

Modeling the Distribution of Primary Schools in Hail, Saudi Arabia, using a Geographic Information System*

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The study seeks to follow the optimal method for distributing primary schools in the City of Hail, Saudi Arabia, to improve the educational level in the city. The educational level depends on the availability of educational services and optimal spatial locating, which is deemed a key indicator to measure spatial development in any region. The study achieves this purpose by providing a factual cadastral vision and correct predictions of future service development and trying to induct the elements of defect of the geographic spatial distribution using modern, updated, accurate methods. Geographic information systems are very important as they present a new strategic dimension for spatial databases by providing information about the best solutions for handling and analyzing spatial data in accordance with the standards of the Ministry of Education in the Kingdom of Saudi Arabia. This is made possible by locating the schools inside the residential districts, obtaining digital maps of the current situation.

Keywords: spatial distribution, geographical information systems, primary schools, spatial data, educational services

1. INTRODUCTION

Geography is the science of natural and anthropogenic phenomena, focusing on the spatial analysis of the phenomena. Study of various types of services, such as educational, services, within and outside cities is one of the important topics in geography.

The geography of services deals with the distribution of the sites of services in the urban and rural regions [1] based on the geographical distribution of general service centers. Thus, it makes it possible to check for the proper distribution and the extent of sufficiency of the services to meet the needs of the inhabitants and to arrive at proposals and solutions for the optimal distribution of services from the perspective of the inhabitants.

The efficiency of spatial distribution is an important topic, particularly since the advances in computing. This topic is to planners and decision makers, who seek to determine the actual need of signature and establishment of schools. Although educational services and their spatial distribution in the Kingdom of Saudi Arabia have been widely studied, their distribution in the City of Hail has not been modeled in detail; this study aims to address this lacuna in research. An earlier work on the patterns and characteristics of the spatial distribution of higher education schools for boys in the City of Taif, which dealt with the spread and development of higher education in the City of Taif, provided encouragement for this study. The previous study had examined the school dis-

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tribution in Taif, identified the effective elements of school distribution, and reported the characteristics and patterns of the distribution and the influence regions of the schools [2].

A study on the characteristics and patterns of the spatial distribution of boys' secondary schools in the Governorate of Al-Qunfidhah, Holy Makkah [3] dealt with the current spatial distribution of boys' secondary schools; in this study, the characteristics and patterns of this distribution and the effective elements were determined the problems related to this distribution were identified to propose solutions, and the characteristics and patterns of the distribution of the boys' government secondary schools in the City of Riyadh as reported by [1] were studied. The aim of [1] study was to specify sites for boys' government secondary schools in the study region. Statistics of the number of the schools, students, and teachers as well as their spatial and volume distribution patters were also reported.

Examined the patterns and characteristics of the spatial distribution of general education schools for boys in Najran [4]. Further, [5] performed a spatial analysis of the distribution of primary education services in Al-Muntazah district by using a geographic information system (GIS). The concept and use of geographical information systems and the system components and the steps for building such a system were discussed, and the spatial analysis results for the current distribution of primary education schools in Al-Muntazah district were provided. The study proved that the current distribution of general primary schools and general preparatory schools in the district is insufficient to efficiently meet the needs of the residents [5].

Performed a spatial analysis of educational services in Nablus city by using the GIS to study the actual conditions of educational services (schools and kindergarten level facilities) in Nablus in terms of their efficiency, distribution, and extent of appropriateness for the urban sprawl and the population growth in the city. This study focused on a descriptive and analytical approach using GIS applications and SPSS Statistics (IBM) and geographical models such as those based on neighborhood relation and influence zone [6].

A spatial analysis was performed for educational services of the public sectors in Al-Khums city in Libya at the level of its stores and residential districts [7]. The aim of this study was to understand the extent of conformity of the educational services in the city with the planning standards applicable to the field of education and to create a database of the public-sector educational services in the city. The study concluded that there was severe deficiency in the kindergarten stage; the services did not conform with the planning standards; and there was a shortage of primary and preparatory education schools compared with the planning standards.

