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# Mapping Spatial Pattern of COVID-19 In Sulaimaniyah City from August 2020 to September 2021 based on Infected Cases recorded in Shahid Hemen Hospital

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***Abstract:***

United Nations has described COVID-19 as a social, human, and economic crisis. Considering the undeniable ability to analyze, display, save and manipulating of spatial data, a wide range of studies have revealed that Remote Sensing (RS) and Geographic Information Systems (GIS) can play a vital role in managing natural hazards as well as worldwide disasters. This paper aim to show the spatial distribution of infection-related factors connected to COVID-19 including age, gender, job, date of infection and distance from the health center using RS/GIS tools across Sulaimaniyah, Kurdistan Region (KR), Iraq based on data recorded in Shahid Hemen Hospital (SHH), which can provide useful insights for policymakers for targeted interventions. Results revealed that, regardless of age it was found that the prevalence of Covid 19 symptoms, as well as, mortality in men is higher than in women. It is also revealed that the highest rang of infection was recorded for the age group 60-69 years old, which was 241 cases of total 1152 cases, which could be due to lack of immunity and chronic diseases, while the lowest infections were between age group 10-19 years old because of high level of immunity, which was 8 cases, altogether. More, the spatial distribution based of age categories show almost a same pattern for all age classes. The worker men were most infected comparison to other jobs due to high level of social contact, while the most infected cases among females were occupied by housekeeper. In other hand the results showed that the October 2020 was the month within the most cases of COVID- 19 were recorded. It's also revealed that, 80% of cases were recorded in September, October, and November. According to results, there has been a lack of COVID health center in the city, since the spatial distribution of infected people who are recorded in SHH was as wide as the area of Sulaimaniyah city and it was not confined to the hospital neighborhood. Since centers are not distributed well among the city,more than 42% had to pass more than 4 km to reach the SHH.

**Key words:** COVID-19, Corona Virus, RS, GIS, Sulaimaniyah, Kurdistan Region, Iraq.

**الملخص:**

وصفت الأمم المتحدة كوفيد -19 بأنه أزمة اجتماعية وبشرية واقتصاديةو بالنظر إلى القدرة التي لا يمكن إنكارها على تحليل البيانات المكانية وعرضها وحفظها ومعالجتها، كشفت مجموعة واسعة من الدراسات أن الاستشعار عن بعد (RS) وأنظمة المعلومات الجغرافية (GIS) يمكن أن تلعب دورًا حيويًا في إدارة المخاطر الطبيعية وكذلك الكوارث في جميع أنحاء العالم . تهدف هذه الورقة إلى إظهار التوزيع المكاني للعوامل المتعلقة بالعدوى المرتبطة بـ COVID-19 بما في ذلك العمر والجنس والوظيفة وتاريخ الإصابة والبعد عن المركز الصحي باستخدام أدوات RS / GIS عبر السليمانية ، إقليم كردستان، العراق بالاعتماد على البيانات المسجلة في مستشفى شهيد هيمن (SHH) ، والتي يمكن أن توفر رؤى مفيدة لواضعي السياسات للتدخلات المستهدفة، كشفت النتائج أنه بغض النظر عن العمر، فقد وجد أن معدل انتشار أعراض كوفيد، وكذلك معدل الوفيات بين الرجال أعلى منه لدى النساء، كما تم الكشف


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عن تسجيل أعلى مدى للإصابة بالفئة العمرية 60-69 سنة، حيث كانت 241 حالة من إجمالي 1152 حالة، والتي يمكن أن تكون بسبب نقص المناعة والأمراض المزمنة، بينما كانت أقل الإصابات بين المجموعة العمرية 10-19 سنة بسبب ارتفاع مستوى المناعة والتي كانت 8 حالات إجمالاً. علاوة على ذلك ، يُظهر التوزيع المكاني المستند إلى الفئات العمرية نفس النمط تقريبًا لجميع الفئات العمرية. وكان الرجال العاملون الأكثر إصابة مقارنة بالوظائف الأخرى بسبب المستوى العالي للتواصل الاجتماعي، في حين أن أكثر الحالات إصابة بين الإناث كانت تشغلها مدبرة المنزل. من ناحية أخرى، أظهرت النتائج أن شهر أكتوبر 2020 كان الشهر الذي تم فيه تسجيل معظم حالات الإصابة بفيروس كورونا. كما تم الكشف عن أن 80٪ من الحالات تم تسجيلها في سبتمبر وأكتوبر ونوفمبر. ووفقًا للنتائج، كان هناك نقص في المركز الصحي لفيروس كورونا في المدينة، حيث كان التوزيع المكاني للمصابين المسجلين في SHH واسعًا مثل مدينة السليمانية ولم يقتصر على الاحياء القريبة من المستشفى. نظرًا لأن المراكز غير موزعة جيدًا بين المدينة، فقد اضطر أكثر من 42 ٪ لعبور أكثر من 4 كيلومترات للوصول إلى..SHH

