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Optimal Spatial Distribution of Gasoline Stations in Baghdad Province Utilizing GIS Techniques

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Abstract:
Studying the spatially distribution pattern of fuel station in province of Baghdad was done by utilizing GIS techniques which they are the most powerful tools for design, display and analysis for the spatial data. Nearest Neighbor Analysis method was applied for analyzing the spatial distributions of the fuel stations. Baghdad was considered to be divided in to two main parts (outskirts of Baghdad and center of Baghdad). The nearest neighbour for all parts of Baghdad indicates for the distribution pattern is random and differs from place to another in randomly rate.

Keywords: Geographic Information System GIS, Fuel Station, Nearest Neighbour.

التوزيع المكاني المثالي لمحطات توزيع البنزين في محافظة بغداد باستخدام تقنيات نظم المعلومات الجغرافية

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الخلاصة:
تم في هذا البحث دراسة نمط التوزيع لمحطات تجهيز الوقود في محافظة بغداد باستخدام تقنيات نظم المعلومات الجغرافية والتي تعتبر من اهم الادوات الفعالة في تصميم وتحليل وعرض البيانات المكانية. تم استخدام طرق احصائية تدعى الجوار الاقرب لتحليل التوزيع المكاني لمحطات الوقود وذلك باعتماد تقسيم محافظة بغداد الى منطقة الرصافة ومنطقة الكرخ كمركز بغداد بالاضافة الى مناطق محيط بغداد. لقد وجد بان نمط التوزيع المكاني لمحطات توزيع الوقود هو عشوائي وبنسب عشوائية مختلفة من منطقة الى اخرى.

Introduction:

A Petrol Station, Filling Station, Gas Station, Fueling Station, or Service Station is a facility which sells fuel and lubricants for motor vehicles; the most common fuel sold is petrol and kerosene. Fueling Station is a retail establishment where motor vehicles are refueled, lubricated, serviced, and sometimes repaired. Fueling stations should be located not only where they are in fact accessible but where they can be easily located by strangers and that, in details, they should be placed where they will little danger and congestion as, much possible Most petrol stations sell petrol or diesel, some carry specialty fuels such as liquefied petroleum gas (LPG), natural gas, hydrogen, biodiesel, kerosene, or butane while the rest add shops to their primary business, and convenience stores [1].

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Due to the increase of urban population and the growth of the number of cars, fuel stations are among the places that residents refer to repetitiously. The transportation and movements of residents is mainly done by private cars, although public buses and taxies are also functioning, considering to location of Baghdad at the center of Iraq made it a central area attract to it and subdivided from it the roads and different transport means to all the provinces of Iraq, Thus, the number of filling stations remained inadequate which was effected in the creation of fuel stations in the province to perform the necessary services to provide the petroleum products required and which increase with the means of transport and along the external roads leading to the provinces of the country.

The distribution of fuel stations is considered one of the problems suffered by residents and planners in the province of Baghdad, and the distribution of fuel stations within the city is inconsistent. Non-compliance with the standards of planning and standards for the distribution of fuel stations led to the planning problems that negatively affect the role of the fuel stations in the provision of service to the citizen. The research aims to find the appropriate planning criteria for the selection of the best sites for fuel stations in the future through a case study of the distribution of the fuel stations in Baghdad neighborhoods.

Geographic information systems (GIS) approaches and related products have been widely used in the people's daily life. GIS provide the appropriate tools for analyzing the effective factors on spatial data and non-spatial data [2]. It is powerful computer-based tools for the capture, storage, management, retrieval, query, analysis and presentation of spatial data. GIS ability as spatial data processing and analyses tools available can be used to manage a wide range of Information [3].The main aim of this study is to analyze the spatial distribution of fuel station in Baghdad province using GIS-based Multi-Criteria Analysis (MCA). The aim of this research can be summarized in:

1- Identifies and locates petrol filling stations in the center of the province of Baghdad and its environs
2- Matching the spatial distribution of gasoline stations with the standards of urban planning.

Study Area:

The study area is located in province of Baghdad the capital city of Iraq from (43º 40'_ 45º 0') E and (32º 40' _ 34º 0') N , and covering an area of (5215) km^2 as shown in figure-1. Baghdad province is divided into Karkh side and Risafa side, Risafa's area is (1904) km^2 and its population is (4295833) with (101) fuel stations in it. Karkh's area is (3310) km^2, population (3161939) and number of fuel stations are (130).