Modeled the distribution of primary in Al-Fallujah city by using GIS to examine the spatial distribution efficiency planning of primary schools and to specify the best sites for locating these services based on the standards of distance, population and nature of use [8]. In another study, the optimal cartographic method was applied to evaluate the actual state of educational services Samarra, Iraq, using GIS-based spatial analysis tools and cadastral information of school sites obtained via a (GPS) device [9]. The study concluded that there the spatial distributions of all the educational services, except primary education services, were unsatisfactory.

The objective of the present research was to develop a model of the spatial signature of primary education services and analyze it by using the GIS software considering the

planning standards of the educational services in the Kingdom of Saudi Arabia and to determine the optimal distribution for the signatures of such services. The research is based on the premise that the modern techniques used in the field of urban service management and planning provide accurate results to overcome the problem. Hail city suffers from an unsatisfactory spatial distribution of primary schools because of a lack of planning and because of not using modern techniques for planning and management.

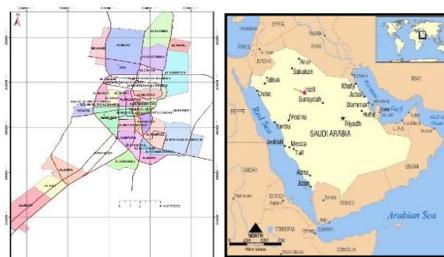
In this study, Arc GIS 10 was used to analyze the planning efficiency of the spatial distribution of primary schools in Hail city. To this end, the spatial and volumetric distributions of primary schools in Hail were identified. The extent of conformity of this spatial distribution with the planning standards applicable in the field of education was determined, and a database on the primary schools in Hail city was created. The residential districts in the city with extra or few services were specified. Recommendations were submitted to the competent entities to promote educational services in the city. Finally, a model of the best spatial distribution of the primary schools in the city was built.

2. THEORETICAL RSSI MODEL

The study is based on an inductive approach, from a part to the whole. This approach helps reveal the mutual relationship between different phenomena, starting from data collection, data processing with GIS software using thematic maps, and finally building models of maps of the spatial distribution of primary schools in the city.

Study Area

The city of Hail ($27^{\circ}31'13''\text{N}$, $41^{\circ}41'25''\text{E}$) is the capital of Hail region, which has a rich history and is an important strategic site located at the center of the northern part of the Kingdom (Fig. 1). Hail is one of the most important geographical sites and cities in this region as it is the center of the business turnover and is important for transportation.



Source: Prepared by researchers based on the map of the administrative division of High Commission for Development in Hail Region and use of Arc GIS Program.

Fig. 1. Hail city and its districts and its geographical location.

The elevation of the city ranges between 825 and 1050 m above the sea level. It is located on Al-Dar' Al-Arabi and has rare subsoil water and deep alluvial arable soil; geologically, the region contains Quaternary deposits. The east of the City consists of indistinct granite rocks. Jabal Aja, which reaches heights of 1490 m above the sea level, lies to the west of the city. The mountain chains of Al-Ahmarat, Mururah and Al-Mughlaq lie

foot. A vicinal (local) road as well as a special road must be available [11].

Schools should be located on block roads.

The site must be away from noise, pollution, smoke, dust and other environmental dangers. Schools should be located near a public park.

1. The sites for primary schools for boys and girls should be separated. It is preferable that the entrance of the boys' school and that of the girls' school should be on different roads and not close by; the schools can be separated by residential district gardens.
2. The schools for girls must not be established near public administrative buildings, markets, government complexes, *etc.*
3. School sites should have sufficient access, enabling students to easily enter and exit school buses. Easy access must also be provided to private and public transport, and the safety and security of students should be assured while entering and exiting the transport [11].

Educational use is one of the most important land uses in contemporary city structures, as it performs a direct, effective function for many age groups and also plays an important role in achieving scientific and economic progress and social development. Thus, it is necessary to set standards to specify the best distribution of educational institutions at different stages, including the primary stage [12]. Hence, we introduce the most important standards for sites of primary schools in the City of Hail in the following subsections.

Capacity. It is the standard that measures the efficiency of the educational service as it serves as an indicator of the population of an age group, the number of students and the number of classes. It serves as the signature of the schools in the KSA and the averages is 3000 to 6000 people at the level of the residential neighborhood by school serves.

A primary school serves the age group from 6 to 12 years for both boys and girls. About 12.26% of the population of the city of Hail belong to this age group, and the approximate number of beneficiaries is approximately 230 people per school. The capacity of a class is not more than 30 students [11].

