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A Framework for Deploying GIS Applications to Monitor the Spatial Distribution of Epidemics

COVID-19 Epidemic in Libya Case Study

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Abstract—**A Geographic Information System GIS is a computer program that can analyze big geospatial data to recognize the patterns of that data and obtain structured and organized information from it. Processing geographic information manually is not an easy task. Additionally, the obtained results often do not meet the needed accuracy. As a result, GIS programs have achieved worldwide success and spread due to their compared accuracy and flexibility. Also, the recent development of artificial intelligence and machine learning techniques significantly contributed to increasing the efficiency and accuracy of these programs. On the other hand, technological advances in digital electronics and the advent of cloud computing have significantly lowered costs, which allowed even small businesses to access satisfactory GIS software. This paper explains the importance of geographic information systems in displaying, tracking, and monitoring spatial data to support strategic decision-making bodies. To illustrate our point, we decided to present a framework for developing a GIS dashboard to track the spread of COVID-19 in Libya as a case study**.

Index Terms: **Spatial Data, Geographic Information System, GIS, GIS Framework, GIS Dashboard, ESRI, Decision-Making Support, Health Information Management, COVID-19, Libya**

I. INTRODUCTION

A Geographic Information System (GIS) can be defined as a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates typical database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits maps can offer. Specifically, GIS is a technological field that incorporates geographical features with structured spatial data for mapping, analyzing, and assessing real-world spatial objects; generally, this data is a set of referenced locations on the earth with attributes. Data attributes represent features of spatial entities to deliver additional information about each spatial object. The spatial data, say, for a hospital object, is the actual location of that hospital, and the attributes are the name, medical specialties, and clinical capacity of the hospital. The GIS frameworks have powerful tools for capturing, managing, analyzing, recognizing patterns, and finally visualizing the information extracted from the geospatial structured and semi-structured data [1], [2]. Usually, it is not easy to process geographical information manually and successfully; for example, preparing map graphics is tedious work, and the output accuracy may be unsatisfactory. Thus, in addition to being complex and time-consuming, manual processing may fail to provide geographic information effectively [3].

The outcomes of GIS frameworks for the data analysis usually come as inferred, incorporated, or prioritized information. These outcomes help decision-makers, researchers, and other interested parties from different fields. For example, most GIS frameworks provide tools to develop and support geographic information display dashboards, which offer a user-friendly GUI to display the significant data points and key performance indicators relevant to the business. Such dashboards can help decision-makers, for instance, in a healthcare organization, to illustrate chronic disease patterns in the country at the major municipalities and city levels [2], [4].

The recent COVID-19 virus of corona disease emerged in China and rapidly spread to other countries around the world. The first human cases of the disease were reported in Wuhan City in Hubei province of Central China in December 2019. Coronavirus disease is a large pandemic the world has witnessed. Despite the massive efforts by China to enclose the disease within Hubei province, millions of people were affected within a few months from the epidemic beginning, hundreds of thousands died, and millions lost their jobs due to various restrictions imposed on them by the governments [5].

Due to the rapid spread of the COVID-19 epidemic, the employment of modern technologies became mandatory

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for all interested parties to cope with viewing the epidemic's situation synoptically and fighting against it. The GIS technology proves itself as a successful tool for achieving that target. GIS was used to track, analyze, and manage the key performance indicators of the COVID-19 epidemic data processing [6]. Geospatial information plays an essential role in preventing and controlling the COVID-19 virus pandemic because this virus spreading is highly dependent on the spatial conditions surrounding it. The assessment of the scale of the COVID-19 pandemic from a geographical perspective can offer a better understanding of the spatial distribution, better management of the disease infection, and effectively studying its impacts. Monitoring the COVID-19 pandemic by GIS tools is valuable, especially for social mobilization and community responses [7], [8]. The striking feature of GIS tools is assisting the health professionals to obtaining a wide range of spatial information about COVID-19 disease to monitor its evolution in real time and moving information faster than the advance of the virus [9].

