Measuring Accessibility to Health Care Centers in the City of Al-Mafraq Using Geographic Information Systems

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Abstract
This study aims at measuring, analyzing, and evaluating accessibility to health care centers in the city of Al-Mafraq in order to determine their distribution efficiency and their spatial suitability for residential neighborhoods in the city using geographic information systems. It also aims at analyzing the geographical characteristics of the health centers locations in the city and determine their service ranges at the level of the residential neighborhoods in the city (Service Areas, Closest Facility, Location-Allocation, Multiple Ring Buffers). The study found that there is a significant difference and disparity in the ease of access to the health centers in the city of Mafraq. Most of the residential neighborhoods on the outskirts of the city suffer from difficult accessibility to the health centers such as the Industrial City, King Abdullah, Prince Hamzah and Al-Mazzeh neighborhoods in the south; and, Al-Nasr and Al-Jundi neighborhoods in the north. The study also found that the locations of Al-Hussein neighborhood health center and the Southern neighborhood health center were the easiest to reach compared to the other health centers in the city based on the distance and time factors. This research contributes to a better understanding of the geographical accessibility of the population to health care center, helping to identify polarization trends. The results obtained can help decision-makers develop urban planning strategies and optimize investments in health care infrastructure. Future studies will consider the use of other means of transport and other time slots.

Keywords: Accessibility, Geographic Information Systems, Health Care Centers, Al-Mafraq

1. Introduction

The processes of growth and development in cities over time lead to changes that directly affect accessibility to various services and activities for the urban and suburban population as accessibility is a fundamental goal in urban transport planning. The structure of transport networks and their carrying capacity directly affects levels of accessibility or ease of access from one place to another. Thus, geographic information systems are widely used in this field, depending on spatial and network analysis [1].

The distribution and organization of services is one of the main goals in urban constructional planning, because of its direct relationship with serving the city's population, meeting their living needs, and facilitating their access to these services [2]. Transport contributes to the linkage between these services and the beneficiaries. Health services differ in their need for transportation; primary health care centers do not require a long journey due to their spread and abundance, while hospitals that are usually fewer in number and more distant need a long journey, especially for residents of rural areas. Thus, accessibility to health services is a vital and indispensable requirement for the population [3].

The use of geographic information systems helped to overcome many of the obstacles faced by previous studies that dealt with measuring the accessibility to public services through traditional methods due to the high potentials of this system represented in the speed and accuracy of measurements and accurate representation of elements of the urban environment such as housing sites, job opportunities, data processing, statistical analysis and graphic representation. This allowed researchers to model the spatial relationships of these elements [4]. Under the current conditions surrounding Jordan which are represented by crises, wars, and political unrests in the neighboring countries, especially the Syrian crisis; Jordan witnessed an influx of large numbers of refugees from these countries and their settlement in the main cities [5]. The city of Al-Mafraq was one of the

Jordanian cities that received a large percentage of refugees due to its location close to neighboring countries and the presence of the largest camp in the Middle East in it, Al-Za'tari Camp. Not to mention the high population density in the city, given that it is the center of the governorate, which led to increased pressure on health services and consequently the emergence of problems related to accessibility, among of which are: long arrival time, high cost, and multiplicity of means of transport used by patients in their journey. Such problems created a state of spatial disharmony among those services. Thus, this study seeks to achieve the following:

1. Analyzing and evaluating the accessibility of health centers as an indicator of their spatial distribution efficiency for the residential neighborhoods in the City of Al-Mafraq, using spatial and network analysis in GIS.
2. Determining the ranges of health centers services at neighborhood level in the City of Al-Mafraq.
3. Analyzing the geographical characteristics of the health centers locations in the City of Al-Mafraq and determining spatial levels according to accessibility.
4. Studying the spatial distribution of health centers in the City of Al-Mafraq and the extent of their efficiency and suitability.

2. Literature Review

Previous studies have shown that spatial accessibility to different types of services of general interest influences, sometimes quite strongly, the addressability of the population to that service. For example, study accessibility and its role in evaluating land use and transportation strategies using a set of criteria including the transportation component, the land use component, the time component, and the individual component. The study showed the importance of addressing these criteria and taking them into account when studying accessibility and presenting results to the decision makers [6]. Analysis the urban road network using geoinformatics techniques in the city of Solapur, India. The study aimed at evaluating the efficiency of the urban road network in accessing public services, including hospitals, and determining the range of the services and the optimal path to reach them. The study showed the importance of geoinformatics technologies in planning public services and facilities and monitoring the urban environment. The study also indicated that the city suffers from a significant shortage of public services and facilities [7]. Geographical information systems were used to measure the accessibility to public services in the city of Hilla in Iraq, including commercial, administrative, educational, health and industrial services. The results showed that educational services had the highest degree of accessibility, followed by the commercial and administrative services with a slight difference, while the health and industrial services were the most difficult to reach [8]. Study the accessibility of public services in the city of Nablus, Palestine, with the aim of identifying these services' status quo and assessing their efficiency. The study found that educational services were the easiest to reach, while hospitals, public libraries, banks, and post offices were more difficult to be reached due to their remoteness, traffic congestion and lack of transportation [9]. A study on the analysis of accessibility of the roads network in Al-Qassim region in Saudi Arabia by calculating the number of direct connections between urban centers and the number of nodes between each two major nodes. The study concluded that the road network in the region is capable of contributing to economic development and reducing distances between major urban centers [10]. A study on accessibility assessment in Sana'a city using isochron maps. The study relied on time to measure the accessibility between the city center and its outskirts in an attempt to identify the causes of low accessibility in the city and then develop a plan to address these causes [11]. A study the obstacles of accessing recreational facilities for Saudi women in the city of Jeddah, using the one-way analysis of variance (ANOVA) and the Scheffe' Test a field sample. The results showed that access constraints to recreational facilities are due to the presence of impacts related to the characteristics of the sample and others related to the locations of recreational services [12]. A study used seven categories of accessibility measures: spatial separation model, contour measures, gravity measures, competition measures, time-space measures, utility measures, and network measures; as well as the rules that govern each of these categories [13]. The geographical assessment of the spatial accessibility to health services in Kafr El Dawwar countryside in Egypt using the GIS. The study concluded that some towns such as Zahra, King Osman and Abis Al-Mustagida are the easiest to reach the Central Hospital in Kafr El Dawwar while the two towns of the Tarh and Sidi Ghazi are the most difficult to reach [3].