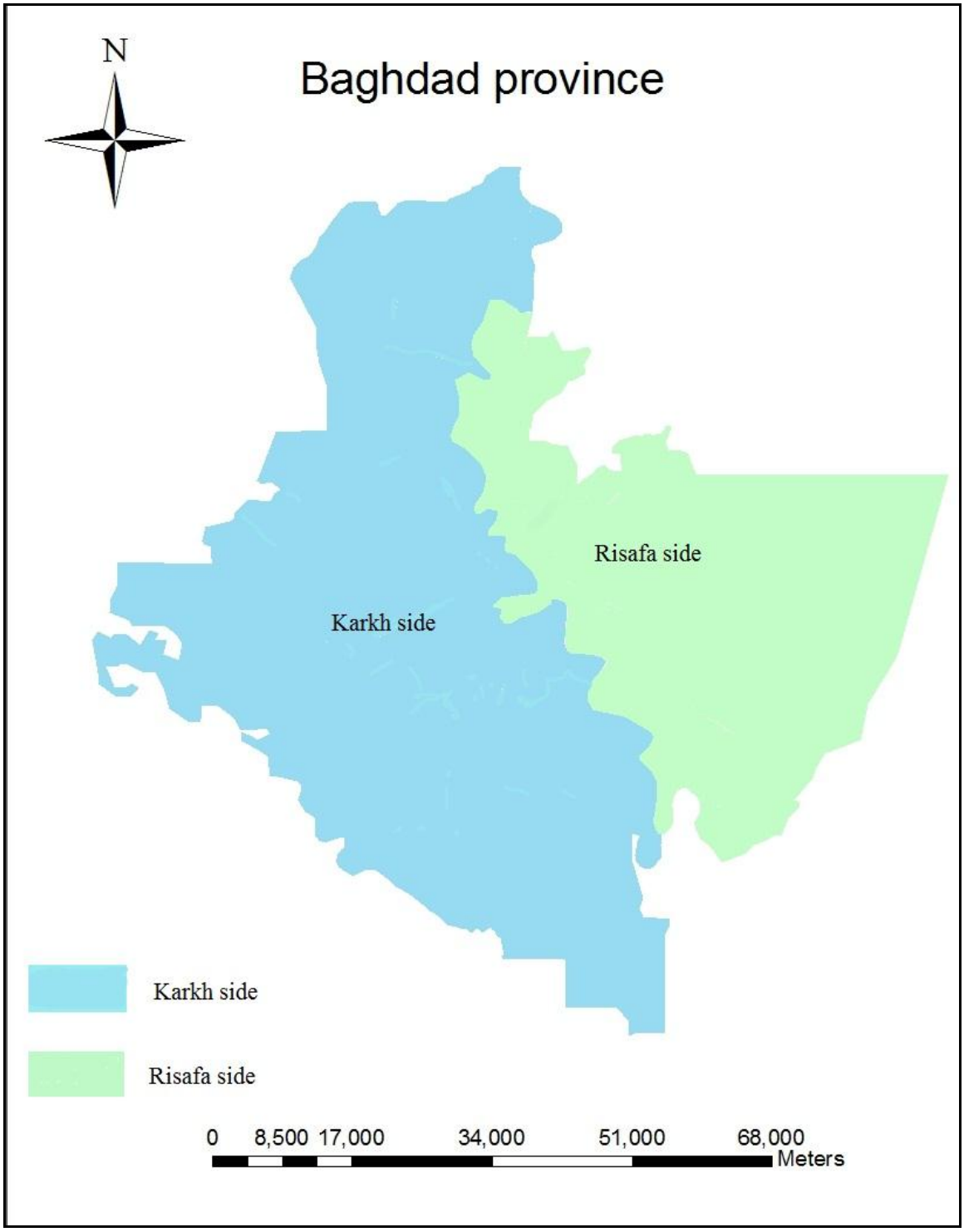

Figure 1- Study area

Province of Baghdad includes (10) district and (32) administrative Unit shown in table-1:

Table 1- administrative Unit in province of Baghdad

ID	District	Administrative Unit
1	Al – Kadhimiya district	Al -Taji sub district
		That Al Salasil sub district
		Al – Kadhimiya district centre
2	Al–Adhamiya district	Al - Rashdia sub district
		Al - Zohour sub district
		Al - Fahama sub district
		Al-Adhamiya district centre
3	Al – Risafa district	Palestine sub district
		Al - Risafa district centre
		Al- Karrada Al-Sharqia sub district
		Baghdad Al - Jedeeda sub district
4	Abu – Ghraib district	Abu - Ghraib district centre
		Al -Nasir & Al -Salam sub district
5	Al - Mada'in district	Al - Jisr sub district
		Al - Mada'in district centre
		Al - Wihda sub district
6	Al - Karkh district	Al – Mansour sub district
		Al - Karkh district centre
		Al – Mamoon sub district
7	Mahmudiya district	Al – Yousifya sub district
		Mahmudiya district centre
		Al - Rasheed sub district
		Al - Latifya sub district
8	Al – Sader 1 District	Al - Sader 1 District centre
		Al- Sadeeq Al- Akbar sub district
		Al- Furat sub district
9	Al – Sader 2 district	Al- Monawra sub district
		Abna Al- Rafedein sub district
		Al – Sader 2 district centre
10	Al – Tarmiya district	Al - Abiaji sub district
		Al – Mishahda sub district
		Al – Tarmiya district centre

