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Using GIS to Analyze the Distribution of Mosques in the Northern Area of Riyadh City

Omer Alrwais, Areej AlHassan, Asma AlDausari, Reem AlSalhi, Ghada AlQahtani and Noura AlArifi

Department of Information Systems
King Saud University, Riyadh

Abstract: This paper aims to study the distribution of mosques in the northern area of Riyadh city in Saudi Arabia in order to uncover the aspects of imbalance distribution of mosques over the 29 districts of the study area in addition to assess the extent of compatibility between the number of mosques in each district and the density of population residing in it. The used dataset is built up of mainly three datasets for mosques, districts and population covering the study area. This research has utilized QGIS software and applied the Point-to-Polygon overlay to locate the mosques in their corresponding districts and three types of analysis were applied which are the Average Nearest Neighbor, Heat Map, and Graduated Symbology Classification with the aim of exploring the clustering patterns of mosques as well as classifying the districts based on the density of mosques relative to population. The study concludes that there is a spatial disparity in the distribution of mosques, mainly in term of their density, in the different districts due to the variation in population. Moreover, a notable inequality of the distribution of mosques with respect to the population has been found.

Keywords: *Riyadh Mosques, QGIS, Average Nearest Neighbor, Point-to-Polygon, Spatial Join*

1. Introduction

In Riyadh city and in Islamic world in general, mosques are of a strategic importance for the quality of religious life of our society. They are considered as critical places for the daily life of Muslim as they serve for the five prayers and they motivate for better social welfare. From this point, we believe in the importance of the balanced distribution of these mosques in the city to make it more convenient for the citizens to reach the mosques from their residential areas. However, the distribution of mosques in Riyadh districts must take into consideration their distance from each other and the number of mosques must be compatible with the population that reside in a certain district. Consequently, having the right assessment of where to locate the mosque, will in result, help authorities to choose the appropriate location for the new mosques proposals.

1.1 Problem Statement

The distribution of the mosques in each residential area in any Islamic city is considered as an urban planning problem that needs critical investigation and better optimization in terms of the spatial locations. In this project we aim to use the GIS services to find practical ways of understanding and assessing the spatial distribution of mosques in the northern areas of Riyadh city, by considering the actual locations of mosques and the corresponding local population in Riyadh. The northern part of the city in particular was determined to cope with population growth and urban expansion in this new area of the city.
We also aim to investigate the adequacy of mosques for each district in Riyadh in terms of the size of the district and use intensity. This can be done by studying the existing locations, distributions of the existing mosques using GIS which is one of the formalized information systems that can integrating data from various sources to provide the information necessary for effective decision-making in urban planning [1]. Spatial data of mosques locations will be used to explore conflicts, investigate current state, also statistical data of the populations will be used to examine the adequacy of mosques.
Considering the actual locations of mosques and the corresponding local population, the assessment will help in better identification of spatial and planning principles to provide an optimum level of utilization of each district mosques and to also identify the most optimal locations for new mosques by establishing effective policies for the right choice of new mosques locations.

1.2 Research Questions

This project is going to answer the following research questions about mosques in northern area of Riyadh city:

- Is there a specific pattern that can be noticed from the spatial distribution of mosques?
- In a particular district, is the number of mosques exceeds the demand of the residents?
    - Or, is there an insufficiency in the number of mosques in that district?
- Is there a consistency between the number of mosques and population on each district?

2. Related Work

In Islamic cities, Mosque is not considered as a religious center only, it is also considered as an organizer of the spatial configuration of the Islamic city. Therefore, the mosque has multiple functions such as social, political, cultural and educational functions besides considering it as a religious center [2]. There are many studies on the spatial analysis of mosques using geographic information that examined Arab and international areas [3]. However, there are a few studies in Saudi Arabia, in particular. In 1995, Aljarallah and Alharigi examined the spatial distribution of mosques in Dammam. Moreover, they focused on service distance, hierarchy, and population served by mosques. According to Aljarallah and Alharigi, mosques are not equally distributed in the city, and there is clear variation in service distances and population served by mosque [4].In 1997, Aljarallah and Alharigi studied the effects of topography in the distribution of services by conducting an analytical study of mosques distribution in Abha city. The study covered the radius, location, distribution hierarchy, and served population. All these elements are analyzed against the topography and particularly the degree of slope which directly affects the efforts put by people to attend the daily five prayers [5]. In 2013, Alhazmi conducted a study about the geographical distribution of mosques in Makkah. The study has several aims which are: to analyze the current geographical distribution of mosques in Makkah, to know the geographical factors affecting it, and to evaluate the efficiency of service based on several standards affecting the quality of the service provided to the population. In order to achieve the desired objectives of the study, the author was relied on quantitative descriptive approach, spatial analysis approach, and diagnostic approach. Moreover, the author used many quantitative methods such as Nearest Neighbor, Mean Center, Standard Distance and more. Based on this study, the following results have been concluded. First, the distribution of mosques is unequal. Most of the mosques are concentrated in the neighborhoods of the downtown and transitional areas. The number of mosques become less on the edge of the city. Second, the distribution of mosques depended on the population only, and that is not reasonable. he distribution of mosques should also depend on the space. The last result was that the distribution of local mosques was efficient. On the other hand, the planning standards that are set by the state was not taken into consideration the distribution of the Eid mosques [6]. In 2013, Aldewaje, Ali, and Alnuaemi investigated the role of the spatial distribution of the mosques in Mosul old city in spatial sustainability. This was done by adopting space-syntax approach and the concept of spatial sustainability focused on the spatial configuration of the city [2]. In 2013, Mansour studied and traced the development and density of mosques in the city of Irbid, north of Jordan. To realize the study objectives, the author used a comprehensive survey as well as descriptive, analytical, and quantitative methods. The study concluded that the mosques are located in certain neighborhoods [7]. In 2017, Alfantsa and Alta'ani studied and evaluated the distribution of mosques in Ma'an city which is a city in southern Jordan. In their study, they used ArcGIS and the location analysis package. To collect the data, they depended on the available data by government agencies. Moreover, they used GPS to determine the locations of mosques accurately. Based on the performed analysis, they concluded the following result: the distribution of mosques is not proportionate to the size and the number of populations. So, the current distribution of mosques in Ma'an is inequality [3]. In 2017, Bourquia conducted a study to identify the standard of site distribution of mosques in

Ajdabiya. He also studied consistency between the site distribution and the population distribution in various city communities. This was done by analyzing the standard of site distribution of mosques using the method of "Nearest Neighbor". The study found out that mosques' distribution is not homogeneous with the population distribution in various city communities. Based on this result, the researcher tried to draw a futuristic picture for the redistribution of mosques in a scientific way using the theory of "Central sites" by Krister [8].

