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Determining the Optimal Fire Station Locations in Baghdad Al-Rusafa Using GIS Models and Data

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Abstract

The study of sitology has a long historical background and has recently attracted the attention of many researchers. One of its most important branches is the location of fire stations, which are of great importance in major cities. One of the most important features of an appropriate location is increasing coverage and reducing access time. In this research, geographic information systems were used to choose the most appropriate sites on the Al-Rasafa side in the city of Baghdad/Iraq to facilitate access to the scene of the accident as soon as possible from the fire stations and through the use of the geographical database of the city of Baghdad. GIS analysis was used to build the mathematical model that was adopted based on a number of criteria, including land use, distance to commercial malls, government and educational institutions, hospitals, and distance from existing fire stations. A weight was given to each of these criteria using the Overlay Weighted tool from spatial analysis in geographic information systems to determine the most appropriate areas. Then the road network was added to the criteria used, and then the selection was made on the areas close to the main roads, so the search results were to determine the best sites in Al-Karrada, Al-Sadr City, and Al-Adhamiya.

Keywords: Fire station, Spatial analysis ,Remote Sensing, Euclidean distance, Conditional Weighted.

تحديد المواقع الأمثل لمحطات الإطفاء في بغداد الرصافة باستخدام النمذجة ونظم المعلومات الجغرافية

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الخلاصة

تتمتع دراسة علم المواقع بخلفية تاريخية طويلة ، وقد جذبت مؤخرا اهتمام العديد من الباحثين ، ومن أهم فروعها مواقع محطات الإطفاء ، حيث يكون لموقع محطات الإطفاء أهمية كبيرة في المدن الكبرى . ومن أكثر. السمات المهمة للموقع المناسب هي زيادة التغطية وتقليل وقت الوصول ، تم استخدام نظم المعلومات الجغرافية من أجل اختيار أنسب المواقع في الرصافة لتسهيل الوصول إلى مكان الحادث في أسرع وقت ممكن من خلال قاعدة البيانات الجغرافية لمدينة بغداد. تم استخدام تحليل نظم المعلومات الجغرافية لبناء النموذج الرياضي الذي تم اعتماده استنادا على عدد من المعايير منها استعمالات الأرض والمسافة إلى المولات التجارية والمؤسسات الحكومية والتعليمية والمستشفيات والمسافة من محطات الإطفاء القائمة. تم إعطاء وزن لكل معيار من هذه المعايير باستخدام أداة Overlay Weighted من التحليل المكاني في نظم المعلومات

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الجغرافية لتحديد أنسب المناطق ، ثم تم اضافة شبكة الطرق الى المعايير المستخدمة ، ثم وقع الاختيار على المناطق القريبة من الطرق الرئيسية لذلك كانت أفضل المواقع في الكرادة ومدينة الصدر والأعظمية.

1- Introduction :

The importance of this research lies in its direct connection to human life, as recently there have been many fires at some state institutions and hospitals. The shortage of fire stations became apparent, prompting the researcher to choose the best places to add new stations characterized by rapid response. With the significant improvement in the economy during that time, over the past 30 years, cites have entered a rapid development stage. or Cities will be built larger and more functionally diverse. The population increased dramatically, and transportation routes become more common. Therefore, we can say that the city is very complex. Dynamic systems in cities, urban planning, and peoples activities are closely related and constrained by urban geography. Although urban development has economic effects, it also leads to increased fire risk. City buildings tend to have the following new characteristics large volumes, complex functions, high crowd density, and high fire hazards [1]. The fire station location is an important decision for city decision makers. Because of potential fire hazards and dangers to society. Fire incidents, on the other hand, can cost lives and property and can put the mayor in a difficult situation. Therefore, city governors or decision makers should take precautions to avoid such harsh conditions. We face fires and factory fires in the shortest possible time. Therefore, decision makers should minimize risks by increasing the importance of fire station locations that stimulate researchers' interest in emergency site selection.[2] Research on fire station location and space optimization has a long history of early work, [3] The key to analyzing firefighting systems is to first determine the optimal number of stations and their most effective locations to reduce damage. Helly[4] argued that the most important attribute of a fire station location should be minimal emergency response time, this factor was used as the basis for the fire department site selection model [4], later which was later developed by Plain and Hendrick [5]. Using the response time as the coverage criterion, we applied the location set covering problem (LSCP) theory to the site selection problem. Riley and Mirchandani, in later works [6] identified the two criteria of maximum and fastest response to potential demand points as keys to fire department site selection and incorporated the use of the p-median problem into their analysis [7]. Erden. et al. [8], and Pandav. et al. [9]. Analysis of site selection and optimization was conducted in different regions and cities using the Analytical Hierarchy Process (AHP) and the Geographic Information System (GIS) consecutively [10]. In 2020, there was a study by the researcher Mufeed Ehsan Shok about the distribution of fire stations in Baghdad. The study concluded that ‘the number of people served by the current coverage rate of fire stations are (1300000) or, (9.95%) and the rest is not served [11].