**الكلمات المفتاحية:** كوفيد -19، فيروس كورونا ، RS، GIS، السليمانية، إقليم كوردستان، العراق.

**پوختە:**

نەخۆشی یەکگرتووەکان کۆڤید-19ی بە قەیرانێکی کۆمەڵایەتی و مرۆیی و ئابووری وەسف کردووە. بە لەبەرچاوگرتنی توانای حاشا هەڵنەگر بۆ شیکردنەوە، پیشاندانی، پاشەکەوتکردن و دەستکاریکردنی داتا شوێنی، کۆمەڵێک لێکۆڵینەوەی بەرفراوان دەریانخستووە کە هەستکردن لە دوورەوە (RS) و سیستەمی زانیاری جوگرافی (GIS) دەتوانن ڕۆڵێکی گرنگ بگێڕن لە بەڕێوەبردنی مەترسییە سروشتییەکان و هەروەها کارەساتە جیهانییەکان . ئامانجی ئەم توێژینەوەیە نیشاندانی دابەشبوونی شوێنی و هۆکارەکانی پەیوەست بە تووشبوون بە کۆڤید-19 لەوانە تەمەن، ڕەگەز، کار، بەرواری تووشبوون و دووری لە بنکەی تەندروستی بە بەکارهێنانی ئامرازەکانی RS/GIS لە سەرانسەری سلێمانی، هەرێمی کوردستان(KR) ، عێراق پشتبەست لەسەر ئەو زانیارییانەی کە لە نەخۆشخانەی شەهید هیمەن (SHH) تۆمارکراون، کە دەتوانن تێڕوانینێکی بەسوود بۆ داڕێژەرانی سیاسەت بۆ دەستێوەردانەکانی ئامانجدار دابین بکەن. ئەنجامەکان دەریانخست کە، بەبێ گوێدانە تەمەن دەرکەوت کە بڵاوبوونەوەی نیشانەکانیCovid 19 ، هەروەها، مردن لە پیاوان زیاترە لە ژنان. هەروەها ئاشکرایە کە بەرزترین مەودای تووشبوون بۆ گروپی تەمەنی 60-69 ساڵ تۆمارکراوە، کە 241 حاڵەت بووە لە کۆی گشتی 1152 حاڵەت، کە دەکرێت بەهۆی کەمی بەرگری لەش و نەخۆشییە درێژخایەنەکانەوە بێت، لەکاتێکدا کەمترین حاڵەتی تووشبوون لە نێوان تەمەنەکاندا بووە گروپی 10-19 ساڵان بەهۆی ئاستی بەرزی بەرگری لەش، کە 8 حاڵەت بوو، بە گشتی. زیاتر، دابەشکردنی شوێنی لەسەر بنەمای پۆلەکانی تەمەن نزیکەی هەمان نەخش بۆ هەموو چینەکانی تەمەن نیشان دەدات. پیاوە کرێکارەکان بە بەراورد لەگەڵ کارەکانی تر بەهۆی بەرزی ئاستی بەرکەوتنی کۆمەڵایەتی زۆرترین تووشبوون، لەکاتێکدا زۆرترین حاڵەتی تووشبوون لە نێوان مێینەکاندا لەلایەن ژنی ماڵەوە داگیرکراوە. لە لایەکی ترەوە ئەنجامەکان دەریانخست کە مانگی تشرینی یەکەمی 2020 ئەو مانگە بووە کە زۆرترین حاڵەتی تووشبوون بە کۆڤید- 19 تۆمار کراوە. هەروەها ئاشکرا بووە کە، 80%ی حاڵەتەکان لە مانگەکانی ئەیلول، تشرینی یەکەم و تشرینی دووەم تۆمارکراون. بەپێی ئەنجامەکان کەمی بنکەی تەندروستی کۆڤید لە شارەکەدا هەبووە، بەو پێیەی دابەشکردنی شوێنی بۆ تووشبووان کە لە SHH تۆمارکراون هێندەی ناوچەی شاری سلێمانی فراوان بووە و تەنها لە گەڕەکی نەخۆشخانەدا نەبووە. بەو پێیەی ناوەندەکان بە باشی لە نێوان شارەکەدا دابەش نەکراون، زیاتر لە 42% دەبوو زیاتر لە 4 کم تێپەڕن بۆ ئەوەی بگەنە SHH.

**کلیلە وشە:** کۆڤید-19، ڤایرۆسی کۆرۆنا، RS، GIS، سلێمانی، هەرێمی کوردستان، عێراق.

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## 1. Introduction

World Health Organization (WHO) officially declared the COVID-19 as pandemic on March 11, 2020 [1]. Now almost all countries are experiencing very urgent situation and the pandemic is being monitored from a variety of perspective **[1].** Due to the rapid spread, Coronavirus disease (COVID-19) recognized as a global health threat. There are a number of variables that contribute to severity of rate of spread pertaining to CONID-19 **[2].** For example, environmental, air pollution, and smoking has been proven to contribute to higher mortality risk **[2].** United Nations, as well, has described the disease as a social, human, and economic crisis **[3].** It is especially evident in developing countries and has left a wide range of socioeconomic impacts on them **[3].** The global trade also predicted to decline by 13% to 32% **[4].** Accordingly, developing a tool to analyze and visualize the spread of COVID-19 seems urgent to give the managers make the best decisions in term of distributing facilities, applying restrictions, etc. **[2].**

At end of 2019 the emergence of COVID-19 in Wuhan was reported and rapidly became a global disaster [5]. The dynamics of infectious diseases, including the Coronavirus, are affected by social and economic factors, according to previous studies and research **[6]**. Understanding the distribution of COVID-19 morbidity rate and its association with social and economic factors can benefit the control of infectious diseases' transmission in the outbreak of infectious diseases, such as COVID-19. It also helps design a healthy city **[7]**. The increasing population density leads to the rapid spread of COVID-19 due to the intense and continuous mixing of people **[7, 8]**. This started a major global crisis affecting various human activities, including travel and tourism **[9]**. The rapid and sudden increase in infections, deaths and critical cases has caused a major challenge to global public health for years through the outbreak of a covid-19 **[10, 11 and 12].**

What raises the concern about the emerging corona virus, even more, is the ambiguity about its origin and treatment, there are no specific answers to many questions about covid-19, such as to what extent will it spread? And how long will it last? How many people will die? Many studies have proved that the host factors, including age, gender, job, and comorbid conditions, are major determinants of disease severity and progression **[13]**. It's also strongly declared that, the best way to protect and slow down transmission is awareness about COVID-19, as well as how it continues and how it spreads, as well as, monitoring active links to control the spread of this epidemic **[14].** Considering the undeniable ability to analyze, display, save and manipulating of spatial data, a wide range of studies have revealed that Remote Sensing (RS) and Geographic Information Systems (GIS) can play a vital role in managing natural hazards as well as worldwide disasters [**14, 15]**. In case of COVID-19, GIS can be used as a reliable tool in decision-making, and most importantly, social mobilization and community responses **[16]**. GIS are considered as an important tool in land data management, which provides the possibility of integrating data from different sources, the possibility of extracting the required information and discovering complex relationships between different phenomena **[17]**. It's also frequently argued that, GIS is an essential tool to model the spatial distribution of infectious diseases, which can aid in the process of combating a pandemic and improving the quality of care **[18]**. Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE), For instance, currently have developed a GIS dashboard that provides live


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data of the worldwide spatial distribution of COVID-19, including the total number of confirmed cases, recovered patients, and mortalities **[18].**

To our best knowledge, this paper aim to show try to classify the confused and unclassified data which are recorded at Shahid Hemen Hospital (SHH) to extract a set of useful information spatially and statistically, as well as, compare them with similar data from other countries. This information is supposed to cover:

- The spatial distribution of infection-related factors connected to COVID-19 (including age, sex, job, and comorbid conditions) using GIS/RS tools across the Sulaimaniyah, Kurdistan Region (KR) which can provide useful insights for policymakers for targeted interventions.
- Furthermore, it will be trying to explain the probable correlation between the abundance of infected people and spatial characteristics of COVID-19 incidence.
- And finally, to see if there are a well-distributed network of health center among the city

Accordingly, these aims are going to answer the following questions:

- How infection has been distributed among the city regarding the factors (age, sex, job, and comorbid conditions) which are connected to the distribution of COVID-19?
- Is there any meaningful spatial and statistical information can be derived from the unclassified data recorded in the hospital?
- Is there enough health center to cover people all over the city without taking long distances?

