Evaluation of the Efficiency of the distribution of Mobile Phone Network Stations in the City of Khobar: A Study in the Geography of Communications

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Abstract

The study aimed to conduct a spatial analysis of the distribution of mobile phone stations in the city of Khobar, focusing on the neighborhoods of Khobar using GIS, specifically the ARCMAP 10.7 software, to analyze geographic distribution and pattern measurements. It also addresses Nearest Neighbor Analysis and spatial proximity metrics to identify distribution patterns of the 444 towers belonging to Saudi Telecom Company (STC), Mobily, and Zain in Khobar. The study concluded that a clustered pattern predominates, with a value of 0.630658, indicating proximity in distribution, although in an irregular form. The Nearest Neighbor Analysis for mobile phone station density in Khobar revealed a high spatial concentration in the center of the study area, a medium concentration in the center and north, and a low concentration in most residential neighborhoods in the south.

The main finding of the study is the inefficiency in the distribution of towers within the neighborhoods. The study recommended revisiting the spatial distribution structure of communication towers in the neighborhoods according to planning standards to ensure a balance between tower distribution, neighborhood area, and population.

Keywords: Spatial Analysis, Communication Towers, Geographic Information Systems.

1. Introduction

Communication geography is a modern field within economic geography, focusing on the transmission of ideas and information, whether written, auditory, or visual, whereas transportation geography focuses on the movement of goods, people, and materials (Sherif, 2011, p. 99). The Kingdom of Saudi Arabia has made significant progress in the Global Competitiveness Index 2019, advancing 16 ranks in the communications and information technology sector, ranking 38th globally, through the expansion of broadband networks and the development of digital infrastructure.

In line with the objectives of Vision 2030, which aims to radically transform the Kingdom into an international hub for information and communication technology (ICT), enabling it to compete globally through modern technologies and fostering an advanced information society, the Kingdom has secured a leading position among the largest economies in the field of technological governance. It ranked third among G20 countries and eleventh globally. This index measures the extent to which the legal frameworks of a country adapt to digital business models, such as e-commerce, the sharing economy, and financial technology (Saudi Press Agency, 2019).

Geography is a discipline that plays a significant role in the study of communications, as communication occurs between a sender and a receiver through a specific communication network, which is fundamentally geographic. Communication

also has spatial connections, contributing to the support of spatial relationships between regions. Geography, as the study of place, intersects with the social, economic, and environmental aspects of communication. Communication involves both quantitative and qualitative dimensions that geography can provide new insights into (Atlem, 2012, p. 212).

Information technology and the communications revolution lie at the heart of economic geography. Information technology and the communications revolution encompass the three core elements of economic geography: production, exchange, and consumption. Industrial goods represent production, while the storage and transmission of information represent exchange. This information ultimately reaches the consumer, thereby entering the realm of consumption (Bakir, 2013, p. 347).

This study addresses the geographic analysis of mobile phones in the city of Khobar, as a vital center from residential, economic, and educational perspectives, examining the distribution characteristics and its efficiency in the study area.

Study Area:

The city of Khobar is located geographically between latitudes 26º 5' and 26º 20' north, and longitudes 50º 5' and 50º 15' east. The city has an almost longitudinal shape and lies within the administrative division of the Eastern Province in the Kingdom of Saudi Arabia. It borders the Arabian Gulf and Saihat Bay to the east, and Half Moon Bay to the south, while Dammam lies to the north, and Dhahran to the west. Khobar covers an area of approximately 245.68 km² and had a population of 476,222 according to the 2010 census, rising to around 658,550 in the 2022 census. It ranks fourth among the cities in the Eastern Province in terms of population. Half of Khobar's population consists of expatriates, due to the presence of oil companies which have increased the demand for engineers and technicians. It is also a popular tourist destination due to its numerous markets and vibrant commercial and recreational activities.
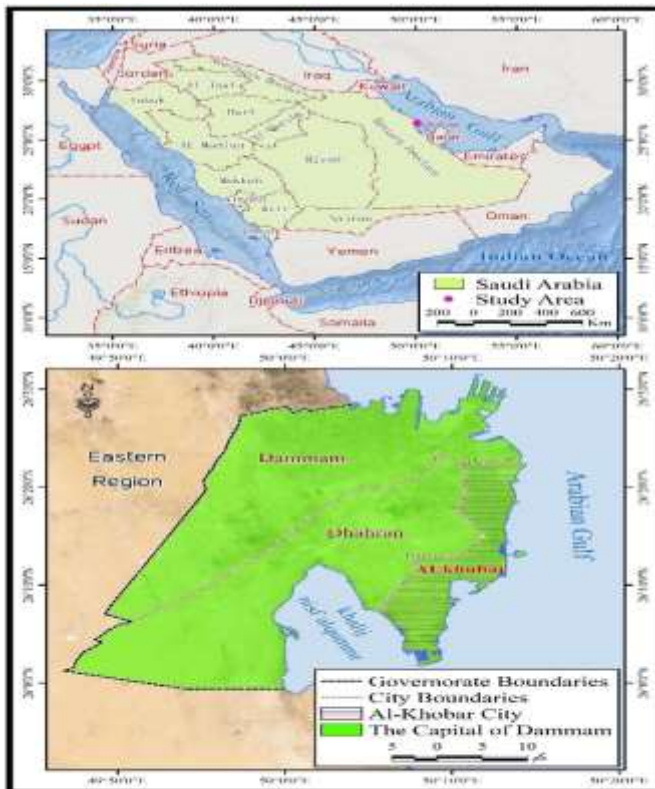
Source: Prepared by the researcher based on:
- General Authority of Survey, Atlas of Maps of the Kingdom, 2020
- Ministry of Municipal and Rural Affairs 2024
- Google Earth 2024.

Figure (1) The geographical location of of Khobar city in the Kingdom and Dammam Governorate 2024 .

Study Problem:

Stability and sustainable development are indicators of the success of any city's infrastructure, which shapes housing and urbanization patterns and their spread, revealing the population and urban concentration in the area. Khobar suffers from shortcomings in communication services and the suboptimal geographic distribution of communication outlets and networks. There are frequent complaints from residents in areas distant from the coverage of these stations and services. Given the importance of providing communication services in Khobar as a vital city in the Eastern Province, this study focuses on the efficiency of mobile communication services in the city and proposes geographical solutions to its issues.

Study Importance:

The study of communication services is a serious and vital topic within the field of geography, shedding light on a significant issue in the geography of communications—namely, the random distribution of stations. The study will address the geographical distribution problems of mobile communications, identify the locations of communication towers, and investigate the causes of weak network coverage to improve the efficiency of communication network distribution in the neighborhoods of Khobar and plan for its future development.

Reasons for Choosing the Study Topic:

Several reasons motivated the choice of this topic, the most important of which are:

1.   The study of communication geography is a new and noteworthy topic for geographical research and aligns with contemporary trends in the field.

2.   Many residential areas in Khobar face serious communication service issues, such as weak signals and insufficient coverage for receiving calls, which are problems that warrant academic study.

Research Questions:

1.   What is the geographic distribution pattern of mobile communication networks in Khobar?

Study Objectives:

This applied study aims to:

1.   Identify the locations of mobile phone stations in Khobar.

2.   Reveal the geographic distribution pattern of mobile phone stations.

3.   Develop a map of communication network distribution in the neighborhoods of Khobar using geographic information systems (GIS).

2. Study Methodology and Techniques:

The methodology of this study is based on the analytical approach, examining the spatial analysis of each element in terms of concentration, geographic localization, relational connections, and influencing factors. It also analyzes communication and information data within the study area, using ARCMAP 10.7 to perform spatial analysis of the towers through geographic distribution measurement, pattern analysis, kernel density estimation, and spatial proximity metrics. The study also adopted the integrated environmental approach, which views the place through its interrelated functional elements, where each affects the others, ultimately producing the overall environmental conditions (Sherif, 2021, p. 732). The cartographic method was used to draw shapes and maps related to the study's variables, crystallizing the analysis results and highlighting geographical facts using geographic information systems.

Field Study:

●   Sampling Method:

The student visited mobile phone station sites in the city of Khobar, which numbered 404 booster stations, to determine the company associated with each station by identifying the code listed on each tower. Mobile towers were used to identify unknown towers, and the mobile phone stations were mapped from June 2020 to March 2021. The student also gathered information on the residents living near these mobile phone stations and their issues.

●   Interview Method:

The student conducted several personal interviews from February 2021 to May 2021 with owners of residential and commercial buildings to determine the type of tower located on the buildings, especially those that are difficult to access. The interviews also aimed to verify which towers were operational and which were out of service. Additionally, some interviews were conducted with officials to understand the status of the service and its issues, such as the reasons for tower inactivity on certain buildings and weak signal strength.

●   Surveying:

The student conducted a survey of several residential neighborhoods using Google Earth Pro, in coordination with the data and maps provided by the Eastern Province Municipality. The mapping was completed using ArcMap 10.7. The

student also used the GPS Save Location application to record the coordinates of mobile phone booster stations, converting the data from KML format into point layers in ArcMap.

Previous Studies:

- Shaneishin (2008): In a study titled "Geographic Evaluation of Mobile Phone Booster Station Distribution in the City of Damanhur," the aim was to identify the distribution pattern and assess the satisfaction levels of residents in properties near the stations. One of the most significant findings was the concentration of stations in the northern part of Damanhur, requiring an adjustment of some current station locations to increase their efficiency.

- Sherif (2010): In a study titled "Geography of Landline Communications in Damietta Governorate," the researcher presented the development of landline services in the governorate and the factors influencing the communication network. The study concluded with a presentation of the future planning for telephone services.

- Sherif (2011): In another study titled "Mobile Phone Network in Port Said Governorate: A Study in Communication Geography," the importance of mobile phones in Port Said was explored, as well as the factors influencing mobile phone ownership. The study also evaluated the current geographic distribution of the mobile phone network in Port Said, highlighting both positive and negative aspects, and proposed better future planning for mobile phone services in the governorate.

- Bakheiry (2015): In a study titled "Spatial Analysis of the Influence of Mobile Phone Booster Stations and Their Efficiency in Benha City," the aim was to perform a spatial analysis of the stations and the factors affecting them, proposing an optimal distribution of the stations using geographic information systems (GIS). The study concluded that the geographic distribution of telecommunication company stations is generally safer across the neighborhoods of Benha, except for new areas.

- Al-Ajlan (2015): In a study titled "Factors Affecting the Distribution of Communication Towers: An Applied Study in East Riyadh," the geographic distribution of the communication network in East Riyadh and the factors influencing the spatial distribution of the towers were examined. The study found that administrative organization plays a role in determining the locations of towers and that some towers were built in rugged, unsuitable areas within the study zone.

- Hakim (2015): In a study titled "Spatial Analysis of Mobile Communication Services in Egypt Using Geographic Information Systems: A Case Study of West Cairo and the Village of Manti (Qalyubia)," the researcher examined the distribution of mobile phone stations for Mobinil and the economic impacts of mobile communications. The geographic model for spatial analysis was applied to West Cairo and the Village of Manti. One of the most significant findings was that 84.6% of the stations were concentrated in urban areas, while 15.4% were located in non-urban areas.

3. Discussion of Results:

First: Geographic Distribution of Mobile Phone Stations and fluencing Factors.

 Introduction:

Geographic distribution is a fundamental concept in the field of geography (Saif, 1998, p. 22). Geographers are known to focus on the spatial distributions of geographical phenomena, whether natural or human-made. In studying any distribution, geographers aim to determine whether the distribution forms a specific pattern with identifiable causes and justifications or whether it is merely random (Al-Farouq & Al-Jabri, 2009, p. 153). Thus, distribution is at the core of geographic work.

Geographic distribution is defined as the method, form, and direction in which the distribution points of geographical phenomena are spread spatially over a given area of the Earth's surface, as well as the relationship between these points (Qadri, 2014, p. 52).

Studying the distribution of mobile phone stations helps in analyzing the efficiency of the current station distribution, the level of service provided by companies to the population, and the ease of access to these services in relation to population distribution. Several criteria must be met to achieve fair and balanced geographic distribution of services, including equality in overall income, real income equality, equality in usage, cost equality, and ultimately, equality in final outcomes (Grang, 2018, pp. 8-9).

Given the population changes in the city of Khobar and the resulting increase in demand for mobile phone services, this has affected the service, both quantitatively and qualitatively, as these factors now form the backbone of modern life.

The city of Khobar includes 444 mobile phone stations, varying in their geographic distribution as illustrated in Figure 2.
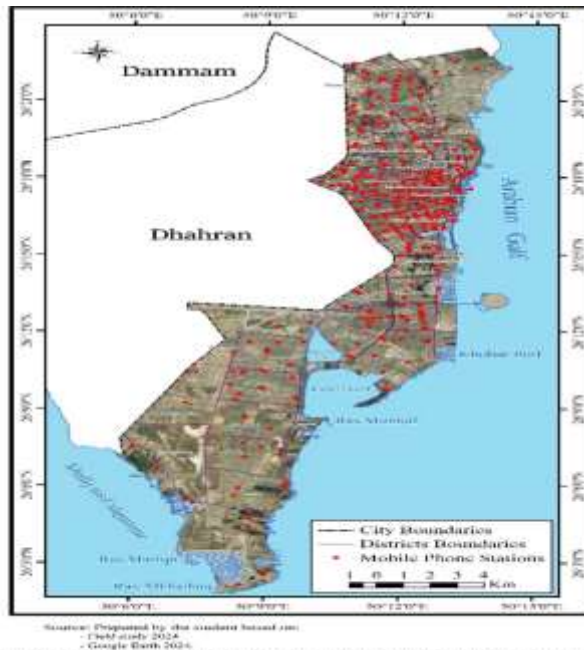
Figure (2) Geographical distribution of mobile phone stations
in the city of Khobar Districts 2020

–Numerical and Proportional Distribution:

Studying geographic distribution is one of the most closely related elements to geography due to its connection with location. It forms the broad geographic framework that defines the relationship between place and other natural and human phenomena, highlighting its spatial variation (Hussein, 2012, p. 276). In other words, it involves studying various phenomena on the Earth's surface with the purpose of describing, analyzing, and interpreting them (Sheikh, 2008, p. 5). Thus, distribution serves as the starting point for any geographic study and is a necessary step for understanding the behavior of any geographic phenomenon. To clarify the spatial distribution efficiency of mobile phone stations in Khobar, it is essential to study and analyze their geographic distribution across various geographic phenomena. Therefore, we will examine the geographic distribution of stations at the residential neighborhood level.

The geographic distribution of mobile phone stations reflects the availability of phone services in different geographic areas and their adequacy for the population. While population size is an important criterion for studying the services provided, its importance lies in comparing the service levels of mobile phone stations at both the local and national levels.

There are several factors leading to the unequal distribution of mobile phone stations in the study area, the most significant being the concentration of the majority of stations in the city center and northern areas, especially in older, densely populated residential neighborhoods. This centralization in distribution results in some residents being deprived of services, and certain residential neighborhoods lacking mobile phone stations.

- Numerical Distribution:

The factors influencing the distribution of mobile phone stations vary, as does their distribution across different residential neighborhoods in terms of quantity and quality. There is significant variation in the distribution of mobile phone stations between the city's neighborhoods, from the center to the north and south, which aligns with one of the study's hypotheses. .