Since the first case of COVID-19 in Libya on 24/3/2020, the number of reported COVID-19 cases around Libya was increased rapidly [10]. Because there were no published reports on the size of the epidemic and the availability of the relevant healthcare facilities in Libya, this study aims to employ the GIS frameworks effectively to view and assess geospatial data to support stakeholders in monitoring, tracking, and controlling the evolution patterns of the COVID-19 pandemic in Libya. We will investigate using GIS dashboards to monitor and control the development of the COVID-19 pandemic in Libya. Consequently, there are two primary aims of this study:

1. We shall propose a precise methodology for a framework to develop a dashboard using the GIS technologies to utilize geospatial data collected for the COVID-19 pandemic in Libya.
2. Use the developed dashboard to monitor the COVID-19 pandemic among the residents and visitors of Libya. We demonstrate that the information obtained from the GIS dashboard illustrates the chronic disease patterns in the major municipalities and city levels. Also, we will suggest how the official Libyan authorities and organizations can take advantage of this information to support their decisions.

The overall structure of the study takes the form of seven sections, including this introductory section. The second section gives a brief review of the related works for this study. The main topic, which is covered in section three, is the GIS Technologies and Tools. Section four presents an information about Libya and the development of COVID-19 pandemic in it. The fifth section is concerned with the proposed framework methodology used for this study. Section six includes a discussion of the implication of the findings to future research. The conclusion of this study is presented in section seven.

II. RELATED WORKS

Since the start of COVID-19 pandemic, a large and growing body of literature has investigated the use of GIS technologies to monitor COVID-19 pandemic development. One important response is the provision of information sharing facilities and monitoring of the spread of COVID-19 cases around the world by Johns Hopkins University (JHU). They developed a GIS dashboard in January 2020. Then, in the same month, the World Health Organization (WHO) created the WHO COVID-19 dashboard. Both dashboards have distributed information as anticipate by the user; however, the JHU Dashboard provides faster information with good access for smart device users, even though the user interface display and color selection are less attractive. Data on the WHO COVID-19 dashboard is frequently late, but with more data appearances and variations, also users can made comparisons between countries [9], [11].

In their review of the process of building an interactive data driven and GIS based COVID dashboard, Bhatia, et al. in [4] implement a methodology to Create GIS based COVID-19 dashboards by utilizing ArcGIS Online tools. The dashboards were created for the country, state, and district. These dashboards provide information about the COVID-19 patients. The patient state dashboard also contains the health institutions' locations, migrant's information and more. The district dashboard contains additional information of the patient. There are lot of tools and widgets included in this dashboard. According to them, the user interface of the dashboard is simple and interactive, and the configured widgets provide almost real time information and they are visible on a single screen. They have implemented dashboards globally and specifically for Indonesia. By using ESRI technology, they have developed a geo-portal health information system for Indonesia. This system integrates information from relevant government agencies and visualizes it on the mapping dashboard. Bhatia, et al claim that the implementation of the GIS based COVID dashboard in relatively straightforward and does not require any programming skills if the Operations Dashboard in ArcGIS Online has been used.

Another work by Razavi-termeh, Sadeghi-niaraki and Choi in [12] who arranged a coronavirus vulnerability map of Iranian provinces using GIS to monitor the disease in those provinces. For this purpose, four criteria affecting coronavirus, including population density, percentage of older people, temperature, and humidity, were prepared in the GIS. A Multiscale Geographically Weighted Regression (MGWR) model was used to determine the vulnerability of coronavirus in Iran. An adaptive neuro-fuzzy inference system (ANFIS) model was used to predict vulnerability in the next two months. Their results indicated that, population density and older people have a more significant impact on coronavirus in Iran. Their findings showed that some Iranian's provinces were more vulnerable in certain year seasons and the other provinces were more vulnerable to coronavirus in other year seasons.