3. Datasets

The data that will be used to solve the presented problem primarily contains three kind of datasets, Mosques dataset, Population dataset and Districts dataset. The first one is concerned with all aspects of mosques, which are located in the northern area of Riyadh city, the second one contains data about the population resides in this area, while the third one shows the division of the districts located in the northern area of Riyadh.

3.1 Description of Datasets

1. Population Dataset: (.xsls file) we've already requested and received an excel sheet from the general authority of statistics entitled "housing and populations by gender and nationality for Riyadh districts". It includes the following:

- Neighborhood name
- Population by gender
- Population by nationality

A pre-processing step needed to be done in this dataset, we will manually select the northern districts of Riyadh from the whole dataset.

The next datasets are digitally represented in their shapefiles using a vector data model in which mosques is represented as points features while districts are represented as areas (polygons) to show the area covered by each district.
So, in total, our dataset contains two sub-datasets (alongside the Population Dataset) each of which has three files that make up the basic shapefile which are:

- The file with extension (.shp) that store the geometry of the sub-dataset features.
- The file with extension (.dbf) that store the attributes associated with the sub-dataset features.
- The file with extension (.shx) that provide indexes for the sub-dataset features in order to be quickly explored by the used GIS application (QGIS in our case).

Besides the location data of each feature in the below datasets, the attribute data that are associated with each dataset are as follow (the tuples that are irrelevant to the presented research problem have been ignored):

2. **Mosques dataset**: (.shp file)which contains Mosque ID, Mosque Name, Type (is it Jamea or a regular mosque), X and Y coordinates of the mosque.
3. **Districts dataset**: (.shp file) District Name and Location.

However, the above datasets, mainly the ones about population and districts, contains many attributes that are irrelevant to our research problem and will only result in taking huge space that may put an excessive overload when loading the data into the GIS application, so we will need to discard those tuples that are unneeded before starting doing the analysis.

3.2 Data Collection

In order to find the required data, we made several requests to several authorities who have been recommended to us that they might have the required data.

3.2.1 Population Statistics

The General Authority for Statistics (GASTAT) provided us with an spreadsheet include the population for each district in the Riyadh region. As pre-processing, we selected only the northern districts which are 29 districts. Then, in the district layer, we defined a new attribute to add the population for each district.

3.2.2 Spatial data of Mosques

In Saudi Arabia, King Abdulaziz City for Science and Technology (KACST) has taken the first initiative to build a project for the spatial data of Riyadh's mosques. In 1437 H, the ministry of Islamic Affair (MOIA) conducted an agreement with KACST by asking KACST to develop a geographical information system and a comprehensive database of the Kingdom's mosques [9]. The National Center for Remote Sensing Technology in KACST [10] was responsible for implementing the system. However, governmental entities take long time to respond to the data requests from researches. Therefore, we decided to manually collect and project the mosques in the northern region of Riyadh city and create a shapefile for the collected mosques. We have covered almost all mosques located in 29 districts, which form the northern area of Riyadh, and the data for each mosque, including its id, projected coordinates X and Y, along with its name and its type (wither it's a Jamea or a regular mosque) was obtained manually from the mosques GIS system that is operated by The Ministry of Islamic Affair (MOIA). The following steps were taken to create a shapefile (.shp) for the surveyed mosques:

1. We use a delimited text file (comma-separated values CSV) to store the mosques data with the following columns: ID, Name, Type (Jamea or a regular mosque), UTM_X and UTM_Y (which are X and Y coordinates of each mosque). A total of 688 mosques were surveyed and stored in the CSV file (All Mosques.csv).

A	B	C	D	E
ID	name	Type	UTM_X	UTM_Y
3876	Munira Ham	Jamea	46.7093589	24.8052988
3864	Mother of Pr	Mosque	46.7130759	24.8047564
3823	Mother of Pr	Jamea	46.7158684	24.803043
3802	Abdullah Al (	Mosque	46.7064761	24.8019502
3782	Ali Hamoud ,	Mosque	46.7103778	24.8005581
3743	Sheikh Abdul	Mosque	46.7149468	24.7984723
3785	Noura AlShe	Mosque	46.6994632	24.8005706
3750	Suleiman Mc	Jamea	46.7026813	24.7986553
3739	Haya bint Ab	Mosque	46.706307	24.7982275
3701	Dar Al Uloon	Jamea	46.7085225	24.7968451
3675	Saleh alMurz	Mosque	46.713866	24.7960369
3694	Hamad Altw	Mosque	46.7194555	24.7963825
3687	AlHaseen	Mosque	46.7000765	24.7961565
3664	AlFaleh	Mosque	46.7046953	24.7955309
3616	Abdulaziz Mi	Mosque	46.7119627	24.7933124
3563	AlTawheed	Jamea	46.7166129	24.791144

Figure 1: Snapshot of the CSV file of the Mosques

2. Then the mosques coordinates were imported to form a point layer by importing the CSV file to QGIS software via Add Delimited Text Layer tool.