Khobar contains 444 mobile phone stations serving an area of approximately 191.65 km² and a population of 476.2 thousand. The stations are unevenly distributed across residential neighborhoods and are operated by four companies: (Etisalat with 218 stations, Mobily with 177 stations, Zain with 48 stations, and Atheeb with one station). The results can be drawn from studying Table (1) and Figure (2):

Table (1): Numerical and Proportional Distribution of Mobile Phone Stations in the Residential Neighborhoods of Khobar City in 2022

No.	Residential Neighborhood	Stations	%	No.	Residential Neighborhood	Stations	%
1	Al-Khobar Al-Janoubia	38	8.6	26	Al-Buhaira	6	1.4
2	Al-Thuqbah	36	8.1	27	Half Moon Beach	5	1.1
3	Al-Khobar Al-Shamalia	31	7.0	28	Al-Hamra	4	0.9
4	Al-Aqrabia	28	6.3	29	Al-Taawun	4	0.9
5	Madinat Al-Umal	25	5.6	30	Al-Lulu	4	0.9
6	Al-Ulaya	21	4.7	31	Al-Bandaria	4	0.9
7	Al-Rakah Al-Janoubia	19	4.3	32	Al-Hada	3	0.7
8	Al-Jisr	18	4.1	33	Ibn Sina	3	0.7
9	Al-Hizam Al-Dhahabi	15	3.4	34	Al-Sahil	3	0.7
10	Qurtuba	15	3.4	34	Al-Sufun	3	0.7
11	Al-Tahlia	15	3.4	36	Al-Amwaj	3	0.7
12	Al-Shiraa	15	3.4	37	Al-Sadfa	3	0.7
13	Al-Rakah Al-Shamalia	14	3.2	38	Al-Bustan	2	0.5
14	Al-Corniche	12	2.7	39	Al-Raja	2	0.5
15	Al-Khuzama	10	2.3	40	Al-Aqiq	2	0.5
16	Al-Sawari	8	1.8	41	Al-Madina Al-Riyadiya	2	0.5
17	Al-Yarmouk	8	1.8	42	Al-Shifa	2	0.5
18	Al-Andalus	8	1.8	43	Al-Kawthar	1	0.2
19	Al-Jawhara	7	1.6	44	Al-Maha	1	0.2
20	Al-Thuqbah Industrial	7	1.6	45	Al-Khor	1	0.2
21	Al-Fawazia Industrial	7	1.6	46	Al-Bahr	1	0.2
22	Al-Hizam Al-Akhdar	7	1.6	47	Ishbilia	-	-
23	Al-Iskan	7	1.6	48	Al-Murjan	-	-
24	Al-Rawabi	7	1.6				
25	Al-Durrah	7	1.6		Total	444	100

Source: Prepared by the student based on field study data.

- The residential neighborhood of Al-Khobar Al-Janoubia ranked first in terms of the number of mobile phone stations in Khobar, with 38 stations. It is followed by Al-
- population size.
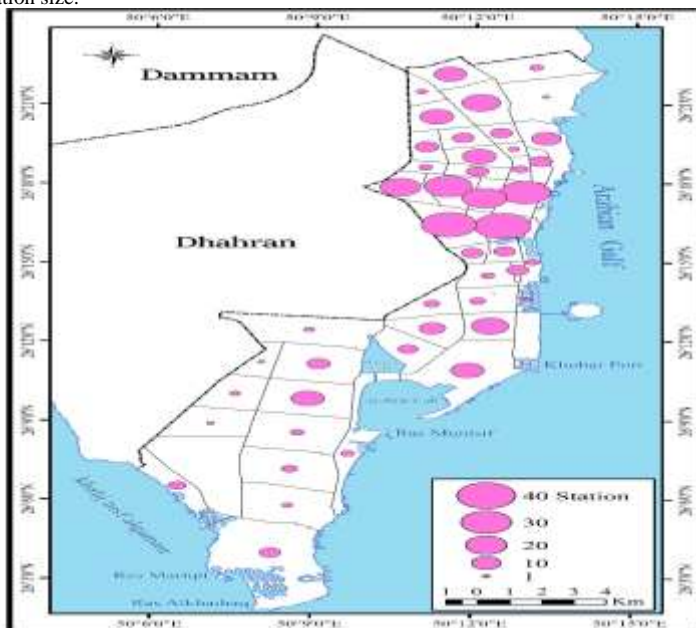
Source: Table (1).
Figure (3) Numerical distribution of mobile phone stations in Districts of Khobar 2020

• Thuqbah with 36 stations in second place, Al-Khobar Al-Shamalia in third with 31 stations, and Al-Aqrabia in fourth place with 28 stations. Meanwhile, Madinat Al-Umal ranked fifth with 25 stations, and Al-Ulaya ranked sixth with 21 stations. These neighborhoods are located in central Khobar, collectively holding nearly half of the total mobile phone stations in the city, with 179 stations. This is due to the fact that these neighborhoods are among the oldest in the city and are home to more than half of Khobar's population.

• The residential neighborhoods in northern Khobar include about 127 mobile phone stations across 16 residential neighborhoods, covering an area of 44.3 km², with a population of 83.2 thousand.

• The residential neighborhoods in southern Khobar include about 138 mobile phone stations across 26 residential neighborhoods, covering an area of 130.2 km², with a population of 62.6 thousand.

• The residential neighborhoods of Ishbilia and Al-Murjan lack mobile phone stations, as they are newly established areas.

• The variation in the number of mobile phone stations between Khobar's residential neighborhoods is attributed to the age of these neighborhoods, as well as their population size.

• Proportional Distribution:

Based on Table (1), Table (2), and Figure (4), the residential neighborhoods in Khobar can be divided into the following categories:

Table (2): Categories of Proportional Distribution of Mobile Phone Stations in the Residential Neighborhoods of Khobar City in 2022

Categories	Residential Neighborhoods	Population	Area	Stations
5% or more	5	320580	15.41	158
3% to less than 5%	8	77904	36.30	132
1% to less than 3%	14	58917	50.41	106
Less than 1%	19	18821	75.92	48
No Stations	2	-	13.61	-
Total	48	476222	191.7	444

Source: Prepared by the student based on data from Table (1).

• 5% or more of the total stations:

The residential neighborhood of Al-Khobar Al-Janoubia ranked first with 8.6%, followed by Al-Thuqbah with 8.1%, Al-Khobar Al-Shamalia with 7%, Al-Aqrabia with 6.3%, and Madinat Al-Umal with 5.6%. These five neighborhoods contain 158 stations, representing 35.6% of the total mobile phone stations in Khobar. These neighborhoods are located in the city center, accounting for 10.4% of the total residential neighborhoods in Khobar. They are home to 320,580 people, which is 67.3% of the total population, and cover an area of 15.41 km², representing 8% of the city's total area.
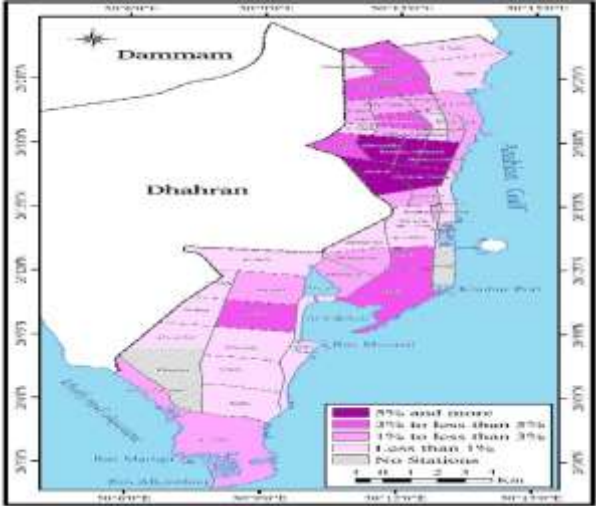
Source: Table (2).
Figure (4) Relative distribution of mobile phone stations in Districts of Khobar 2020

- 3% to less than 5% of the total stations:

Eight residential neighborhoods, distributed between the north and south, make up 16.7% of the total residential neighborhoods in Khobar, and include 132 stations, representing 29.7% of the total mobile phone stations in the city. These neighborhoods cover an area of approximately 36.3 km², representing 18.9% of the city's total area, with a population of 77.9 thousand, which is 16.4% of the total population.

- 1% to less than 3% of the total stations:

Fourteen residential neighborhoods, spread across the north, center, and south, account for 29.2% of the total residential neighborhoods in Khobar. These neighborhoods contain 106 stations, representing 23.9% of the total mobile phone stations in the city. They cover an area of approximately 50.4 km², which is 26.3% of the city's total area, and are home to 58.9 thousand residents, representing 12.4% of the total population.

- Less than 1% of the total stations:

Nineteen residential neighborhoods, spread across the north, center, and south, make up 39.6% of the total residential neighborhoods in Khobar. These neighborhoods contain 48 stations, representing 10.8% of the total mobile phone stations in the city. They cover an area of approximately 75.9 km², which is 39.6% of the city's total area, and have a population of 18.8 thousand, representing 4% of the total population.

- Residential neighborhoods without stations:

The residential neighborhoods of Ishbilia and Al-Murjan lack mobile phone stations, as they are newly developed areas.

2- Qualitative Distribution (by Company)

The types of mobile phone stations in Khobar vary based on the companies, including Etisalat, Mobily, Zain, and Itihad Atheeb. Analyzing Table (3), and Figures (5) and (6) reveals the following:

Table (3): Distribution of Mobile Phone Stations by Company in the Residential Neighborhoods of Khobar City in 2022

No.	Residential Neighborhood	Etisalat	Mobily	Zain	Itihad Atheeb	Total	%
1	Al-Khobar Al-Janoubia	18	19	1	0	38	8.6
2	Al-Thuqbah	28	6	2	0	36	8.1
3	Al-Khobar Al-Shamalia	19	12	0	0	31	7.0
4	Al-Aqrabia	10	15	3	0	28	6.3
5	Madinat Al-Umal	15	10	0	0	25	5.6
6	Al-Ulaya	8	9	4	0	21	4.7
7	Al-Rakah Al-Janoubia	8	9	2	0	19	4.3
8	Al-Jisr	7	7	4	0	18	4.1
9	Al-Tahlia	6	6	4	0	16	3.6
10	Qurtuba	8	5	2	0	15	3.4
11	Al-Shiraa	6	6	2	0	14	3.2
12	Al-Rakah Al-Shamalia	8	6	0	0	14	3.2
13	Al-Corniche	7	5	0	0	12	2.7
14	Al-Hizam Al-Dhahabi	4	5	3	0	12	2.7
15	Al-Jawhara	5	3	2	0	10	2.3
16	Al-Khuzama	4	5	1	0	10	2.3
17	Al-Sawari	4	3	2	0	9	2.0
18	Al-Yarmouk	5	2	1	0	8	1.8
19	Al-Andalus	4	3	1	0	8	1.8
20	Al-Thuqbah Industrial	4	2	1	0	7	1.6
21	Al-Fawazia Industrial	2	3	2	0	7	1.6
22	Al-Hizam Al-Akhdar	3	3	1	0	7	1.6
23	Al-Iskan	4	2	0	1	7	1.6
24	Al-Durrah	3	2	2	0	7	1.6
25	Al-Buhaira	2	3	1	0	6	1.4
26	Al-Rawabi	2	3	1	0	6	1.4
27	Half Moon Beach	3	1	1	0	5	1.1
28	Al-Hamra	1	2	1	0	4	0.9
29	Al-Taawun	1	2	1	0	4	0.9
30	Al-Lulu	1	2	1	0	4	0.9
31	Al-Bandaria	2	2	0	0	4	0.9
32	Al-Hada	1	2	0	0	3	0.7
33	Ibn Sina	2	1	0	0	3	0.7

34	Al-Sahil	3	0	0	0	3	0.7
35	Al-Sufun	1	1	1	0	3	0.7
36	Al-Amwaj	1	2	0	0	3	0.7
37	Al-Sadfa	1	2	0	0	3	0.7
38	Al-Bustan	1	1	0	0	2	0.5
39	Al-Raja	1	1	0	0	2	0.5
40	Al-Aqiq	1	1	0	0	2	0.5
41	Al-Madina Al-Riyadiya	0	1	1	0	2	0.5
42	Al-Shifa	2	0	0	0	2	0.5
43	Al-Kawthar	0	1	0	0	1	0.2
44	Al-Maha	0	1	0	0	1	0.2
45	Al-Khor	1	0	0	0	1	0.2
46	Al-Bahr	1	0	0	0	1	0.2
47	Ishbilia	0	0	0	0	0	0
48	Al-Murjan	0	0	0	0	0	0
Total	No.	218	177	48	1	444	100
	%	49.1	39.9	10.8	0.2	100	
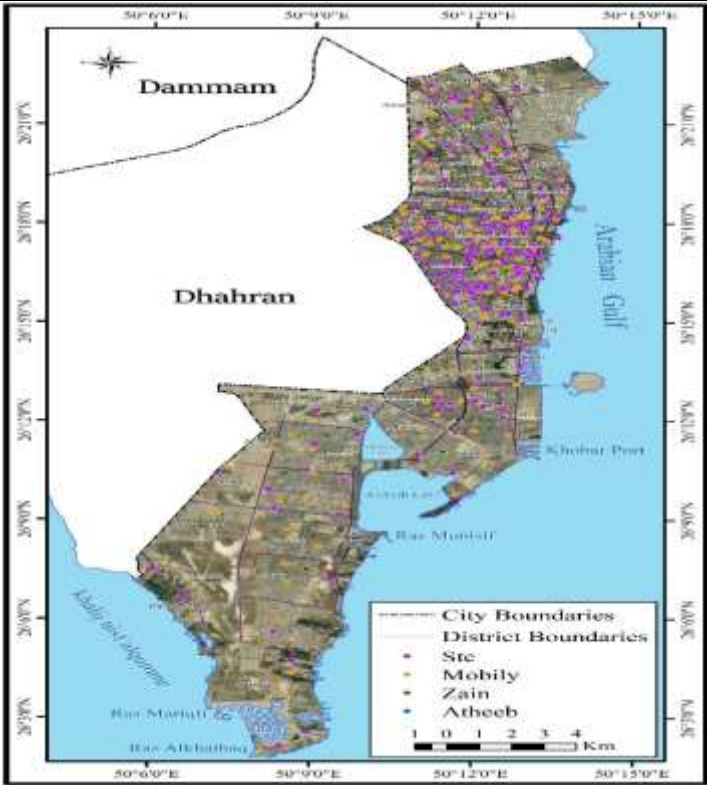
Source: Table (3).
Figure (5) Geographical distribution of mobile phone stations in Khobar city according to company type 2022
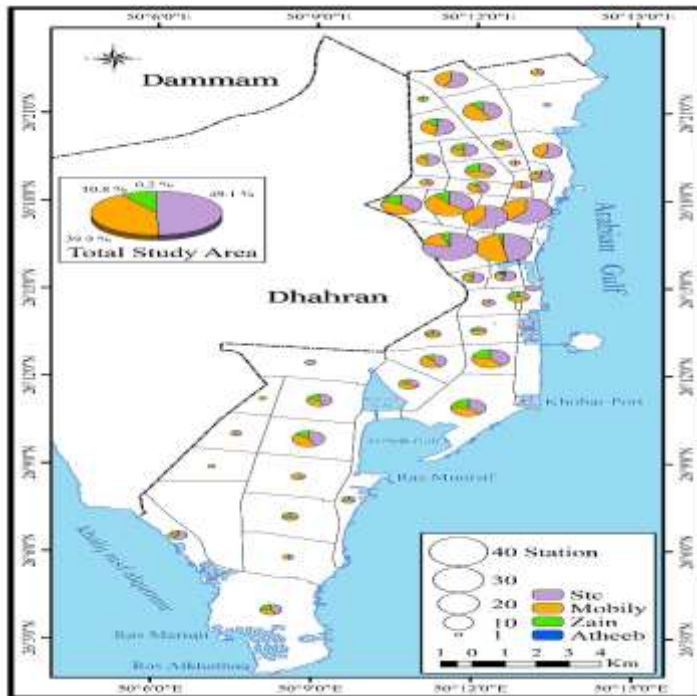
Source: Table (3).