Methodology

There are several steps in this study as follows:

1. Preparing the basic maps for the study area including satellite image with high resolution and creating shape files for Baghdad Provence and its districts.
2. Collecting spatial data and non-spatial data which include (a satellite image of the study area shown in figure-2, shape file for province of Baghdad polygon contains all district and administrative unit for the study area, information about fuel stations such as coordinates, types of fuel stations, capacity storage and number of pumps, data about all district in study area as population and the area of each district).
3. Convert the data in an appropriate way with ArcGIS software.
4. Implement statistical processes on the data to contribute the relations between (population density with number of gasoline stations, population density with number of gasoline pumps).
5. Analysis the spatial patterns for fuel stations by using (average nearest neighbour technique).

Figure 2- a satellite image of the study area from quick bird 2010 with a high resolution (0.6 Meter)

The population distribution of Baghdad province

A fuel stations are one of service facilities in the city because of its role to provide of various kinds of oil products to citizens and vehicles, This study needs a basic knowledge about the population and its expansion for the study area as well as deployment areas the population because of its impact on the increasing number of vehicles which leads to increased number of fuel stations.
Table-2 notices the increase of population in the province and the increasing rate for each year, which requires increased fuel stations.

Table 2- number of population in province of Baghdad according to data from the Ministry of Planning / Central Statistical Organization

ID	Year	Number of population	Increasing rate %
1	1997	5423964	
2	2003	6386067	
3	2004	6554126	2.6 %
4	2005	6726432	2.6 %
5	2006	6962650	3.5 %
6	2007	7145470	2.6 %
7	2008	6903920	-3.3 %
8	2009	7314257	5.9 %
9	2010	6878039	-5.9 %
10	2011	7055196	2.5 %
11	2012	7255278	2.8 %
12	2013	7457772	2.7 %

Also, there is variation in the population density of the province of Baghdad from one region to another, so the distribution of the service depending on the differences in population density from one region to another, Table-3 shows the area of each district, population density and number of gasoline stations in the province of Baghdad.

Table 3- based on the data from the Ministry of Planning / Central Statistical Organization
The area was calculated by program (GIS)

ID	Name district	Area(m^2)	Population density (person/km^2)	No. of station which provide gasoline
1	Al- Kadhimiya	477072000	1726	39
2	Al–adhamiya	278798020	3955	24
3	Al–Risafa	239003010	6941	28
4	Abu–Ghraib	629190980	444	9
5	Al- Mada'in	1336850000	3166	9
6	Al - Karkh	320383010	4560	22
7	Mahmudiya	1404300000	318	20
8	Al- Sader 1	27773400	23384	4
9	Al- Sader 2	22091100	20894	3
10	Al–Tarmiya	479987010	279	9

Table-3 and figure-3 refers to differences in population density recorded the highest density in (Sadder / 1) district within Risafa side by (23,384) people/km^2, while less density populated it is in (Tarmiya) district within the Karkh side by (279) people/km^2. This difference is one of many reasons that affect the distribution pattern of all Service facilities in each district.

To show the real distribution of the fuel services figure-4 & 5, shows the relationship between the population density, number of gasoline stations and gasoline pumps.