## 2. Study Area

This study concentrates on Sulaimaniyah City (**Fig. 1**) in the Iraqi Kurdistan Region (IKR), which is located in the North of Iraq. The IKR borders Syria in the west, Iran in the east, and Turkey in the north, where fertile plains meet the Zagros mountains **[19]**.

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**Fig.1:** Sulaimani city, located in Kurdistan Region, North of Iraq.

Sulaimani city is the capital of the Sulaimani Governorate, located in eastern IKR; it borders the Erbil in the north, Kirkuk in the west and south west, and Iran in the east. The study area is one of the most popular and populated cities of IKR, resided by more than 800,000 residents. It also called the cultural capital of Kurdistan. Geographically, its located in a mountainous area surround by, Baranan and Qaradagh mountains are to the south, Tasluja hills are in the west, the Qaiwan range in the north east with the ranges of Azmar and Goizha also located towards the north. This area is hot during the summers and rainy and in cold winters regarding its semi-arid climate **[20]**.

## 3. Material and Methodology

Two sets of data have been used in this research. The first dataset was satellite derived images which have been provided by Google and Being companies (Figure 2). To provide a thorough view of the city Universal Image Downloader was used to download the satellite image of Sulaimaniyah which is owned and developed by allmapsoft website **[21]**. This software let users to easily download real color geo-referenced satellite images (RGB bands) provided by official Google Earth websites which is free of charge and also one of the most easily access data set. Many studies have used Google Earth images as a reliable data to show spatial aspects of social and environmental studies **[19, 22, 23].**


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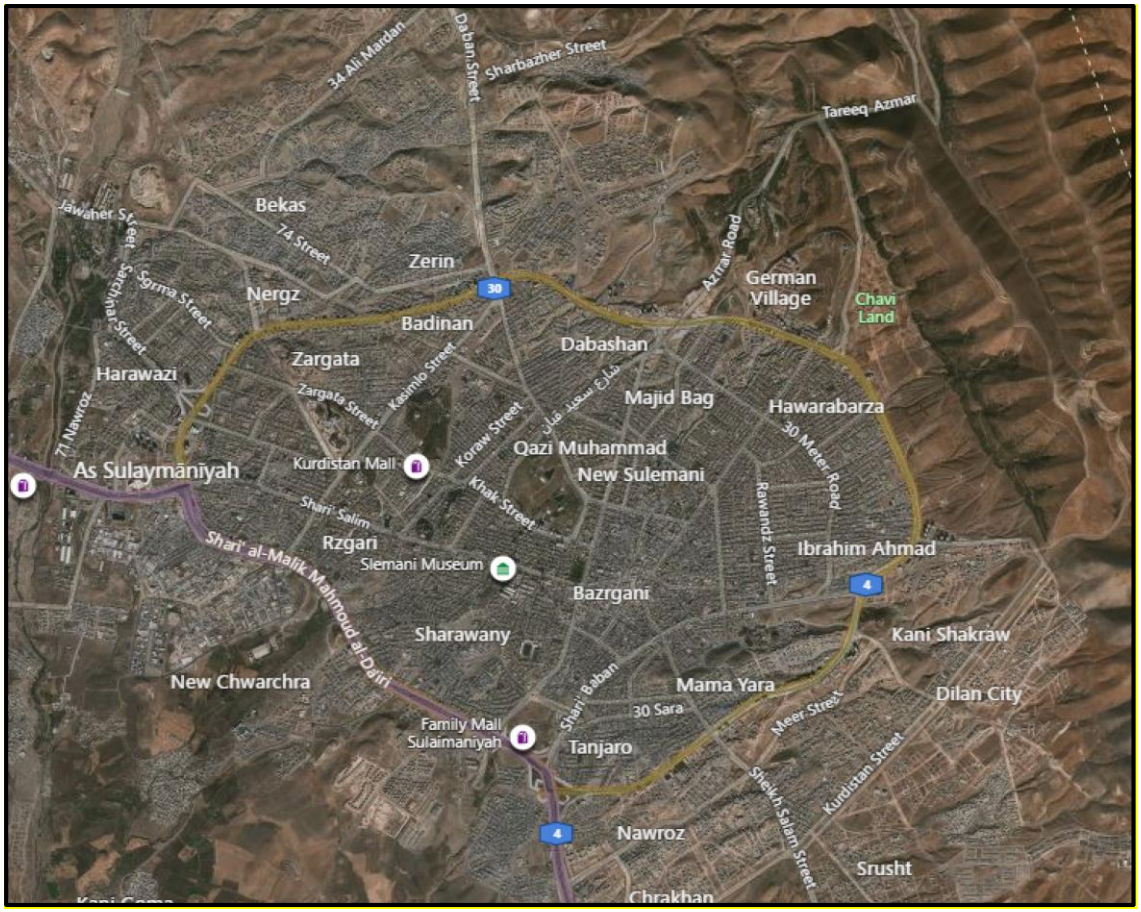


**Fig.2:** Satellite image of Sulaimaniyah provided by Bing Engine downloaded by Allmapsoft software

The second data set includes the statistical data provided by Shahid Hemin Hospital for Corona Virus including recorded data of 1152 cases from 25 August 2020 to 17 February 2021. The provided data was recorded on paper which includes the Sex, Job, Age, date of infection, and address of patients which were totally unclassified.

At the first step, we transferred them into an Excel file then the location of patients on Universal Transfer Mercator (UTM) coordinate system was determined roughly based on their rough address using ArcGIS then they were added to attribute data to access spatial characteristic of the infected people and to see the distribution of COVID infection spatially. The geometric position of patients' addresses determined based on UTM coordinate system. Accordingly, the available attribute of all 1152 recorded cases transferred into GIS database. Now each cases have its own number, age, job code, gender, address, date of record, and UTM coordinate (Table 1).

To classify the major classes, (jobs, gender, age, and date of infection) into some subclasses it's tried to create a new layer for each subclass regarding the characteristics of the major categories or major classes. For example, job layer as a major class divided into 11 subclasses. Each class was selected using ArcMap query method which is using python and Java language. Using this tool all 11 job classes selected from the job attribute data and transferred as a new job subclass as mentioned in table (2). Using this way, a user can easily deal with the different classes separately. It let a user to

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turn them off, turn them on, change symbols and do any attributive or geometrical calculation to extract any potential information.