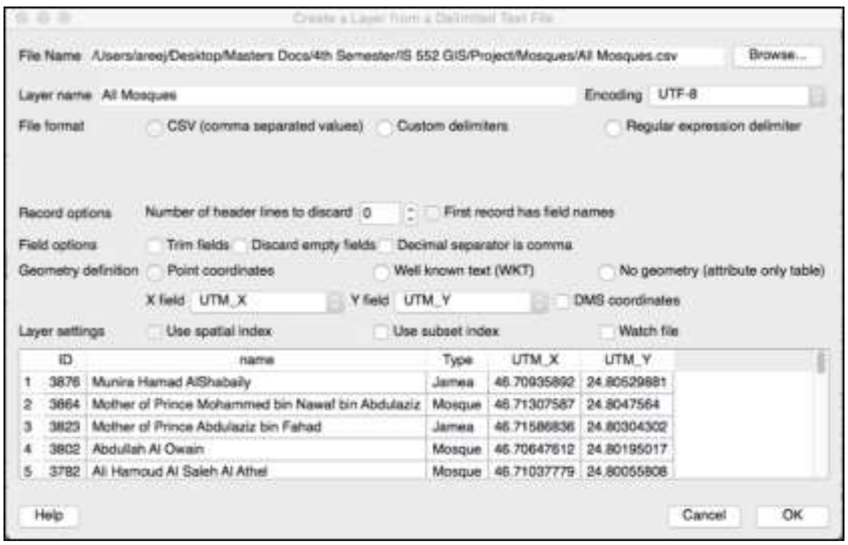

Figure 2: Snapshot of Importing the CSV file of the Mosques

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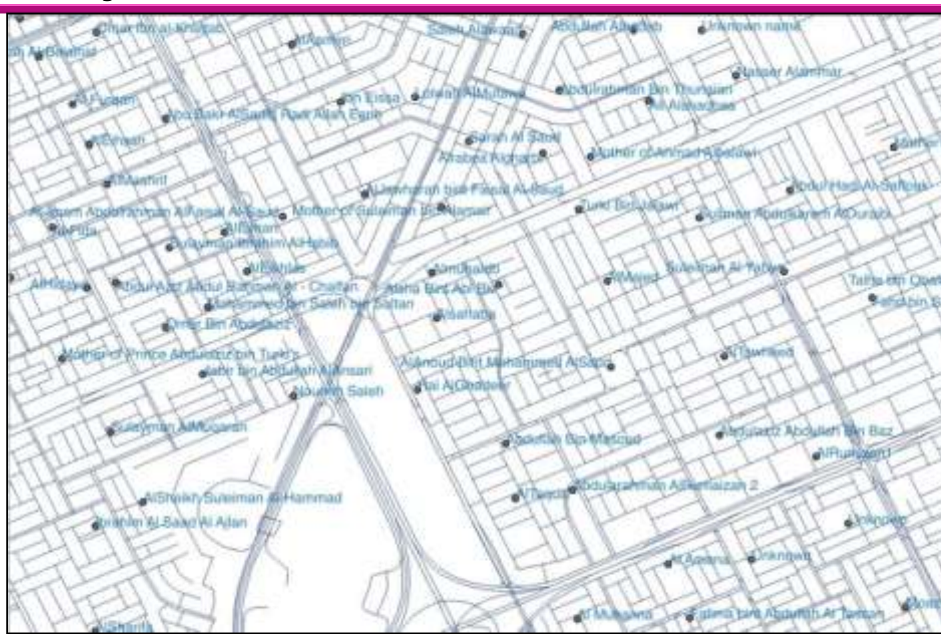


Figure 3: Snapshot of the projected AlGhadeer Mosques

3. Finally, this layer is a rendering of the tabulate data and not a standalone GIS layer (it cannot be edited), so we have converted it to a standalone shapefile by saving it as ESRI shapefile. In the end of this process we got all mosques in the northern districts as (.shp) file (Mosques.shp).

3.2.3 Spatial data of Districts

1. We decided to use a map of Riyadh city from the open street map and use it as a base to divide the districts in Which the study focuses on (29 districts in the northern areas of Riyadh).
2. We create A new vector layer above the Riyadh open street map (Raster image of Riyadh created by right click on openstreetmap layer to save this layer as .TIFF image).

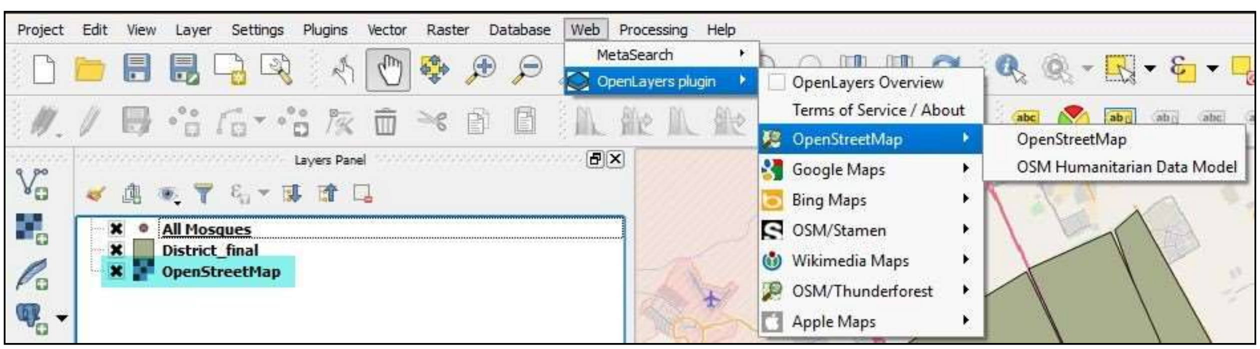


Figure 4: Add Riyadh Image layer from openstreetmap (Riyadh.tiff).

3. Using "Toggle tool" in the created vector layer to add a new feature (the feature in here is polygon district) by selecting each district area and add its information to the attribute table (ID, Name of the district, population in this district) to each one of them.