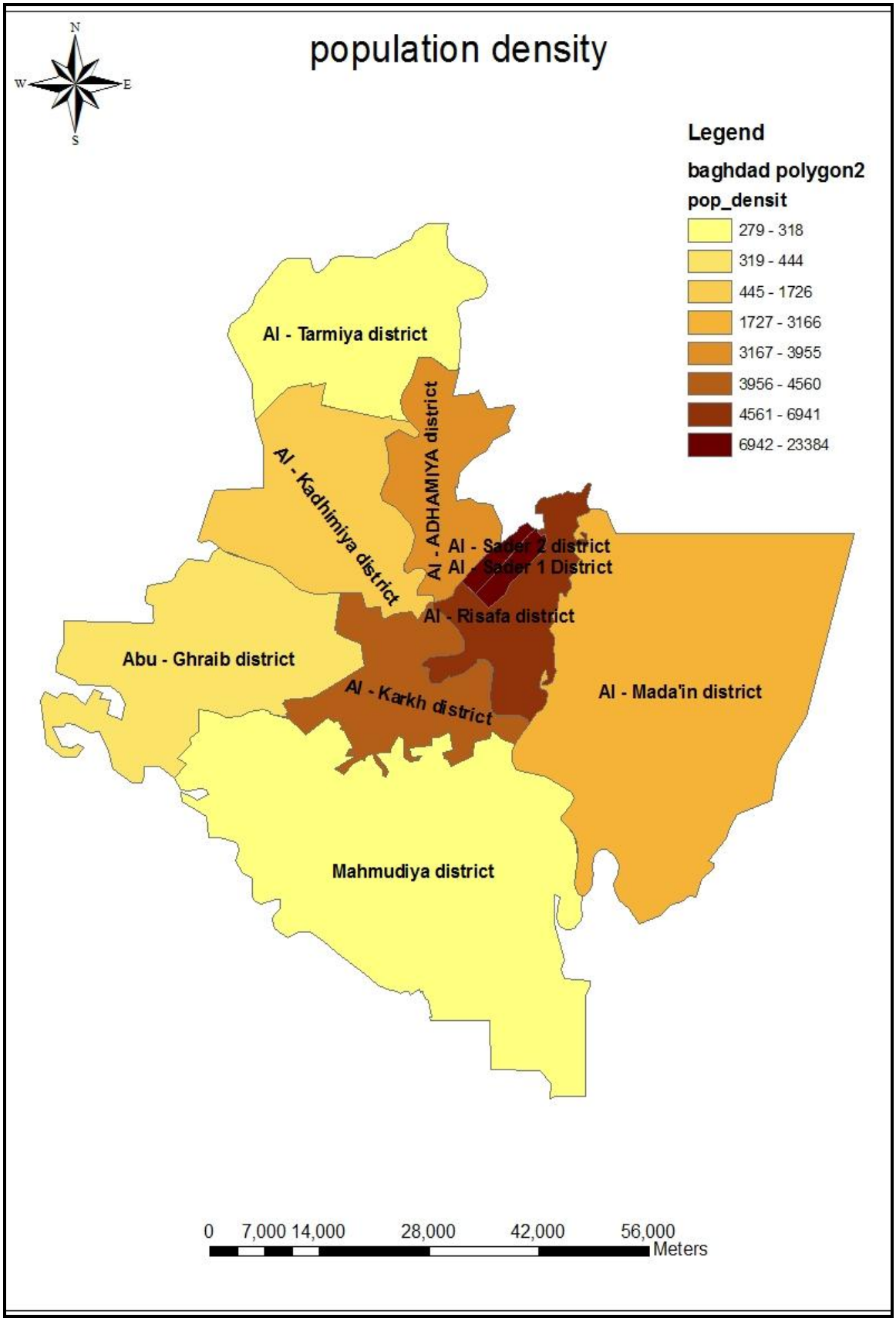

Figure 3- the province of Baghdad according to density Population relying on a table-3.