To inspect the spatial patterns and areas of clustering detection to describe the pattern of coronavirus in Iraq, Jaber, et al. in [13] established a study to apply spatial statistics to describe the pattern of coronavirus in Iraq by using a GIS-based methodology to examine the relationship between the reported incidence of coronavirus and spatial patterns analysis in eighteen provinces of Iraq during 2020. The authors of this study have used local spatial autocorrelation analysis (Local Moran's I) to measure the correlation between a single geographic region and its neighbors at a specified distance. It has been applied to measure spatial distribution of coronavirus in the study area and examined how provinces were spread or clustered. Their results described spatially random clustered and spatial pattern of this disease in the study area. The study determined that the coronavirus cases were increased in certain provinces of Iraq.

In a follow-up study, Sahu, et al. in [14] performed a GIS to map COVID-19 cases across India. According to them, because the COVID-19 has had a distinct influence on different parts of India, their research proposed a connection between past, current, and future COVID-19 infected cases in India employing prediction by using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model to forecast time series. Several databases are utilized to collect data for mapping and displaying cases across the country. These databases are combined to get the required output that is to be plotted and displayed. They claim that their methodology results showed a high accuracy.

Shadeed and Alawna in [15] developed a COVID-19 vulnerability map for the West Bank in Palestine. They utilized the Analytic Hierarchy Process (AHP) to develop the COVID-19 vulnerability map. The GIS in combination with Multi-Criteria Decision Analysis (MCDA) was adopted to estimate the COVID-19 Vulnerability Index (CVI) based on some selected potential criteria including population, population density, elderly population, accommodation and food service activities, school students, chronic diseases, hospital beds, health insurance, and pharmacy. The results of their study show that some parts of the West Bank are under very high vulnerability; however, other parts are high-vulnerable to COVID-19. Furthermore, they found that 82% of the West Bank population are under-high to very-high COVID-19 vulnerability class, 14% of West Bank population are medium COVID-19 vulnerability class and 4% of West Bank population are low to very-low COVID-19 vulnerability class.

Schmidt, et al. in [16] conducted a study to describe the development of a Web GIS or a GIS dashboard based on open source GIS tools for the collection and analysis of COVID-19 cases and its feasibility in terms of technical implementation and data protection. By using the developed dashboard, the data is collected voluntarily from the Germany Cologne city area. According to the authors of this study, their results show that open source GIS tools can be manipulated to develop a Web GIS or GIS dashboards for the generation and evaluation of Volunteered Geographic Information. They confirmed that open-source GIS tools consider the data protection, ethical aspects, and legal requirements. The consideration not only affect Volunteered Geographic Information itself but also the IT security. The concluded that the separation of data collection and data evaluation is important.

Overall, these studies clearly indicate the importance of using GIS technologies and dashboards to monitor COVID-10 pandemic development in any county around the world, although, they use different framework methodologies and tools. This study will attempt to exploit the GIS framework powerful characteristics to develop a dashboard to monitor COVID-19 pandemic in Libya to support the Libyan authority's decision makers,

III. GIS TECHNOLOGIESAND TOOLS

As forementioned in the introduction, GIS is computer-based tool or information system for mapping both the existing spatial objects and the occurrence of spatial events on the earth space. It can collect, store and analyse the requested information from the specific geographic location and displaying that data as a reference to get accurate cartographic representation of an object in the spatial-temporal space. However, GIS has some features which are distinguishing it from other information systems. For instance, GIS is designed for generating maps by using spatial data. These data can be extracted by scanning existing paper maps, collecting coordinates of maps through surveying techniques or Global Positioning Systems (GPS) or using aerial photograph or satellite imagery maps. GIS could congregate the extracted information from the collected spatial data in relations to significantly solves geological problems in many fields such as business, science, government, and industry. The applications of GIS can be accommodation of population, air pollution, and climatic changes for disaster management and mitigation, natural resource management, street network, facilities management planning and engineering and public health-related problems evaluation. In fact, GIS is very convenient for directional data analyses and can provide a basic framework on public health research and evaluation [3], [17].

The GIS structure should include several principles to perform its functionality. Firstly, the spatially reference data should be collected and stored in relational geodatabase. To physically collecting and storing this data, a hardware tools are required. Secondly, users should have the ability to access the geodatabase, query, and analyse the data by assembling user-interface algorithms and data management procedures. GIS can be considered as a geodatabase which may be used by different users to meet various information needs. Lastly, the GIS should consider all kinds of people who deal with it. They could be producers and consumers of spatial data [17].