The Concept of Accessibility; there are multiple definitions due to the variation in the fields of using the concept of accessibility and the multiplicity of factors affecting it. Simmonds [14] defined it as the amount of ease that enables a specific type of individuals to reach a specific set of goals destination (D) starting from specific origins (O); as different groups have different levels of accessibility. Hansen [15] considers it a measure of the potential ability of opportunities to interact with one another. While Dalvi and Martin [16] see it as the ease of accessing various activities from any site using a specific transportation system. Burns [17] considers it a measure of individual's freedom to make the decision to communicate with different activities. Litman [18] defined it as the possibility of access to goods, services and various activities, which in total are called "opportunities" and which are affected by three factors: mobility, land use accessibility and alternative means such as communication and delivery services. From an economic point of view, Ben-Akiva and Lerman [19] define it as the benefits that can be gained from the transportation and the land-use system. Ross [20] sees it as the cost of access measured by the time or distance of arrival.

Through the above set of definitions, four important main elements that are included in the concept of accessibility can be identified, as shown in Figure 1. These components are represented by the following elements:

1. Land-use (spatial distribution of activities and events): It represents the available opportunities, as the presence of a school or university represents an opportunity for learning and the presence of a hospital or health center an opportunity for treatment ... and so on.
2. Transportation (road network and transport means): It is related to the concept of access represented by the possibility of using the road network, and the concept of mobility represented by the qualitative value of the movement on the network, which is measured through service level, rate of speed and operational capacity.
3. The social, economic, and physical characteristics of individuals: social characteristics are related to indicators of social affiliations, educational and health level, and others. Economic characteristics are related to indicators of income levels, vehicle ownership and others. Physical characteristics are related to indicators of age groups and factors affecting mobility.
4. The temporal component of the service or activity availability: It is related to the amount of time during which the service is available as well as its timing during the hours of the day. As there is variation in the time periods of the various activities; For example, government activities are available in periods that differ from periods of commercial or recreational activities.

5.

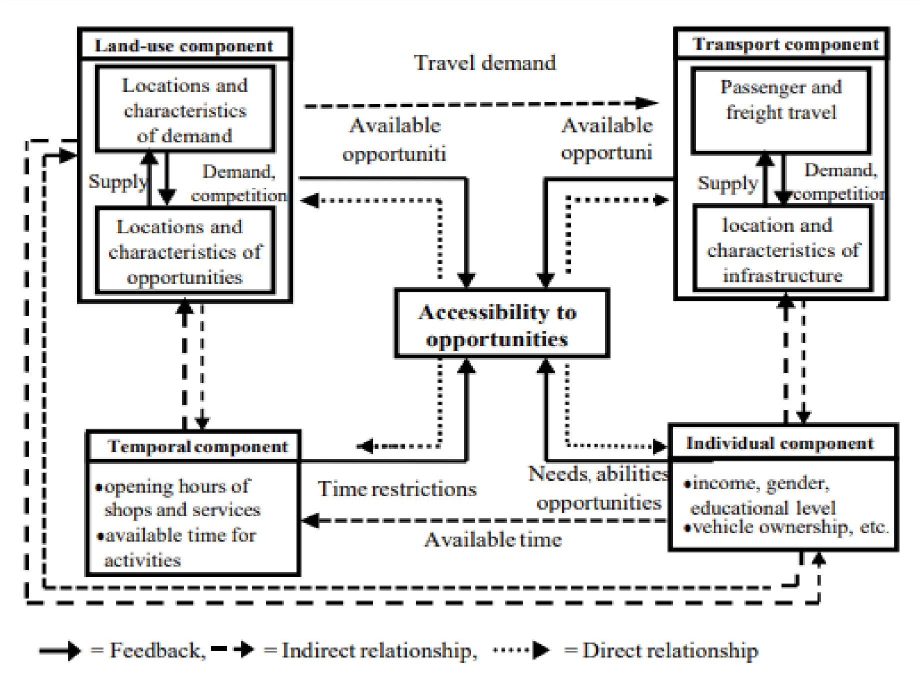

Figure 1: Accessibility Components [6]