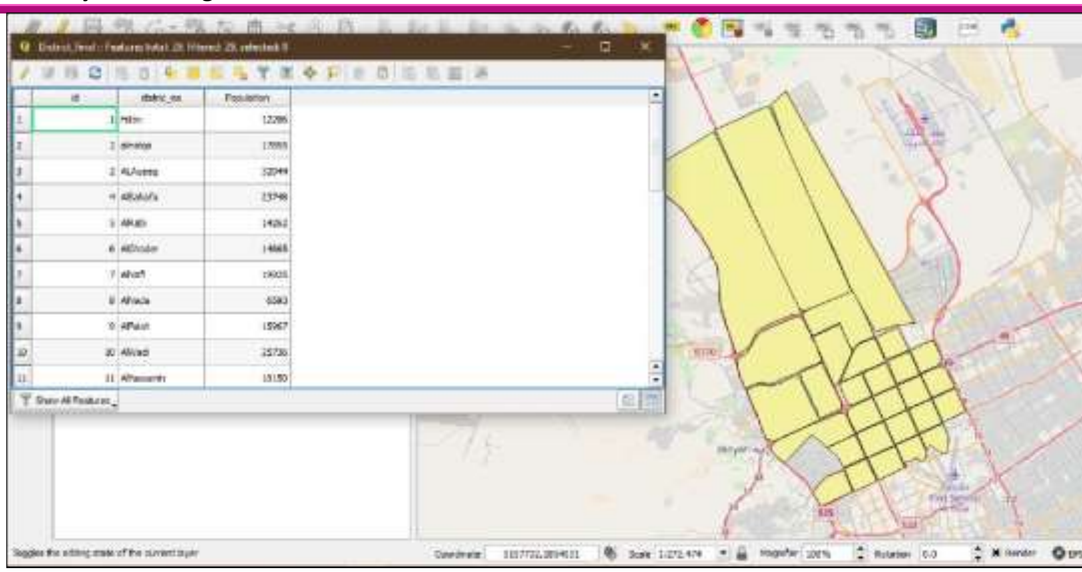


Figure 5: Attribute table of district layer

4. At the end of this process we get all the northern districts as (.shp) file.

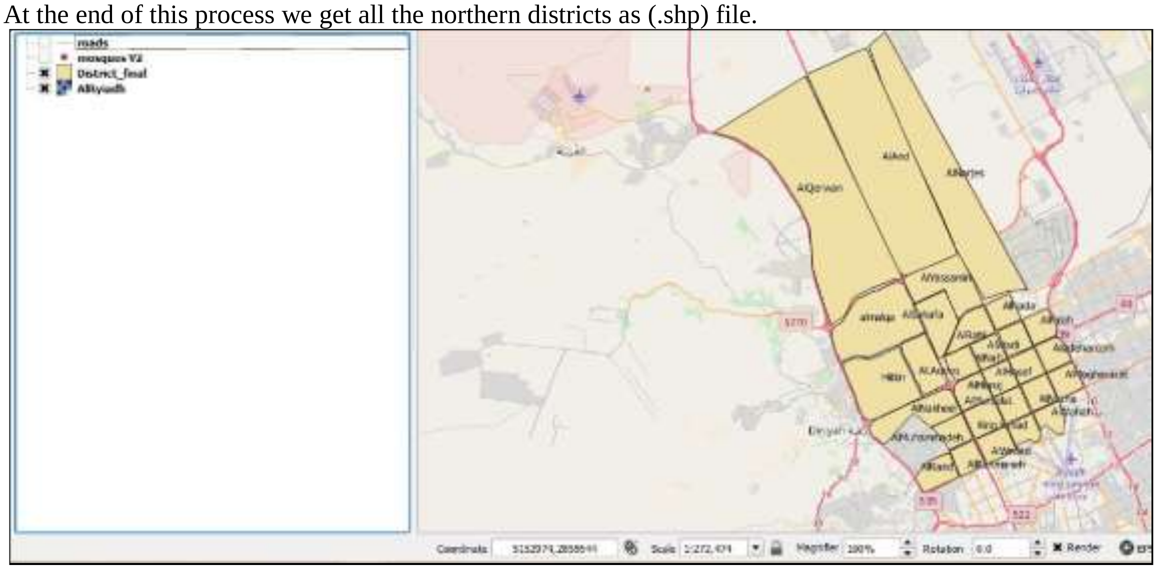


Figure 6: The district Layer with label (Name of districts)

4. Analysis:

To get the expected outcome, after entering or importing data into the GIS we try to explore the general distribution patterns of the mosques and perform vector analysis that may include one of the proximity spatial analysis methods to check if there is a pile of mosques in certain district, while not found in other parts and we will use point to polygon overlay to check if the mosques distribution is consistent with the number of resident in this district. This type of analysis is helpful to generate and observe patterns in the data.

4.1 Point-to-Polygon Overlay

A spatial operation (vector overlay) in which points from one feature dataset are overlaid on the polygons of another to determine which points are contained within the polygons. In our case, we overlay the mosques in points on the districts which is represented by the polygons.

This operation used here to show out the location of the mosques in each district by applying the point layer up-off the polygon layer.

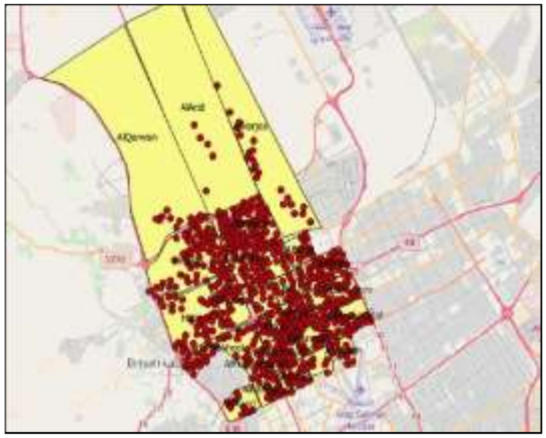


Figure 7: The map after Adding the districts layer and mosques layer.

We have polygons representing the districts, and the points representing mosques. It will help to count the number of mosques in each polygon.

4.2 Average Nearest Neighbor Analysis

The analysis tool used is considered as spatial statistics tool for vectors, which tries to analyze and identify some patterns in the dataset. This tool basically calculates nearest neighbor index based on the average distance from each point feature to its nearest neighboring feature. In this study, our point pattern is a layer with 688 points, each representing mosque location on a study area indicated by the polygon boundary.

The average nearest neighbor index (ANNI) is a global spatial clustering statistic that will indicate if the mosques locations are either: random, dispersed or clustered on the landscape. This would be useful to know if the mosques are clustered or not by using the mosque data to test for clusters. We run this test using QGIS 3.2 and the extent of the landscape considered for the analysis is represented by bounding rectangle capturing the area contained within the outermost of the north, south, east and west boundaries of our dataset (Figure 11).