Accessibility. Students must be at the distance of 500m at most and need a period of minutes to go to their school on foot from their homes via a route safe for walkers; schools should also have access through a vicinal (local) road and their own special roads.

Environmental Considerations

The environmental requirements of the primary schools are as follows:

1. The site must be away from noise, pollution, smoke, dust and other environmental dangers. A school should be near a public park.
2. Schools for girls must not be established near public administrative buildings, markets, government complexes, *etc.*
3. A school site should allow easy access to school bus as well as private and public transport and should make possible the safe and secure entry and exit for students into and from transport vehicles.

Spatial Distribution of Primary Schools in Hail

The spatial pattern of distribution of geographical structures or facilities via quanti-

tative analysis is usually performed to reveal the method of distribution, the nature of the spread and arrangement, and to ascertain whether there are distinct distribution patterns with regularity, similarity, concentration, clustering or randomness resulting from hap-hazard or advanced planning by the competent entities. Such analysis also aims to do justice to the residents, who desire such facilities to meet their needs so that the time spent and effort exerted is reduced, particularly the individuals who are involved in different types of services. These services should, hence, be distributed in a specific manner that is conformable with the nature of the geography of the region and the human factors [13].

The pattern of the spatial distribution of services in different regions is mostly influenced by the area of the residential region, population size, plan of street networks, pattern of distribution of other services, historical development of the region and the relationship with the neighboring regions, which contributes to the appearance of some types of complexes of service [14].

In all, there are 287 schools in the districts in Hail. Girls' schools make up 56% of the total number of schools in the city, and boys' schools make up the remaining 44%. Primary schools make up 48% of the total number of schools with a total of 165 schools; of these, 87 are girls' schools and 78 are boys' schools, respectively making up 53% and 47% of the total number of primary schools (Table 1). Further, the 126 public primary schools make up 76% of the total number of primary schools in the city; the remaining comprise private schools (15 schools), public Quran memorization primary and foreign primary schools (11 schools each) and private Quran memorization primary schools (2 schools).

Hail has 37,872 primary stage students, who make up 12.26% of the total inhabitants of the city with a population of 308,712 people in 2018 [10].

Of these primary students, 19,129 are boys and 18,743 are girls.

Fig. 3 shows the differences in the distributions of boys' and girls' primary schools in the districts in Hail. The distribution of schools is concentrated in the old and traditional districts, such as Al-Matar (3 for boys, 4 for girls), Al-Mahata (3 for boys, 4 for girls), Al-Muntazah Al-Sharqi (4 for boys, 3 for girls), Al-Wasitaa (5 for boys, 7 for girls), Al-Muntazah Al-Gharbi (4 for boys, 5 for girls), Al-Naqra (3 for boys, 7 for girls), Al-Samra (3 for boys, 4 for girls), Al-Jam'iyyin (3 for boys, 4 for girls), Al-Badiya (2 for boys, 5 for girls), and Al-Zebara (2 for boys, 4 for girls).

Table 1. Distribution of numbers of schools, classes, teachers and students in boys' and girls' primary education schools in Hail in 2017.

Type	The boys' schools						The girls' schools					
	Number	Number of Students	Number of Teachers	Number of Classes	Number of Owned Buildings	Number of Rented Buildings	Number	Number of Students	Number of Teachers	Number of Classes	Number of Owned Buildings	Number of Rented Buildings
A	61	14041	1266	653	38	23	65	15325	1593	682	48	17
B	7	3021	286	146	1	6	8	883	88	63	0	8
C	4	834	87	51	4	0	7	1086	150	74	6	1
D	1	289	30	16	1	0	1	13	0	2	0	1
E	5	944	44	52	0	5	6	1436	116	65	1	5

A-public primary schools, B-private education schools, C-Quran memorization primary schools, D-private memorization drill primary schools, E-the foreign primary

Source: Prepared by researchers based on data of General Authority for Statistics, Statistics of Government Services, Manual of Services, Hail Region, 2017).

