

Use of nearest neighbor factor to analyze the distribution patterns

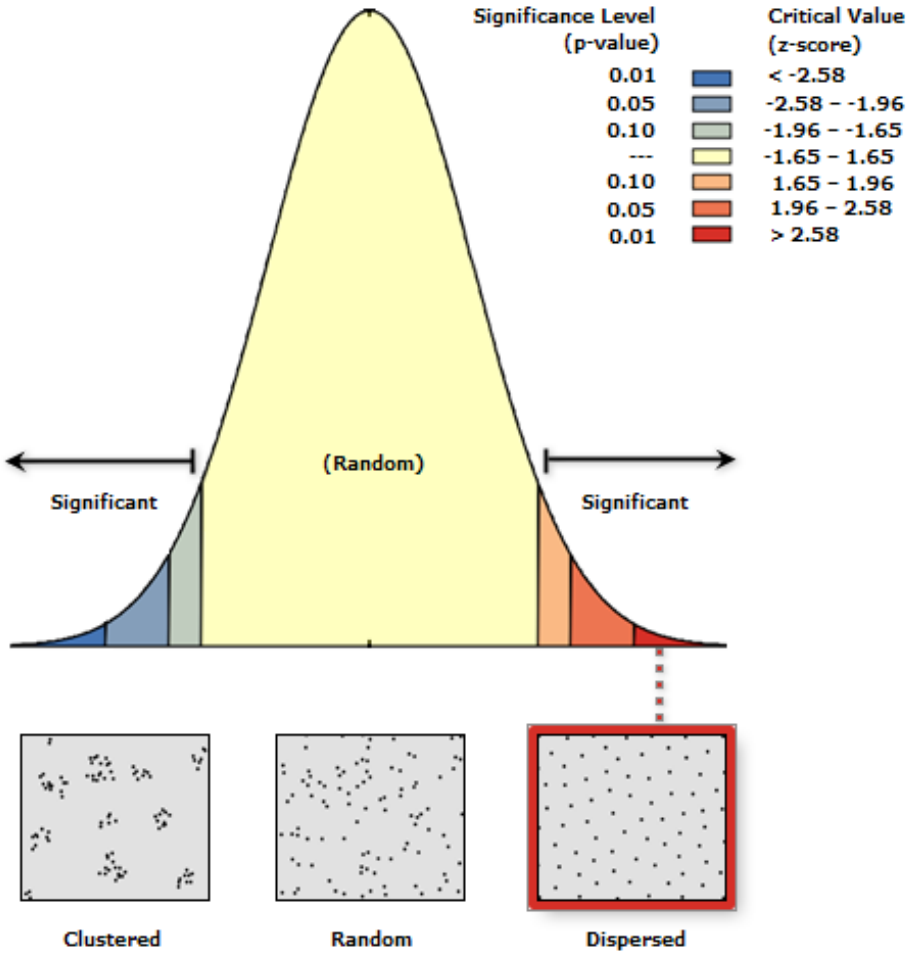
The nearest neighbor analysis is used as one of the special statistical tests to analyze the real distance between the distributed points on the outline, relating their average to the expected distance average that is between the points on the random distribution pattern. The spatial statistical analysis findings, using nearest neighbor analysis the study containers distribution pattern (Soulef Rakab, Ibid).

After applying nearest neighbor analysis of 182 urban waste containers that are distributed over El Khroub city, the real distance average between the containers is 120 meters, leading to the registration of a nearest neighbor of 50 m. This pattern indicates the existence of containers in populated urban areas from medium to high density (figure 02), with no containers in many districts. Thus, identifying the area through the nearest neighbor analysis; therefore, the citizen can reach the waste containers easily on one hand. While, on the other hand, identifying the required covered distance to throw the waste by determining the best distance between containers themselves and between containers and collective and individual residences (figure 03).



p-value: **z-score:** 1.353290 **Nearest Neighbor Ratio:** 1.056456
0.175963

Figure 02: *Waste Containers Spatial Spread (El Khroub City) – Carson Factor (The Current Distribution)*



p-value:	**z-score:** 6.753328	**Nearest Neighbor Ratio:** 1.538335
0.000000		

Figure 03: *Waste Containers Spatial Spread (El Khroub City) – Carson Factor (The Proposed Distribution)*