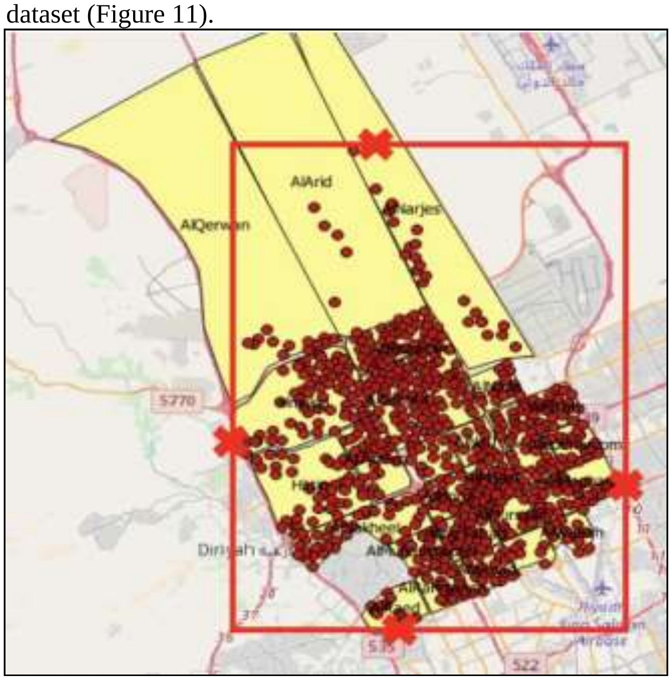


Figure 8: The considered boundary for Average Nearest Neighbor Analysis. The output of this analysis is numerical and it will be saved as an HTML file. In the result we can see our observed mean distance, our expected mean distance,our nearest neighbor index, the number of mosques and the z-score. (figure 8)

Observed mean distance: 0.003220383000879746

Expected mean distance: 0.004055780922274455

Nearest neighbour index: 0.7940229175578293

Number of points: 688

Z-Score: -10.335797792543767

Figure 9: Results of Average Nearest Neighbor for mosques.

4.3 Heat Map Analysis

This analysis method is used to showing the geographic clustering of a phenomenon. Heat maps show locations of higher densities of geographic entities. The 'heat' in the term refers to the concentration of the geographic entity within any given spot. Heat mapping is a way of geographically visualizing locations so that patterns of higher than average occurrence of things. Heat maps take noncontiguous point data and display them as being continuous. Heat maps show the density of points in an area as a raster. They are formed by creating a distance buffer around each point in a data set.
This would be useful to know if the mosques are randomly distributed in or not and the density of the mosque in each district by using the mosque data to perform the heat map analysis.We create the map using QGIS 3.2 and the heat map plug-in and apply the function to the mosques point layer with the radius 6000 for the output layer to cover only the study area and this analysis represented by the raster layer showing the area where the mosques concentrated.

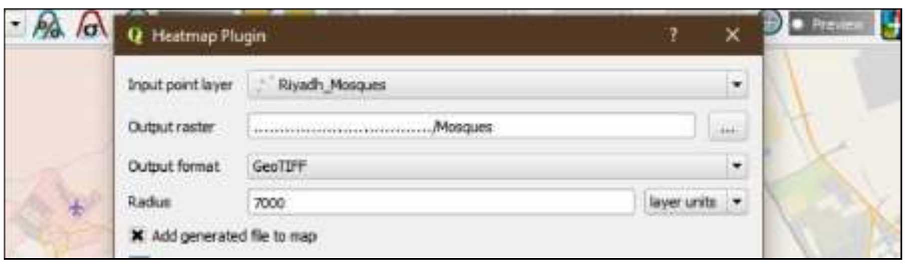
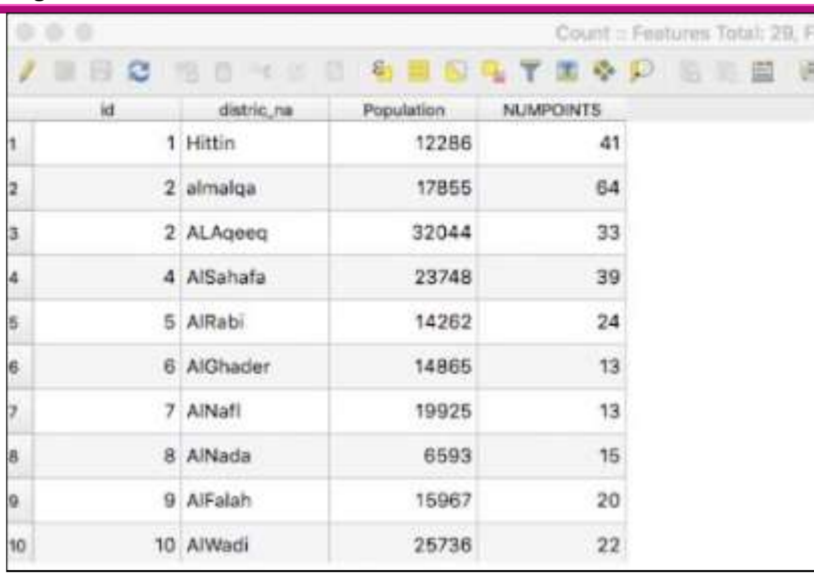


Figure 10: Creating A Heat Map with Radius 7000

4.4 Count Points in Polygon

QGIS offers a vector analysis tool that counts the number of points present in each feature of a polygon layer. This tool is called "Count Points in Polygon" and it is very convenient for counting the number of mosques in each district. This would be useful to compare the number of mosques in each district against the population in that district. For this analysis, we will take the District as the polygon parameter and the Mosques as the points parameter.



	id	distric_na	Population	NUMPOINTS
1	1	Hittin	12286	41
2	2	almalqa	17855	64
3	2	ALAqeeq	32044	33
4	4	AlSahafa	23748	39
5	5	AlRabi	14262	24
6	6	AlGhader	14865	13
7	7	AlNafl	19925	13
8	8	AlNada	6593	15
9	9	AlFalah	15967	20
10	10	AlWadi	25736	22

Figure 11: Count Points in Polygon result

This analysis will result in a layer with the attribute table containing the new column of the points count. Here we can see the NUMPOINTS column which refers to the number of mosques in that district.

After the derivation of district-level counts of mosques, we are now able to calculate the "Mosques to Population ratio" which refers to the number of mosques in a district to the number of residents in this district, here we will express it as the number of available mosques for every 1,000 population. This was done using the "Field Calculator" by writing the formula shown in figure 14.