2- Methodology

Position science has a large body of literature that offers many applications and theories for study. These academic resources provide an opportunity to evaluate existing technologies and their applications. Using geographic information system technology, the distribution of fire station locations on the ALRussafa side of the city of Baghdad was studied to create a map of the ALRusafa area.

This approach provides access to high levels of identification of the detailed street network of the city of Baghdad, Rusafa, and precise determination of the fire station site, as well as the precise determination of the locations of government hospitals, educational institutions, ministries, and commercial malls. Geographical information system technology for evaluating distribution and conducting spatial analysis through a database of geographical information,

which was built using the ArcGIS program. It works as a mathematical model that determines the best places to establish new fire stations.

2.1- The optimal location model:

Using GIS techniques to create a model using spatial analysis tools, we can find the best place to build a new fire station based on many criteria, which we will refer to later.

Step one (Input Datasets): Many criteria were considered when choosing the best place to set up a fire station. Among the most important of these criteria are the locations of hospitals, commercial malls, government institutions (ministries), and educational institutions, in addition to where, in the first stage, the distribution of these criteria is studied in the Rusafa area. Figure (1) represents the locations of the Baghdad Al-Rusafa fire stations.

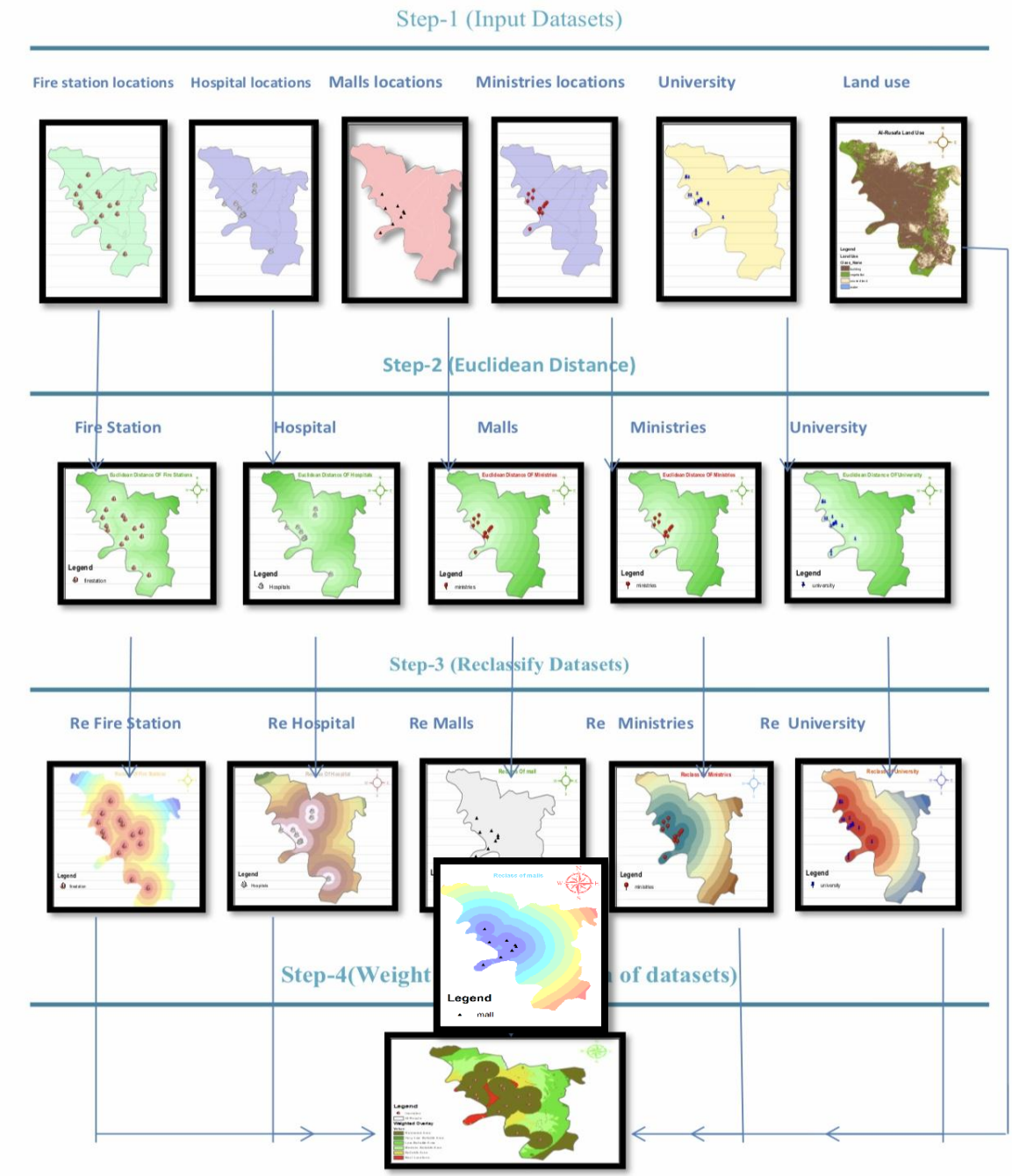

Figure 1: Optimal Selection of Fire Station Locations

Table 1: (Fire stations location)

Stations	Longitude	Latitude
Al-Karrada	44.44038	33.3017
Al-Zafaraniyah	44.478	33.239
Al-Madain	44.525	33.2195
Al-Shorja	44.3971	33.339
Al-Adhamiya	44.3816	33.3725
Al-Sheikh Omar	44.3935	33.3505
Al-Shaab	44.4166	33.4227
Al-Binok	44.3927	33.3934
Al-Baladiyat	44.4802	33.3434
Al-Kamaliyah	44.5032	33.3499
Zionh	44.4563	33.3178
Al-Moalimien	44.5024	33.3224
Al-Sadir	44.4449	33.3773
Al-Habibiiya	44.4512	33.3679
Al-Karrada	44.44038	33.3017
Al-Zafaraniyah	44.478	33.239
Al-Madain	44.525	33.2195

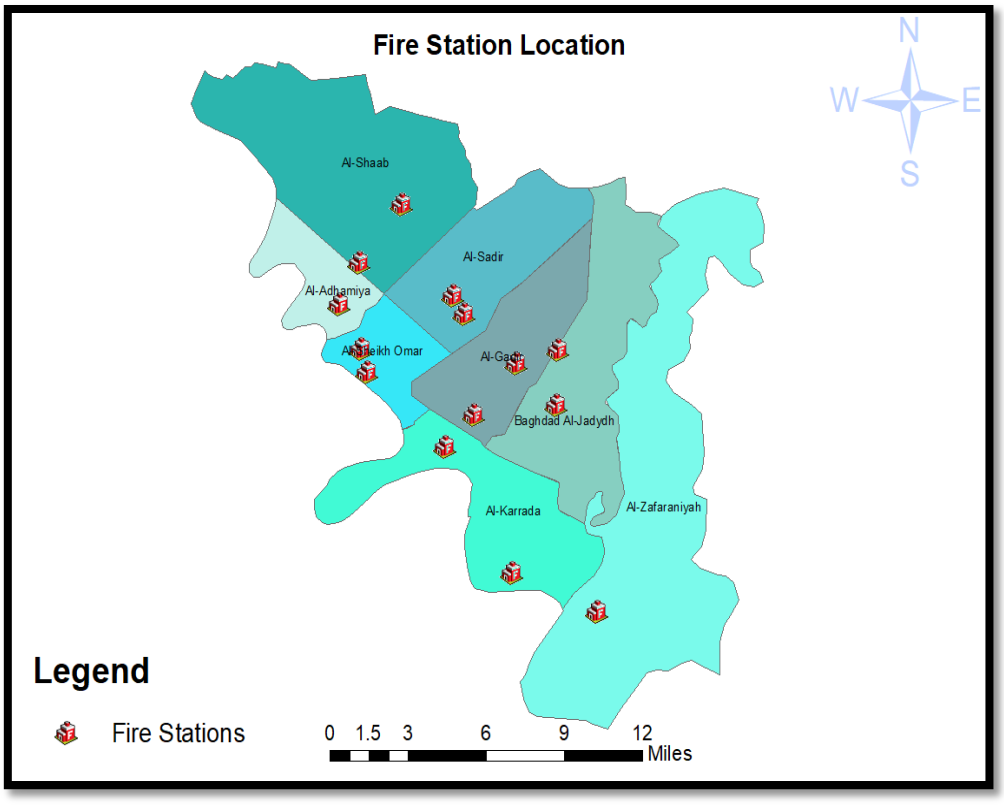

Figure2 : Fire Station Distribution in the study area.