Schools are more scattered in the informal and old districts, such as LebDAH, Al-Ma-sif, Al-Salam, Salah El-Dein Al-Gharbi, Samah and Al-Khuzami. Further, 17 districts do not have any primary schools for boys; these districts include Al-Aziziyah, Al-Worood, Al-Buhaira, Al-Olaya, Hadri Al-Balad, Maghida, Sababah, Industrial region, Al-Rasf, Al-Wadi, Barzan, A'airif, Al-Nafl, Al-Yasmin, Mashar, Al-Shubaily and Al-Khuzami.

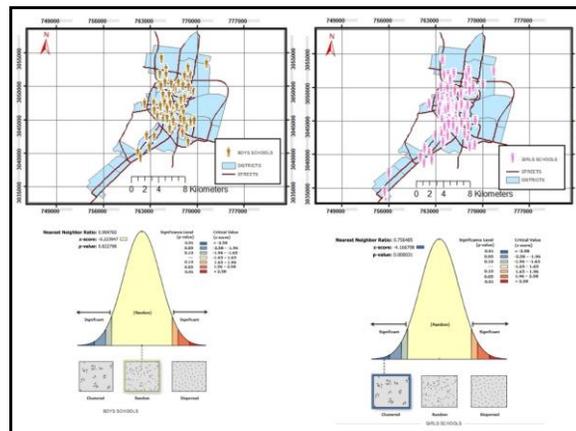
Similarly, there are no primary schools for girls in 14 districts: Al-Khuzami, Industrial region, Al-Buhaira, Al-Shobaily, Al-Rasf, Sababah, Maghida, A'airif, Al-Olaya, Sa-mah, Al-Nafl, Al-Yasmin and Mashar. This is because most of these districts are margin-al and away from the city, and some of these districts provide industrial jobs.

Fig. 3 shows the results of application of the nearest neighbor method to the govern-ment primary schools for boys. The figure reveals the prevailing of the random pattern of schools, with a significance level ($P > 0.1$), for a Z value of -0.22 , which is less than the critical Z value. The value of the coefficient of the nearest neighbor is 0.985, validating the random distribution of the points. The clustered pattern prevails in the case of girls' schools with a significance level ($P < 0.01$) for a Z value of -4.16 , which is less than the critical Z value. The value of the coefficient of the nearest neighbor is 0.756, validating the non-random distribution of the points, and there is less than 1% probability that this clustered pattern may have formed haphazardly.

To determine the directional distribution of spread of the educational service sites on the landscape of the city, the standard deviational ellipse (ellipsoid) was used.

This technique specifies the directional distribution of geographic phenomena based on the measurement of the distance of the standard deviation in X and Y directions separately, as the axes of the geometric shapes (ellipse) are specified from the centroid, and the resultant shape must be an oval centered at the mean center because of the difference or dispersion in values of the distance of the standard deviation along the two axes.

The oval may be circular if the distribution of the phenomenon is semi-balanced in all directions. The shape may be a longitudinal oval, similar to a rectangle, if the repre-sented phenomenon is distributed more in one specific direction. This technique is useful for specifying the nature of relationship between the type of service and the manner of its connection with the natural or human geographic phenomena [15].



Source: Prepared by researchers depending on the administrative division map of Hail Region Development Authority and the General Department of Education in Hail and based on the results of analysis of the nearest neighbor by using ArcGIS Program.

Fig. 3. Geographical distribution and Nearest Neighbor Ratio of government primary schools in Hail in 2018.

Fig. 4 shows the general direction of distribution of the sites of boys' primary schools in Hail; the figure reveals that the oval is smaller than its equivalent for girls' primary schools. The shape is directed northeast – southwest with a deviation angle of 24.5° . The distribution is concentrated in the downtown and the commercial center and conforms with the urban sprawl of the city.

Fig. 4 also shows that the oval of the general direction of distribution of the girls' primary schools in the city is much bigger than its equivalent for boys' primary schools. It extends from the northeast to the southwest with a deviation angle of 34.5° . The distribution is focused on the downtown and commercial center and conforms with the urban sprawl of the city.

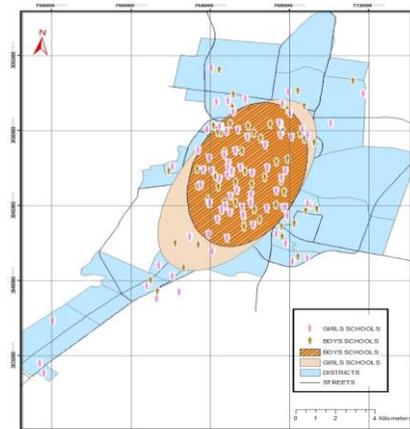


Fig. 4. General trend of distribution of government primary schools for boys and girls in Hail in 2018.