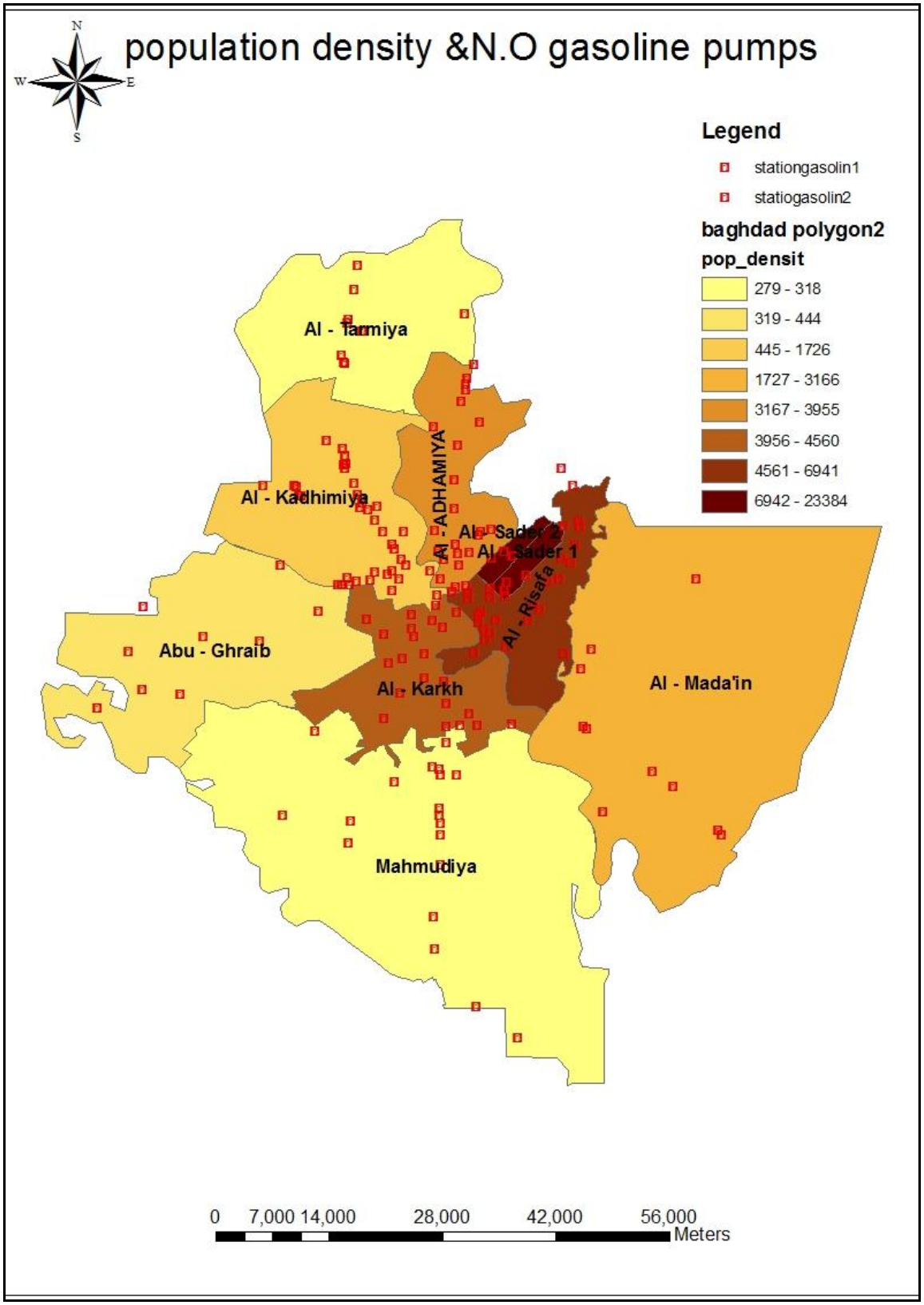

Figure 4- the province of Baghdad according to density Population with the distribution of gasoline station and gasoline stations