In the same way, the locations of other factors (hospitals, commercial malls, government institutions (ministries), and educational institutions) were studied. These were used to determine the best new fire station location.

Also, in this step, we will study land use within the study area by using images from Landsat 8 in 2022, where it appeared according to Figure. (3)

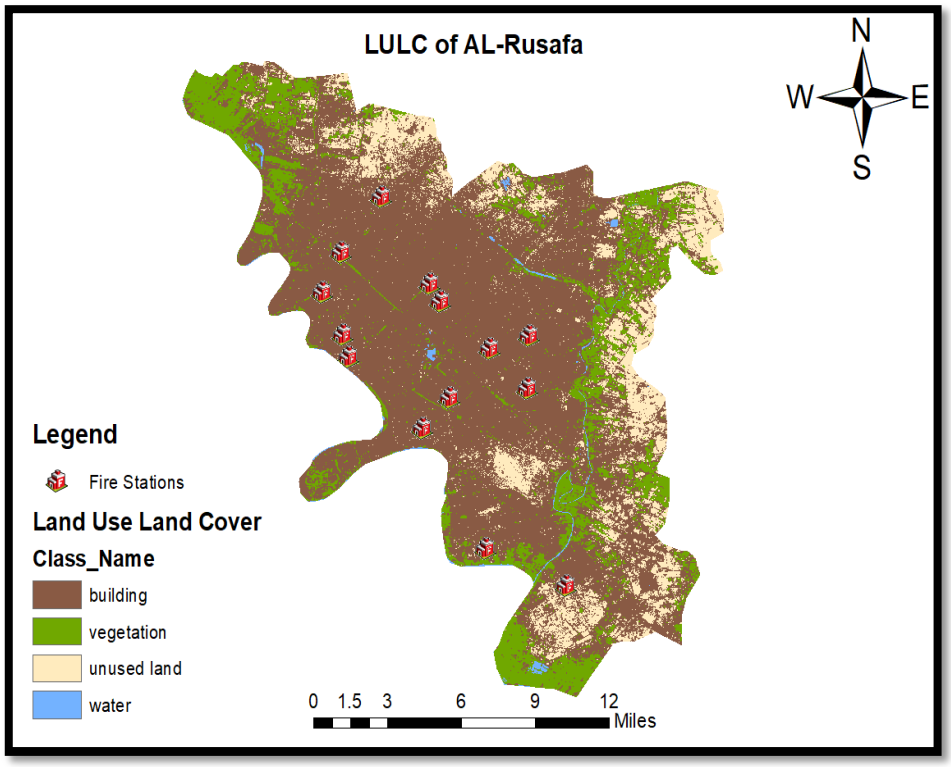

Figure 3: Land use in Rusafa

Figure (3) shows that there are four types of land use: brown represents building area, green represents vegetation, unused land is represented by sand, areas covered by water, represented by blue are considered restricted areas where no buildings can be built above the water. Each category has a certain weight of preference in choosing a suitable location, the following percentages (were given out of ten) of influence (weights) were given: (The Building: (06 of 10), Vegetation: (05 of 10), Unused Land: (08 of 10), and the Water is restricted).

Step two (Euclidean distance, Reclassify dataset) :

The Euclidean Distance tool describes each cell's relationship to a source or set of sources in terms of straight-line distances. The Euclidean distance from each cell to the nearest source is calculated. The study area was divided into several parts according to the distance between the elements, as shown in Figure (4). The light green color represents the areas closest to the malls. The color gradient represents the areas according to their distance from those features, while the darker color represents more distant areas.