Standard Distance and Directional Distribution

The standard distance depends on the comparison between points distributions of various spatial phenomena on the chart; the larger standard distance, the spread is dispersed and random. Through chart 04 of the system analysis of drawing a circle around with 2145 m radius, the random containers distribution over a wide area of the city, is explained. Inside the circle, there are 153 containers out of the total containers number in El Khroub (64%), i.e. containers located outside the area have a dispersed distribution away from the spatial distribution center (the city center). The existence of containers outside the circle reflects the impact of the longitudinal expansion (east-north/south-west), as well as the city's longitudinal streets nature according to the containers geographical distribution. The green oval shape of the directional distribution extends casually toward southeast to northwest, affected by the containers longitudinal geographical distribution around the point of their geographical centre. Outside of the oval shape, the existence of the containers does not represent a positive spatial distribution. That latter, requires a redistribution of these containers proportionately to the produced waste quality, as well as the given space with the population density.

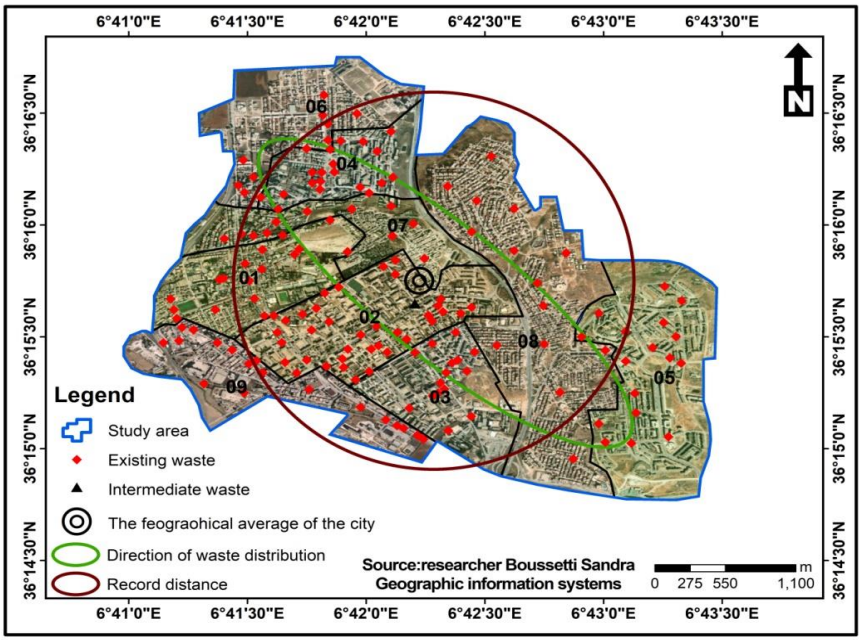


Chart 04: *Waste Directional Distribution and Containers Standard Distance (El Khroub City)*

According to Chart 04, 5th, 6th, 7th Sectors intersections area is not commensurate with the serviced space, i.e. it needs extra containers to cover the entire space, as well as reviewing the existing containers distribution, while the remaining sectors intersections areas are significantly higher than the serviced space, in term of the number of containers that cover the districts service area, in addition to the bad containers geographical distribution.

Using Pie Charts with Thiessen Polygons to Measure Container Efficiency (El Khroub City)

This analysis is used to identify the existing containers service scope and whether they cover the city's sectors. Consequently, there is a very significant overlap in the container influence sphere over the El Khroub city urban sectors (Chart 05), based on the approved distances to distribute the containers (100 m between each container and the next one as the service influence extent, to infer the areas cover more than 60% of the total area of the urban sectors.