**Table 1:** A sample of statistical data which covers basic information of infected people.

| No. | Gender | Age | Job code | Address | Date (MM.DD.YY) | UTM coordinate E (m) | UTM coordinate N (m) |
|---|---|---|---|---|---|---|---|
| 1 | M | 77 | 0 | Fermanberan | 8.25.2020 | 536709.07 | 3938628.47 |
| 2 | M | 61 | 1 | Rapareen | 8.29.2020 | 529785.4 | 3937529.75 |
| 3 | M | 86 | 0 | Kostay Cham | 8.29.2020 | 533318.79 | 3933962.12 |
| 4 | M | 52 | 1 | Sarchnar | 8.30.2020 | 534553.04 | 3937758.04 |
| 5 | M | 52 | 1 | Sarchnar | 8.30.2020 | 534558.02 | 3937749.23 |
| 6 | M | 55 | 3 | Kurdsat | 8.30.2020 | 539591.57 | 3939022.25 |
| 7 | F | 80 | 2 | Bekrejo | 8.30.2020 | 532336.01 | 3934147.76 |
| 8 | F | 40 | 2 | Bekrejo | 8.30.2020 | 532336.01 | 3934147.76 |
| 9 | F | 54 | 2 | Bekrejo | 8.30.2020 | 532336.01 | 3934147.76 |
| 10 | M | 34 | 1 | Sheakhan | 8.30.2020 | 539709.09 | 3937353.45 |

**Table 2:** Jobs codes and their frequency

| Code of Jobs | Fre. |
|---|---|
| 0 = Dosent work | 236 |
| 1 = Worker | 242 |
| 2 = Housekeeper | 450 |
| 3 = Employee | 74 |
| 4 = Hospital staff | 15 |
| 5 = Doctor | 4 |
| 6 = Police | 14 |
| 7 = Retired | 79 |
| 8 = Teacher | 26 |
| 9= Presion | 2 |
| 10= Peashmerga | 2 |
| 11= Student | 8 |

To see how far have the patients been from SHH we decided to create a layer to classify and show the distance of recorded cases from their residency the SHH. The distance classified into 8 classes starting from almost 114 m to 16800 m. First subclass encompasses the cases whose distance from SHH was between 114m to 2000m. Other classes step forward by 2km except the final class which is between 14000 to 16800m. Table (3) displays the distance subclasses and the frequency of patients per each one. To create distance layers from distance database, firstly, using ArcMap proximity tool, the distance from each case calculated from SHH. The output was in form of table, this table then transferred into a new field in attribute data of recorded cases to link it with the UTM coordinate and other attributes of the main layer which include recorded cases and their geometric properties. These distances are straight distances and the road networks or traffic timetable have not been regarded.


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**Table 3:** Frequency of patients per Distance subclasses

| Distance from SHH (m) | Frequency |
|---|---|
| 0-2000 | 261 |
| 2000-4000 | 399 |
| 4000-6000 | 291 |
| 6000-8000 | 65 |
| 8000-10000 | 89 |
| 1000-12000 | 42 |
| 12000-14000 | 0 |
| 14000-16800 | 5 |

Finally, each influencing factors (Sex, Job, Age, date of infection, and distance from SHH) was displayed in two forms, as a chart, and on the map created in ArcMap GIS, to see the comparative view of them, and the spatial distribution of the factors among the study area, respectively. Using the charts and maps it will be more convenient to analyze and discover any probable correlation between the distributions and abundance of COVID-19 cases and the factors which are supposed to be influencing. Figure (3) shows the steps that are taken to produce the results.

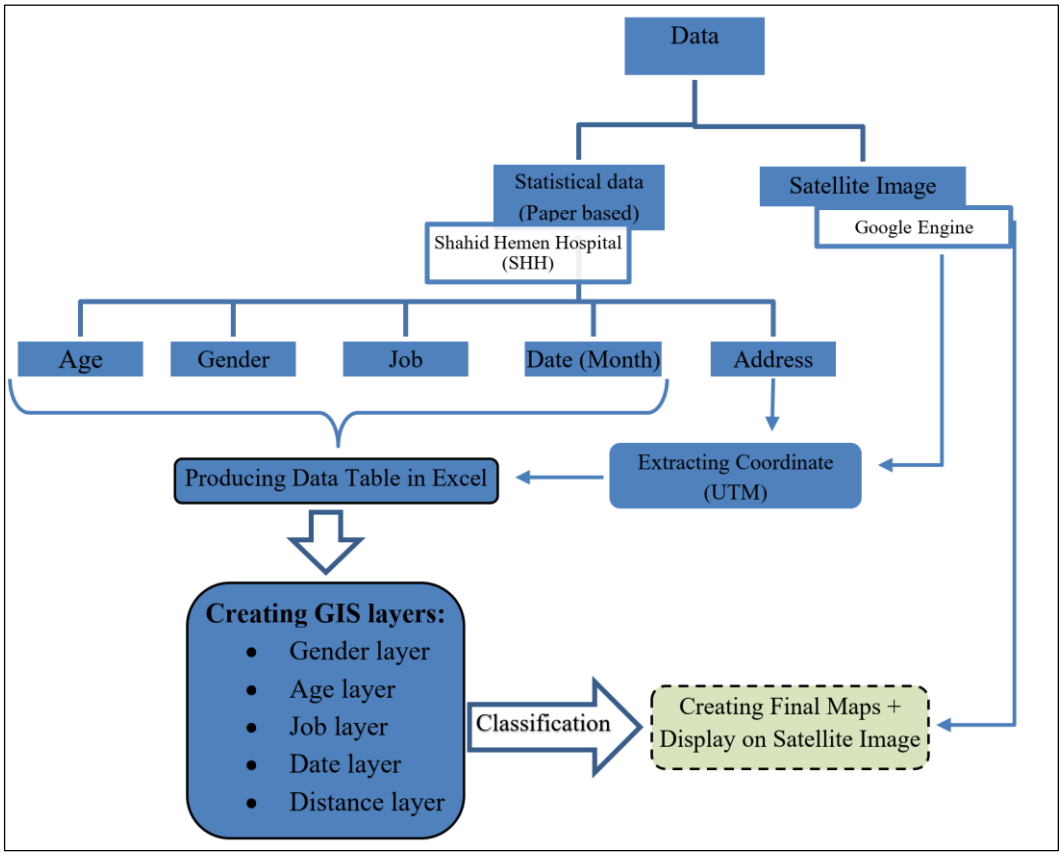


**Figure 3:** Methodological framework, which consists of data collection, data processing

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## 4. Results and discussion

The study shows that the number of infected people recorded in Shahid Hemin Hospital is 1152 for that period (25th August 2020 to 17th February 2021) across Sulaimaniyah city center only which is equal to 67.61% of cases that have been recorded at Shahid Hemin hospital. Classifying the data based on gender revealed that the males have been infected more than females, 56.33% vs 43.66% respectively. (Figure 4).