In the same way, the Euclidean distance was calculated for the hospitals, universities, ministries and fire stations. Then we separately reclassify each Euclidean distance

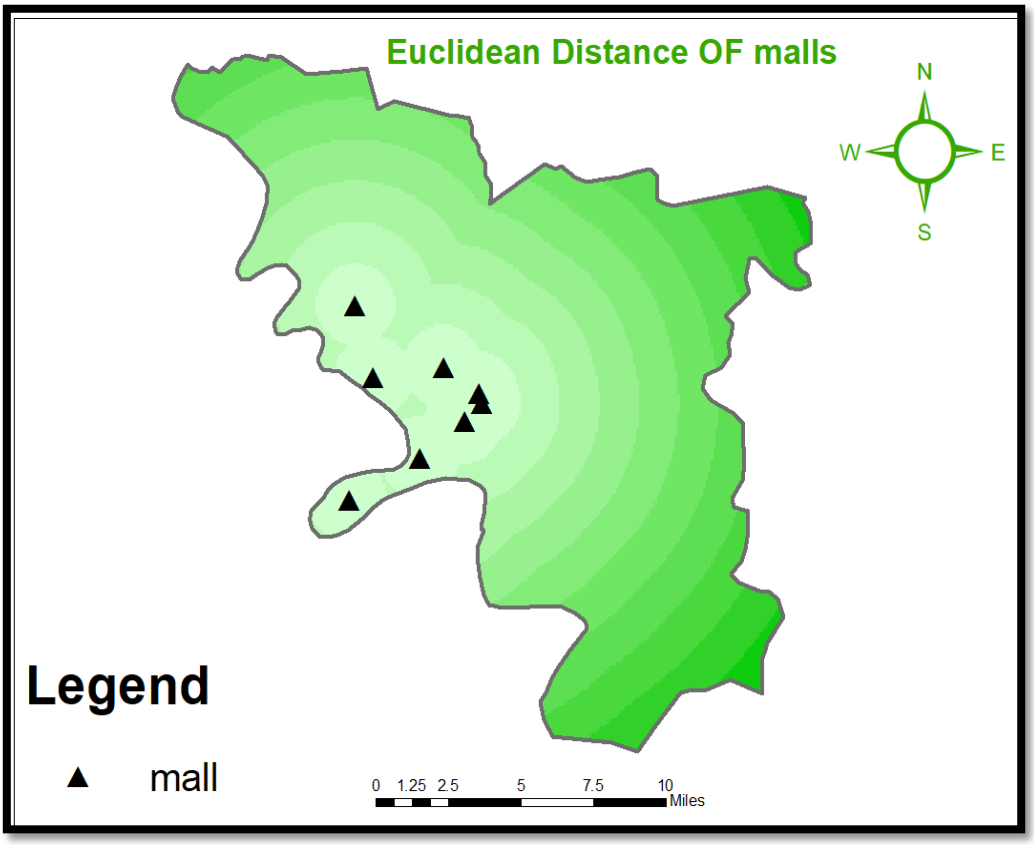

Figure 4: The Euclidean distance of the malls.

For example, areas with a distance of (0 - 0.039399716) from the locations of the malls in the Euclidean distance will represent number (1) when making a reclassification, and the distance that follows will be represented with (2), and thus the other areas a according to the distance of features.

After performing the Euclidean distance for all the criteria mentioned, a reclassification procedure is followed for each of them, and by reclassification we mean to rename each distance after dividing the distances into 10 categories from 1 to 10- see Figure (5)