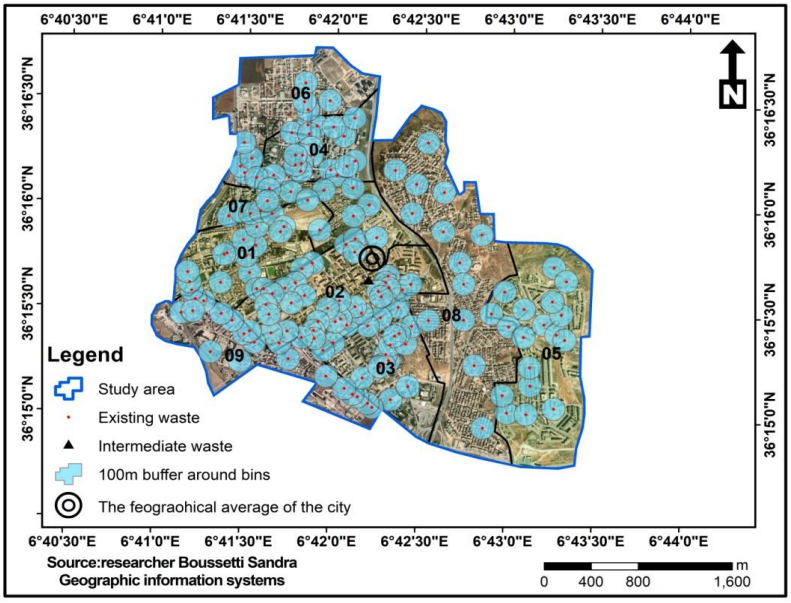


Chart 05: *Estimated Spaces of Container Influence Using Pie Charts (El-Khroub City)*

Calculating the area of each container using Thiessen Polygons method (chart 06) outlines the following findings:

Containers distribution discrepancies over El Khroub city (43.17%), in which each container is under the service of at least 4 to 15 hectares, due to the unfair distribution according to the locations. While 16.81% of the containers that serve 15-30 hectares per are distributed. That latter reduces the capacity of the container. However, the lowest percentage was 6.49%, with a rate of 45-118 hectares per container, where the population and residential density are very low in east and south of the city. That is as result of the used collection method of door-to-door collection system.

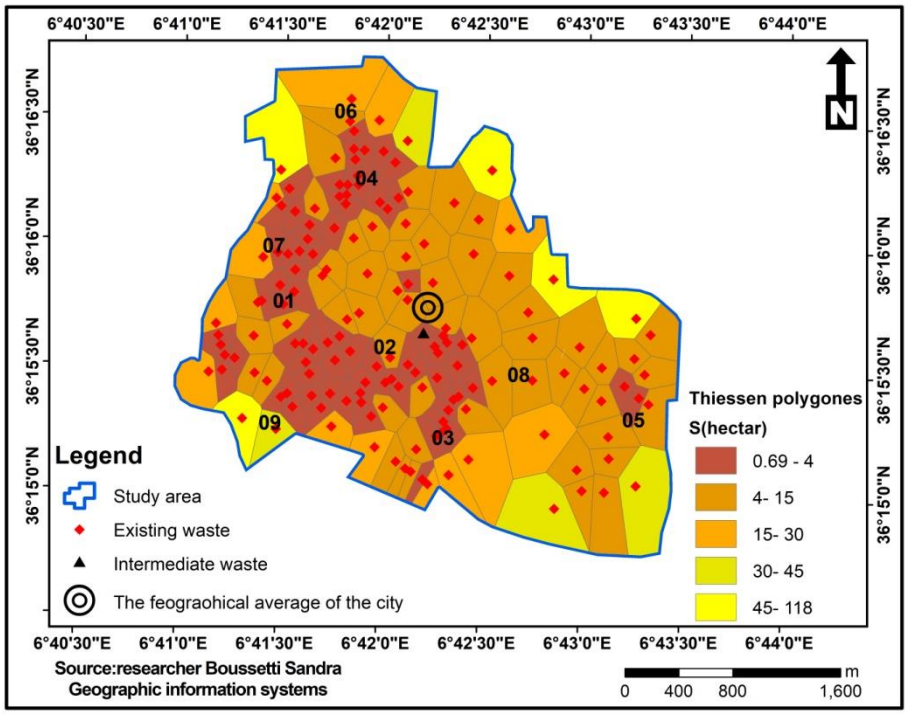


Chart 06: *Estimated Spaces of Container Influence Using Thiessen Polygons (El-Khroub City)*

6. Paradigmatic Analysis for a Set of Residential Districts

As a case study, we have selected a set of residential districts (900 district, 500 dwellings CNEP, and 450 dwellings), located in the northern of El Khroub city, and built across an area of approximately more than 44 hectares.

- ✓ Location Advantages: The physical location is proper and significant; flat topography; less steeply sloping; rocky nature; residential districts with a large population density, largely mass housing; equipped and structured roads with perfect mobility; and a crucial distribution of various land services.
- ✓ Location Disadvantages: lack of functional integration between population distribution, land uses and many vacant places; limit number of urban spaces; indiscriminate throwing of waste and rubbish spread; Lack of the containers that are distributed unfairly in the east and south of the districts. That latter leads to absence of the containers; i.e. the distance between the containers is 100 m, while almost no containers in the south, as well as their deteriorating physical status (Chart 07, 08).