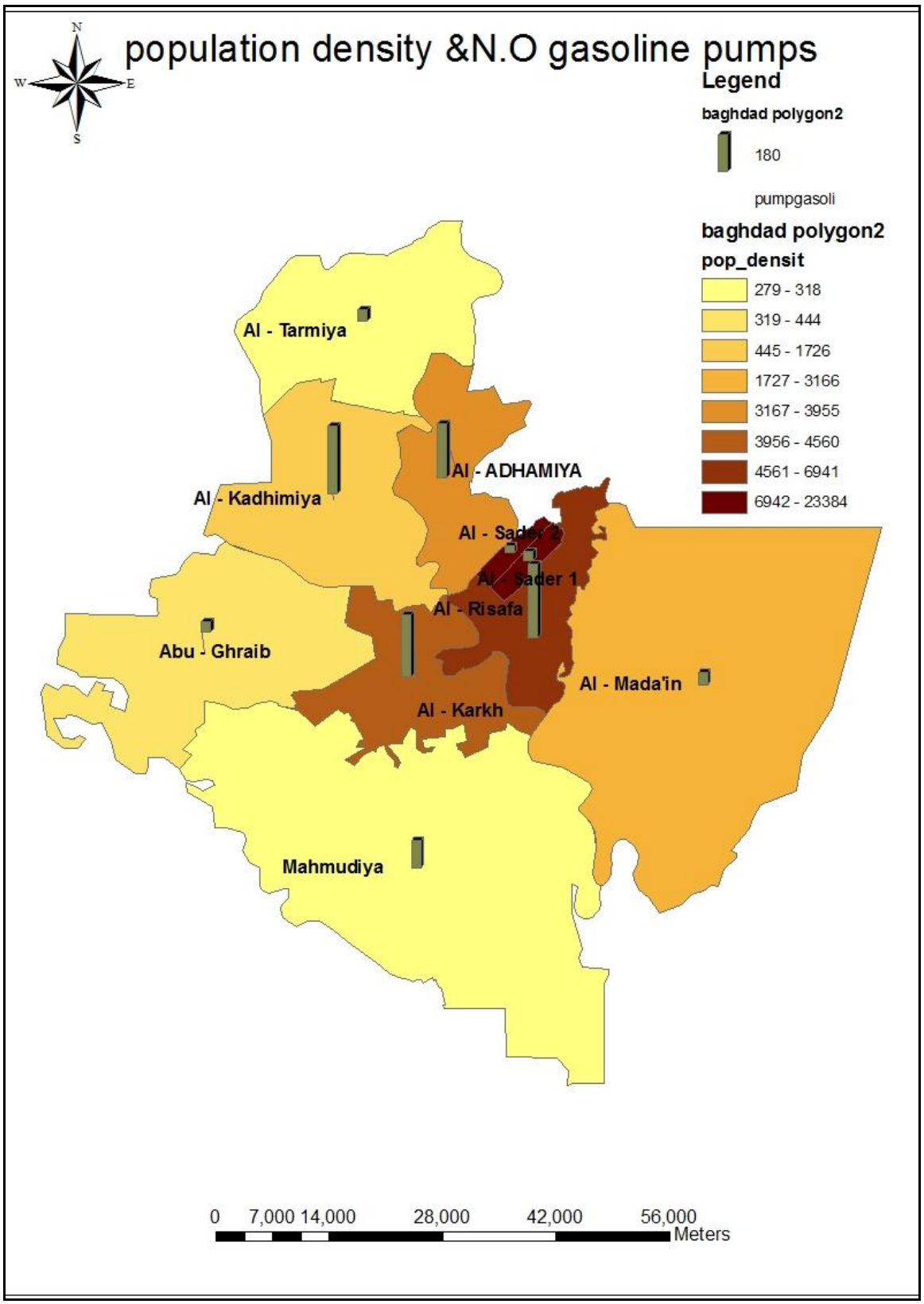

Figure 5- the province of Baghdad according to density Population with the distribution of gasoline station and gasoline pump

From table-3 and figures-4 &-5, the variation in fuel stations distribution between the areas of Baghdad where noted in some areas that in spite of being the densest population but they less than the number of stations compared with other regions which have less intensity.

Nearest Neighbor Analysis

Point processes provide models for irregular patterns of points (fuel stations). The theory was developed in response to various problems of physics, biology and queuing theory. There are several examples of spatial processes in which the events can be adequately represented as points (seedlings in a field, stars in space, etc.). This is either because the events' sizes are extremely small or the point approximation is reasonable taking into account the scale at which one is working. The analysis and statistics methods which have been used to know the pattern of fuel stations distribution and its relations with the other parameters.

The Average nearest neighbor distance distribution function is a relatively simple description of the spatial distribution of points based on the measurement of the distance from a typical point of the pattern to its nearest neighbor. By its nature this statistic focuses on short-range interactions between points [4]

Average nearest Neighbor is a ratio of average distance between each real point (fuel stations) and the nearest point that is adjacent to the site in the study area to the average expected distance (theoretical) between the same numbers of points (fuel stations) if they were distributed randomly in the same area [5].We can extracted standard closest neighbor through the mathematical relationship:

$$R = 2F\left(\frac{N}{A}\right)^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (1)$$ [6]

Where

R = standard closest neighbor.

F= average distance between the points (the sum of the distances between the nearest stations / number of fuel stations).

N = number of points (fuel stations).

A = area of study.

Results and discussions

To find the patterns that is distribution phenomena according to the closest neighbor, the value of (R) ranging from (0 to 2.15), If the value of (R) equal to (1) the distribution pattern is random , and if the value of (R) equal to (0) , the distribution Flocked which all points are clustered at one point , but if the value of (R) equal to (2.15), the distribution pattern is prevalent on a regular basis in the study area [6].By studying the distribution of the population in the province of Baghdad we noted a difference in the distribution of the population from one region to another as well as the contrast between the city center and the Remote regions so when you study the pattern of the spatial distribution for fuel stations in Baghdad province by using any tool from ArcGIS, it requires taking into consideration the nature of the distribution of the population, which affect on the an optimized way distribution of services In the province .

When applied this statistics on Baghdad its divide them into two types of areas according to the nature of urban planning for each regions, outskirts of Baghdad which include (Al- mahmodiea, Abu–Ghraib district, Al–Mada'in district, Al–Tarmiya district) and center karkh and Risafa side which include for Risafa side (Al - Fahama , Baghdad Al - Jedeeda , Al - Risafa , Al - Karrada, Al - Sader 2 , Al - Sader 1 and Al - Adhamiya. In center Karkh side the districts are (Al - Kadhimiya, Al - Karkh, Al – Mansour and Al - Mamoon) .

The sum of the distances between the nearest stations which provide gasoline in AL Mahmodiea district = 69085 m, Number of fuel stations (N =20) then

F = 69085 / 20 = 3454 m = 3.454 km

By applied the Equation (1)

R = 2 * 3.454 * (20 / 1404.3)

R = 0.82 m (Nearest neighbor for AL-Mmahmoodiea district)

This value mean the distribution pattern in AL-Mmahmoodiea district is random. This procedure was done by using GIStools software at spatial statistics tools category for AL-Mahmoodiea district and the result was shown in figure-6.