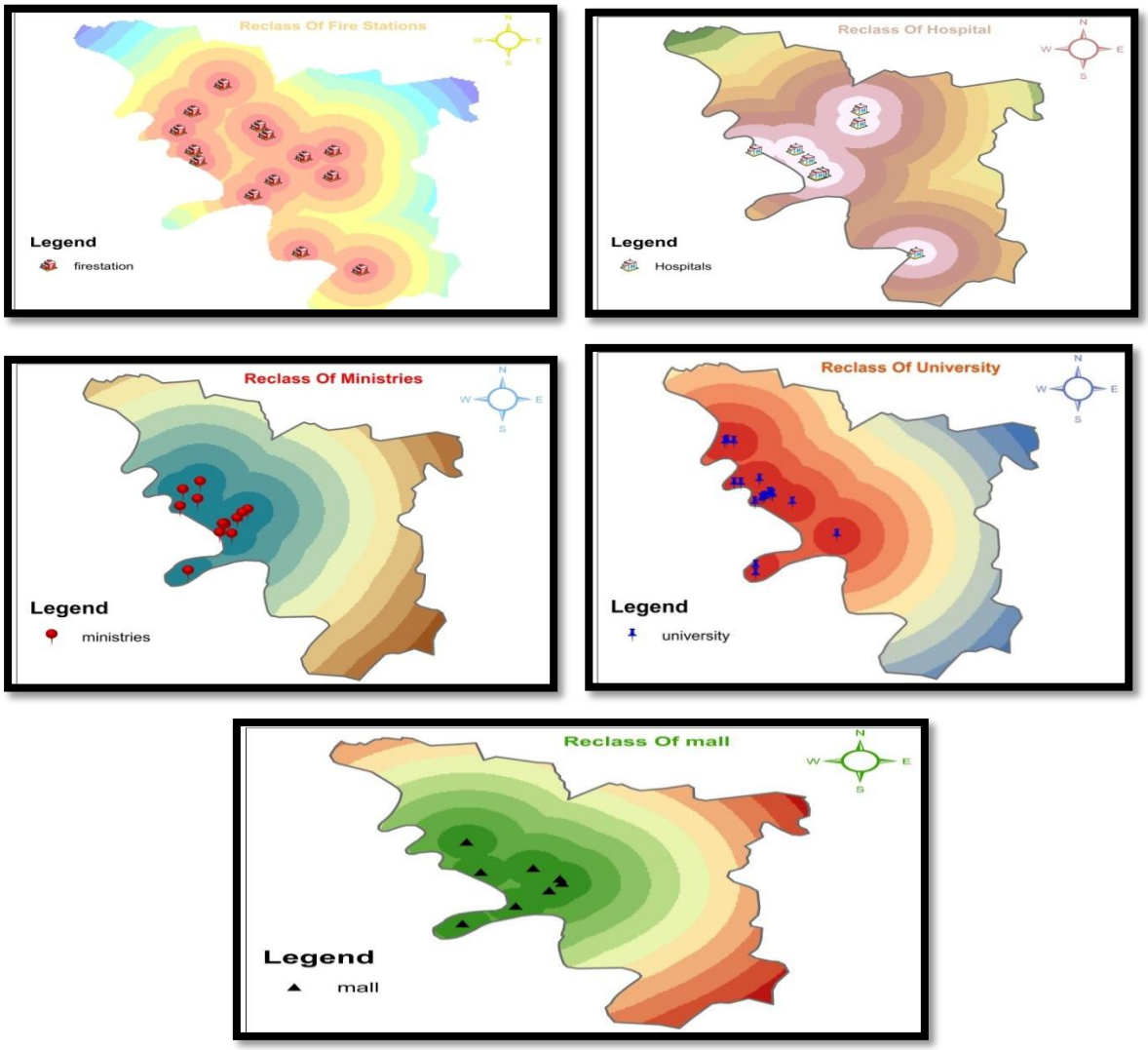

Figure 5 : Reclassification of fire stations, hospitals, ministries, universities, and malls.

Step 3 (Spatial Analystis):-

As discussed in the criteria section the weighted overlay tool can calculate multicriteria analysis between multiple rasters based on their importance. For example, the distance between fire stations, hospitals, shopping malls, government agencies (ministries), and educational institutions is given a value, and land use is weighted and added up to obtain the attractiveness value (suitability of location). The attraction value is between 0 and 10. A zero value is assigned; a zero value is assigned to restricted locations. Positions with higher values are more appropriate than positions with lower values.

Following the percentages of influence (weights),

•Distance to the fire station: 20%
•Distance to hospitals: 30%
•Distance educational institutions: 10%
•Distance to commercial malls: %17
•Distance to government institutions: 15%
•Land use: 8%

Figure 5 represents the weighted overlay product, where red areas are the best areas to build a new fire station, while yello areas are considered suitable areas. Thus the other regions are divided according to importance. Dark olefinite color areas are considered restricted areas.