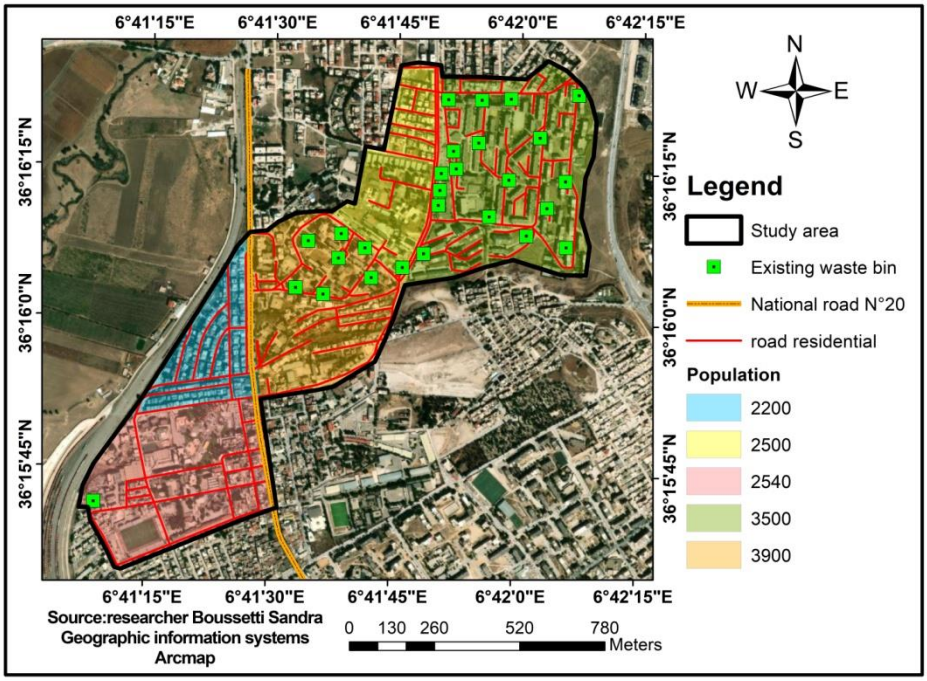


Chart 07: *Containers Current Distribution over the Examined Districts*

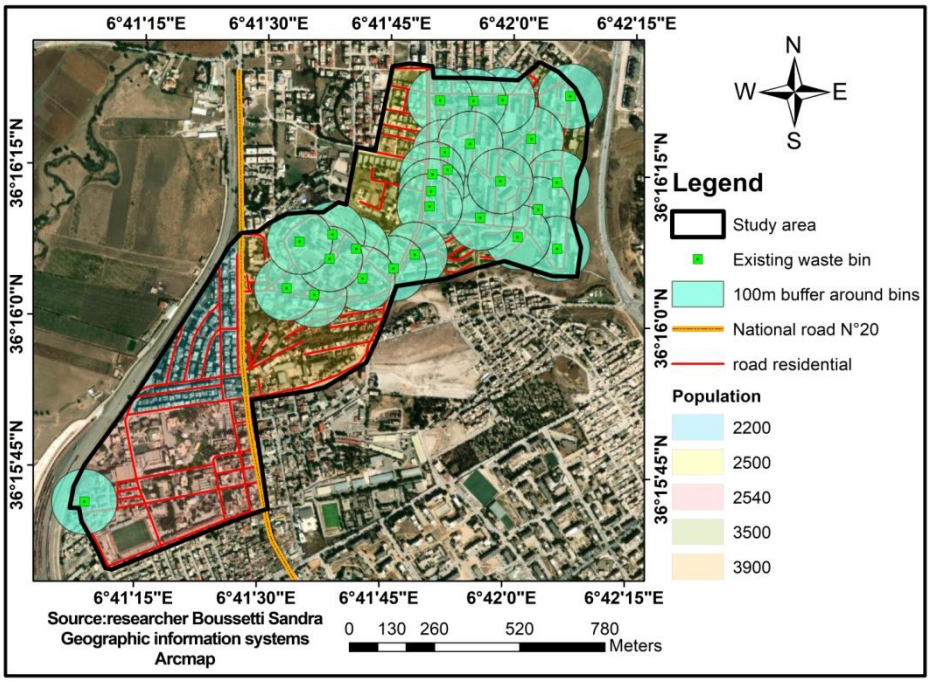


Chart 08: *Waste Containers Influence Sphere over the Examined Districts (100m)*

Therefore, to identify an appropriate strategy in line with of these location potentialities, namely knowing roads efficiency; and determining the best collection points, commensurately with people needs, as well as the produced waste quantity; to determine the vacant places for future containers that ascertain self-sufficiency. Also, to improve the residential districts urban landscape; to eliminate the waste visual pollution, while limiting pollutant sources, as: waste smell and insects' flight; planning and selecting the appropriate places to install subterranean selective sorting containers according to the land topography. In addition to standardizing containers size to ensure a smooth waste collecting and passing processes, as well as bringing containers closer to the citizen to ensure rapid and safe mobility and ideal containers

distribution. Thus, the examined residential districts have applied the aforementioned technique (Chart 09).

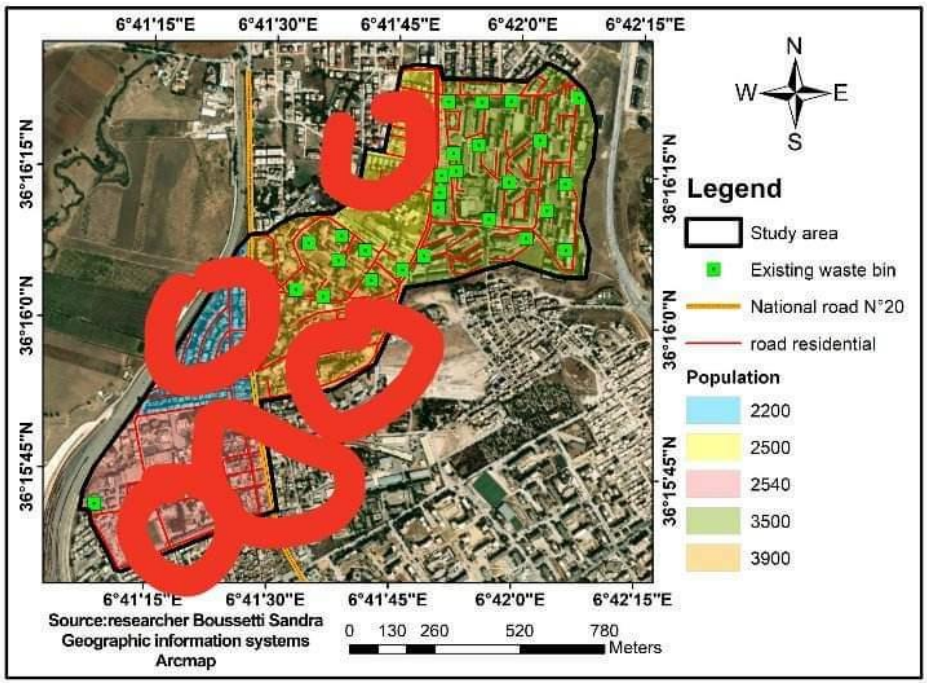


Chart 09: *Proposed Places to Install Waste Containers over the Examined Residential Districts in the Future*

Findings Analysis

Theoretical and applied studies with the field diagnosis gave us the opportunity to note several inadequacies throughout the waste management authority performance. Therefore, the following findings could be presented as follows:

- ✓ The absence of adequate waste collection process, especially in the suburbs leads to enormous waste quantity in many vacant places and streets.
- ✓ Mila's city waste nature that is generally different because of overlapped human activities and it consists of 65% of organic ingredients more than all household solid waste.
- ✓ Various waste collecting methods in El Khroub city according to place nature, however using containers is the dominant collecting way without forgetting the random areas.
- ✓ This research study has demonstrated that population and the produced waste quantity have the major effect to know the exact containers number that their distribution is not subject to particular planning standards
- ✓ Lack of enough waste containers over the examined residential districts, in which the existed containers are about 44.56% of the needed ones.
- ✓ The containers current geographical distribution assessment (in the examined residential districts) turns to be random, looks more like longitudinal extension blocks without taking into consideration the distance to reach the container, and this is a great problem. That leads to waste accumulation over the roadsides and vacant spaces.
- ✓ The failure to establish an independent authority overlooking the planning and applying of recommendations to collect household solid waste, as well as the poor efficiency waste-pickers, contribute to an ineffective and unsafe management. This in turn led to heighten waste terrible risks that negatively affect the environment.