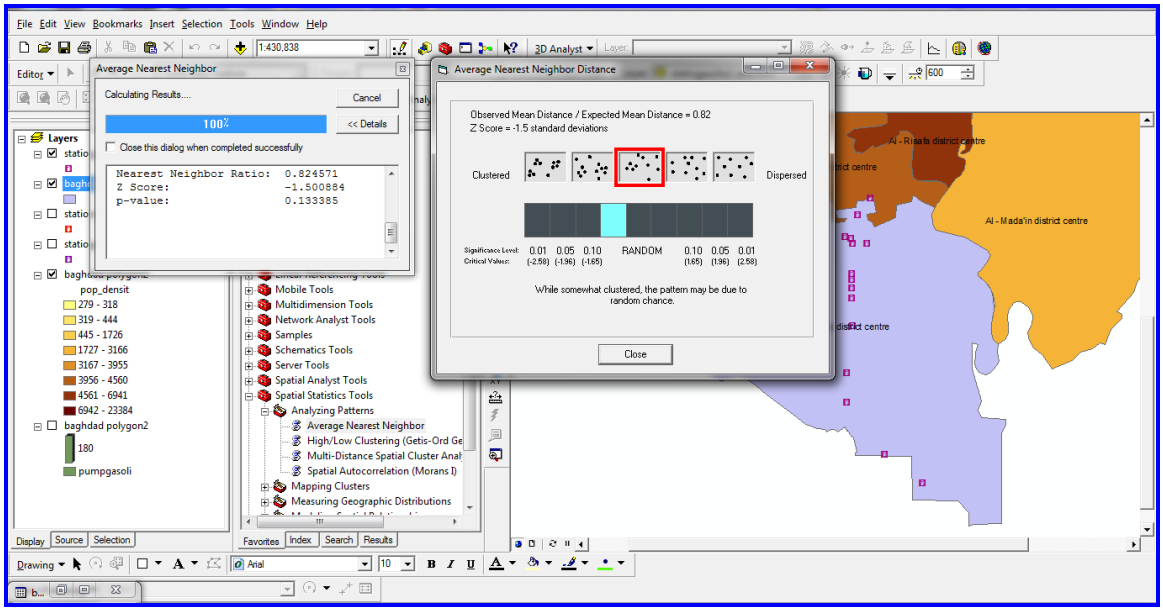

Figure 6- the nearest neighbour for AL-Mahmoodiea district, where the value of R = 0.82 which mean the distribution pattern is random

The sum of the distances between the nearest stations which provide gasoline in center AL-Rusafa side = 64852.5 m
Number of fuel stations which provide gasoline (N =47)
Then F = 64852.5 / 47 = 1379.8 m = 1.38 km
By applied the equation (1)
$R = 2 * 1.38 * (47 / 409)^{1/2}$
R = 0.93 (Nearest neighbor for centre AL Rusafa side)
When applying the same standard (closest neighbor) for areas located within the center AL Rusafa side which means the distribution pattern is random as shown in figure-7:

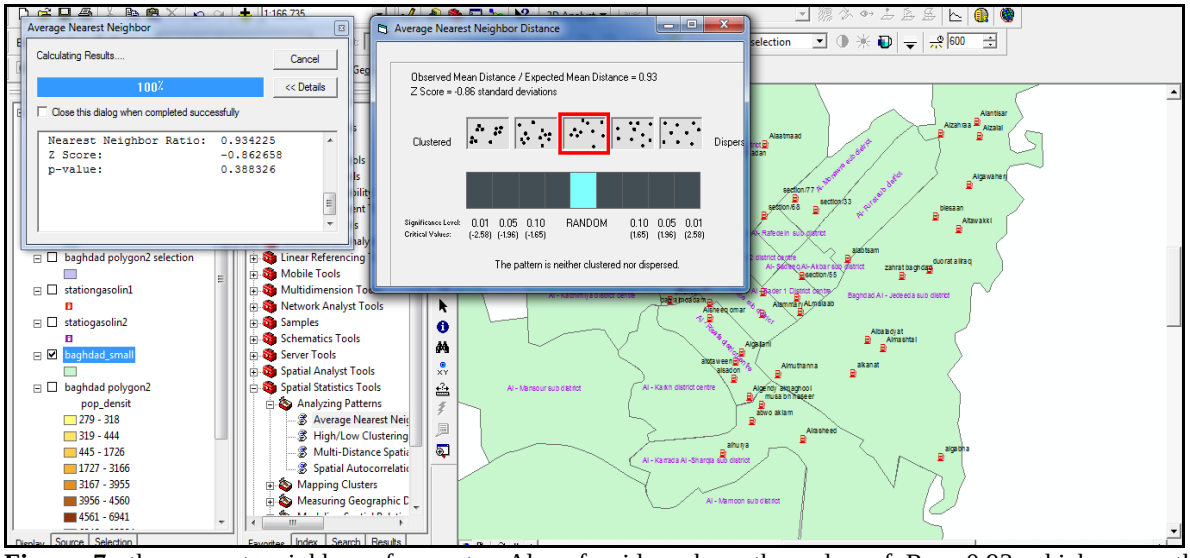

Figure 7- the nearest neighbour for centre Alrusafa side, where the value of R = 0.93 which mean the distribution pattern is random