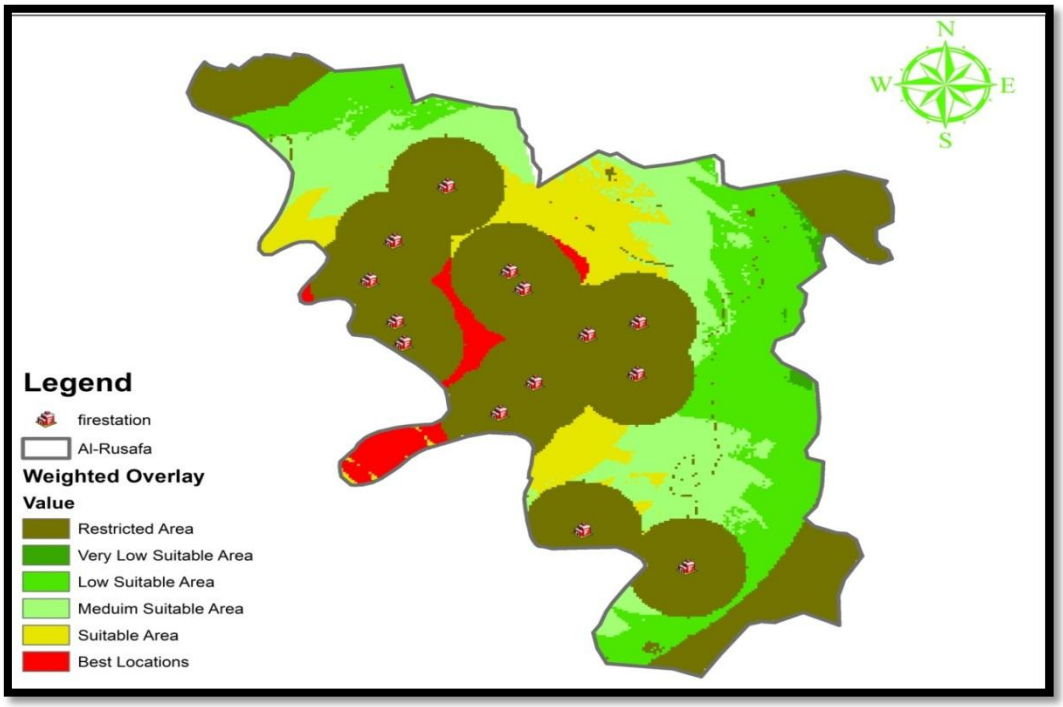

Figure 6: the best areas to set up new fire station.

2.2 Conditional Weighted :

Then we perform conditional weighting of the above map, which is simply extracting any value or class from the raster, so we choose value 6, which represents a red color in Figure 5, which is one of the best areas suitable for building new fire stations. These areas were determined by weight overlay based on the criteria mentioned earlier. Then wemake a major filter of the conditional weight raster, which means that it replaces grid cells based on the most adjacent cells. In Figure 6 the area with green colors represent the conditional weight and product of the majority filter process and are considered the most important areas to achieve the desired goal.

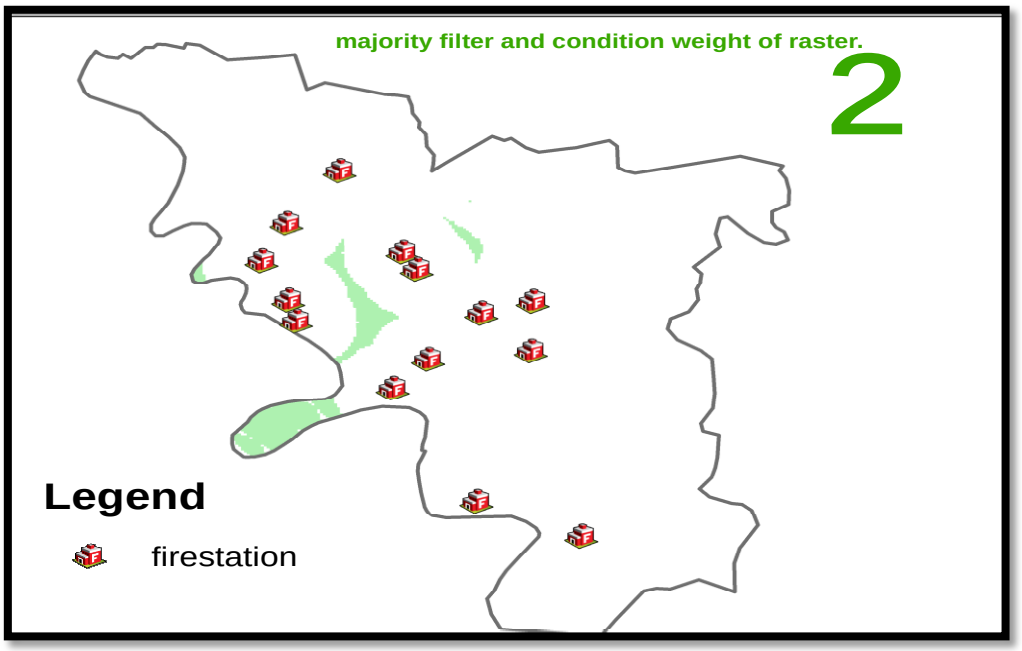

Figure 7: Majority filter and condition weight of raster.