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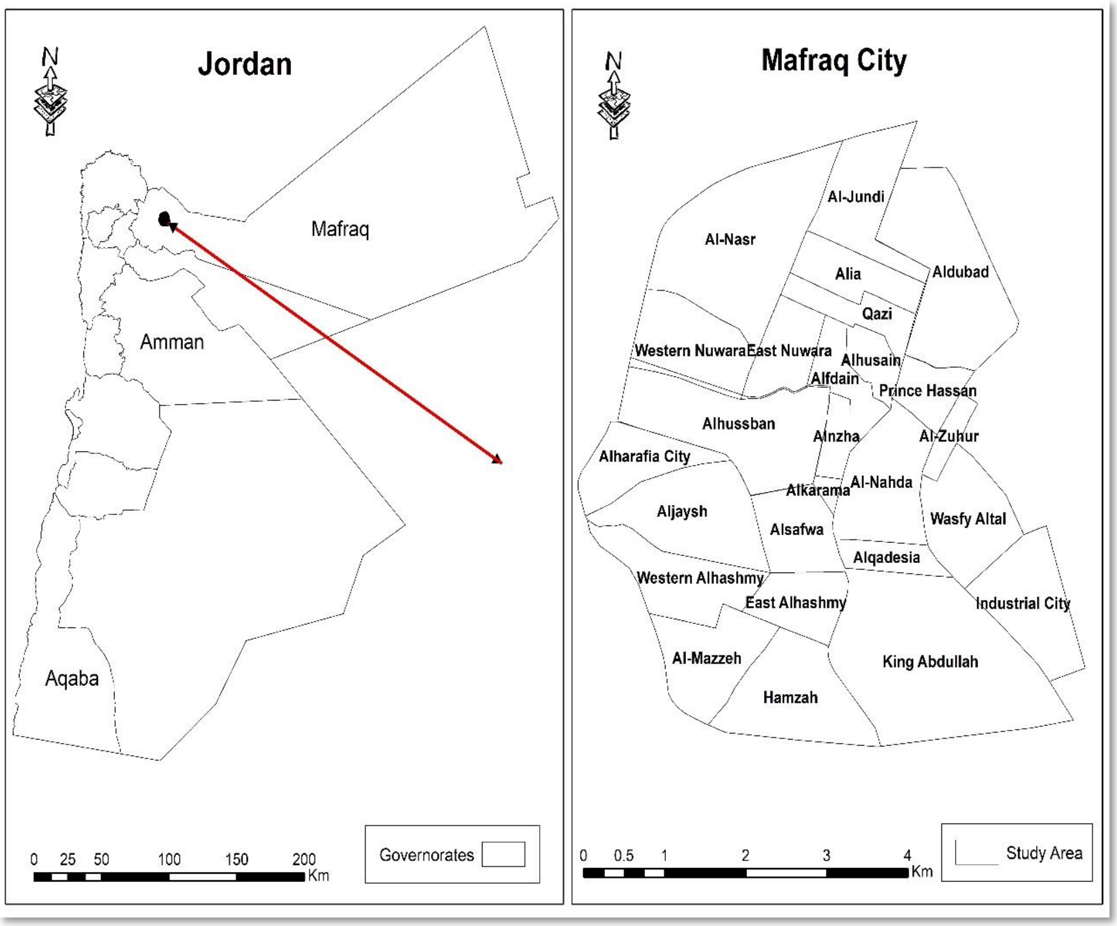

Figure 2: Study area and neighborhoods boundaries

3. Study Area

The city of Al-Mafraq is located in the northeastern part of Jordan, about 69 km away from the capital, Amman. It extends between longitudes 36° 16′12″ - 36°12′ 36″ E; and latitudes32° 18′ 36″ - 32° 21′ 49″ N. It consists of 26 residential neighborhoods, as shown in Figure 2. It was called "Al-Mafraq" because of its location at the international crossroads heading to Syria in the north, Saudi Arabia in the south, and Iraq in the east. The importance of the city is due to being one of the oldest commercial stations on the Levantine Pilgrimage Road and a link point with the rest of the region. Moreover, the Trans-Arabian Pipeline which used to carry Iraqi oil from Kirkuk to the ports of Haifa in Palestine, passes through the city of Al-Mafraq, which formed the first nucleus of the population centers in it. Later, Al-Mafraq became one of the main stations on the Hejaz Railway.

The city of Al-Mafraq played a historical role in the Islamic era, as it was the main route for the Levantine Pilgrimage and became one of the main stations in the Ottoman Empire on the Hijaz railway. Since 1945 AD, the city began to push forward the process of local development, and it witnessed a comprehensive service development renaissance that had the greatest impact on changing the features of life in the city for the better.

4. Methodology and Data

The study adopted the Systems Analysis Approach in analyzing data and creating maps and analyzing them using GIS. There was more emphasis on spatial analysis and grid analysis which include the quantitative procedures used in analyzing locations. The researcher aimed at understanding the spatial organization of spatial phenomena and finding a solution to a problem through knowing, understanding and interpreting the patterns and relationships of the natural and human geographical phenomena, depending on the measurement, classification, arrangement, spatial circumferences, and surface analysis [21].