In fact, GIS is used as a tool to manage spatial datasets or geodatabases. They consist of a series of information that called layers, which can be explained as a table or a user-view. They can be stacked to show the relationship between them. Each of these layers contains attribute data which is either raw data such as topographic or satellite data or thematic data such as health services. GISs can convert spatial data into the geographic or coordinate system. The data management process starts with outlining a link amongst the map and attribute data. The process of linking the attribute data with the spatial coordinates of the map is known as Geocoding [3], [17].

The attribute data in the dataset layers can be graphically combined using analytical operators and displays. A user can work with these layers to explore critically important questions and find answers to those questions. In addition to locational and attributive information, spatial data inherently contains geometric and topological properties. Geometric properties include position and measurements, such as length, direction, area, and volume. Topological properties represent spatial relationships such as connectivity, inclusion, and adjacency. Using these spatial properties, users can ask even more types of questions to gain deeper insights. As a result, GIS can perform a spatial analysis by using spatial information to support the decision makers. GIS also provides data manipulation functionality and statistical tools that are useful for data transformation and model implementation during these analyses. Visualization is one of the most critical aspects of GIS as it allows users to envision the spatial data and help them identify the links or associations. GIS can visualise the spatial data by presenting multiple datasets on a map simultaneously because datasets are treated as different individual layers [3], [17].

A. GIS Tools for Public Health research and evaluation

Nowadays, health quality in any society is increasingly necessary that requires a faithfully, rapidly diagnose and evaluate the public health problems, which in turn becomes an urgent issue. On the other hand, the geospatial information is considered as an important part of preventing and controlling of the epidemics and pandemics deceases. It is because the epidemics and pandemics deceases are completely spatial in nature. For this reason, GIS tools with their analytical characteristic and performance have the ability to achieve an influential role in health data collection and analysis to support the evaluation of the occurrence of common diseases and summarizes the significant impacts of that diseases on the quality of life. GIS manages the collected spatial data, which is related to the epidemics and pandemics deceases, to describe the severity of disease, assess the occurrence in different geographical regions. Furthermore, GIS tools can predict, surveil, manage, and analyse the infectious diseases [17].

Aghajani, et. al., in [17] claim that major causes of deaths occur because of human infection with many epidemic diseases such as, HIV/AIDS, Tuberculosis (TB), and Malaria. They added that the epidemiological analysis showed more than 95% of these deaths in the developing nations. They recommended the GIS tools which could support researchers to apply remote sensing, performance, and monitoring of these infectious diseases. They confirm that GIS tools should be considered as an important tool that is actively engaged in public health. They assert that GIS tools provide accurate information, make robust visualization, and monitor public health-related problems. GIS tools record and display the available resources and material in any given geographical region. Overall, GIS tools have become an essential tool that upgrades the knowledge and understanding on public health problems.

B. GIS Tools Examples

According to Usmani, et al., in [3], there are several types GIS tools, some of them are free and open-source such as Quantum GIS (QGIS) and others are commercial and licensed such as ArcGIS. The rest of this sub-section will provide a brief description about these two tools.

1) Quantum GIS (QGIS)

Quantum GIS (QGIS) is an open-source cross-platform GIS which runs as a desktop application besides supporting all the facilities of GIS. By using QGIS, spatial data can be efficiently viewed, edited and analysed. Development of QGIS began in 2002 under Gary Sherman and its first version was released in 2009. QGIS has a large and active community of users from diverse domains. QGIS is the first option for open-source GIS users. Researchers have created different QGIS extensions to facilitate other geographic or geospatial services in their studies.