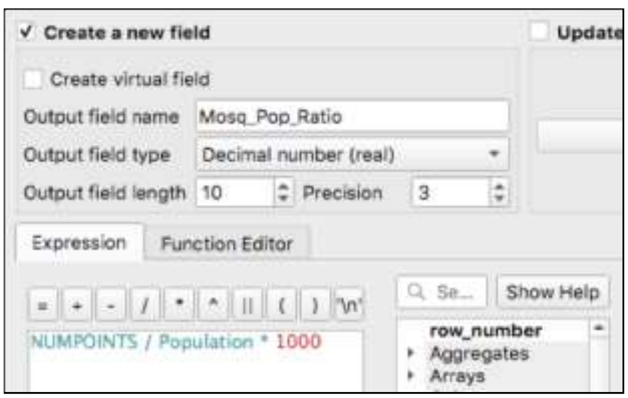


Figure 12: Mosque to population ratio formula

The resulted ratio will help us to determine the relationship between the number of mosques and the respective population.

id	distric_na	Population	NUMPOINTS	Mosq_Pop_Ratio
1	Hittin	12286	41	3.337
10	AlWadi	25736	22	0.855
11	AlYassamin	10150	72	7.094
12	AlNarjes	2482	23	9.267
13	Alizdeharcom	28299	18	0.636
13	AlMasef	52527	25	0.476
14	AlMogharazat	13677	15	1.097
14	AlMursalat	23059	18	0.781
15	King Fahad	43167	24	0.556
15	AlMoroj	39033	22	0.564
15	AlNuzha	28753	22	0.765
16	Altaoun	21513	18	0.837

Figure 13: Mosque to population result

4.5 Join Attributes by Location

The previous count analysis produced only a new layer containing the count. In order to spatially merge that new count layer with the district polygons, we will join these two vectors using " Join attributes by location" tool, which will produce a relationship between the features in those two layers by spatially joining the attributes of two layers based on the location of the features in the layers. The output feature wii contain the shape and attributes from the target layer and the matching attributes from the join layer. In our case, we have the district as the target layer and the mosques as the join layer. Doing this will allow us to change the symbology of the district polygons based on the newly merged columns.

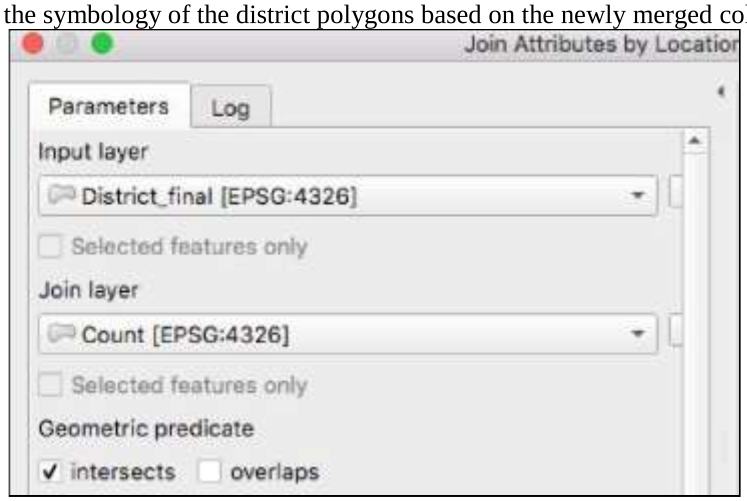


Figure 14: Join Attribute by Location

After joining the two vectors, we will be able to take advantage of the mosques to population ratio by classifying the districts based on that ratio. To do that, we will change the symbology of the resulted joined layer and apply a graduated symbology which will be based on the attribute "Mosq_Pop_Ratio". Since we are dealing with a ratio or percentage,using "Equal Interval" classification method is better for our case.

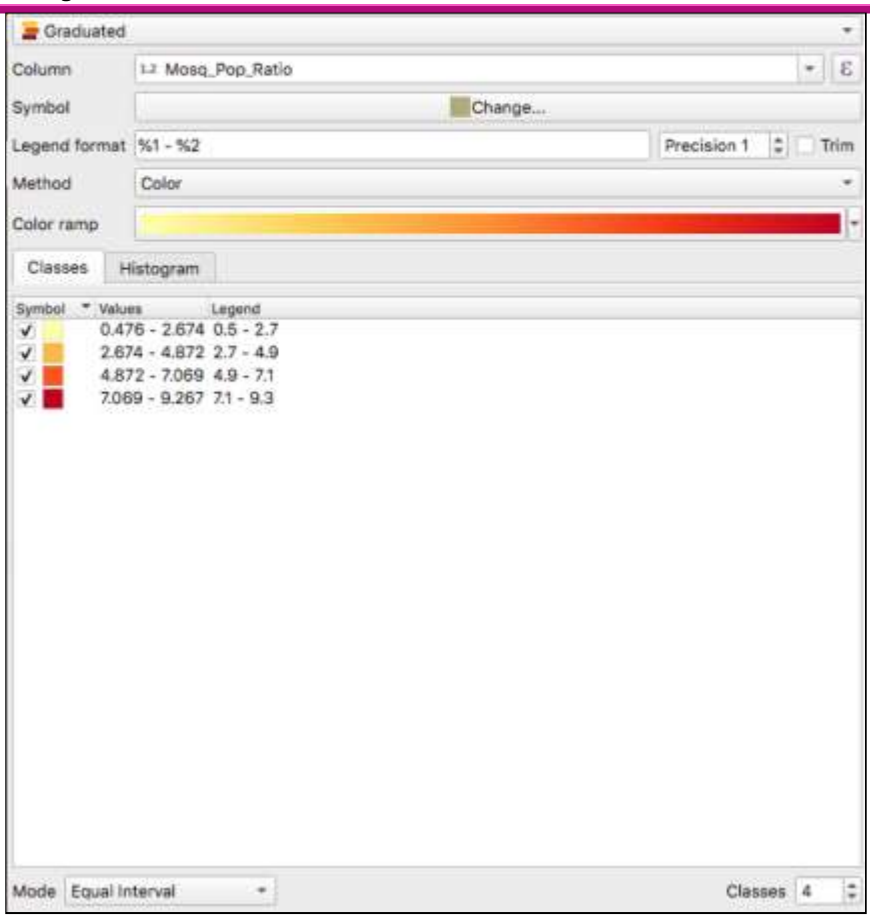


Figure 15: Districts classification

The classification graduates between yellow and red, where yellow indicates a rage of 1 to 5 mosques per 1000 residents and the red indicates a range of 5 to 9 mosques per 1000 resident in a specific district.