Figure (6) Numerical distribution of mobile phone stations in Khobar city according to company type 2022

Khobar City includes 444 mobile phone stations, distributed among four companies:

Etisalat operates 218 stations, representing 49.1% of the total stations in Khobar.

Mobily operates 177 stations, representing 39.9%.

Zain operates 48 stations, representing 10.8%.

Itihad Atheeb operates 1 station, representing 0.2%.

‒ Etisalat Saudi Telecom Company:

Etisalat ranks first in terms of the number of mobile phone stations in the study area, with 218 stations, representing 49.1% of the total stations in Khobar. Based on the analysis of Table (3), and Figures (5) and (6), the following can be noted:

• Al-Thuqbah residential neighborhood ranks first in terms of the number of Etisalat stations, with 28 stations (12.8% of the total Etisalat stations), followed by Al-Khobar Al-Shamalia with 19 stations (8.7%), Al-Khobar Al-Janoubia with 8.3%, and Madinat Al-Umal in fourth place with 15 stations (6.9%). These neighborhoods are located in the center of Khobar and contain 80 mobile phone stations, which represent 36.7% of the total Etisalat stations in the city.

• The central neighborhoods of the city rank first in terms of the number of Etisalat stations, with 120 stations (55% of the total Etisalat stations in Khobar), distributed across a quarter of the city's neighborhoods. These stations serve more than three-quarters of the city's population and cover an area of less than one-fifth of Khobar's total area.

• The northern neighborhoods of the city rank second, with 53 Etisalat stations (24.3%), spread across 15 neighborhoods, which represent 31.3% of the total number of residential neighborhoods in the city. These stations serve 16.9% of the population and cover 20.3% of Khobar's total area.

• The southern neighborhoods of Khobar rank last, with approximately 45 stations (20.6%), spread across 21 neighborhoods. These stations serve 6.6% of the population and cover 63.2% of Khobar's total area.

‒ Mobily Company:

Mobily ranked second in terms of the number of mobile phone stations in the study area, with 177 stations, representing 39.9% of the total stations in the city of Khobar. By analyzing Table No. (3) and Figures No. (5) and (6), the following is evident:

● The residential district (Al-Khobar South) ranked first in terms of the number of mobile stations for Mobily, with 19 stations, representing 10.7% of Mobily's total mobile stations. It is followed by Al-Aqrabiyah with 15 stations, representing 8.5%, then North Khobar with 6.8%. In fourth place came the residential district (Madinat Al-Omal) with 10 stations, representing 5.6%, followed by Al-Rakah South and Al-Olaya, with 9 stations each. These residential districts, located in central Khobar, housed 74 mobile stations, representing 41.8% of Mobily's total mobile stations in Khobar.

● The residential areas in the city center ranked first in terms of the number of Mobily stations, with 84 stations, representing 47.5% of the total Mobily mobile stations in Khobar, distributed across a quarter of the city's residential neighborhoods, serving more than three-quarters of the city's population, and spread over less than one-fifth of Khobar's total area.

● The northern neighborhoods of the city came in second place, with 47 Mobily stations, representing 26.6%, spread across 15 residential neighborhoods, making up 31.3% of the city's residential areas, serving 16.9% of the total population, and covering 20.3% of the total area of Khobar.

● The southern residential districts of Khobar ranked last, with 46 stations, representing 26%, spread across 21 residential neighborhoods, serving 6.6% of the total population, and covering 63.2% of Khobar's total area.

● Zain Company:

Zain ranked third in terms of the number of mobile stations in the study area, with 48 stations, representing 10.8% of the total stations in Khobar. By analyzing Table No. (3) and Figures No. (5) and (6), the following is evident:

● The residential areas (Al-Olaya, Al-Jisr, Al-Tahlia) ranked first in terms of the number of mobile stations for Zain, with four stations each, representing 8.3% of Zain's total mobile stations. This is followed by Al-Aqrabiyah with 3 stations, representing 6.3%, then Al-Hizam Al-Dhahabi with 6.3%. In third place came the residential districts (Al-Rakah South, Al-Jawhara, Al-Sawari, Industrial Al-Fawazia, Qurtuba, Al-Shira'a, Al-Durra, Al-Thuqbah), with two stations each, representing 4.2% of the total. Meanwhile, 14 residential neighborhoods registered one Zain station each, while 21 residential neighborhoods had no Zain stations.

● The residential areas in southern Khobar ranked first, with 21 stations, representing 43.8%, spread across 21 residential neighborhoods, serving 6.6% of the total population, and covering 63.2% of Khobar's total area.

● The northern neighborhoods of the city ranked second, with 14 Zain stations, representing 29.2%, spread across 15 residential neighborhoods, covering 31.3% of the city's residential areas, serving 16.9% of the total population, and spanning 20.3% of Khobar's total area.

● The residential areas in the city center ranked last in terms of the number of Zain stations, with 13 stations, representing 27.1% of the total Zain mobile stations in Khobar, distributed across a quarter of the city's residential neighborhoods, serving more than three-quarters of the city's population, and covering less than one-fifth of Khobar's total area.

– Etihad Atheeb Company:

Etihad Atheeb ranked last in terms of the number of mobile stations in the study area, with just one station, representing 0.2% of the total stations in Khobar, concentrated in the residential neighborhood (Al-Iskan).

3. Distribution Based on Population, Area, and Buildings: The population equation is considered the primary equation for measuring the distribution of mobile stations across residential neighborhoods (Maki, 1989, p. 221). While the area element generally plays a key role in measuring any distribution, it can be noted that there are large areas, even within the city, particularly in the south, where some populated neighborhoods have not yet reached the population density necessary to attract these stations for settlement and expansion. Accordingly, the geographic distribution of mobile stations across Khobar's residential neighborhoods can be analyzed based on population, area, and number of buildings.
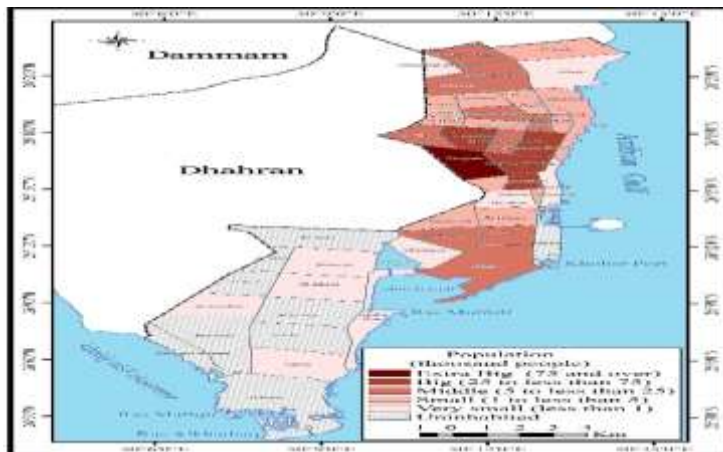
A- Population:

1. Population Size: Table (4) and Figure (7) illustrate the population sizes and their relation to the number of mobile phone stations in Khobar city in 2022. The following can be observed:

Table (4): Population Sizes and Their Relation to the Number of Mobile Phone Stations in Khobar City in 2022

Population Size (thousands)	Residential Areas		Population		Mobile Stations	
	Number	%	Number	%	Number	%
Very Large (75 or more)	1	2.1	119,483	25.1	36	8.1
Large (25 to less than 75)	4	8.3	205,290	43.1	104	23.4
Medium (5 to less than 25)	10	20.8	111,328	23.4	156	35.1
Small (1 to less than 5)	13	27.1	35,980	7.6	79	17.8
Very Small (Less than 1)	10	20.8	4,141	0.9	44	9.9
Uninhabited	10	20.8	-	0.0	25	5.6
Total	48	100	476,222	100	444	100

Source: Prepared by the student

● Very Large Population (75,000 people or more): This category includes only the Al-Thuqbah neighborhood, which ranked first in terms of population size, comprising a quarter of Khobar's population. It ranked second in the number of mobile phone stations, with about 36 stations, representing 8.1% of the total mobile phone stations in Khobar. This neighborhood is one of the oldest and most densely populated areas.

● Large Population (25,000 to less than 75,000): This category includes four residential neighborhoods (Al-Khobar South, Al-Khobar North, Al-Aqrabiyah, and Al-Iskan). These are old neighborhoods located in the center of Khobar, comprising 43.1% of the city's population, with 104 stations, representing 23.4% of the total mobile stations in Khobar.

● Medium Population (5,000 to less than 25,000): This category includes ten residential neighborhoods, making up 20.8% of the total residential areas in Khobar. They comprise 23.4% of the city's population and have 156 stations, representing 35.1% of the total mobile phone stations in Khobar, concentrated in the northern part of the city.

● Small Population (1,000 to less than 5,000): This category includes 13 residential neighborhoods, representing 27.1% of the total residential areas in Khobar. These neighborhoods comprise 7.6% of the city's population and have 79 stations, representing 17.8% of the total mobile phone stations in Khobar.

● Very Small Population (less than 1,000): This category includes 10 residential neighborhoods, representing 20.8% of the total residential areas in Khobar. They comprise 0.9% of the city's population and have 44 stations, representing 9.9% of the total mobile phone stations in Khobar, concentrated in the southern part of the city.

● Uninhabited Areas: This category includes 10 residential neighborhoods, representing 20.8% of the total residential areas in Khobar. These areas have 25 stations, representing 5.6% of the total mobile phone stations in Khobar, concentrated in the southern part of the city.

Source: Table (4).
Figure (7) Population categories in Al-Khobar city 2022

Average Number of People Served by Each Mobile Phone Station:

Table (5), (6), and Figure (8) illustrate the average number of people served by each mobile phone station (people/station) in the residential areas of Khobar in 2022. The following can be observed:

Table (5): Categories of the Average Number of People Served by Each Mobile Phone Station in Khobar in 2022

People/Station	Residential Areas		Population		Mobile Stations	
	Number	%	Number	%	Number	%
Very High (2000 or more)	3	6.3	212,395	44.6	74	16.7
High (1500 to less than 2000)	2	4.2	79,678	16.7	42	9.5
Medium (1000 to less than 1500)	4	8.3	76,232	16.0	64	14.4
Low (500 to less than 1000)	8	16.7	56,126	11.8	78	17.6
Very Low (less than 500)	21	43.8	51,791	10.9	161	36.3
Uninhabited	10	20.8	-	0.0	25	5.6
Total	48	100	476,222	100	444	100

Source: Prepared by the student based on field study data.

The average number of people served by a mobile phone station in Khobar is approximately 1,073 people/station. The Al-Iskan neighborhood ranked first with 3,662 people per station, attributed to the large population of the neighborhood (25.6 thousand people) served by only 7 mobile stations. Meanwhile, the Al-Sawari neighborhood ranked last with 14 people per station, as it has a small population of 113 people served by 8 mobile stations.

● Very High (2000 people or more/station): This category includes three residential neighborhoods (Al-Iskan, Al-Thuqbah, and North Khobar), which are old neighborhoods located in the center of Khobar, comprising 44.6% of the city's population, with 74 stations, representing 16.7% of the total mobile stations in Khobar.

Table (6): Average Number of People Served by Each Mobile Phone Station (People/Station) in Khobar Residential Areas in 2022

No.	Residential Area	Population	Stations	Average People Served/Station
1	Al-Khobar South	73,655	38	1,938
2	Al-Thuqbah	119,483	36	3,319
3	North Khobar	67,277	31	2,170
4	Al-Aqrabiyah	38,723	28	1,383
5	Madinat Al-Omal	21,442	25	858
6	Al-Olaya	9,874	21	470
7	South Al-Rakah	19,032	19	1,002
8	Al-Jisr	12,770	18	709
9	Al-Hizam Al-Dhahabi	7,280	15	485
10	Qurtuba	6,356	15	424
11	Al-Tahlia	6,714	15	448
12	Al-Shira'a	591	15	39
13	North Al-Rakah	15,287	14	1,092
14	Al-Corniche	2,686	12	224
15	Al-Khozama	6,550	10	655
16	Al-Sawari	113	8	14
17	Al-Yarmouk	3,337	8	417
18	Al-Andalus	4,493	8	562
19	Al-Jawhara	3,674	7	525
20	Industrial Al-Thuqbah	3,077	7	440
21	Industrial Al-Fawazia	1,177	7	168
22	Al-Hizam Al-Akhdar	4,706	7	672
23	Al-Iskan	25,635	7	3,662
24	Al-Rawabi	3,146	7	449
25	Al-Durra	-	7	-
26	Al-Buhaira	323	6	54
27	Half Moon Beach	-	5	-
28	Al-Hamra	1,480	4	370
29	Al-Taawon	1,720	4	430
30	Al-Lu'lu'a	-	4	-
31	Al-Bandariah	6,023	4	1,506
32	Al-Hada	1,443	3	481
33	Ibn Sina	789	3	263
34	Al-Sahil	530	3	177

35	Al-Sufun	999	3	333
36	Al-Amwaj	-	3	-
37	Al-Sadfa	3,190	3	1,063
38	Al-Bustan	1,851	2	926
39	Al-Raja	-	2	-
40	Al-Aqiq	87	2	44
41	Sports City	54	2	27
42	Al-Shifa	-	2	-
43	Al-Kawthar	15	1	15
44	Al-Maha	0	1	-
45	Al-Khor	0	1	-
46	Al-Bahr	640	1	640
47	Isbilia	-	-	-
48	Al-Murjan	-	-	-

Total: 476,222 people, 444 stations, and an average of 1,073 people per station.

Source: Prepared by the student based on field study data, with percentages calculated by the student.

The high number of people served per station is due to the large population of 25.6 thousand people being served by only 7 mobile phone stations, as seen in the Al-Iskan neighborhood. Meanwhile, in the Al-Quba and North Khobar neighborhoods, both the population and the number of stations are high.

High (1,500 to less than 2,000 people per mobile phone station): This category includes the neighborhoods of Al-Khobar South and Al-Bandariah, which represent 4.2% of the total residential areas, containing 16.7% of the city's population, and 42 stations, representing 9.5% of the total mobile phone stations in Khobar. The population and the number of stations increase in Al-Khobar South, an old, densely populated residential area, while both the population and the number of stations decrease in Al-Bandariah.