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The descriptive and analytical approach was also adopted through its multiple fields of studying represented by mutual relationships, causal relationships, interconnectivity, and others to achieve the objectives of the study in order to identify the most important problems arising from the transport system [22]. It must be noted that the study tool used in the analysis, evaluation and determination of accessibility patterns was represented by the applied capabilities of GIS, especially the tools of spatial analysis and network analysis. Those tools were used in proximity analysis, structure analysis, service range, and the shortest path, which would reveal results that raise the knowledge and methodological level of applied transport geography.

It is worth noting that the study was based on official data issued by the Ministries of Health, Transport, Municipalities, Public Works and Housing, the Department of Statistics, and the Royal Geographical Center. Also, 2014 satellite visuals QuickBird for the study area were used, with a distinct accuracy of up to 0.5 m, in addition to a base map for the city prepared by the Royal Geographical Center, showing the local road network, residential neighborhoods of the city, and the boundaries of each neighborhood as shown in Figure 3.

4.1 Procedures

4.1.1 Entering spatial data

Uploading the satellite visual to the GIS program (Arc Map 10.2) in order to convert it from Raster format to Vector format. Matching the base maps issued by the Royal Geographical Center with the satellite visual to ensure the validity of the road network, the neighborhood boundaries, and the health center locations prepared by the Royal Geographical Center. Determining the Geometric Centroid for each residential neighborhood through the feature to point tool, to be used later in measuring distances from health centers, as it is considered the origin of the trip and a representative of the geographical location of the population. Through the command (Calculate Geometry), the X and Y coordinates of the Geometric Centroid of each residential neighborhood were found.

4.1.2 Entering metadata

The data that will be utilized later in measuring the accessibility at the level of the residential neighborhood, such as neighborhood names; population numbers; neighborhood area; geometric centroid coordinates; road names, lengths, speeds, types and directions; in addition to health centers names, their coordinates, etc.. Other fields can also be added that represent results of mathematical or statistical operations that serve the objectives of the study.

4.1.3 Designing the map of the geographical distribution of health centers

To assess and measure accessibility from residential neighborhoods, which represent the origin (O) of the departure trips to the city of Al-Mafraq, the city's four health centers were selected, which represent the destination (D) of the trips. The locations of the health centers were determined on the road network map in the form of points, whose coordinates were determined through the GPS device, as shown in Figure 4.