Distribution According to Education Standards

The total number of classes in government primary schools is 653 for boys and 682 for girls. These classes are equally distributed because the schools located in districts with more residents have more classes than those in districts with fewer residents.

The number of classes in accordance with the planning averages for the primary schools in the Kingdom (from 20 to 30 students per class) has a capacity of approximately 40,050 students, comprising 19,590 students at the boys' schools and 20,460 students at the girls' schools). However, currently, there are 290,366 students in all, with 14,041 boys and 15,325 girls. These values indicate the extent of the current capacity of schools for students in the primary stage. There is a clear difference in the numbers of classes at schools, as the maximum number of classes in a school in accordance with the planning average of the primary schools in the Kingdom is 24. We noticed that The Twentieth Girls' Primary School has 35 classes with a total number of 265 students, and Ibn Qudamah Boys' Primary School has 30 classes with a total number of 517 students.

Many schools have less than 12 classes. Examples are The Forty-Eighth Girls' Primary School, which has 6 classes with a total of 92 students; Al-Sowaiflah Girls Primary Schools, which has 6 classes with a total of 92 students; The Tenth Primary School, which has 8 classes with a total of 160 students; Ibn Al-Qayim Primary School, which has 6 classes with a total of 101 students; and Al-Esraa Primary School, which has 7 classes with a total of 129 students.

We note that for the given population of the city, which is 30,8712 people, 102 schools in total are needed based on the standard of capacity (*i.e.*, 240-720 students) to serve from 2000-6000 residents.

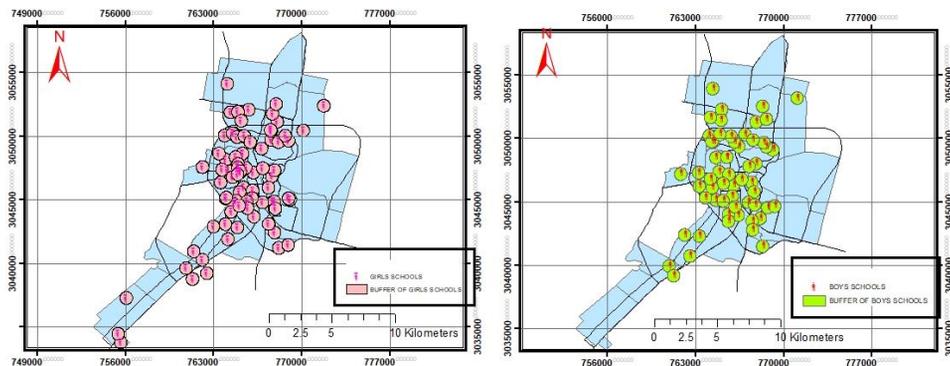
Accordingly, the city of Hail needs 51 schools each for boys and girls. However, there are 128 schools, *i.e.*, a surplus of 26 schools (6 boys' schools and 20 girls' schools). This distribution clarifies the differences depending on the residential district. We find that some districts have more schools than required for the given population of the district; for example, Al-Naqrah has 6 extra schools, and Al-Muntazah Al-Gharbi has 3 extra schools, and Al-Jam'iyyin, Al-Tarifi and Al-Muzabar each have 2 extra schools. In contrast, in some districts, the number of schools falls short of the required number for the given population of the district. Examples are Al-Aziziyah, which has 9 schools less than desired, and Al-Shifaa, which has 4 schools less.

Distribution According to the Accessibility Standard

The distance to a service site is an important factor in the analysis of the geographical distribution of services, as distance is a basis of understanding any spatial organization in a geographic space. The analysis of the distance of access includes using the scope or buffer distance or the scopes of the spatial influence of the services. For this purpose, a circle is drawn centered on the target service. The spatial scope can be plotted by using spatial analysis tools to determine the access distance or the field of the service influence after determining the distance in accordance with the applicable standards of the distances of the access to the service.