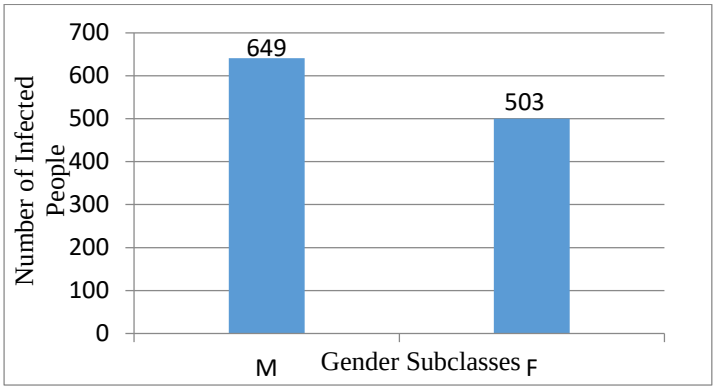


**Figure 4:** 649 infected males VS 503 infected females.

Although the spatial density of infected males and females are different in many locations among the study area, but, the spatial distribution showed almost the same pattern for both sex (figure 5).

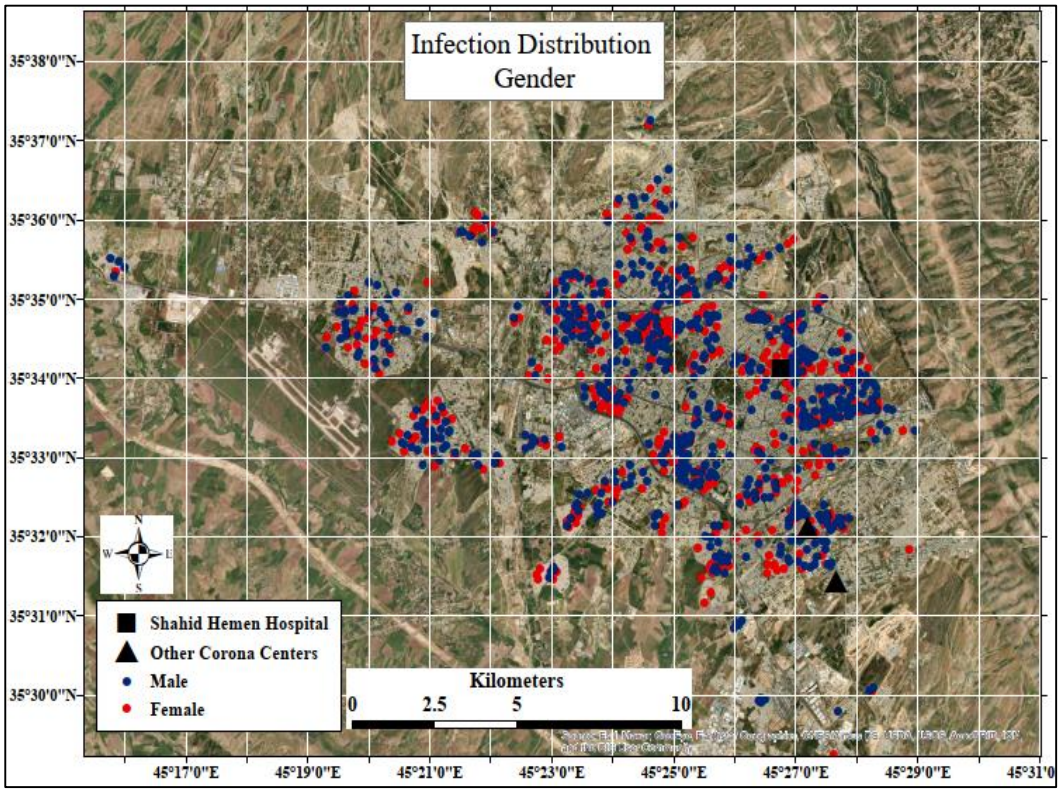


**Figure 5:** Spatial distribution of infections among the city based on gender


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The percentage of male were 56.33 % while the female was 43.66%, proving that the ratio of infection is more among males by almost 12.67%. These results agreed with the results which obtained by [**24, 25 and 26]**. The high infection ratio among the male could be due to the high rate of smoking, drinking alcohol, as well as the fact that men are outdoor especially for working most of the time. This result is concluded in many studies. Regardless of age, the covid-19 affects men more than women in terms of symptoms, worse outcomes and mortality **[26].** In a study that included 425 patients with covid-19, it was found that 56% were men and 44% were women **[27]**. In another study **[23]**, it was found that the spread of covid-19 symptomatic was greater in men than in women, as smoking and alcohol consumption had a role in the rate of covid-19 spread among men.

The results also showed that wide range of age categories were infected ranged between 10 and 100 years old in different places who have visited the Shahid Hemin Hospital for Corona Virus. According to data, the rate of infection was higher among the older age group (figure 6).

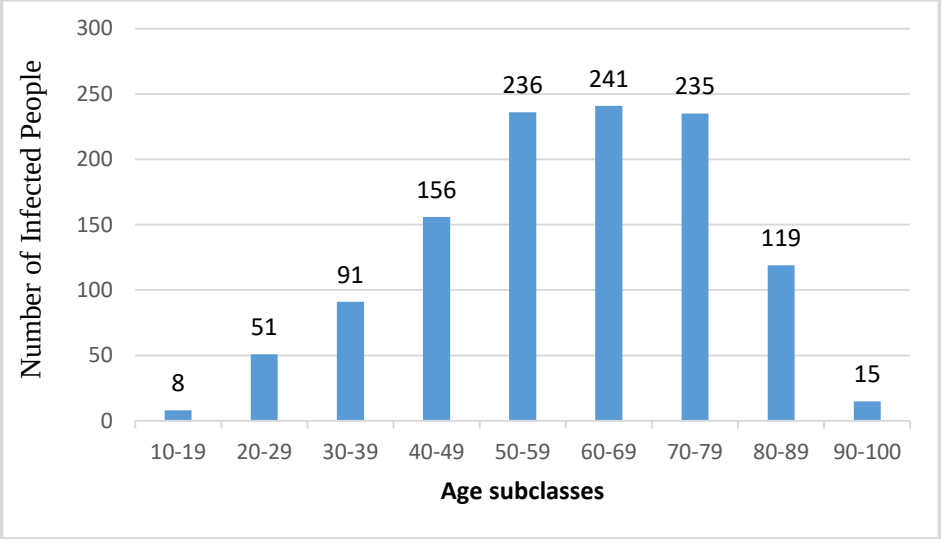


**Figure 6:** infection frequency based on age

It is also revealed that the highest rang of infection was recorded for the age group 60-69 years old, which was 241 cases of total 1152 cases, which could be due to lack of immunity and chronic diseases, while the lowest infections were between age group 10-19 years old because of high level of immunity, which was 8 cases, altogether. More, the spatial distribution based of age categories show almost a same pattern for all age classes (Figure 7). In China, also, it is proved that the ratio of mortality by covid-19 was higher in older age, from 0.4% or less in patients aged 40 or younger, to 1.3% in fifties, 3.6% were in 60s, 8% in 70s to 14.8% in 80s or older **[28, 29]**. In another study **[30]** which has been conducted in Italy, the results followed the same pattern in China. A study showed, patients with an average age of 65 years were more severely exposed to the covid-19 **[26]** which highly proved the results concluded in this study. Regarding age and gender simultaneously, reports from Switzerland and Germany have recently reported incidence rates (cases per 100,000 populations by age and Gender), confirming an increased incidence of the disease in men over 60 years of age [**31**].