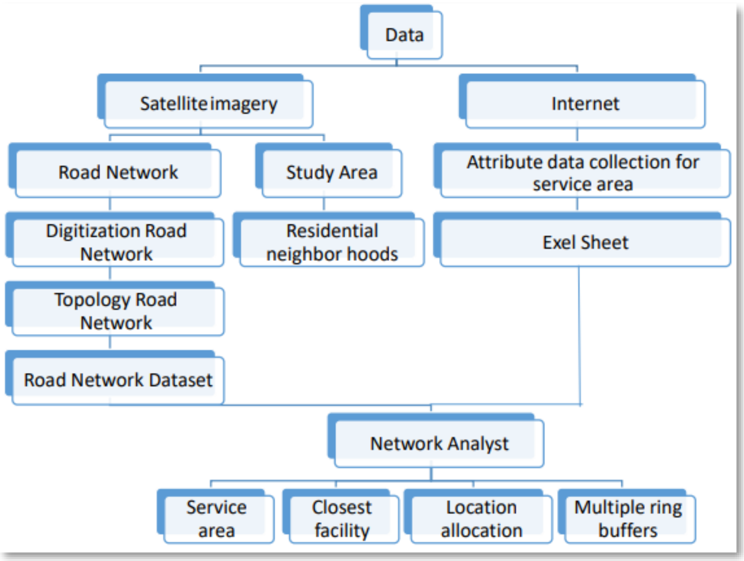

Figure 3: Research methodology

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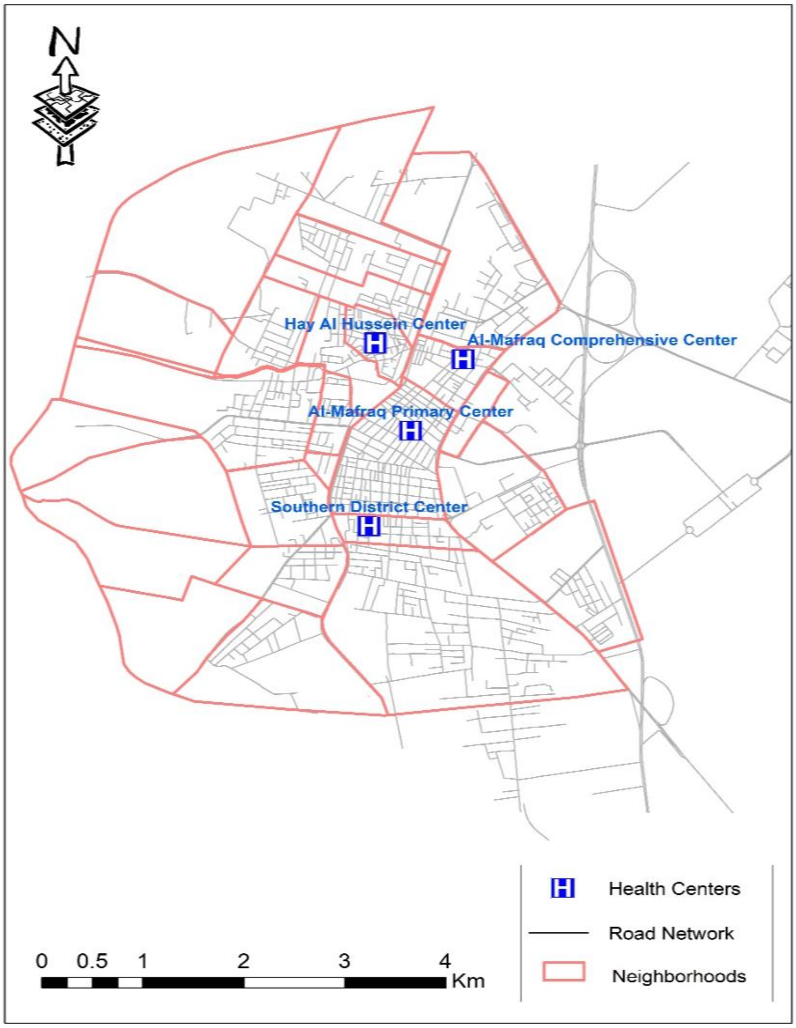

Figure 4: Road Network and health centers in Mafraq

4.1.4 Designing the road network map

The road network is an essential pillar in measuring accessibility, as all measurement methods using GIS depend mainly on it. Based on the road network base map from the Royal Geographical Center, the following procedures were performed:

1. Designing a Geodatabase within ArcCatalog, which includes feature dataset that contains a set of feature classes represented by roads, city limits, and health centers locations, as they form the basis on which network analysis is based. Applying topology rules to the network before performing the analysis to verify the correctness of road network drawing in the GIS program.
2. Collecting the metadata of the road network, such as lengths, directions, speeds, names and other from various sources as shown in Table (1). Then processing and analyzing them by the GIS program, and drawing thematic maps of the road network and its variables.

4.1.5 Types of distances used to measure accessibility

There are four ways of expressing distance as shown in Figure 5. 1. Euclidean distance, which represents the direct distance between the center of the starting point (O) and the point of the arrival area (D). 2. Manhattan distance, which represents the distance along the two straight sides opposite the hypotenuse (the direct distance). 3. The shortest distance on the road network (shortest network distance) between the center of the starting point (O) and the center of the arrival point (D) and the shortest network time taken for the distance between the center of the starting point (O) and the center of the arrival point (D) [23]. The method used in this study is the shortest network distance method, which is considered the most accurate, but requires the availability of electronic data files for the road network.

Table 1: Attributes of road network

Field name	Type	Description
Name	Text	Road name
Type	text	Main; Secondary
Length	short	Length of the road in meters; by Calculate Geometry
Speed	short	Speed on road Km/h; by Field Calculator
Trip time	short	Time taken on the road; by Field Calculator
Direction	short	The road direction, the roads drawn with the direction of traffic took the symbol FT, the opposite took the symbol TF, and the two-way roads took Null.
Height	short	Bridges and Tunnels

Figure 5: Methods for expressing distance [23]

Based on the Network Analyst the GIS, the available data, and the suitability of the method for measurement, three methods were chosen to measure accessibility, which are:

1. Finding the service area of health centers, this analysis is used to determine the range of a specific service by using the network analyzer tools. The service area is defined as the area that includes all the streets that connect between health centers and demand points and can be reached within a certain time or distance. The service areas created by the network analyzer help to assess accessibility. The concentric service areas show the extent of the difference in reaching depending on the difference in Impedance [24], where the distances (500m, 1000m and 2000m) from the center of each neighborhood were adopted.
2. Finding the closest service for each neighborhood, this analysis is used to find the closest service for a group of areas, and the best pathways between them based on distance, cost, and time factors [25].
3. The Location-allocation model, the importance of this analysis lies in identifying the locations of the facilities that provide services to the demand points which represent the population in a manner that achieves the greatest efficiency [26]. The location allocation model aims to represent the spatial relationship or spatial interaction between a group of demand sites and a group of service centers with the aim of achieving the best compatibility of the spatial relationship or interaction between the two groups [27]. The process of determining the spatial relationship or interaction depends on the characteristics

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associated with the road network, such as time and distance, and therefore the main goal of this analysis is to reduce the distance between the demand sites and the service sites [28].

4. The Multiple Ring Buffer test, the multiple ring buffers in GIS are represented by the borders that surround one of the geographical phenomena on the map (Point, Line, Polygon) with equal distances starting from those phenomena, so that the map separates two types of areas, one of which is located within a specified distance called the (buffer zone) which expresses a specific event, and the other falls behind it.