5. Results

In this section, we are going to present the results obtained from the previous analysis, also a brief interpretation of the results will be discussed.

5.1 Examining the Spatial Pattern of Mosques

To evaluate our spatial pattern of distances among the mosques, we will interpret the results obtained from previously performed Average Nearest Neighbor analysis. Our ANNI value is 0.794 which indicates a clustering pattern in our dataset. Also, to know if our data are statistically significant, we will see the Z-score. The result shows a value of -10.3357 which indicates a non-significant z-score and less than 1% likelihood that this clustered pattern could be the result of random chance. From this analysis we can conclude that the mosques locations on the northern area of riyadh city are not random or dispersed and they are spatially clustered.

Data set	Sample Size	Observed Distance	Expected Distance	ANNI	Z-Score	Pattern
Mosques	688	0.00322	0.004055	0.794	-10.3357	Clustered

Overall, the spatial pattern of mosques in northern Riyadh tends to be concentrated in the districts that are located in the south and the middle of the northern districts (e.g. Al Morouj, Al Ezdehar, Al Woroud). This concentration distribution is due to the

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higher number of residents in these districts, on the other hand, the extreme northern districts (e.g. Al Qairawan, Al Arid, Al Narjis) are lower in population and still subject to the urban expansion and new house buildings.

5.2 Districts Under or Over Coverage of Mosques.

In our study, we used heat maps to analyze the distribution of mosques in the northern districts of Riyadh. We noticed the concentration of mosques in the middle of the districts. Generally, the analysis showed that the expected pattern of distribution of mosques in the study area is a random pattern.

In this analysis, the density of mosques in the geographical area, which extends through the gradations of red to white, where the color of dark red indicates the increase in the number of mosques in the region to 41 mosques and the areas of white color to the absence of mosques in it.

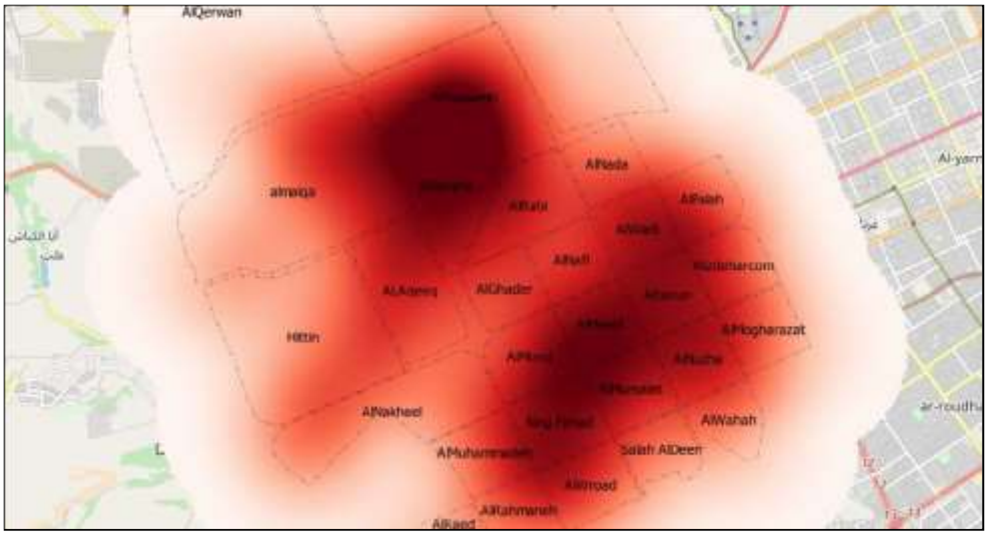

Figure 16: Zoom in to the Heat Map For the Distribution of the Mosques

In contrast, the density of mosques is very low, in such districts (AlQerawan, AlArid, AlNarjes), which are a relatively new area, in the other side, it is very high in the relatively old districts of the north of Riyadh.

Figure 17: The Heat Map For the Distribution of the Mosques

After the heat map analysis, we should recommend to preparing a plan to distribute the mosques in a balanced manner, not randomly in the areas that are covered by the white color which represents the empty areas.

5.3 Mosques to Population Ratios

After the derivation of the "Mosques to Population ratio" and the classification of the districts based on that ratio, the following map was generated:

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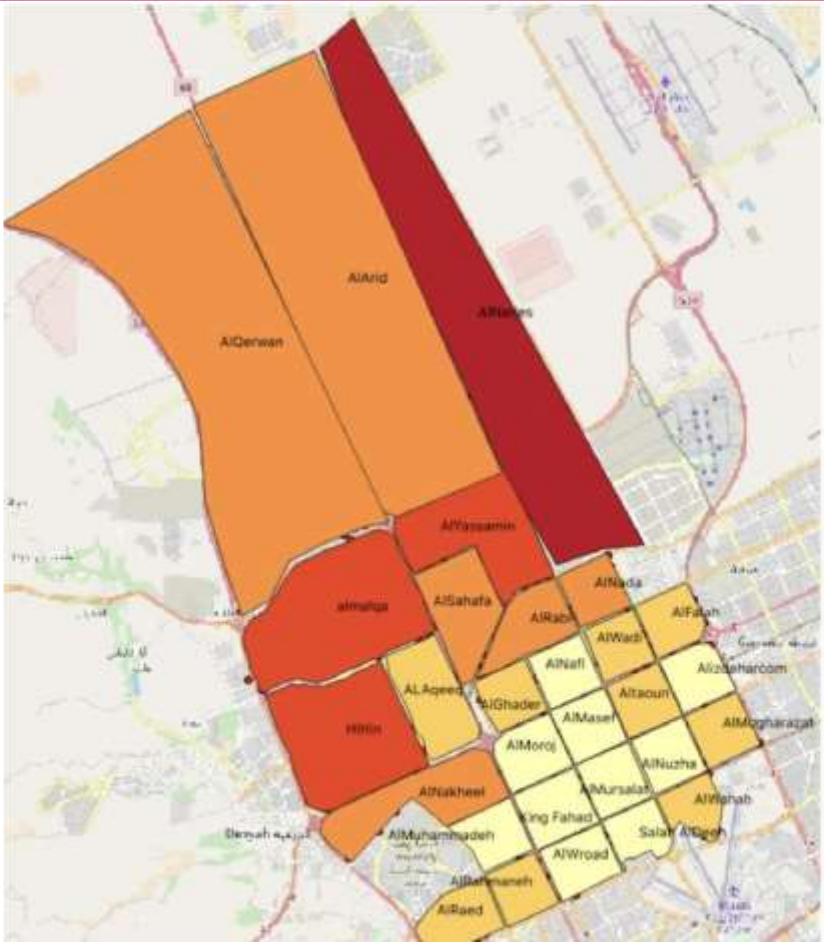