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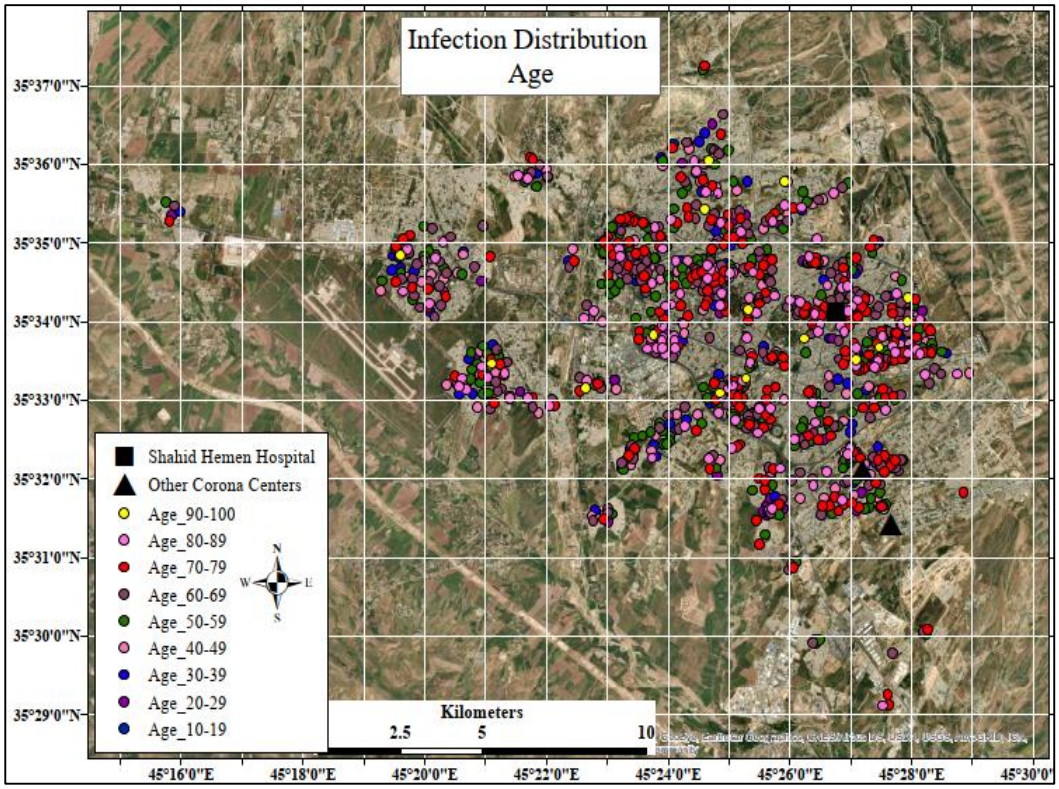


**Figure 7:** Spatial distribution of patients' ages

The worker men were most infected comparison to other jobs due to high level of social contact, while the most infected cases among females were occupied by housekeeper. As shown in (figure 8) the housekeepers were at the highest level of infections by covid-19, because they contain most of women ratio. (Figure 9) show the spatial distribution of the patients' jobs which is clear that the housekeeper records the heights level.