Medium (1,000 to less than 1,500 people per mobile phone station): This category includes the neighborhoods of Al-Aqrabiyah, North Al-Rakah, Al-Sadfa, and South Al-Rakah, representing 8.3% of the total residential areas, containing 16% of the city's population, and 64 stations, representing 14.4% of the total mobile phone stations in Khobar. Both the population and the number of stations increase in Al-Aqrabiyah, an old, densely populated residential area, while both the population and number of stations decrease in Al-Sadfa. North Al-Rakah and South Al-Rakah have moderate populations and a moderate number of stations.
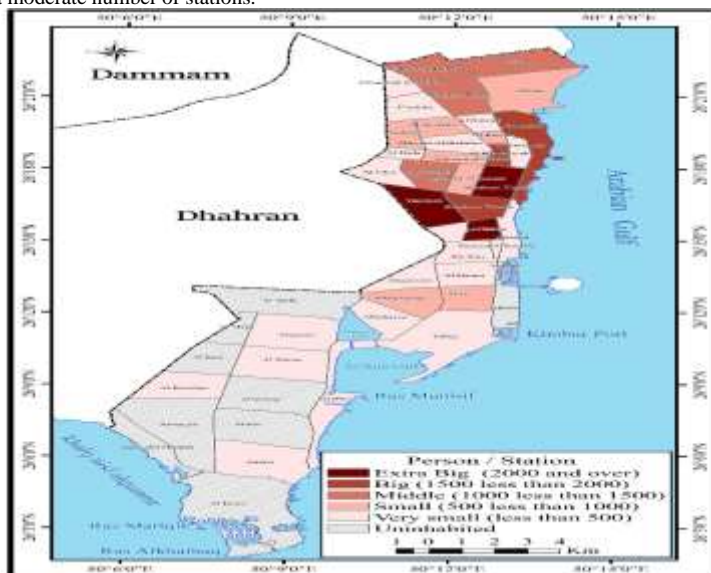
Source: Table (6).

Figure (8) Average population served by mobile phone station (person/station) in Al−Khobar city 2022

Low (500 to less than 1,000 people per mobile phone station): This category includes 8 residential neighborhoods, representing 16.7% of the total residential areas, containing 11.8% of the city's population, and 78 stations, representing 17.6% of the total mobile phone stations in Khobar. These neighborhoods are concentrated in the north and south of the city.

Very Low (less than 500 people per mobile phone station): This category includes 21 residential neighborhoods, representing 43.8% of the total residential areas, containing 10.9% of the city's population, and 161 stations, representing 36.3% of the total mobile phone stations in Khobar. These neighborhoods are concentrated in the north and south of the city.

Uninhabited Areas: This category includes 10 residential neighborhoods, representing 20.8% of the total residential areas in Khobar, containing 25 stations, which account for 5.6% of the total mobile phone stations in the city. These areas are concentrated in the south of the city.

B- Area:

1.	Area Categories: Table (7) and Figure (9) show the categories of residential area sizes and their relation to the number of mobile phone stations in Khobar city in 2022, as follows:

Table (7): Area Categories and Their Relation to the Number of Mobile Phone Stations in Khobar City in 2022

Area Categories (km²)	Residential Areas	Area (km²)	Mobile Stations
	Number (%)	km² (%)	Number (%)
Very Large (8 km² or more)	4 (8.3%)	43.6 (22.8%)	24 (5.4%)
Large (6 to less than 8 km²)	6 (12.5%)	43.0 (22.4%)	33 (7.4%)
Medium (4 to less than 6 km²)	8 (16.7%)	37.6 (19.6%)	81 (18.2%)
Small (2 to less than 4 km²)	18 (37.5%)	52.4 (27.4%)	226 (50.9%)
Very Small (less than 2 km²)	12 (25.0%)	15.1 (7.9%)	80 (18.0%)
Total	48 (100%)	191.7 (100%)	444 (100%)

Source: Prepared by the student.

●	Very Large Area (8 km² or more): This category includes four residential neighborhoods (Al-Durra, Al-Murjan, Al-Tahlia, and Al-Shifa), which are newly developed areas in the southern part of Khobar, representing 8.3% of the total residential areas, covering 43.6% of Khobar's total area. These neighborhoods contain 24 mobile stations, representing 5.4% of the total stations in the city.

●	Large Area (6 km² to less than 8 km²): This category includes six residential neighborhoods (Al-Lu'lu', Al-Amwaj, Al-Aqiq, Al-Bahr, Al-Sawari, and Al-Shira'a), which are newly developed areas in the southern part of Khobar, representing 12.5% of the total residential areas, covering 22.4% of Khobar's total area. These neighborhoods contain 33 mobile stations, representing 7.4% of the total stations in the city.

●	Medium Area (4 km² to less than 6 km²): This category includes eight residential neighborhoods, located in both the northern and southern parts of Khobar, representing 16.7% of the total residential areas, covering 19.6% of the city's total area. These neighborhoods contain 81 mobile stations, representing 18.2% of the total stations in the city.

●	Small Area (2 km² to less than 4 km²): This category includes 18 residential neighborhoods, located in the central and northern parts of Khobar, representing 37.5% of the total residential areas, covering 27.4% of Khobar's total area. These neighborhoods contain 226 mobile stations, representing 50.9% of the total stations in the city.

●	Very Small Area (less than 2 km²): This category includes 12 residential neighborhoods located in central and northern Khobar, representing 25% of the total residential areas in the city, covering 7.9% of the total area. These neighborhoods contain 80 mobile stations, accounting for 18% of the total mobile phone stations in Khobar.
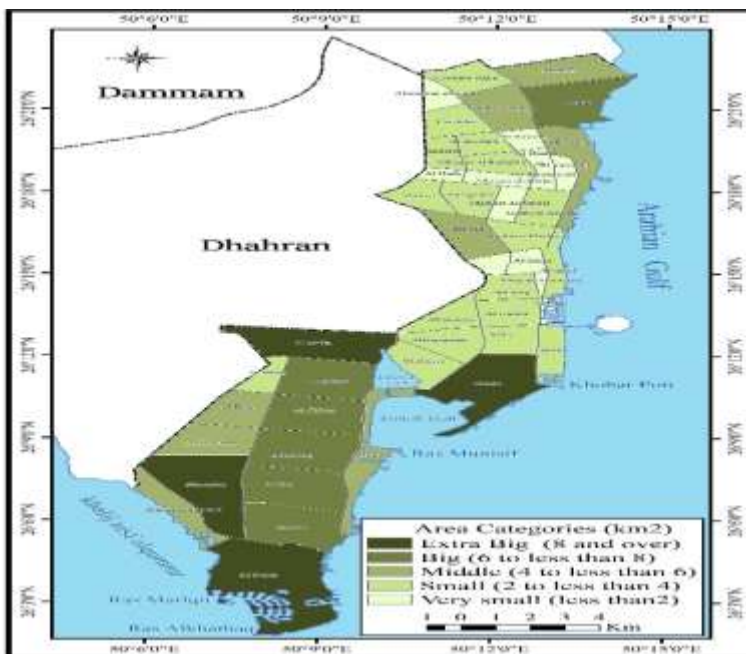
Source: Table (7).
Figure (9) Categories of Districts area in the city of Khobar 2022

• Average Number of Mobile Phone Stations per Area: Table (8), (9), and Figure (10) illustrate the average number of mobile phone stations per area (stations/km²) in the residential neighborhoods of Khobar in 2022. The following can be observed:

Table (8): Categories of the Average Number of Mobile Phone Stations per Area in Khobar Residential Neighborhoods in 2022

Stations/km²	Residential Areas	Area (km²)	Mobile Stations
	Number (%)	km² (%)	Number (%)
Very High (8 or more)	5 (10.4%)	11.3 (5.9%)	129 (29.1%)
High (6 to less than 8)	2 (4.2%)	7.5 (3.9%)	57 (12.8%)
Medium (4 to less than 6)	10 (20.8%)	24.2 (12.7%)	117 (26.4%)
Low (2 to less than 4)	8 (16.7%)	22.8 (11.9%)	61 (13.7%)
Very Low (less than 2)	21 (43.8%)	112.2 (58.5%)	80 (18.0%)
No Stations	2 (4.2%)	13.6 (7.1%)	-
Total	48 (100%)	191.7 (100%)	444 (100%)

Source: Prepared by the student.

The average number of mobile phone stations per area in Khobar is approximately 2.3 stations/km². The Industrial Al-Fawazia neighborhood ranked first with 16.7 stations/km² due to its small area of 0.42 km², served by 7 mobile stations. Meanwhile, Madinat Al-Omal ranked second, and Al-Khobar South third, both with 13.3 stations/km². The Al-Bahr neighborhood ranked last with about 0.1 station/km² due to its large area being served by just one mobile station.

• Very High (8 or more mobile phone stations per km²): This category includes five residential neighborhoods (Industrial Al-Fawazia, Madinat Al-Omal, Al-Khobar South, North Khobar, and Al-Aqrabiyah), which are located in central Khobar, representing 10.4% of the total residential areas, covering 5.9% of the total area, and containing 129 mobile stations, accounting for 29.1% of the total stations in the city.

Table (9): Average Number of Mobile Phone Stations per Area in Khobar Residential Neighborhoods in 2022 (Stations/km²)

No.	Residential Area	Area (km²)	Stations	Average Stations/Area (Stations/km²)
1	Al-Khobar South	2.85	38	13.3
2	Al-Thuqbah	4.54	36	7.9

3	North Khobar	3.03	31	10.2
4	Al-Aqrabiyah	3.11	28	9.0
5	Madinat Al-Omal	1.88	25	13.3
6	Al-Olaya	2.93	21	7.2
7	South Al-Rakah	4.66	19	4.1
8	Al-Jisr	3.08	18	5.8
9	Al-Hizam AlDhahabi	2.52	15	5.9
10	Qurtuba	3.24	15	4.6
11	Al-Tahlia	9.85	15	1.5
12	Al-Shira'a	6.64	15	2.3
13	North Al-Rakah	3.38	14	4.1
14	Al-Corniche	5.26	12	2.3
15	Al-Khozama	3.83	10	2.6
16	Al-Sawari	6.75	8	1.2
17	Al-Yarmouk	1.41	8	5.7
18	Al-Andalus	2.18	8	3.7
19	Al-Jawhara	2.01	7	3.5
20	Industrial Al-Thuqbah	1.26	7	5.6
21	Industrial Al-Fawazia	0.42	7	16.7
22	Al-Hizam Al-Akhdar	1.65	7	4.3
23	Al-Iskan	1.63	7	4.3
24	Al-Rawabi	1.43	7	4.9
25	Al-Durra	14.74	7	0.5
26	Al-Buhaira	3.72	6	1.6
27	Half Moon Beach	4.12	5	1.2
28	Al-Hamra	3.26	4	1.2
29	Al-Taawon	3.26	4	1.2
30	Al-Lu'lu'	7.65	4	0.5
31	Al-Bandariah	1.10	4	3.6
32	Al-Hada	1.06	3	2.8
33	Ibn Sina	2.76	3	1.1
34	Al-Sahil	2.29	3	1.3
35	Al-Sufun	4.83	3	0.6
36	Al-Amwaj	7.57	3	0.4
37	Al-Sadfa	5.09	3	0.6
38	Al-Bustan	0.75	2	2.7
39	Al-Raja	4.09	2	0.5
40	Al-Aqiq	7.42	2	0.3
41	Sports City	1.70	2	1.2
42	Al-Shifa	8.32	2	0.2
43	Al-Kawthar	5.01	1	0.2
44	Al-Maha	2.06	1	0.5
45	Al-Khor	0.79	1	1.3
46	Al-Bahr	6.92	1	0.1
47	Isbilia	2.91	-	-
48	Al-Murjan	10.70	-	-

Total: 191.65 km², 444 stations, 2.3 stations/km²
 Source: Prepared by the student.

–   High (6 to less than 8 mobile phone stations/km²): This category includes the neighborhoods of Al-Thuqbah and Al-Olaya, which are located in central Khobar. They represent 4.2% of the total residential areas in the city, covering 3.9% of the total area. These neighborhoods contain 57 mobile stations, accounting for 12.8% of the total mobile phone stations in Khobar.

–   Medium (4 to less than 6 mobile phone stations/km²): This category includes 10 residential neighborhoods, located in central and northern Khobar. They represent 20.8% of the total residential areas in the city, covering 12.7% of the total area. These neighborhoods contain 117 mobile stations, accounting for 26.4% of the total mobile phone stations in Khobar.

–   Low (2 to less than 4 mobile phone stations/km²): This category includes 8 residential neighborhoods, located in northern Khobar. They represent 16.7% of the total residential areas in the city, covering 11.9% of the total area. These neighborhoods contain 61 mobile stations, accounting for 13.7% of the total mobile phone stations in Khobar.

–   Very Low (less than 2 mobile phone stations/km²): This category includes 21 residential neighborhoods, located in southern Khobar. They represent 43.8% of the total residential areas, covering 58.5% of the total area of Khobar. These neighborhoods contain 80 mobile stations, accounting for 18% of the total mobile phone stations in the city.

–   No Stations: The neighborhoods of Al-Murjan and Isbilia have no mobile phone stations. These areas represent 4.2% of the total residential areas, covering 7.1% of the total area of Khobar.
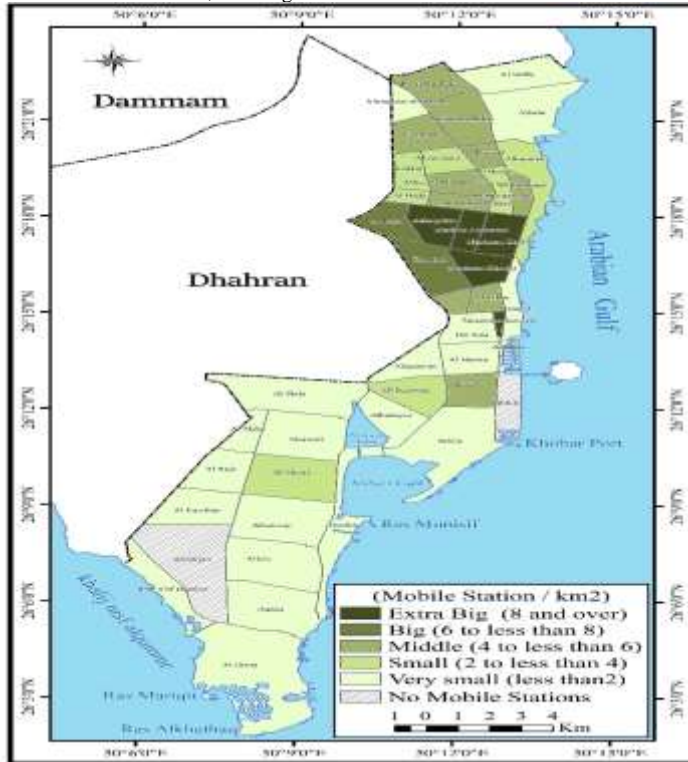
Source: Table (9).