✓ This research study is a basic unit of waste collecting and transferring management process, in which its data is useful in detecting the best containers locations. Accordingly, the adequate paths of waste collection trucks are selected, leading to collecting process management in examined residential districts. (Chart 10)

The research study findings present the importance of using GIS in spatial and descriptive data analysis process and linking them to select typically the best containers locations over the residential districts through proposing a particular containers number to collect waste accurately, quickly and with less effort, in line with population's needs according to the produced waste quantity (Chart 10)

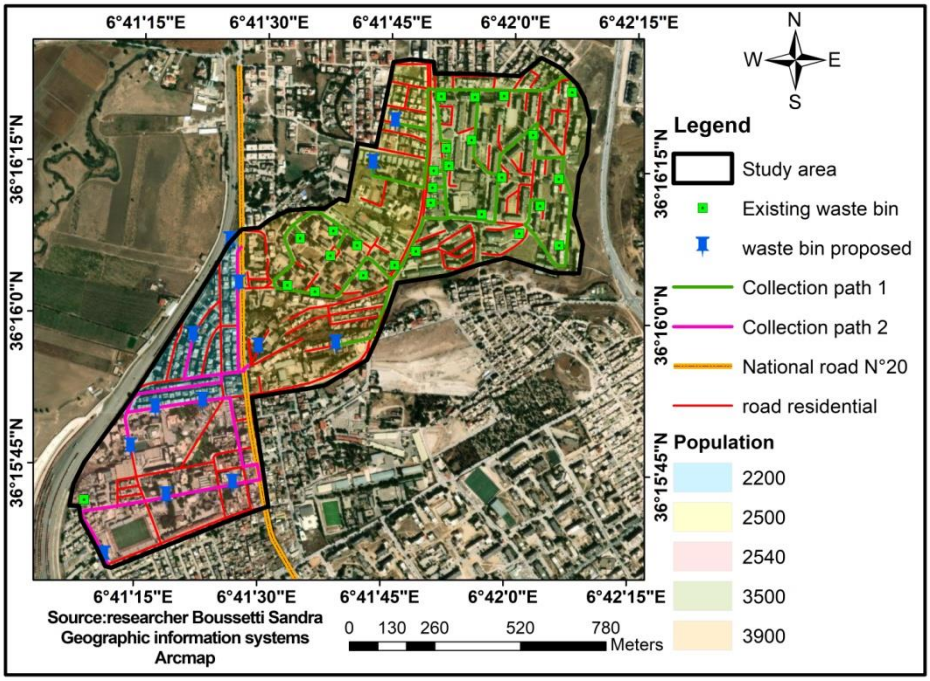


Chart 10: *The Best Waste-Collecting Paths with the Proposed Containers Distribution over El Khroub City District*

Conclusion

Through this research paper, we attempt to tackle urban household solid waste management issue, using geographic information systems (GIS) at various levels. Though, these systems are deeply and clearly neglected. Accordingly, this research is based on a diagnosis of the urban household solid waste management reality in Algeria generally, and El Khroub city particularly. Therefore, the produced household waste quantity increase is due, mainly, to the large demographic growth in this city; the urbanization rate; population's income level, and people's consumption habits in particular.

Moreover, urban waste management mismanagement in El Khroub city is mainly due to the wrong way of managing the responsible administrations of waste management, which requires improved urban waste management system, as well as the population, direct and indirect stakeholders' roles in taking an active part in the urban waste management to ensure the local management effectiveness.

Based on the abovementioned study and findings, some recommendations have been reached that would improve the efficiency of the solid waste management service, using

geographic information systems in El Khroub city generally, and the examined residential districts in particular. These recommendations are as follows:

- Establish an independent law regulating the solid waste management system and activating it by providing regulations that coordinate efforts and define responsibilities among various overlapping authorities pertaining to the subject of household solid waste, as a general reference.
- The city's inhabitants should be obliged to throw away waste only in their premises allocated through legislating binding laws.
- Eliminate random waste sites in order to eradicate pollution and its negative effect on the environment and human health, as well as improving the residential districts.
- Having new waste collection equipment with rolling out domestic and institutional waste storing techniques, especially in the health sector.
- Organizing national and international training courses to share experiences nationally, as well as benefitting from international experiences that contribute to solid waste management, especially household waste, with a view to protecting the environment.
- Creating social awareness and establishing effective mechanisms for wastes collecting and sorting, drawing on GIS, along with trying to make recyclable wastes as an economic asset while sorting it out in technical landfill centre.

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