A distance of 500m is approved as the scope of primary school service in accordance with the planning averages of primary schools in the Kingdom [11]. A primary school must have a safe route for walkers, a vicinal (local) road and its own special road.

Fig. 5 shows that primary schools are concentrated in the internal districts of the city, and some of the marginal districts, such as Al-Rasf, Mashar, Al-Nafl and Al-Khuzami, are deprived of the service of government boys' and girls' primary schools. Also, the influence scope is concentrated on the districts at the city center. This indicates that every primary school within the study region serves every student and schoolgirl residing within 500 m around the school.

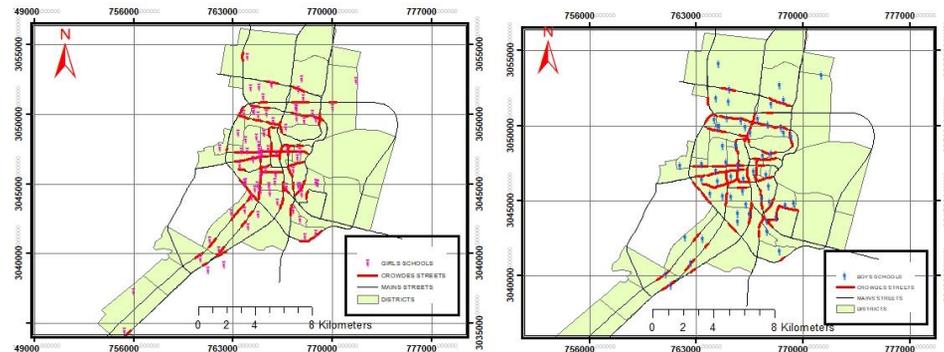


Source: Prepared by researchers based on the administrative division map of the Hail Development Authority and the results of spatial domain analysis using ArcGIS

Fig. 5. Ideal distance model for the ease-of-access criterion based on the domain analysis of government primary schools for boys and girls in Hail in 2018.

Fig. 6 shows the mean central site of the boys’ primary schools in the city of Hail. The area of the circle, which represents the standard distance of distribution, is approximately 51.09 km². This area is 29.2% of the total area of the city. The figure also shows that the circle of the standard distance is small, indicating the spatial clustering of distribution of the boys’ primary schools around the mean central site of distribution.

For the girls’ schools, the area of circle is approximately 74.7 km², which is 42.68% of the total area of Hail. The figure indicates that the circle of the standard distance is relatively big, indicating the remoteness of the sites of the girls’ primary schools from the mean central site of distribution.



Source: Prepared by researchers based on the administrative division map of the Hail Development Authority – and the results of the standard distance analysis using ArcGIS

Fig. 6. Standard distance for the distribution of government primary schools for in Hail in 2018.

Distribution According to the Standard of Environmental Considerations

The principle of this standard is based on excluding dangerous regions, which are the main and crowded streets as well as industrial, commercial and polluted regions.

Fig. 7 shows the model of accessibility according to the standard of distance to the schools, excluding the main and crowded streets. It shows the differences in the scope of coverage of schools as schools are concentrated in the traditional districts, and the distributions of schools within the marginal planned and non-planned districts are different.

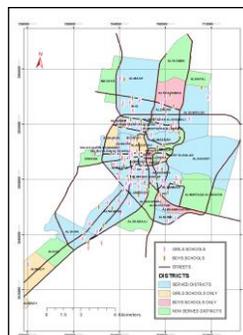


Fig. 7. Distribution of crowded roads in consideration of government primary schools for boys and girls in Hail in 2018.

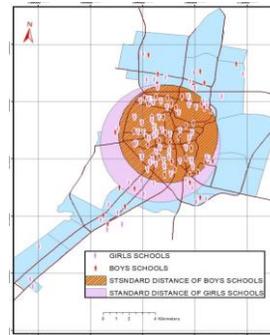


Fig. 8. Distribution of districts that have access to government primary schools for boys and girls in Hail in 2018.

Source: Prepared by researchers based on the administrative division map of the Hail Development Authority – and the results of analysis of the deduction by use of Arc GIS Program

Some places in some districts lack primary schools; for example, Al-Muzabar, Al-Khumasia, Al-Buhaira, Al-Shefa, Aziziyah and Al-Badia. The marginal and new districts, particularly Al-Yasmin, Al-Wadi, Al-Shubaily, Al-Khuzami, Hadri Al-Balad, Al-Worood and Al-Nafl, need primary schools.