Figure (10) Average area served by mobile phone stations in the districts of Khobar city 2022

C. Buildings:

Table (10) and Figure (11) illustrate the categories of building sizes in residential areas and their relation to the number of mobile phone stations in Khobar city in 2022, as follows:

Table (10): Categories of Building Sizes and Their Relation to the Number of Mobile Phone Stations in Khobar City in 2022

Building Size Categories (Buildings)	Residential Areas	Buildings	Mobile Stations
	Number (%)	Number (%)	Number (%)
Very Large (4000 or more)	7 (14.6%)	34,822 (36.2%)	87 (19.6%)
Large (3000 to less than 4000)	6 (12.5%)	21,455 (22.3%)	55 (12.4%)
Medium (2000 to less than 3000)	6 (12.5%)	16,638 (17.3%)	102 (23.0%)
Small (1000 to less than 2000)	11 (22.9%)	16,397 (17.0%)	122 (27.5%)
Very Small (less than 1000)	18 (37.5%)	6,990 (7.3%)	78 (17.6%)
Total	48 (100%)	96,302 (100%)	444 (100%)

Source: Prepared by the student.

1- Building Size Categories:

The total number of buildings in Khobar city is 96,302. The Al-Sawari neighborhood ranked first with approximately 6,437 buildings, representing 6.7% of the total buildings in the city, followed by Al-Shira'a and Al-Thuqbah, each with approximately 5,390 buildings, representing 5.6% of the total. The Half Moon Bay neighborhood ranked last with around 5 buildings, representing 0.01% of the total buildings in Khobar.

• Very Large Building Size (4000 or more buildings): This category includes 7 residential neighborhoods, representing 14.6% of the total residential areas in Khobar. These neighborhoods contain about 36.2% of the total buildings in the city and are served by 87 mobile phone stations, accounting for 19.6% of the total stations in Khobar.

• Large Building Size (3000 to less than 4000 buildings): This category includes 6 residential neighborhoods, representing 12.5% of the total residential areas in Khobar, containing 22.3% of the total buildings in the city. These neighborhoods are served by 55 mobile phone stations, accounting for 12.4% of the total stations in Khobar.

• Medium Building Size (2000 to less than 3000 buildings): This category includes 6 residential neighborhoods, representing 12.5% of the total residential areas in Khobar, containing 17.3% of the total buildings in the city. These neighborhoods are served by 102 mobile phone stations, accounting for 23% of the total stations in Khobar.

• Small Building Size (1000 to less than 2000 buildings): This category includes 11 residential neighborhoods, representing 22.9% of the total residential areas in Khobar, containing 17% of the total buildings in the city. These neighborhoods are served by 122 mobile phone stations, accounting for 27.5% of the total stations in Khobar.

• Very Small Building Size (less than 1000 buildings): This category includes 18 residential neighborhoods, representing 37.5% of the total residential areas in Khobar, containing 7.3% of the total buildings in the city. These neighborhoods are served by 78 mobile phone stations, accounting for 17.6% of the total stations in Khobar
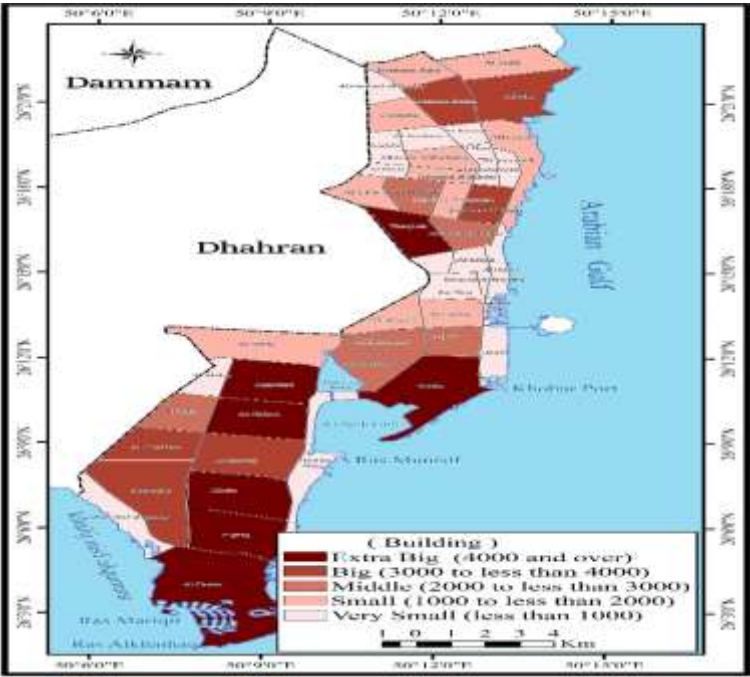
Source: Table (10).

Figure (11) Size categories of buildings in the districts of Khobar city 2022

Average Number of Buildings Served by Each Mobile Phone Station:
Table (11), (12), and Figure (12) show the average number of buildings served by each mobile phone station (buildings/station) in Khobar's residential areas in 2022, as follows:

Table (11): Categories of Average Number of Buildings Served by Each Mobile Phone Station in Khobar Residential Areas in 2022

Buildings/Station		Residential Areas	Buildings	Mobile Stations
		Number (%)	Number (%)	Number (%)
●	Very Large (1500 or more)	3 (6.3%)	10,963 (11.4%)	4 (0.9%)
●	Large (1000 to less than 1500)	3 (6.3%)	11,321 (11.8%)	9 (2.0%)
●	Medium (500 to less than 1000)	5 (10.4%)	14,658 (15.2%)	21 (4.7%)
●	Small (100 to less than 500)	20 (41.7%)	44,158 (45.9%)	247 (55.6%)
●	Very Small (less than 100)	15 (31.3%)	11,393 (11.8%)	163 (36.7%)
●	No Stations	2 (4.2%)	3,809 (4.0%)	-
Total		48 (100%)	96,302 (100%)	444 (100%)

Source: Prepared by the student.

● The average number of buildings served by each mobile phone station in Khobar is about 217 buildings/station. Al-Kawthar neighborhood ranks first, with 3,517 buildings served by one mobile phone station, due to the large number of buildings and only one station. Al-Bahr neighborhood ranks second, with 3,071 buildings/station. The Half Moon Bay neighborhood ranks last, with one building/station, due to the small number of buildings (5 buildings) and 5 mobile phone stations.

● Very Large (1500 or more buildings/station): This category includes 3 residential neighborhoods, representing 6.3% of the total residential areas in Khobar. These neighborhoods contain 11.4% of the total buildings and are served by 4 mobile phone stations, accounting for 0.9% of the total stations in the city.

● Large (1000 to less than 1500 buildings/station): This category includes 3 residential neighborhoods, representing 6.3% of the total residential areas in Khobar. These neighborhoods contain 11.8% of the total buildings and are served by 9 mobile phone stations, accounting for 2% of the total stations in the city.

● Medium (500 to less than 1000 buildings/station): This category includes 5 residential neighborhoods, representing 10.4% of the total residential areas in Khobar. These neighborhoods contain 15.2% of the total buildings and are served by 21 mobile phone stations, accounting for 4.7% of the total stations in the city.

● Small (100 to less than 500 buildings/station): This category includes 20 residential neighborhoods, representing 41.7% of the total residential areas in Khobar. These neighborhoods contain 45.9% of the total buildings and are served by 247 mobile phone stations, accounting for 55.6% of the total stations in the city.

Table (12): Average Number of Buildings Served by Each Mobile Phone Station (Buildings/Station) in Residential Areas of Khobar City in 2022

No.	Residential Area	Buildings		Stations		Average Number of Buildings Served per Station (Buildings/Station)
		Number	%	Number	%	Stations
1	Al-Khobar South	2,976	3.1%	38	8.6	78
2	Al-Thuqbah	5,390	5.6%	36	8.1	150
3	North Khobar	3,565	3.7%	31	7.0	115
4	Al-Aqrabiyah	2,847	3.0%	28	6.3	102
5	Madinat Al-Omal	1,837	1.9%	25	5.6	73
6	Al-Olaya	1,639	1.7%	21	4.7	78
7	South Al-Rakah	3,844	4.0%	19	4.3	202
8	Al-Jisr	2,557	2.7%	18	4.1	142
9	Al-Hizam Al-Dhahabi	1,429	1.5%	15	3.4	95
10	Qurtuba	1,580	1.6%	15	3.4	105
11	Al-Tahlia	4,290	4.5%	15	3.4	286
12	Al-Shira'a	5,390	5.6%	15	3.4	359
13	North Al-Rakah	1,994	2.1%	14	3.2	142
14	Corniche	1,587	1.6%	12	2.7	132
15	Al-Khozama	2,330	2.4%	10	2.3	233
16	Al-Sawari	6,437	6.7%	8	1.8	805
17	Al-Yarmouk	687	0.7%	8	1.8	86
18	Al-Andalus	677	0.7%	8	1.8	85
19	Al-Jawhara	279	0.3%	7	1.6	40
20	Industrial Al-Thuqbah	655	0.7%	7	1.6	94
21	Industrial Al-Fawazia	226	0.2%	7	1.6	32
22	Al-Hizam Al-Akhdar	1,371	1.4%	7	1.6	196
23	Al-Iskan	447	0.5%	7	1.6	64
24	Al-Rawabi	260	0.3%	7	1.6	37
25	Al-Durra	4,544	4.7%	7	1.6	649

26	Al-Buhaira	2,969	3.1%	6	1.4	495
27	Half Moon Bay	5	0.0%	5	1.1	1
28	Al-Hamra	1,144	1.2%	4	0.9	286
29	Al-Taawon	1,090	1.1%	4	0.9	273
30	Al-Lu'lu'a	4,396	4.6%	4	0.9	1099
31	Al-Bandariah	562	0.6%	4	0.9	141
32	Al-Hada	648	0.7%	3	0.7	216
33	Ibn Sina	447	0.5%	3	0.7	149
34	Al-Sahil	128	0.1%	3	0.7	43
35	Al-Sufun	130	0.1%	3	0.7	43
36	Al-Amwaj	3,966	4.1%	3	0.7	1322
37	Al-Sadfa	1,641	1.7%	3	0.7	547
38	Al-Bustan	264	0.3%	2	0.5	132
39	Al-Raja	2,959	3.1%	2	0.5	1480
40	Al-Aqiq	4,375	4.5%	2	0.5	2188
41	Sports City	18	0.0%	2	0.5	9
42	Al-Shifa	1,085	1.1%	2	0.5	543
43	Al-Kawthar	3,517	3.7%	1	0.2	3517
44	Al-Maha	951	1.0%	1	0.2	951
45	Al-Khor	289	0.3%	1	0.2	289
46	Al-Bahr	3,071	3.2%	1	0.2	3071
47	Isbilia	317	0.3%	-	-	-
48	Al-Murjan	3,492	3.6%	-	-	-
Total		96,302	100	444	100	217

Source: Prepared by the student.
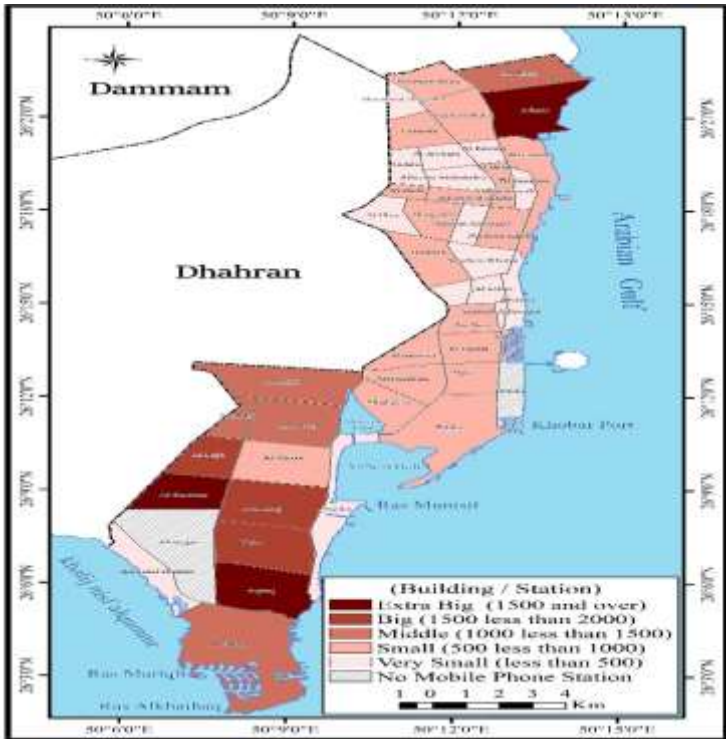
Source: Table (12).
Figure (12) Average number of buildings served by a mobile phone station in the districts of Khobar city 2022

- Very Small (Less than 100):

Includes 15 residential neighborhoods, representing 31.3% of the total residential neighborhoods in Khobar city. These neighborhoods contain about 11.8% of the total number of buildings and are served by 163 mobile phone stations, which accounts for 36.7% of the total mobile phone stations in Khobar city.

- No Stations:

Includes Al-Murjan and Ishbiliyah neighborhoods, where no mobile phone stations are present. These neighborhoods represent 4.2% of the total residential neighborhoods in Khobar city, covering 7.1% of the total area of the city, and include 3,809 buildings, representing 4% of the total number of buildings in Khobar city.

4- Distribution According to the Road Network:

The road network, availability of suitable transportation means, and distance impact the journey to mobile phone stations. Paved roads contribute to shortening the trip duration, making access easier, and facilitating the required maintenance and monitoring tasks. The road network also facilitates the movement of maintenance vehicles and specialized technical staff responsible for monitoring and maintaining the mobile phone networks.

Ease of access to mobile phone stations is an important factor reflecting the importance and efficiency of the service, which primarily depends on a well-planned and distributed road network. The distribution of mobile phone stations was calculated relative to the roads, particularly the main roads where parking is available, by creating a buffer around the roads at varying distances, as shown in Table (14) and Figure (13), from which the following can be observed:

Table (14) Mobile Phone Stations Location Relative to Educational Services in Khobar City, 2022

Road Distance (m)	Telecom	Mobily	Zain	Etihad Atheeb	Total
Less than 100	116	89	24	-	229
100 to less than 200	33	28	12	-	73
200 to less than 300	26	23	4	-	53
300 to less than 400	19	17	2	-	38
400 or more	24	20	6	1	51
Total	218	177	48	1	444

Source: Prepared by the student

Khobar city's road network is characterized by its straight and perpendicular layout, covering the entire city. The main roads extend for about 336.7 km, while the length of the secondary roads and streets reaches 2,227.7 km.

- Less than 100 meters from the road:

Includes 229 mobile stations, representing 51.6% of the total mobile stations in Khobar city, with 116 Telecom stations, 89 Mobily stations, and 24 Zain stations, indicating ease of access to these stations.

- 100 to less than 200 meters from the road:

Includes 73 mobile stations, representing 16.4% of the total mobile stations in Khobar city, with 33 Telecom stations, 28 Mobily stations, and 12 Zain stations.

- 200 to less than 300 meters from the road:

Includes 53 mobile stations, representing 11.9% of the total mobile stations in Khobar city, with 26 Telecom stations, 23 Mobily stations, and 4 Zain stations.

- 300 to less than 400 meters from the road:

Includes 38 mobile stations, representing 8.6% of the total mobile stations in Khobar city, with 19 Telecom stations, 17 Mobily stations, and 2 Zain stations.