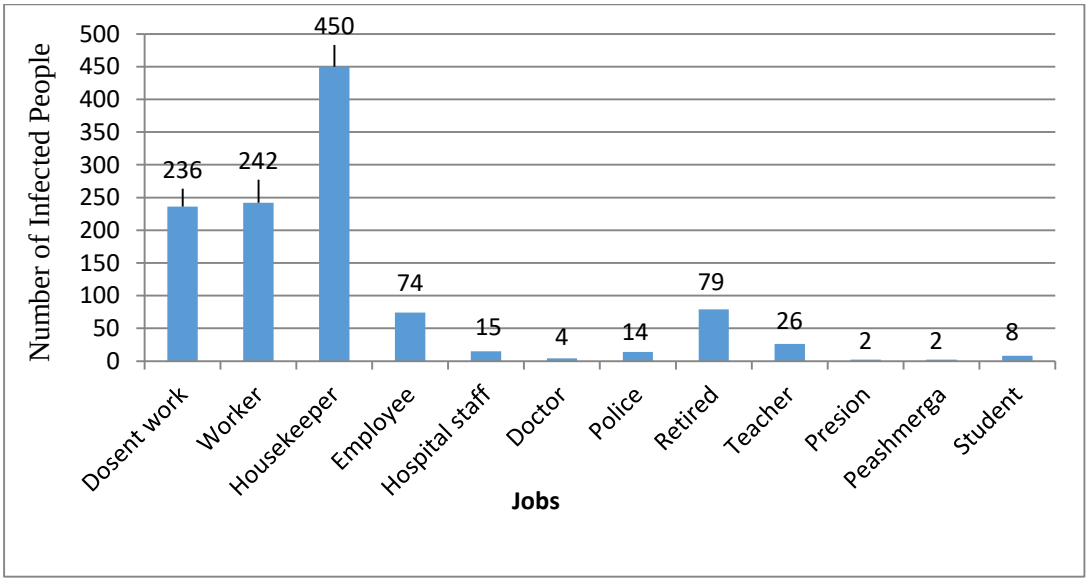


**Figure 8:** Infection frequency based on job


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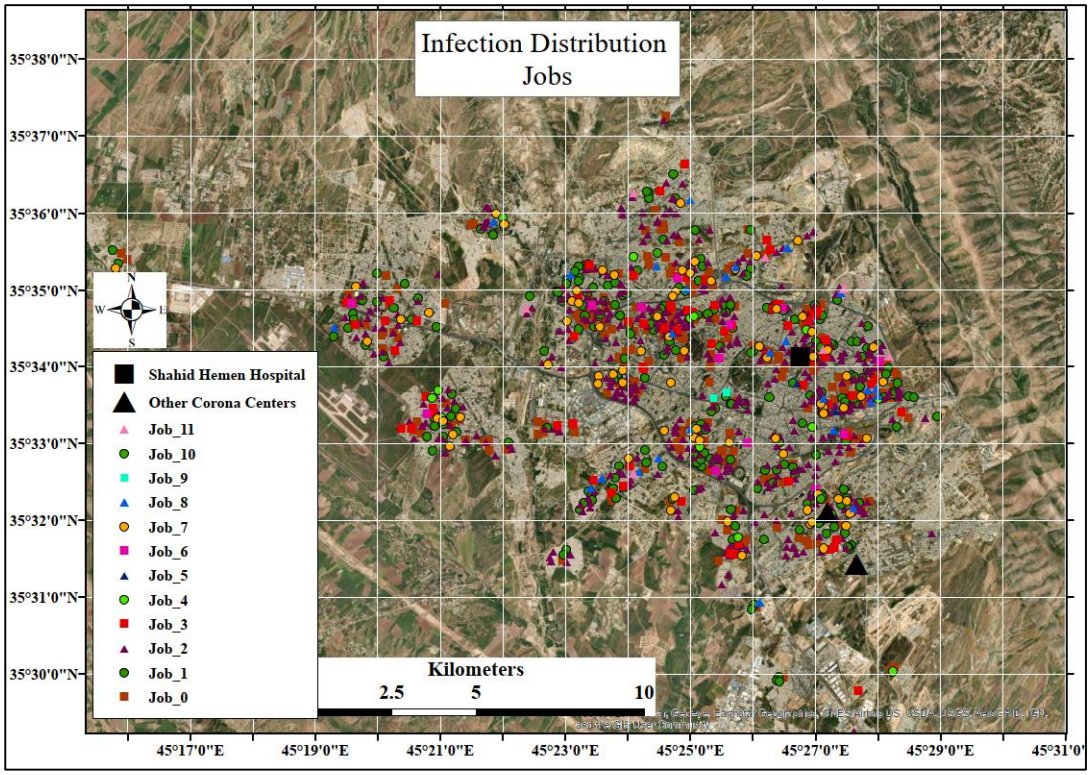


**Figure 9:** Spatial distribution of the jobs of the patients

In other hand the results showed that the October 2020 was the month within the most cases of COVID-19 were recorded (figure 10), and (figure 11) show the spatial distribution of infections per months during the period. Accordingly, the density of infection in September and October was at its highest rate, and August, on the other hand, has recorded the lowest value. Based on the data, over 80% of cases were recorded in September, October, and November. It's also revealed that the frequency of infection has declined since October 2020 in a way that there were only 33 infected cases recorded in SHH.

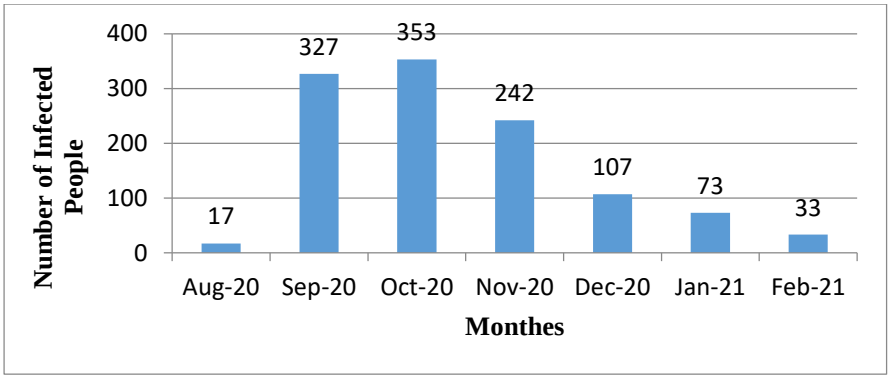


**Figure 10:** Infection frequency per Months

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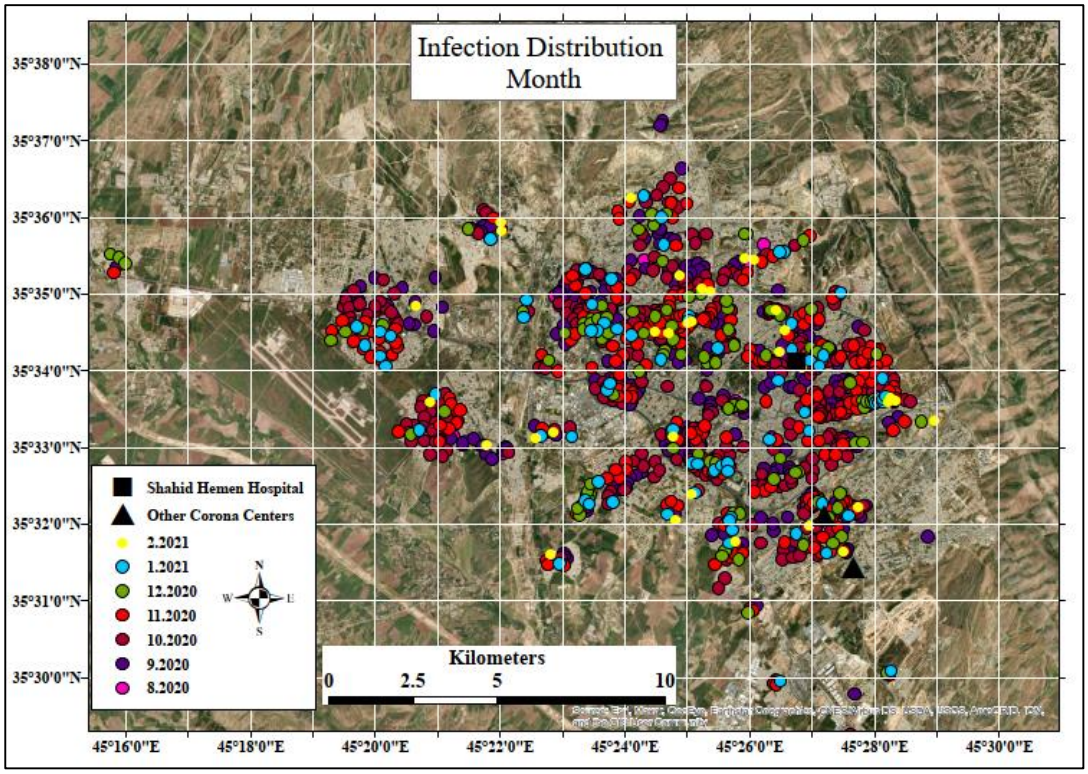


**Figure 11:** Spatial distribution of infected residents per months

Statistical data on distance from SHH revealed that more than 42% of recorded cases have passed more than 4 km to reach the hospital. The data also showed that more than 17% have traveled more than 6 km to get medical health. There are even cases who have passed more than 16 km to catch the hospital (Figure 12).