5. Results and Discussions

5.1 Finding the Service Areas

This analysis was conducted and applied to all health centers in the Al-Mafraq City, as shown in Figure 6. Determining the range of service for health centers helped in determining the residential neighborhoods covered by the service so that the maximum distance to reach the health center does not exceed 2 km, which is the value adopted in this study. There is no doubt that the range of distances traveled from the residential neighborhoods towards the health centers varies. The area of coverage varies according to the specified value, as three distances were specified: 500 m, 1000 m, and 2000 m. Thus, there are three zones appear around each health center with different colors depending on distance. This figure gives a good insight that most residential neighborhoods are covered by health service within the specified distance criterion, as the percentage of the area covered by the health centers according to the distance criterion (2000 m) is about 69% of the total area of the City (29 km). It is noticed that most residential neighborhoods that fall outside the scope of service within the specified criterion are located on the outskirts of the city, particularly in the northern and southern parts, specifically the Industrial City, King Abdullah, Prince Hamzah, and Al-Mazzeh neighborhoods in the south, and Al-Nasr and Al-Jundi neighborhoods in the north.

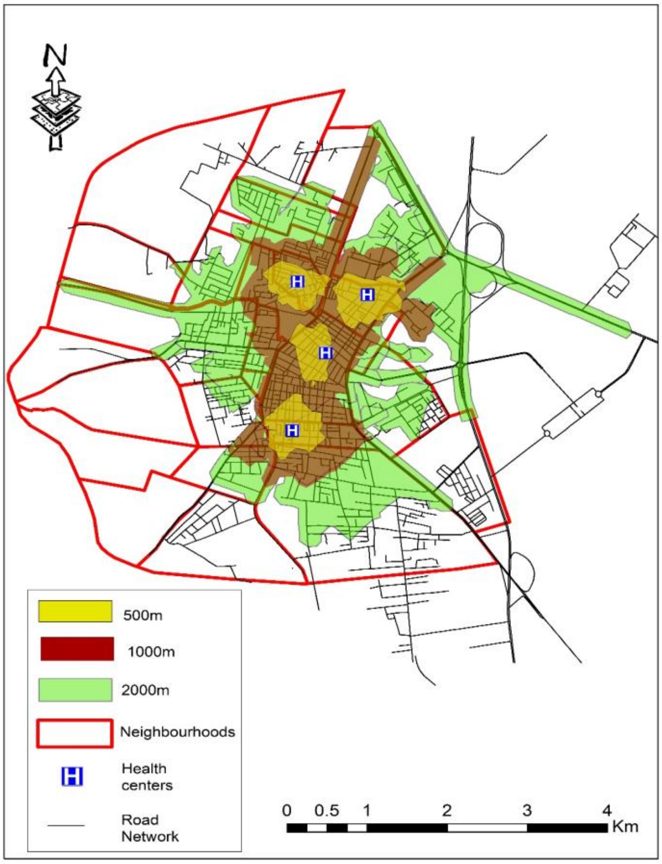

Figure 6: Health centers service area within a distance (500m, 1000m, and 2000m)

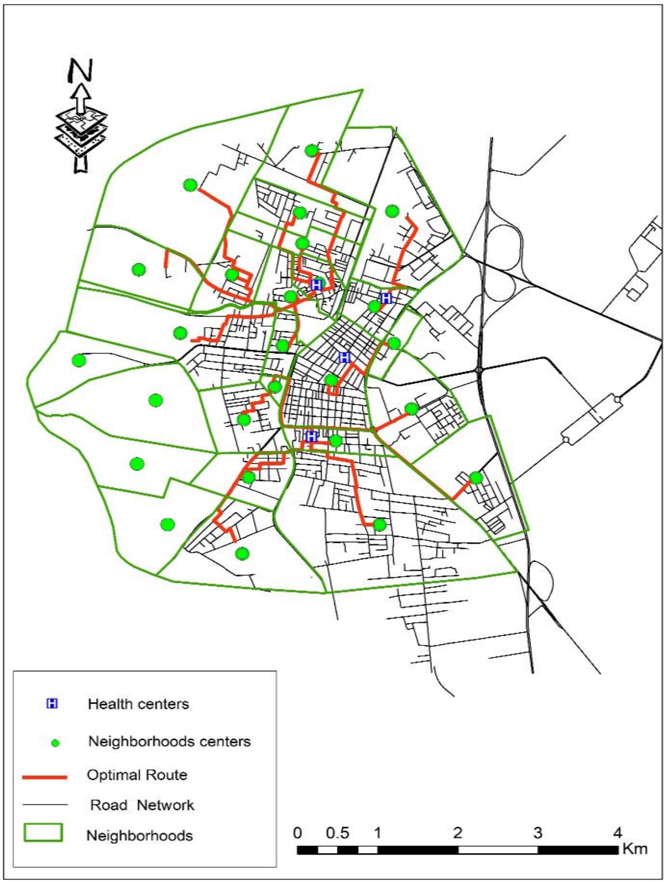

Figure 7: Outputs of the Closest Facility Analysis

5.2 Finding the Closest Facility

The closest facility analysis was applied to find the closest health center to the neighborhoods centers in Al-Mafraq. The importance of this analysis lies in reducing the distance, time, and costs, especially in emergency situations such as traffic accidents. Through this analysis, the nearest health center is determined for each residential neighborhood, as shown in Figure 7.