The scope of school service overlaps with the usages of residential and commercial lands in old and commercial districts, such as Barzan, Al-Mahata, Al-Matar, Al-Olaya, Samah, Al-Muntazah Al-Gharbi and Al-Jam'iyyin, along with the remoteness from the non-residential districts, particularly (the industrial districts and noisy regions) such as the industrial region, Al-Khuzami, Al-Yasmin, Mashar, Al-Shubaily and Al-Rasf.

Model of the best distribution of primary schools in Hail. The determination of the best site is crucial. This aspect has been recently studied, particularly by using GIS, which assists the planners in determining the proper sites for schools, taking into account the planning standards of the primary schools in the Kingdom. The proposals for planning the best distribution of schools include the following points:

1. Building new schools – This proposal depends on building new schools in accordance to the need of the districts, and taking into account the environmental conditions, population and distance standard among schools, particularly in the new and marginal districts.
2. Expanding and rehabilitating old schools – This proposal aims to increase the school capacity in overcrowded districts as this is an economical alternative to establishing new schools. It also offers additional benefits in overcrowded and small regions, thereby fulfilling the distance condition for schools.
3. Changing the sites of some schools – This proposal suggests transferring surplus schools in traditional regions to alternative regions and changing some sites to increase their functional efficiency, expand the service scope and serve a larger area. This proposal can be applied under the following conditions:
 - (a) It can be applied to old schools as they are deprived of the environmental and urban requirements.
 - (b) It can be applied to replace the sites of some double schools with other schools to ensure the maximum benefit from the site.
 - (c) It proposes using vacant areas specialized for educational services and public buildings for establishing new schools.

Fig. 8 shows that the districts of Al-Naqrah, Al-Muntazah Al-Gharbi, Al-Jam'iyyin, Al-Tarifi and Al-Muzabar have 2, 3, and 6 schools, respectively, while Al-Aziziyah and Al-Shifaa need 9 and 4 schools, respectively, for both boys and girls.

4. PERFORMANCE EVALUATION

Results

1. The geographic distribution of government primary schools for boys and girls in the districts of Hail is deficient.
2. The nearest neighbor analysis of all the government primary schools for boys reveals the prevailing random pattern of schools. This confirms the random distribution of the points represented by the phenomenon. Meanwhile, a clustered pattern is observed for girls' schools. The value of the nearest neighbor coefficient was 0.756, which is in agreement with the non-random distribution of the points represented by the phe-

nomenon. There is a probability of less than 1% that this clustered pattern may have happened haphazardly.

3. The general direction of the distribution of boys' primary schools in Hail reveals that the schools are distributed within a small oval region extending from the northeast to the southwest with a deviation angle of 24.5° . The shape is concentrated in the downtown and the commercial center of the city and conforms with the urban sprawl of the city. Girls' primary schools are distributed within a relatively larger oval region extending from the northeast to the southwest with a deviation angle of 34.5° . The shape is concentrated in the downtown and the commercial center of the city and conforms with the urban sprawl of the city.
4. There is a clear difference in the numbers of classes across the schools in the city.
5. There is clear difference in the capacity according to the residential districts. Some districts have surplus schools in comparison with the population of the district, Conversely, some districts have fewer schools than required as per their population
6. The primary schools are concentrated in the internal districts of the city, and some of the marginal districts lack government primary schools for boys and girls, and the influence scope is concentrated in the districts of the city center.
7. The model of accessibility according to the standard of distance to the boys' and girls' schools, excluding the main and crowded streets, indicates the differences in the scope of coverage of schools, as schools are concentrated in the traditional districts. Some places in some districts lack primary schools, while marginal and new districts are deprived of primary schools. Thus, the scope of service of schools also overlaps with residential and commercial land use in old and commercial districts.

5. CONCLUSIONS

1. It is recommended to build a digital database for all schools and all academic stages to provide information about the distribution of educational services.
2. The standards of planning and establishing primary schools are different from those for other schools, as the particularity of this stage and the bodily ability of the students must be taken into account.
3. The planning standards of the capacity and accessibility and the environmental considerations must be taken into account.

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