- 400 meters or more from the road:

Includes 51 stations, representing 11.5% of the total mobile stations in Khobar city, with 24 Telecom stations, 20 Mobily stations, 6 Zain stations, and the only station for Etihad Atheeb, reflecting the difficulty in accessing these stations from the main roads.
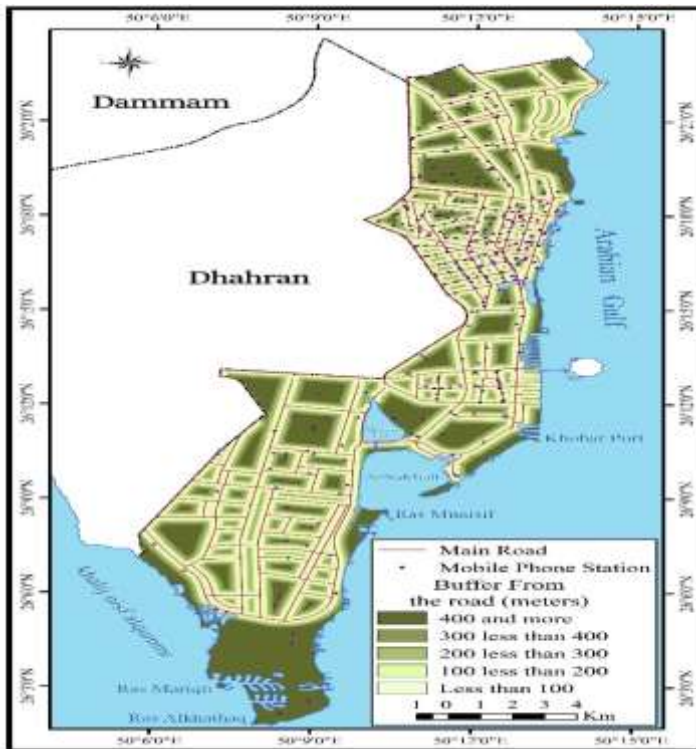
Source: Prepared by the student using Arc Map 10.7

Figure (13) Location of mobile phone stations on the main road in Khobar city 2022

Second: Spatial Analysis of the Distribution of Mobile Phone Stations in Khobar City

Introduction:

Many spatial features and phenomena can be cartographically represented as points (disregarding their spatial extent), such as schools in a neighborhood or city, and cities or villages in an administrative region. The same applies to mobile phone stations. Thus, point phenomena analysis becomes one of the most important spatial analyses within Geographic Information Systems (GIS), enabling the study of distribution, geographic patterns, spread, dispersion, and centrality between the geographic locations of this phenomenon (Daoud, 2012, p. 162).

GIS technologies, through program outputs and analysis tools, assist in interpreting and analyzing the spatial distribution of mobile phone stations in Khobar city.

The spatial distribution pattern of mobile phone stations in Khobar city is the result of a combination of geographic factors that affect both efficiency and safety levels. To evaluate this distribution objectively, it was necessary to study and analyze it from two perspectives: one involving the spatial analysis of the mobile phone station locations, and the other studying the actual coverage areas of the stations and comparing them with the spatial analysis results to determine the degree of overlap, similarity, or difference. This helps in proposing the best locations to achieve the study's main goals: assessing the efficiency and safety levels of the stations (F and K, 2003, pp. 767-787).

The field study revealed that Khobar city has 444 mobile phone stations serving an area of about 191.65 km² and a population of 476.2 thousand people. These stations are distributed among four companies: Telecom (49.1%), Mobily (39.9%), Zain (10.8%), and Etihad Atheeb (0.2%).

1- Geographic Distribution Analysis:

Geographic analysis involves the repetition of certain phenomena in a location, referring to the arrangement or organization resulting from the distribution of phenomena in a particular pattern, i.e., the distribution system of a

phenomenon on the earth's surface. The distribution of mobile phone stations in Khobar city was analyzed using Geographic Information Systems (GIS) to process and analyze the available data for the study area (Khair, 1990, p. 315). The spatial analysis of mobile phone stations in Khobar city allows for identifying the pattern and distribution characteristics of these stations using GIS, which links spatial information with descriptive information to assist decision-makers. Many spatial features, such as schools, mosques, and banks, are represented as points (Shahri, 2020, p. 30).

Mobile phone stations in Khobar city are thus among the spatial features represented as points. Analyzing their distribution, geographic pattern, and concentration is one of the most critical spatial analyses within GIS. The study used several spatial statistical analyses on mobile phone stations in Khobar city to achieve the study's goals, including:

A- Mean Geographic Center (Mean Center):

The mean center is used to calculate the arithmetic mean of non-spatial data to determine the spatial mean of the phenomenon under study. This is known as the simple spatial mean, representing the average of a set of individual data values and applicable to any phenomenon represented as a point on the map. The point signifies the central location around which the phenomenon's data points are distributed, facilitating analysis and interpretation.

A grid of squares covering the study area is used to measure the locations of points according to their distribution on the X and Y axes, referred to as the ideal virtual pivot point. This point represents the location around which the phenomenon's data points are equally distributed, similar to the arithmetic mean for spatial data (Daoud, 2012, p. 162). The geographic center of mobile phone stations in Khobar city is identified as the location with the shortest distance to all other points.

From the analysis of Figure (14), the mean geographic center of mobile phone stations in Khobar city is as follows:

● The mean geographic center of mobile phone stations in Khobar city is located in the middle of the city, in the Thuqbah neighborhood, at the intersection of latitude 26°16'7" N and longitude 50°11'36" E. This reflects the concentration of the majority of mobile phone stations—about three-quarters of them—on approximately one-third of the city's residential neighborhoods.

● The mean geographic center of Telecom's mobile stations in Khobar city is located similarly in the middle of the city, in the Thuqbah neighborhood, at the intersection of latitude 26°16'19" N and longitude 50°11'41" E.

● The mean geographic center of Mobily's mobile stations is also located similarly in the middle of the city, in the Thuqbah neighborhood, at the intersection of latitude 26°16'15" N and longitude 50°11'35" E.

● The mean geographic center of Zain's mobile stations, however, is located differently from the previous points, outside the study area, to the west of the Ibn Sina neighborhood in the western part of the city, at the intersection of latitude 26°14'48" N and longitude 50°11'11" E.
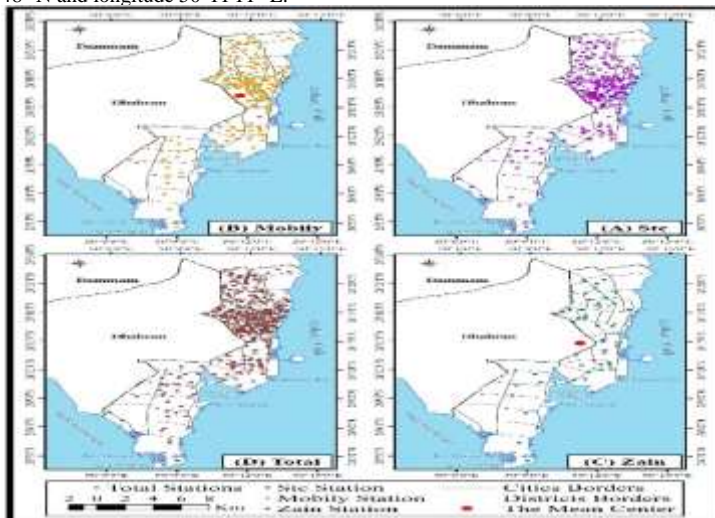
Source: Prepared by the student using Arc Map 10.7.
Figure (14) The Mean Center for the distribution of mobile phone stations in the city of Khobar 2022

-      B- Standard Distance

The standard distance is one of the key measures of spatial dispersion for spatial distributions. It is conceptually similar to the standard deviation in calculating the distance between the adjusted center and each point representing a mobile station in the study area. The standard distance is derived by squaring the standard deviation values on both the X and Y axes from their averages. It is used to measure the spread of a phenomenon around its geographic mean center, serving as an indicator of how far apart or close the individual points of the phenomenon are. It reflects the deviation of values from their mean, providing a description of the scatter of points around the adjusted center. Since the adjusted center alone is insufficient for a complete picture, this comparison makes the situation clearer.

The value of the standard distance is represented by a circle with the adjusted geographic center as its center, referred to as the standard circle. The center of the circle is the location of the actual mean center of the phenomenon (Central Feature). The smaller the circle, the more spatially concentrated the phenomenon; the larger the circle, the more spatially dispersed the phenomenon (Daoud, 2012, pp. 41-44).

The standard distance is a measure of spatial dispersion and concentration that functions similarly to standard deviation and is widely used for distributing locations around their mean center. This method is one of the most prominent measures of spatial distributions and is used to measure how far the phenomenon has spread from its center (Al-Otaibi, 2013, p. 138).

,From Figure (15), the standard distance for the distribution of mobile phone stations can be understood as follows:

The standard circle for all mobile phone stations covered an area of approximately 183.5 km², which represents 95.1% of the total area of the city. The circle for Telecom stations covered 162.9 km², representing 84.5% of the total city area, while the circle for Mobily stations covered 182.5 km², accounting for 94.6% of the city area. The circle for Zain stations, however, covered about 260.9 km², equivalent to 135.3% of the total city area. Most of the previous standard circle areas extend beyond the study area's boundaries, which is attributed to the linear shape of the study area stretching from north to south along the Arabian Gulf.

The basic model assumes that the standard circle contains 68% of the total points. However, the actual results indicated that the standard distance circle for all stations included 320 stations, accounting for 72.1% of the total mobile phone stations in Khobar city. This suggests that the geographic distribution pattern of mobile phone stations in Khobar is a regular distribution. As the percentage increases, the distribution pattern tends toward a more regular shape, while a lower percentage indicates a random spread. This was also observed for the standard circle of Telecom stations, which contained 158 stations, representing 72.5% of the total Telecom stations in Khobar. Similarly, the circle for Mobily included 125 stations, accounting for 70.6% of all Mobily stations in the city, and the Zain station circle included 33 stations, representing 68.8% of all Zain stations in Khobar.
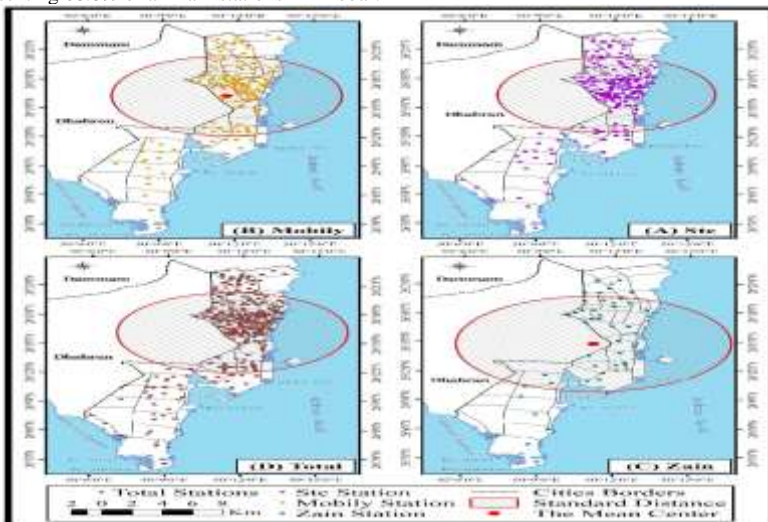
Source: Prepared by the student using Arc Map 10.7.

Figure (15) Standard Distance for the distribution of mobile phone stations in the city of Khobar 2022
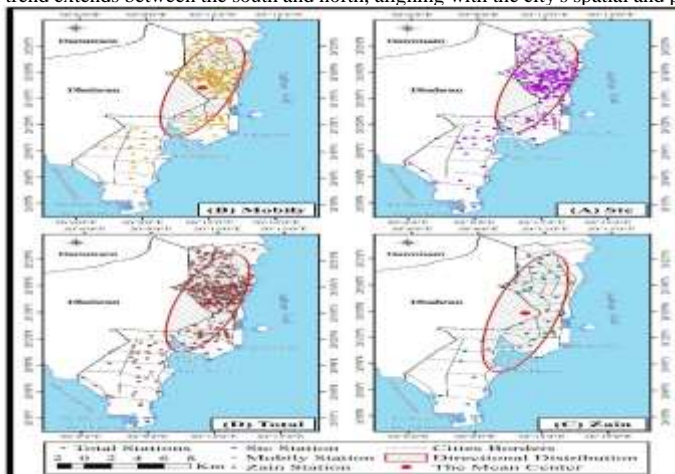
C- Directional Distribution

This tool is used to determine the general direction of the distribution of a spatial phenomenon by drawing an ellipse with a tilt angle that indicates the distribution direction of most points in the study area. This helps to understand the spatial concentration and spread of the phenomenon. The center of the ellipse represents the actual mean center of the phenomenon, with the north direction represented at a 0° angle, east at 90°, south at 180°, and west at 270°. The more the shape contracts, the more spatially concentrated the phenomenon is. Conversely, as the shape expands, the value of the standard distance increases, indicating the wider spatial spread and distribution of the phenomenon. This means the circle's radius is directly proportional to the degree of spatial spread and distribution (Daoud, 2012, pp. 14-44).

The concept of directional distribution is very similar to the standard distance but focuses on the concentration and distribution direction of the phenomenon's elements, whereas the standard distance measures spatial dispersion and concentration. The eastern and northern standard deviations from the mean center are calculated to determine the directional distribution shape over the study area. The mean center represents the center of the ellipse for all points, and each ellipse has two axes (X-Y) (Abdulrahman, 2014, p. 11).

From the analysis of Figure (16), the directional distribution of mobile phone stations in Khobar city can be understood as follows:

● The center of the ellipse overlaps with the mean center, and its major axis measures the direction taken by most of the points of the phenomenon. The length of the major axis is 10.5 km for all mobile phone stations, 9.9 km for Telecom stations, 10.5 km for Mobily stations, and 12.6 km for Zain stations.

● The minor axis is 2.4 km for all mobile phone stations, 2.4 km for Telecom stations, 2.45 km for Mobily stations, and 2.5 km for Zain stations.

● The directional distribution angle was recorded at 11.3 degrees for all mobile phone stations, 11.7 degrees for Telecom stations, 11.3 degrees for Mobily stations, and 9.4 degrees for Zain stations.

● The general direction of distribution for all mobile phone stations extends from the south to the north in the city center, where the majority of the mobile stations are concentrated. This south-to-north trend was consistent across all the active companies in the city (Telecom, Mobily, Zain).

● The area of the ellipse for all mobile phone stations in the city was 80.2 km², representing approximately two-fifths of the city's total area. The ellipse for Telecom stations covered 73.5 km², accounting for 38.1% of the total city area, while Mobily's ellipse covered 80.8 km², representing 41.9% of the city. Zain's ellipse covered 100.2 km², slightly more than half of the city's total area.

The results of the directional distribution analysis of mobile phone stations in Khobar City show a clear concentration of these facilities in the city center and the northern part of the city. The stations are noticeably clustered together, and the overall distribution trend extends between the south and north, aligning with the city's spatial and population expansion.

Source: Prepared by the student using Arc Map 10.7.

Figure (16) Directional Distribution for the distribution of mobile phone stations in the city of Khobar 2022

2- Analyzing Patterns

Geographic studies focus on revealing the patterns of spatial distribution of phenomena, which allow for assessing the balance of their distribution across the occupied spatial area. Several measures can be used to analyze the spatial distribution patterns of mobile phone stations in Khobar's residential neighborhoods, including:

A- Nearest Neighbor Analysis

The spatial distribution pattern of mobile phone stations in different areas is influenced by the residential area's size, shape, population, street network design, distribution pattern, historical development, and proximity between areas. These factors contribute to the appearance of service institution clusters (Mislhi, 2007, p. 359).