Based on the outputs of the analysis of the closest facility, it appears that the locations of Hay Al Hussein Health Center and the Southern District Health Center were easier to reach than the locations of Al-Mafraq Comprehensive Health Center and Al-Mafraq Primary Health Center, where the Al Hussein Health Center and the Southern District Health Center are the closest to most residential neighborhoods based on time and distance. Al-Hussein Health Center was the closest and easiest to reach for ten residential neighborhoods and the Southern District Health Center was the closest and easiest to reach for eight residential neighborhoods in the city. In contrast, Al-Mafraq Comprehensive Health Center and Al-Mafraq Primary Health Center were the most difficult to reach for most residential neighborhoods in the city. We notice that Al-Mafraq Comprehensive Health Center was the closest to Al-Nahda and Prince Hassan neighborhoods only, while Al-Mafraq Primary Health Center was closest to Al-Zuhur and Al-Nahda neighborhoods, based on distance and time factors.

5.3 Location-Allocation

The standard response time or distance used in the analysis is one of the most likely factors that affect the performance of the location-allocation model in selecting the appropriate location and its accessibility. Naturally, the result from using different measures of time or distance will affect the optimal locations that were determined using this model. As each type of measurement may yield different results depending on the time taken or the length of the distance between the location of the service demand and the closest service provider facility.

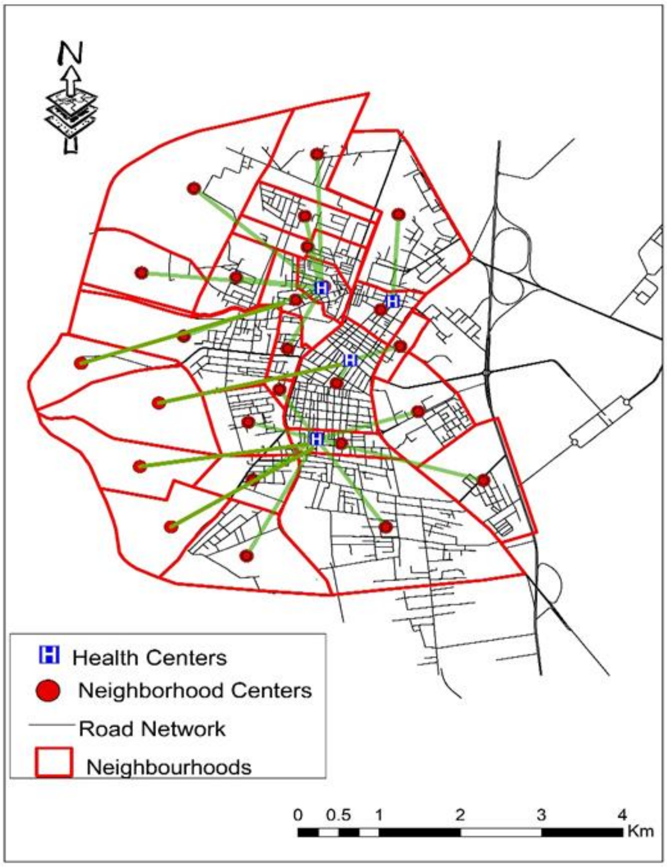

Figure 8: Location-allocation analysis form for health centers in Al-Mafraq city

After applying the location-allocation model to health centers in Al-Mafraq city, as shown in Figure 8, it appears that there is a clear discrepancy between the locations designated for health centers in providing health services based on the time factor that was set at 7 minutes. Hay Al-Hussein Health Center is ranked first in terms of its location in providing health services to residential neighborhood centers, as it covers about 10 residential neighborhoods. The Southern District Health Center is in second place, as it covers about 8 residential neighborhoods, while both of Al-Mafraq Comprehensive Health Center and Al-Mafraq Primary Health Center ranked last in terms of coverage, as they covered only two residential neighborhoods. We conclude that the accessibility of both Hay Al Hussein Health Center and the Southern District Health Center were the best compared to other health centers that include Al-Mafraq Comprehensive Health Center and Al-Mafraq Primary Health Center, and this result is consistent with the outputs of the analysis of the facility closest to the health centers in Al-Mafraq city that were reached previously.

5.4 Multiple Ring Buffers

Buffer zones were established around every health center in the city with a radius of 500 m, 1000 m, and 2000 m. Then, enumerating the number of residential neighborhood centers located within these ranges, as shown in Figure 9. By applying this analysis to the health centers in the city of Al-Mafraq, it was found that the first zone (500 meters) which is supposed to be more accessible to obtain service, contained only 5 residential neighborhoods. The second zone (1000 m) provided access to health service for about 12 residential neighborhoods. While the third zone which extended to a distance of 2000 m from each health center contained about 19 residential neighborhoods that could access the health service within this distance. It was also found that some residential neighborhoods located on the outskirts of the city are outside these areas, especially the northwestern and southeastern sides of the city, specifically the Industrial City neighborhood, King Abdullah neighborhood, Al-Nasr neighborhood and the western Nuwara neighborhood.