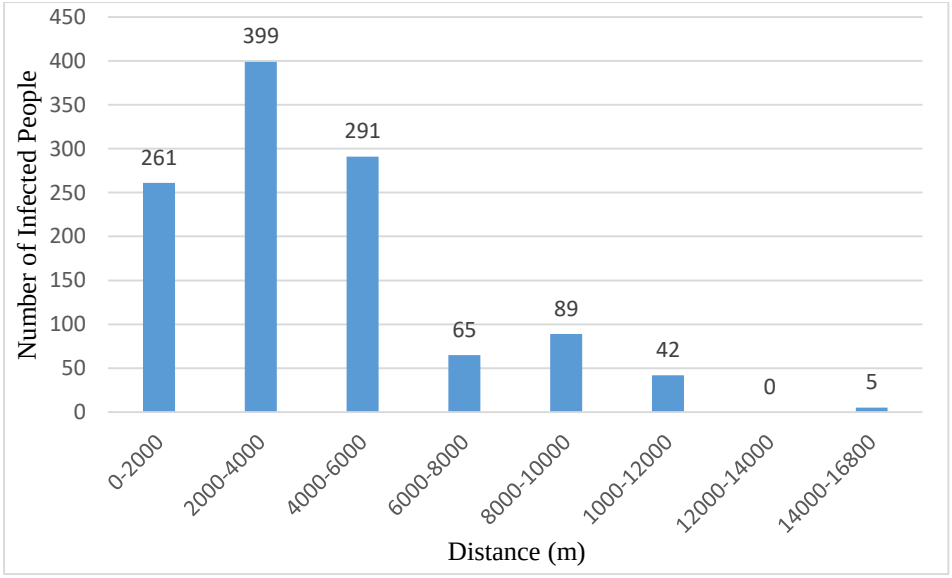


**Figure 12:** Number of infected people per distance from Shahid Hemen Hospital. More than 42% of patients have travel more than 4 km to arrive at the hospital


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Based on distance subclasses and as clearly seen in figure (13) there has been a lack of COVID health center in the city, since the spatial distribution of infected people who are recorded in SHH was as wide as the area of Sulaimaniyah city and it was not confined to the hospital neighborhood. As seen on the map which is classified based in the distance from the SHH, the other centers are not distributed well among the city. There are even many cases in other corona centers' neighborhood which have gone to SHH to take medical treatments.

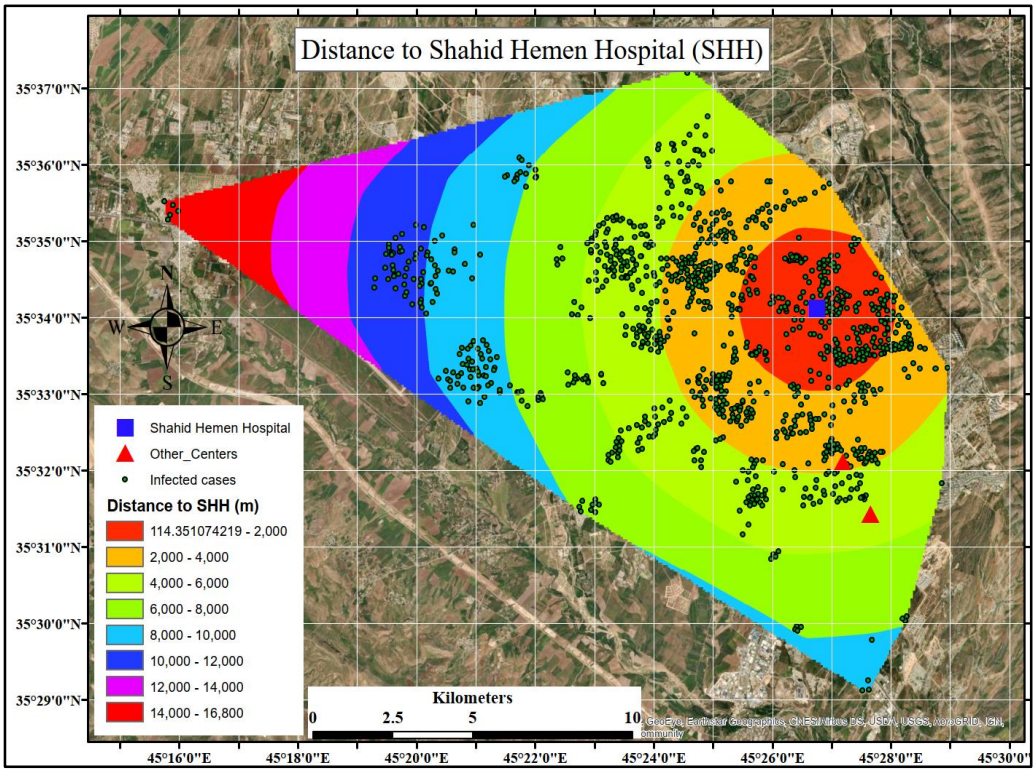


**Figure 13:** Distribution of infected people per distance from Shahid Hemen Hospital. Many people had been to travel long distances (more than 4 km) to get the SHH Corona center. The map displays an inappropriate distribution of corona-related health centers

## 5. Conclusions and recommendations

Regardless of age it was found that the prevalence of Covid 19 symptoms, as well as, mortality in men is higher than in women. Heavy smoking and excessive alcohol consumption have contributed to the high prevalence of Covid-19 among men **[30]**. The body's predisposition to catching Covid-19 is linked to age, biological sex, and chronic diseases as also proved in other researches **[32]**. The results also showed that COVID-19 is not only dangerous for the elderly and infirm but also for healthy middle-aged adults. Whereas, infection fatality rate of the population is intrinsically related to age-specific infection pattern. Therefore, taking public health measures to protect vulnerable age groups can drastically reduce the death rate **[33]**. It is also revealed that the highest rang of infection was recorded for the age group 60-69 years old, which was 241 cases of total 1152 cases, which could be due to lack of immunity and chronic diseases, while the lowest infections were between age group 10-19 years old because of high level of immunity, which was 8 cases, altogether. More, the spatial distribution based of age categories show almost a same pattern for all age classes. The worker men

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were most infected comparison to other jobs due to high level of social contact, while the most infected cases among females were occupied by housekeeper. In other hand the results showed that the COVID-19 is time dependent and more than 80% of cases were infected during September, October, and November. The population increase in the city center contributed to the spread of the disease due to the lack of distance between people and the increase in social relations and thus the increase in direct contact between people. The study also suggests that the spatial distribution of COVID health centers are not well-distributed and lots of residents had to pass a long way to reach the SHH center.

It's also proved that the spatial analytical data tools provided by RS and GIS are highly useful in understanding and managing pandemic infections, like COVID-19, since these tools help us to see how people may connect each other in a greater scale, e.g., across a city or a region. Furthermore, GIS is considered as an important tool in land data management, which provides the possibility of integrating data from different sources, the possibility of extracting the required information and discovering complex relationships between different phenomena **[14, 15, 17]**.

It’s highly recommended that:

1. To digitize the data has been recorded in the related centers.
2. To conduct cooperative research including specialists from different sectors including GIS and health specialists.
3. Using digital data form instead of paper forms to record patients information in the centers which are dedicated for COVID-19.
4. To conduct researches on hazard managements using GIS network analysis.


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