Figure 18: Mosques to Population Districts classification

From the resulted map, we can easily identify the quality of mosques distribution based on the population for the Northern districts of Riyadh. The darker red indicates a higher mosques ratios, where the lighter yellow indicates lower ratio. Highest ratio means that the percentage of mosques per 1000 resident in that district is higher than other districts. In our map, we can see that all of (Al-Narjis, Al-Yassmin, Al-Malqa, Hittin) relatively have the highest number of mosques compared with number of residents. On the other hand,all of (Alnafl, Al-Ezdihar, Al-Morouj, Al-Masef, Al-Muhammadiah, King Fahad, Al-Mursalat, Al-Nuzha, Al-Woroud and Salah Aldeen) have the lowest number of mosques with respect to their population.

To interpret these results, we can compare between two district examples from each category, lets say (Hittin and King Fahad) to figure out the reasons behind this ratio. Based on our map, Hittin has a ratio of 3.337 where King Fahad has a ratio of 0.556. That means, Hittin has about 3 mosques for 1000 residents, where King Fahad has about 1 mosques for 1000 residents. If we look closer at the different properties (land, income, streets, buildings) for each district, we will realize that our ratio is very rational. The following points can summarize the spatial and non spatial properties differences between Hittin and King Fahad district:

- Hittin is relatively new district ,there are lots of vacant lands that have not been constructed yet. Where King Fahad can be considered as an old district and all the lands are already occupied and inhabited.
- Hittin is a luxurious district and it is divided to big land blocks which means bigger houses are constructed in that area. However, King Fahad has smaller lands and the sizes of houses are smaller than Hittin, which means that King fahad has higher number of houses.
- Mostly all the buildings in Hittin are Houses, where in King Fahad many apartments and compounds can be found their.
- King Fahad district has very narrow streets compared with Hittin, which implies more houses and more residents.

All the mentioned points explains why the ratio of mosques to population in Hittin is larger than King Fahad. These points can be generalized to include all districts belonging to the same category of Hittin and King Fahad. We can conclude that there is a spatial contrast in the distribution of mosques with respect to the population, this contrast can be seen from the uneven values of the mosque-to-population ratio, which means that the distribution of mosques in the northern areas of Riyadh is imbalanced.

Finally, we can use this map to recommend the authorized entities about which districts have the highest mosques insufficiency. In our case, obviously the Yellow marked districts are the highest in demand of new mosques. For that reason, we recommend the work on rebalancing the distribution of mosques in the yellow areas of the presented map.

6. Discussion and Conclusion

On account of the great standing of mosques in Muslims life as the places for performing the prayer obligation which is ranked as the second pillar of Islam, and the fact that the distribution of mosques in any residential area in any Islamic city is considered one of the most significant urban planning problems that demand to be analyzed for optimizing the way of allocating new mosques or even giving a rethink of the current distribution of them; the spatial distribution of mosques in the northern areas of the capital of Saudi Arabia, Riyadh, was chosen to be analyzed and investigated against any signs of a spatial disparity in the distribution of mosques over the study area taking into account the districts dividing it in addition to the local population residing in these districts. Three datasets were used to conduct this research which are Mosques dataset, Districts dataset, and Population dataset. These datasets are describing the following respectively: the mosques located in the northern of Riyadh, the division of the 29 districts located in this area, and the population resides in each of these districts.

After mapping and analyzing these data, the following two outcomes have been reached upon. First, there is a spatial disproportion in the distribution of mosques in the different districts of northern Riyadh due to the variation in population. Generally speaking, the old districts which have high number of residents have more mosques comparing with the newly developed districts which have not been fully populated. This fact made the latter left with nearly no mosques despite the fact that they are in the phase of development. Second, despite of this relation between mosques and residents, there is no clear relation could be found between the number of residents in a certain district and the number of mosques in it as a notable inequality of the distribution of mosques with respect to the residents has been found between the different districts.

Based on these outcomes, the authorized entities are advised to follow a clear plan for locating mosques taking into consideration two aspects which are: First, the balanced distribution of mosques to avoid having areas with too many mosques near to each other or empty areas with no mosques at all. Second, having a steady positive correlation between the number of residents in a certain district and the number of mosques in it to avoid having under-covered/over-covered districts. The authorized entities can make use of the produced maps to locate those districts which have great demand for new mosques as well as to balance the distribution of mosques over the entire study area, which can be considered as the main contribution of this research.

And though of this contribution, this research has two limitations. First, the research did not take into account the areas of mosques. It is rational that an area attribute would be a strong indicator for sufficiency/insufficiency of number of mosques in a certain district as a big mosque in a specific swath may be enough and meets the need while a very small one may not accommodate the number of residents in this spot. Taking the area into account could change the results of the analysis of mosques distribution. For instance, a district with 2000 residents and 15 small mosques may be of desperate need to a new mosque comparing to a district with the same number of residents but has 7 big mosques and so on. Second, although mosques dataset has an attribute that indicate the mosque type (Jamea or a regular mosque), this research did not employ it while doing the analysis. Regardless of how much regular mosques a district may has, if it has not even a single Jamea in it, this could be a sign of insufficiency.

So, regarding these limitations, a future work can make use of them and refine the current study by analyzing the distribution of mosques while taking into account the area and the type of each mosque to accurately address all aspects which may denote the imbalance distribution of mosques over the study area. And in addition to addressing the previously mentioned limitations, the future work may extend the study area to cover the entire Riyadh city as well as producing a map suggesting optimal sites for establishing new mosques or Jameas based on the need of each district, taking into consideration the area of each mosque or Jamea and the district population.

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