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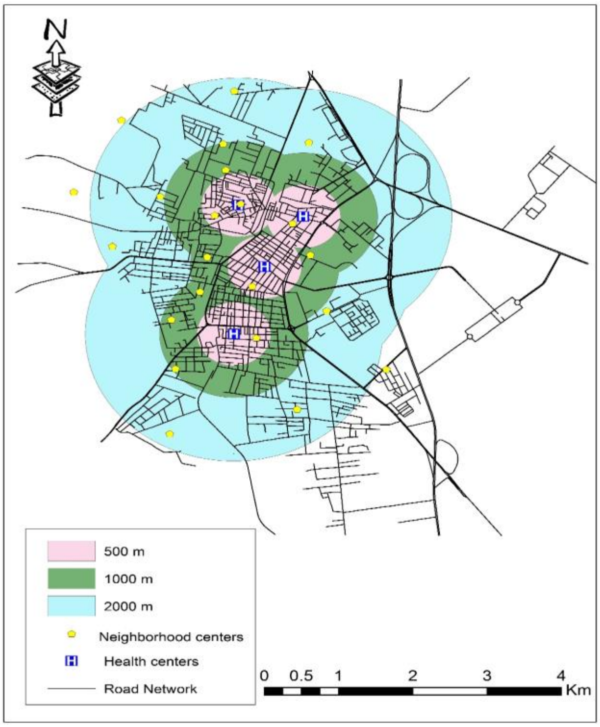

Figure 9: The multiple ring buffers of the health centers service in Al-Mafraq

Therefore, these neighborhoods suffer from difficulty in accessing the health service provided by the health centers. It must be noted that the results of this analysis are consistent with the results of the health centers service area analysis previously obtained using network analysis in GIS. Based on the foregoing, it is evident that most of the residential neighborhoods in the city of Al-Mafraq fall within the scope of the health centers services based on the time and distance factors, except for some residential neighborhoods located on the outskirts of the city.

Moreover, it was found that Al-Hussein neighborhood health center and the Southern neighborhood health center were the easiest to reach by the residential neighborhoods. It was also found that there was a discrepancy between the health centers' locations in providing the service based on the time factor according to the location-allocation model. In general, all residential neighborhoods were within 2 km of the existing health centers. Thus, this study was able to achieve its objectives in measuring and evaluating accessibility to health services in the city of Al-Mafraq using GIS technology.

6. Conclusion

In light of the analysis, research and evaluation conducted, it was found that the spatial distribution of health centers in the city of Al-Mafraq provides generally acceptable accessibility if compared to the distance standards adopted for these services, with a distinctive relative difference between them. It was found the importance of network analysis using GIS in assessing and measuring the accessibility to health services in particular and other public services in general, whose results can be adopted as a general indicator of the efficiency of the spatial distribution of services, and cannot be adopted as an assessment tool in isolation from other tools and criteria. The area covered by the health centers, according to the analysis of the service areas of the health centers and based on the criterion 2 km^2, about 69% of the total area of the city which is about 29 km^2. Most of the residential neighborhoods located on the outskirts of the city, especially in the northern and southern parts of it, suffer from difficulty in accessibility because they are outside the zones of the health service, specifically the Industrial City, King Abdullah, Prince Hamzah and Al-Mazzeh neighborhoods in the south; and Al-Nasr and Al-Jundi neighborhoods in the north. According to the analysis of the nearest health center, it was found that the locations of Al-Hussein Health Center and the Southern District Health Center were easier to reach than the locations of Al-Mafraq Comprehensive Health Center and Al-Mafraq Primary Health Center based on distance and time factors. There is a clear discrepancy between the locations designated for health centers in providing health services with respect to neighborhood centers, based on the time factor that was set at 7 minutes. According to the multiple ring buffers analysis, it was found that the first zone (500 meters) contained only 5 residential neighborhoods. The second zone (1000 m) provided access to health service for about 12 residential neighborhoods. While the third zone which extended to a distance of 2000 m from each health center contained about 19 residential neighborhoods that could access the health service within this distance. There is a fairly large agreement in the results reached using the different methods of measuring accessibility that were adopted in this study. Among the limitations that the researcher faced in this study is the lack of other necessary data such as buildings, road network, speed data, field work and tracking the movement of cars on the roads.

This research contributes to a better understanding of the geographical accessibility of the population to health care centers, helping to identify polarization trends. The results obtained can help decision-makers develop urban planning strategies and optimize investments in health care infrastructure in other cities. Future studies will consider the use of other means of transport and other time slots, the methodology used in this study and the application of network analysis can be utilized in measuring and evaluating the accessibility to public services in other Jordanian cities such as Amman, Zarqa and Irbid, which suffer from distributing public services problems, traffic congestion, and high population density.

Finally, the real value of this study stems from the application of GIS and network analysis in evaluating the geographical distribution of health centers in the city of Al-Mafraq and its accessibility, and determining the residential neighborhoods that need establishing new health centers. Geographical Information Systems and related spatial analytic techniques provide a set of tools for analysing the spatial provision of services, such as healthcare, by examining its relationship to healthcare access and outcomes, and for exploring how healthcare provision can be improved. It considers the use of GIS in analyzing health care need, access, and utilization; in planning and evaluating service locations; and in spatial decision support for health care delivery. The adoption of GIS by health care researchers and policy-makers will depend on access to integrated spatial data on health services utilization and outcomes and data that cut across human service systems.

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