The spatial distribution of phone stations is influenced by area and distance, which are the main factors in most nearest neighbor analysis measures. This study used the nearest neighbor analysis to detect the current distribution pattern.

This method is one of the most suitable for analyzing spatial patterns of phenomena as it includes all locations in the study area and their relationships to each other. It also relies on the distances between each site and its nearest neighboring locations, helping to identify the distances needed to access services, thus enabling accurate determination of the distribution characteristics—whether they are clustered, dispersed, or random (Al-Saleh, 1420 AH, p. 51).

GIS technology analyzes the average distance to the nearest neighbor, sometimes referred to as neighborhood connectivity, by calculating the geographic distance between each station and its nearest neighbor. Then, the average distances between all stations are calculated and divided by the expected average distance for a completely random distribution. If the calculated average distance is less than the expected average, the distribution is clustered. If the calculated average distance is greater than the expected random distribution, the distribution is dispersed. A value between these two indicates a random distribution (Daoud, 2012, pp. 51-52).

Detecting the distribution pattern is a priority for geographers when studying the spatial distribution of phenomena. The spatial distribution of any geographic phenomenon is one of its fundamental characteristics. The nearest neighbor index describes the spatial distribution pattern of phenomena represented as points on maps. It reflects whether the distribution pattern is regular, random, or clustered (Al-Jurash, 2004, p. 425).

In an attempt to analyze the geographic distribution pattern of mobile phone stations in Khobar City, the Spatial Analyst extension in ARC GIS was used. The results are shown in Table (15) and Figure (17) as follows:

Table (15) Spatial Distribution Patterns of Mobile Phone Stations in Khobar City According to the Nearest Neighbor Value in 2022.

No.	Type	Nearest Neighbor Value	Sub-pattern of Nearest Neighbor
1	Telecom	0.996224	Clustered, tending towards random
2	Mobily	1.082998	Dispersed
3	Zain	1.233339	Dispersed
4	All stations	0.630658	Clustered, tending towards random

Source: Prepared by the student using (ARC GIS10.7).

• The geographic distribution of mobile phone stations in Khobar City predominantly follows a clustered pattern, with the nearest neighbor value for all stations in the city recorded at 0.630658, indicating a clustered but somewhat irregular distribution.

• The nearest neighbor value for Telecom stations was 0.996224, showing a random (clustered, tending towards random) distribution, while the distribution pattern for Mobily and Zain stations was dispersed (greater distances between stations).

• Etihad Atheeb was excluded from the geographic distribution analysis due to having only one station, making it difficult to apply the calculation.

• The distribution patterns of mobile phone stations in Khobar City represent the combined outcome of natural and human factors that define the distribution, axes, and varying sizes of these facilities.
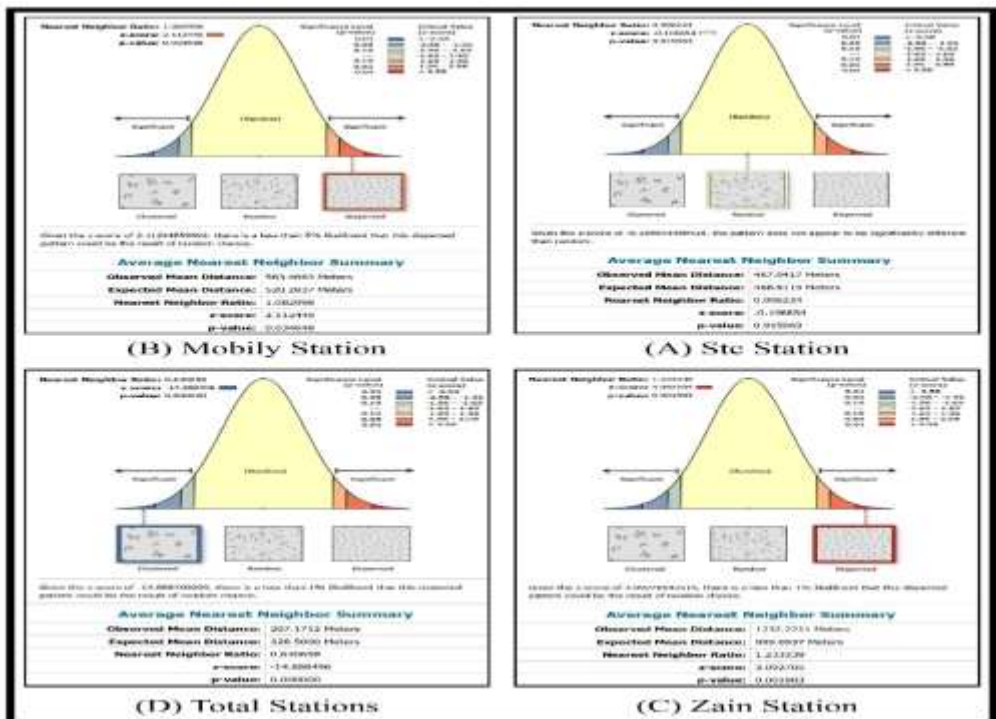
Source: Prepared by the student using Arc Map 10.7.

Figure (17) Neighborhood Analysis Results for the distribution of mobile phone stations in the city of Khobar 2022

4- Spatial Proximity Measures (Proximity Analysis):Proximity Analysis.

Also known as Proximity Analysis, it is used to determine how close spatial features are to one another. This will be addressed through allocation areas, spread around the geometric center of the study area, buffer zone analysis, and average distance as follows:

A- Allocation Areas Analysis (Allocation Areas To Center):

Known as the Thiessen polygon, it is used to determine the spatial allocation areas. This tool deals with point-type layers, studying wide areas through points only. It generates polygons where each polygon contains a single point. The boundaries of this polygon depend on the points surrounding the central point, where distances are classified between the point inside the polygon and the other nearest points. This process is applied to all points in the layer (Al-Tayeb, 2017, p. 129).

The importance of this analysis lies in identifying the locations of facilities that provide services to a group of demand points, representing the population segment, in a way that achieves the highest efficiency (Ayasrah, 2017, pp. 39-61). The location allocation model aims to represent the spatial relationship or interaction between a group of demand points and a group of service centers, intending to achieve the best spatial interaction between the two groups (Alshwesh, 2015, pp. 52-55). The process of determining the spatial relationship or interaction depends on the characteristics associated with time and distance factors. Thus, the main objective of this analysis is to minimize the distance between the demand points and the service locations (Sule, 2001).

Table (16) Numbers and Areas of Allocation Polygons (Thiessen Polygon) for Mobile Phone Stations in Khobar City in 2022

	Category	Polygons		Area			Category	Polygons		Area	
		Number	%	km²	%			Number	%	km²	%
Total Stations	More than 5 km²	5	1.1	22.0	11.4	STC Stations	More than 5 km²	8	3.7	53.5	27.7
	3 km² to less than 5 km²	6	1.4	21.5	11.1		3 km² to less than 5 km²	9	4.1	33.0	17.1
	1 km² to less than 3 km²	38	8.6	63.1	32.7		1 km² to less than 3 km²	29	13.3	50.6	26.3
	Less than 1 km²	395	89.0	86.3	44.7		Less than 1 km²	172	78.9	55.7	28.9
	Total	444	100	192.9	100		Total	218	100	192.9	100

	Category	Polygons		Area			Category	Polygons		Area	
		Number	%	km²	%			Number	%	km²	%
Mobily Stations	More than 5 km²	7	4.0	52.4	27.2	Zain Stations	More than 5 km²	10	20.8	105.2	54.5
	3 km² to less than 5 km²	7	4.0	26.4	13.7		3 km² to less than 5 km²	12	25.0	49.3	25.5
	1 km² to less than 3 km²	35	19.8	61.9	32.1		1 km² to less than 3 km²	20	41.7	35.1	18.2
	Less than 1 km²	128	72.3	52.2	27.1		Less than 1 km²	6	12.5	3.3	1.7
	Total	177	100	192.9	100		Total	48	100	192.9	100

Source: Prepared by the student using the Arc Map 10.7 software.

The standard response time or distance used in the analysis is one of the most influential factors on the performance of the location allocation model in choosing the appropriate site and its accessibility,Naturally, the result of using different measures of time or distance will affect the optimal locations determined using this model, as each type of measurement can produce different results, depending on the calculation of the time taken or the length of distance between the location of the service request and the nearest service provider. (Taran, 2019, p. 115).

From the analysis of Figure (18), it is clear that the allocation areas for mobile phone stations in Khobar City are as follows:
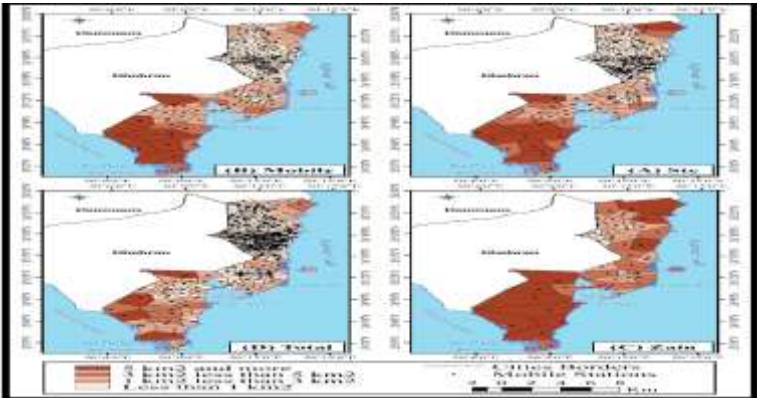
Source: Prepared by the student using Arc Map 10.7.

Figure (18) Thiessen polygon for mobile phone stations in the city of Khobar 2021

The number of polygons totaled 444 for all mobile phone stations, covering the city's area of 191.65 km². The number of polygons for the Etisalat network stations was 218, for Mobily network stations was 177, and for Zain network stations was 48.

The areas shrink in the city center, where most of the mobile phone stations are concentrated, and expand as they move away from the center, reaching their maximum width in the southern part of the city. This applies to the total stations as well as the Etisalat and Mobily network stations. However, for Zain network stations, the situation differs significantly, as the polygons expand across the entire map, with the largest expansion in the southern and northern parts of the city, where the number of mobile phone stations is lower.

From Table (17) and Figure (19), the following observations can be made:

Polygon Area Category (5 km² or more):

For the total stations, the number of polygons was 5, representing 1.1% of the total number of polygons (444), covering an area of 22 km², or 11.4% of the city's total area, concentrated in the southern and northern parts of the city. As for the Etisalat network stations, the number of polygons was 8, representing 3.7% of the total number of polygons (218), spreading over an area of 53.5 km², or 27.7% of the city's total area. For Mobily network stations, the number of polygons was 7, representing 4% of the total number of polygons (177), spreading over an area of 52.4 km², or 27.2% of the city's total area. Meanwhile, Zain network stations comprised 10 polygons, representing 20.8% of the total number of polygons (48), spreading over an area of 105.2 km², or 54.5% of the city's total area.

Polygon Area Category (3 km² to less than 5 km²):

Included 6 polygons for the total stations, representing 1.4% of the total number of stations, covering an area of 21.5 km², or 11.1% of the city's total area. The number of polygons for the Etisalat network stations was 9, representing 4.1%, spreading over an area of approximately 33 km², or 17.1%. For Mobily network, 7 polygons represented 4%, spreading over an area of 26.4 km², or 13.7%. Zain network, however, included 12 polygons, representing 25%, covering an area of 49.3 km², or 25.5% of the city's total area.

Polygon Area Category (1 km² to less than 3 km²):

For the total stations, this category included 38 polygons, representing 8.6% of the total number of stations, covering an area of 63.1 km², or 32.7% of the city's total area. The number of polygons for Etisalat network stations was 29, representing 13.3%, spreading over an area of approximately 50.6 km², or 26.3%. For Mobily network, 35 polygons represented 19.8%, spreading over an area of 61.9 km², or 32.1%. Meanwhile, Zain network included 20 polygons, representing 41.7%, covering an area of 35.1 km², or 18.2% of the city's total area.

Polygon Area Category (less than 1 km²):

For the total stations, this category included 395 polygons, representing 89% of the total number of stations, covering an area of 86.3 km², or 44.7% of the city's total area. The number of polygons for Etisalat network stations was 172, representing 78.9%, spreading over an area of approximately 55.7 km², or 28.9%. For Mobily network, 128 polygons represented 72.3%, spreading over an area of 52.2 km², or 27.1%. Meanwhile, Zain network included 6 polygons, representing 12.5%, covering an area of 3.3 km², or 1.7% of the city's total area.

B- Buffering Analysis.

Buffering is one of the widespread spatial loading methods, revealing the relationship between distance and the phenomenon, placing boundaries around phenomena (Buffers), whether in point or linear patterns, using specific criteria created based on spatial analysis results (Okabe, 2006, p. 5). The following steps are performed:

Drawing boundaries around the phenomenon is a difficult process manually. Buffers are created around a phenomenon by specifying the distance we want to define around it, such as 200 meters, 500 meters, or 1000 meters, for the impact of stations on the population, and the area surrounding the station. The software creates a buffer around it. We can also create a "circular" buffer around the phenomenon by specifying the diameter of the circle we want to draw (Ahmed & Qader, 2020, p. 15).

The Buffer operation identifies zones or belts around targets, whether points, lines, or polygons, with a value or distance specified by the user. The spatial buffer has several uses, such as defining a specific distance around a road to prevent any buildings within the road's buffer zone (Kazem, 2019, p. 173).

This tool is used to identify the areas where service is available and covered, as well as areas deprived of service based on planning criteria. In other words, it reflects the coverage of the service area in the study region around its perimeter with a constant width. From the analysis of Table (18) and Figure (20), the following can be concluded:

Table (18) Geographical Influence Level of Mobile Phone Stations in Khobar City in 2022

Spatial Range (meters)	Etisalat		Mobily		Zain		Total	
	km²	%	km²	%	km²	%	km²	%
Less than 500	80.7	41.8	79.4	41.2	33.1	17.2	102.8	53.3
500 to less than 1000	59.5	30.9	58.8	30.5	57.5	29.8	59.1	30.7
1000 to less than 1500	27.2	14.1	29.8	15.4	43.7	22.7	20.3	10.5

|							
1500 or more	25.4	13.2	25.0	12.9	58.5	30.3	10.7	5.5
Total	192.9	100	192.9	100	192.9	100	192.9	100

Source: Prepared by the student using Arc Map 10.7 software.

- Spatial Range (less than 500 meters):

Covered an area of 102.8 km², representing 53.3% of the total area of Khobar City, for the overall mobile phone stations in the city. These stations are distributed across the northern, central, and eastern parts of the city, where the majority of the mobile phone stations are concentrated. For the Etisalat network, 80.7 km², or 41.8%, is mainly concentrated in the northern and central parts of the city, while Mobily network covered 79.4 km², or 41.2%. For Zain, the network occupied 33.1 km², representing 17.2% of the total area of Khobar City.