The sum of the distances between the nearest stations which provide gasoline in center Alkarkh side = 57213.54 m
Number of fuel stations which provide gasoline (N =26)
Then F = 57213.54 / 26 = 2200.5 m = 2.2 km
By applied the equation (1):

$R = 2 * 2.2 * (26 / 348.9)^{½}$
R = 1.2 (Nearest neighbor for center Alkarkh side)
When applying the same standard (closest neighbor) for areas located within the center al karkh side which means the distribution pattern is random too this showed in figure-8:

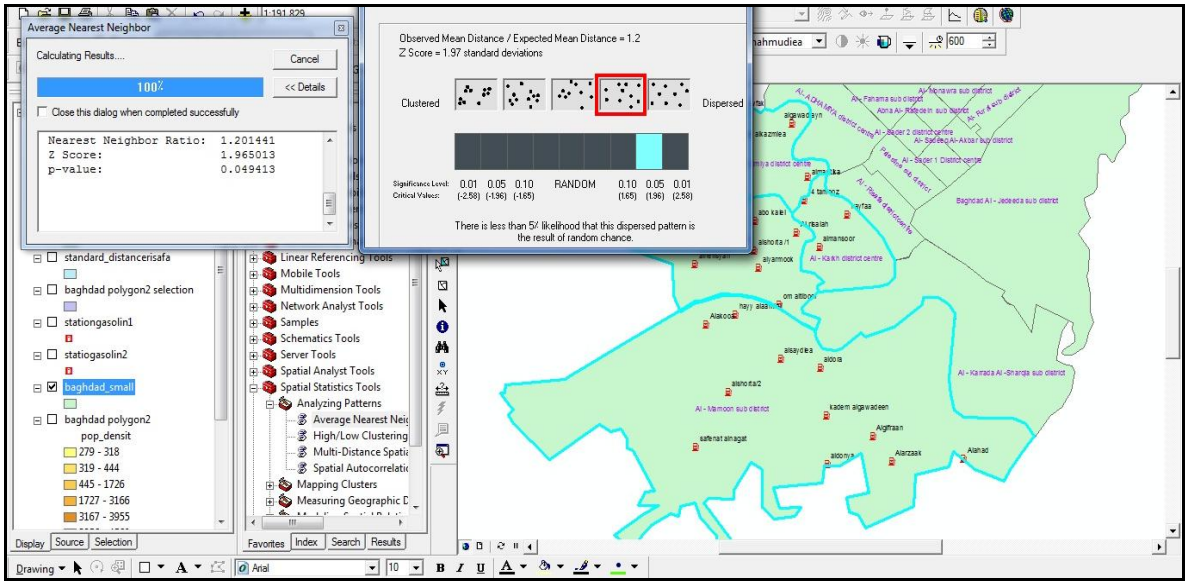

Figure 8- the nearest neighbour for center Al karkh side, where the value of R = 1.2 which mean the distribution pattern is random too

This study and its analysis leads to major result about the distribution pattern for fuel stations in each district of Baghdad are random and this pattern means that the distribution of fuel stations is irregular.

Conclusions

1. In Baghdad, the site selection for constructing fuel stations is carried out by means of traditional methods that are incapable of implementing all effective parameters. This deficiency leads to inappropriate site selection, which brings more inefficiency in this area.

2. The current distribution pattern fuelling stations in Baghdad province (study area) reflect clear focus in some area, for example we find that there is a clear discrepancy in the spatial distribution for the fuel stations between Al - Kadhimiya district which have (Population density 1726, number of gasoline stations 39) while Al - Sader 2 district (Population density 20894, number of gasoline stations 3).

3. Study showed through spatial analysis for fuel stations that most of the fuel stations in the province of Baghdad established without considering the standards and requirements of the site's construction, developed by the competent authorities and that there is a district serve from more than one fuel station while that there are neighborhoods there is no such service and the neighborhoods need to expand the fuel stations.

4. When planning to create a fuel station it is necessary to take into account the population density of the area and the activities available in them and the region's need for them and must locate public services and fuel stations especially and not neglect those services.

5. Activating the role of GIS technology as a tool in all government departments planning and regulatory because they provide the potential contribute to finding solutions for most planning problems for services generally to help to reach the best decisions in order to improve the service level.

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