Since the best suitable places have been identified, it has become necessary to know the relationship between those places and the main roads and to choose the closest ones to the main roads. A road network has been drawn in Rusafa, and then areas that are located at a distance of five meters from the road are preferred, show Figure (8)

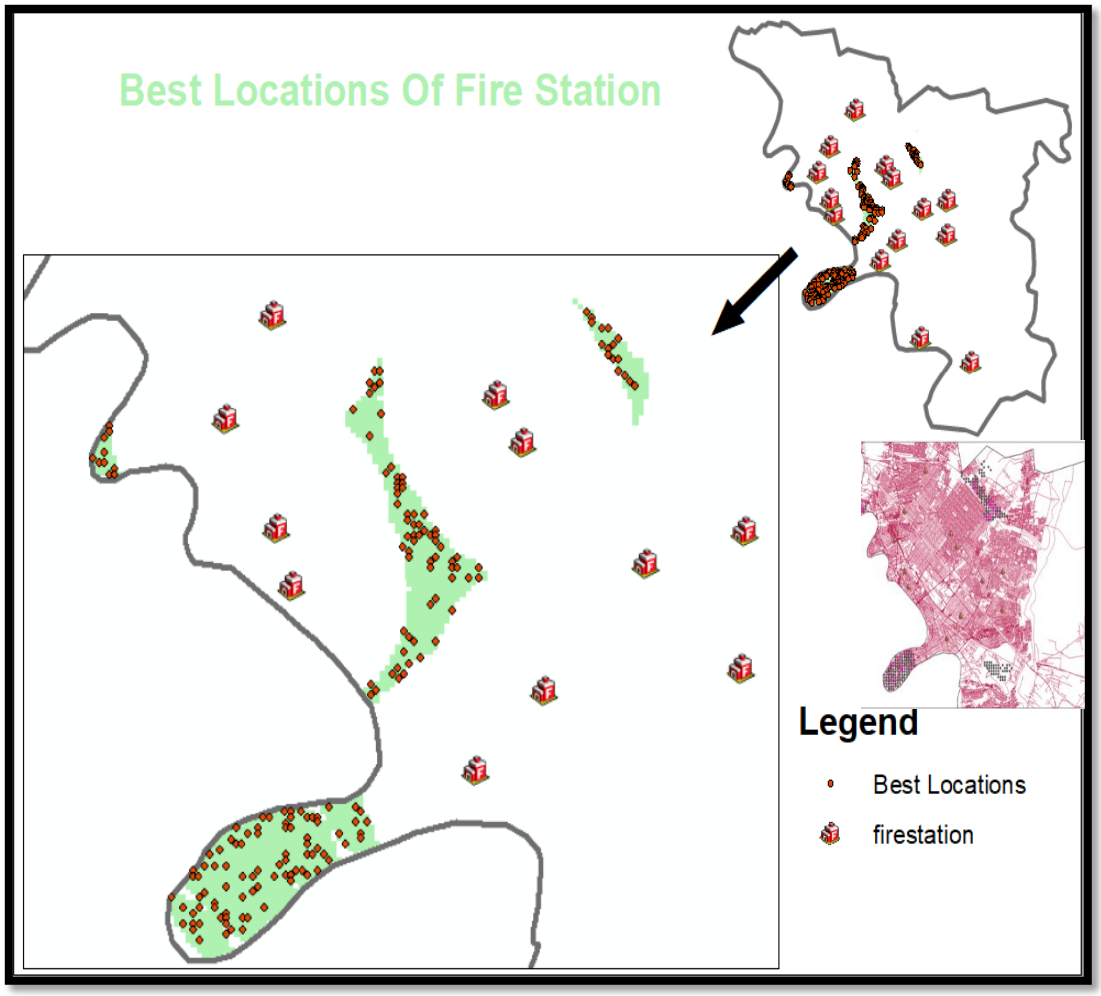

Figure 8: The best locations of new fire stations.

First, we convert a raster dataset to point features. A point is created in the input raster dataset's output feature class for each cell. points are positioned at the centers of the cells to which they are represented. Then, identify the points near the main roads. In Figure (8), the points in pink are closest to the roads, so they are the most appropriate among the other points.

3- Conclusion:

This research focused on evaluating the best locations for establishing a fire station. The results were obtained with respect to the multiple criteria that were illustrated in the introduction. The main output of this research was the highlighted shortcomings in the presence and distribution of fire stations. The next objective of this research is to locate the best locations for new fire stations. The best and most suitable locations were Al-Karrada, Al-Sadr City, and Al-Adhamiya. with admiration to our criteria. The results demonstrate that the GIS program is very useful in choosing the best locations. the designed model succeeded in achieving the desired goal. The construction of the model made it possible to shorten many steps in one step, and all the standards adopted through it were of high importance.

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