- Spatial Range (500 to less than 1000 meters):

Covered an area of 59.1 km², representing 30.7% of the total area of Khobar City, for the overall mobile phone stations in the city. For the Etisalat network, it covered 59.5 km², or 30.9%, while Mobily network covered 58.8 km², or 30.5%. For Zain, the network occupied 57.5 km², representing 29.8% of the total area of Khobar City.
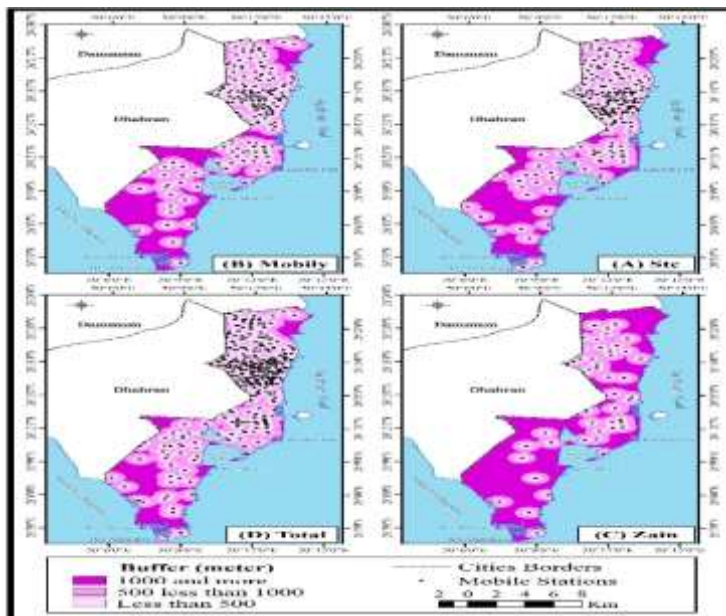
Source: Prepared by the student using Arc Map 10.7.
Figure (19) Geographical Buffering for mobile phone stations in the city of Khobar 2021

- Spatial Range (1000 to less than 1500 meters):

Covered an area of 20.3 km², representing 10.5% of the total area of Khobar City, for the overall mobile phone stations in the city. For the Etisalat network, it covered 27.2 km², or 14.1%, while Mobily network covered 29.8 km², or 15.4%. For Zain, the network occupied 43.7 km², representing 22.7% of the total area of Khobar City.

- Spatial Range (1500 or more):

Covered an area of 10.7 km², representing 5.5% of the total area of Khobar City, for the overall mobile phone stations in the city. The Etisalat network covered 25.4 km², or 13.2%, while Mobily network covered 25 km², or 12.9%. For Zain, the network occupied 58.5 km², representing 30.3% of the total area of Khobar City.

Third: The Future of the Mobile Phone Network in Khobar City.

Introduction:

Planning or evaluation means appropriate distribution and high-efficiency relationships, both of which depend on selecting the suitable location. The goal is to achieve the best distribution of spatial elements, whether in terms of location, size, or dimensions. In other words, it is about searching for the optimal location, the most appropriate size, and the nearest path, which includes the shortest route in the transportation network (Khayr, 2000, p. 403).

Planning is a systematic and disciplined approach that enhances execution capacity in facing any challenges, seeking superiority, enforcing will, and confirming the success of the development process. The purpose of planning is not merely to calculate what is possible in improving use but often to calculate the impossible, aiming to aspire toward hope and achieve it in reality for the sake of life's progression (Al-Shami, 2000, p. 128). In this part of the study, the focus will be on attempting to plan fuel stations in Khobar Province optimally, based on the population criterion and suggesting locations where mobile phone stations are needed due to population growth in these areas, especially in residential neighborhoods that lack this service.

The telecommunications and information technology sector in the Kingdom of Saudi Arabia has witnessed remarkable development in recent years. It is one of the sectors experiencing rapid change and growth, and the outcomes of this sector have become an essential factor for various developmental and economic aspects. The technological development we see in mobile phone technology results in new technological products, services, and applications, leading to a continuous increase in demand for mobile phone network services, given their importance and role in driving economic, social, and even political development (Aloua, 2007, p. 32). This part of the study addresses two aspects:

1- The Future of Mobile Phone Lines in Khobar City

The diversity of mobile phone networks and the competition between them has led to a variety of services and offers from their companies, giving users alternative mobile networks. The following table shows the number of mobile lines required until the year 2050:

Table (19) The Required Mobile Phone Lines and the Shortfall in Khobar City Until 2050

Year	Population	Number of Required Lines		Shortfall (Lines)	
------	-----------	According to the average number of lines per person in KSA (1.5 lines/person)	According to the average number of lines per person in Khobar City (1.04 lines/person)	According to KSA average	According to Khobar City average
2010	476222	–	–	–	–
2022	685550	713402	713402	0	0
2025	751012	1126518	781052	413116	67650
2030	874298	1311447	909270	598045	195868
2035	1017823	1526735	1058536	813333	345134
2040	1184909	1777364	1232306	1063962	518904
2045	1379424	2069136	1434601	1355734	721199
2050	1605871	2408806	1670106	1695404	956704

Source: - Table prepared by the student based on:

- Prepared by the student based on:

• The population using the exponential equation and the expected population growth rate of the city.

• The number of mobile phone lines required based on the average number of lines per person in KSA (1.5 lines/person) in 2022, and the average number of lines per person in Khobar City (1.04 lines/person).

• Shortfall = Number of lines required – 713,402 mobile phone lines.

By analyzing the previous Table (19) and Figure (21), based on population growth rates in Khobar City, the future needs for mobile phone lines were estimated. It was determined that the optimal number of mobile phone lines per person in the city is 1.04 lines per person. Therefore, by 2025, it is estimated that 781,052 mobile phone lines will be required, while the current availability is 713,402 lines, resulting in a shortfall of 67,650 lines. The number of required lines and the shortfall will continue to increase in the mentioned years until 2050, reaching a total of 1,670,106 required lines and a shortfall of 956,704 lines.

2- The Future of Mobile Phone Stations in Khobar City
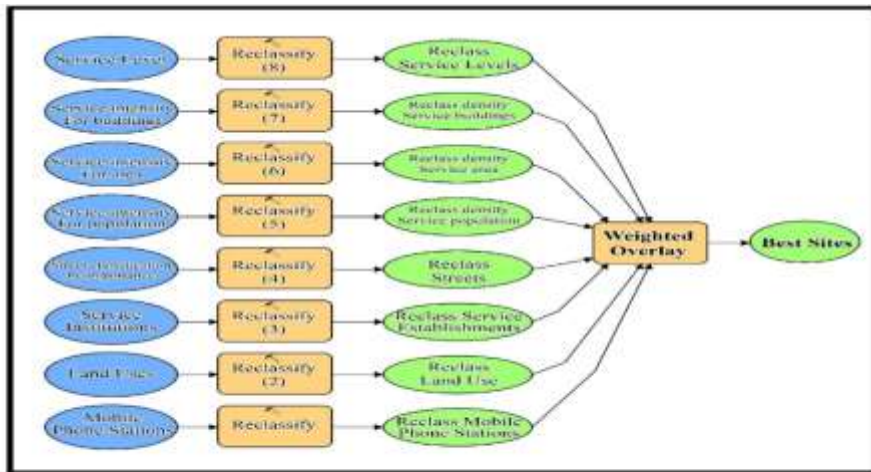
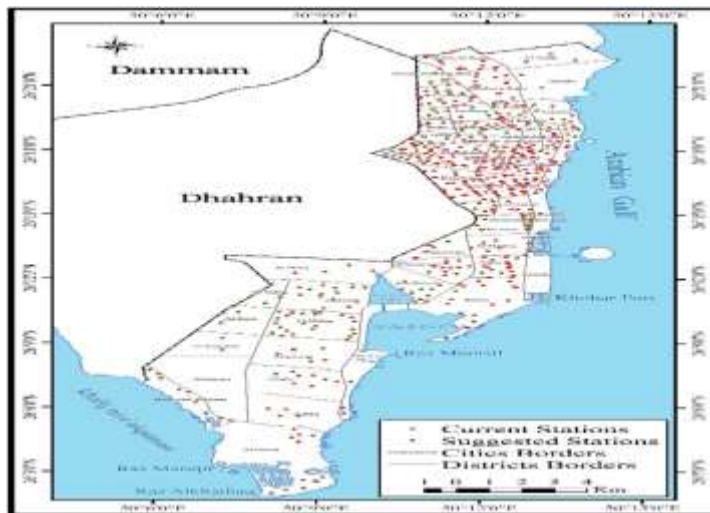Source: Prepared by the student using Model Builder in Arc Map 10.7.

Figure (20) Model to specify the most appropriate locations
for mobile phone stations in the city of Khobar.

It is clear from the general evaluation of the efficiency of mobile phone station distribution in Khobar City, and the challenges it faces, that some neighborhoods suffer from a shortage of stations, while others do not have any stations at all. This is due to the clustered distribution pattern, where most stations are concentrated in the central area, as it is the hub of commercial activity and service operations in the city. However, stations should also be established in neighborhoods that are experiencing a shortage. Based on this, and in light of the proposed modification to the station distribution pattern in Khobar City from a clustered to a dispersed form, a Model was built using Geographic Information Systems (GIS), as shown in Figure (20), to determine the most suitable locations for establishing new or proposed stations, as illustrated in Figure (21), based on important criteria, including:

• The new stations should serve neighborhoods and areas deprived of service or those that suffer from a shortage.

• They should serve high-density population areas with increased density of establishments.

• They should serve areas with high traffic and commercial and service-oriented uses.

• They should achieve a balance in service, ensuring both sufficiency and efficiency.

According to this concept, the shortage and surplus of mobile phone stations in the neighborhoods of Khobar City in 2022 are shown in Figure (21) as follows:

Based on the previous table, as well as Figures (21) we find that the priorities for adding more mobile phone booster stations should depend on the population weight of the neighborhoods, in addition to other criteria, such as the concentration of commercial activities and services in the area. According to these considerations, the distribution of mobile phone station needs across the neighborhoods of Khobar City is as follows: Al-Shiraa neighborhood requires 14 stations, and Al-Ulaya requires 10 stations; this is due to the large area of Al-Shiraa and the high population density in Al-Ulaya. Al-Corniche follows with 9 stations, and 8 stations are needed for each of the following neighborhoods: Al-Sawari, Qurtuba, and Al-Tahlia. Additionally, 7 stations are required for Al-Hizam Al-Dhahabi and Al-Durra, while 6 stations are needed for each of Al-Bahr and Al-Fawazia Industrial, and 5 stations for Half Moon Beach. Four stations are needed for each of the following neighborhoods: Al-Jisr, Al-Thuqbah Industrial, Al-Yarmouk, Al-Lulu, and Al-Rawabi. Three stations are required for each of the following neighborhoods: Al-Jawhara, Al-Khuzama, Al-Andalus, and Al-Amwaj. Two stations are needed for each of the following: Ibn Sina, Al-Raja, Al-Hamra, Al-Sahel, Al-Safan, Al-Taawun, Al-Hizam Al-Akhdar, Al-Aqiq, Labor City, Sports City, and Al-Shifa. One station is required for each of Al-Hada, Al-Kawthar, Al-Maha, Al-Khor, and Al-Bahr.

Source: Prepared by the student based on the data in Table (20) Arc Map 10.7.

Figure (21) Geographical distribution of current and Suggested mobile phone stations in the city of Khobar in 2023

As for the future station requirements for the city, they are shown in the following Table (21):

Table (21) Required Mobile Phone Stations and the Shortfall in Khobar Province Until 2050

Year	Population (persons)	Number of Required Stations		Shortfall (Stations)	
		According to the average number of people served by a station in KSA (1 station/919 persons)	According to the average number of people served by a station in Khobar City (1 station/1544 persons)	According to KSA average	According to Khobar City average
2010	476,222	–	–	-	-
2022	685,550	444	444	-	-
2025	751,012	817	486	373	42
2030	874,298	951	566	507	486
2035	1,017,823	1,108	659	664	215
2040	1,184,909	1,289	767	845	323
2045	1,379,424	1,501	893	1057	449
2050	1,605,871	1,747	1,040	1303	596

Source: Table prepared by the student based on:

– The population using the exponential equation and the expected population growth rate of the province.

– The number of mobile phone stations required based on the average number of people served by a station in KSA (1 station/919 persons) in 2022, and the average number of people served by a station in Khobar City (1 station/1544 persons).

– Shortfall = Number of required stations – 444 mobile phone stations.

After analyzing the previous table and based on population growth rates in Khobar City, as well as estimating the future needs of the city for mobile phone stations, it was determined that the optimal number of mobile phone stations per population is 1 station per 1,544 persons. Therefore, by 2025, the city is expected to require 486 mobile phone booster stations, while currently, there are 444 stations, resulting in a shortfall of 42 stations. The number of required stations and the shortfall will continue to increase in the mentioned years, reaching 1,040 required stations by 2050, with a shortfall of 596 stations.

Results:

• There is a disparity in the numerical and proportional distribution of mobile phone stations, as they are unevenly distributed across the residential neighborhoods of Khobar City.

• Mobily stations are the closest to hospitals, with 19 stations representing 10.7% of the total Mobily stations located within a distance of less than 250 meters, followed by STC with 17 stations (7.8% of STC stations), and Zain with 5 stations (10.4% of Zain stations).

• The Mean Center for mobile phone stations in Khobar City is located in the central area of the city, in the Thuqbah neighborhood, which explains the concentration of the majority of the mobile phone stations in about three-quarters of the stations across one-third of the residential area in the city center.

• A clustered distribution pattern was observed for the geographic distribution of mobile phone stations in Khobar City, with the nearest neighbor index for all the stations in the city being 0.630658, indicating that the distribution is relatively close but irregular.

• From the Buffering analysis, it is evident which areas are covered by mobile phone service and which are deprived. The spatial range (less than 500 meters) covered 102.8 km², representing 53.3% of the total area of Khobar City. These stations are distributed across the northern, central, and eastern parts of the city, where the majority of mobile phone stations are concentrated. The spatial range (500 to less than 1,000 meters) covered 20.3 km², representing 10.5% of the total area of Khobar City, followed by the range (1,000 to less than 1,500 meters), which also covered 20.3 km², and finally, the range (1,500 meters or more), which covered 10.7 km², representing 5.5% of the total area of Khobar City.

• From the study of the future of mobile phone stations, it is clear that some neighborhoods suffer from a shortage of stations, with the highest deficit in Al-Shiraa neighborhood, which requires 14 stations, and Al-Ulaya, which requires 10 stations.

• The estimated optimal number of mobile phone stations for Khobar City is 486 stations by 2025, and the optimal number of mobile phone lines is estimated to be 781,052 lines by 2025.

Recommendations and Suggestions:

• Strengthen the network and reduce its frequent outages by increasing the number of towers in neighborhoods with high population density and areas with a shortage of booster stations, while reducing the cost of calls and minutes.

• Provide devices that automatically detect faults and locate them for repair without the customer needing to report issues or file complaints, thus improving the quality of the service provided.

• Activate the use of geographic information systems (GIS) to support decision-making related to booster stations, offer consultations, and conduct scientific studies.

• Merge the stations of the three companies into a single site, which will help reduce their risks.

• Khobar City will need 1,670,106 mobile phone lines by 2050 and will require 1,040 mobile phone stations by 2050.

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