2) ArcGIS

ArcGIS is developed and licensed by Environmental Systems Research Institute (ESRI) company. It was initially released on the end of 1999. ArcGIS is usually referred to as a desktop suite of GIS applications; currently, it refers to an entire platform of tools for mapping, spatial analysis, and visualization. The tools, domains of application, and data that can be accessed and used from traditional client/server on-premise installations to a fully mobile web-based/cloud-powered implementation. According to Usmani, et al., in [3], Although ArcGIS platform tools integration across these environments is not 100% perfect, it is in lead for the other tools in the GIS world. The ArcGIS platform is quite dominant in the enterprise and government worlds. It is now making inroads into new areas traditionally outside the core group of GIS users and customers.

C. GIS Dashboards and ArcGIS Dashboards

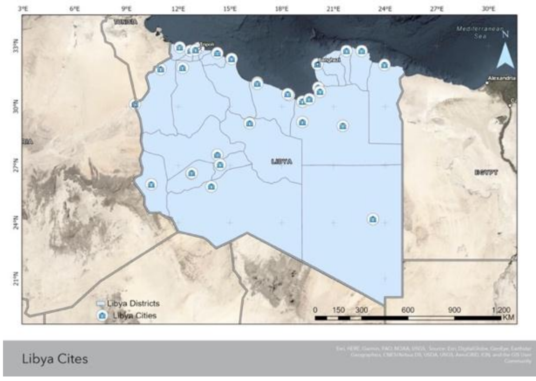
A dashboard is a view of geographic data for supporting decision-making and monitoring location-based events or activities. The integrated dashboards with GISs have the ability to view, analyse and manage the spatial information with the key performance indicators of a process or business. Not only GIS dashboard has a complex structure, but also its development is sophisticated. Web based dashboards are usually developed using programming languages like CSS, HTML, JavaScript, R Script, Python and others. A programmer needs to have knowledge of various technologies to build responsive web-based dashboards. Dashboards are essential information products, like maps and applications, providing a critical component to user geospatial infrastructure [4], [6].

GIS serves as a public platform for the convergence of multi-disease surveillance activities. Public health resources, specific diseases, and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information, when mapped together, creates a powerful tool for monitoring and management of epidemics. After COVID-19 pandemic higher infections, GIS dashboards become significant instrument because they can accomplish spatial information representation objectives and allow people to understand the latest situation and visualize the COVID-19 virus distribution pattern. In addition, the number of confirmed cases, dead cases, recovery cases, and cases still hospitalized for investigation and virus trends are available immediately. GIS dashboards are used to identify disease foci, monitor sensitive populations areas that have been newly infected or re-infected, and identify vulnerable populations in order to target cost-effective interventions and monitor eradication efforts. The visual display of spatial phenomena in the dashboards provides a very useful analytical tool. Healthcare is an important topic, for medical and healthcare geography as the modern world pressure to re-evaluate the health care system to accommodate current health care needs. GIS dashboards add a great value to public health planning and potential disease prevention, combining population distribution, elevation, land use and cover, location and capacity of existing health services [4], [18].

ArcGIS Dashboards enables users to convey information by presenting spatial-based analytics using intuitive and interactive data visualizations on a single screen. Every organization using the ArcGIS platform can take advantage of ArcGIS Dashboards to assist making decisions, visualizing trends, monitoring status in real time, and informing their communities. Tailor dashboards to specific audiences, giving them the ability to slice the data to get the answers they need. ArcGIS online can be used to develop web based responsive GIS based dashboards in a quick and easy manner. ArcGIS software provides the necessary tools that are appropriate to conduct the mapping. ArcGIS dashboards are easy to understand. They are visual displays that present data in an easy-to-read format. All relevant information can be seen on a single screen, facilitating understanding quickly and easily. ArcGIS Dashboards leverages all the ArcGIS data and takes it further with the ability to bring in data from other sources, including real-time feeds, to give additional context and scope. ArcGIS Online gives the users full control of sharing the dashboards so they can decide who sees them, a specific team, an organization, or in public.

There are many types of dashboards that can be built with ArcGIS Dashboards. From all levels within an organization to the public, anyone can use them. The ArcGIS dashboard types are خطأ! الإشارة المرجعية غير معرّفة.:

1- Strategic dashboards assist executives track Key Performance Indicators (KPIs) and make strategic decisions by evaluating performance based on their organization's goals.



2- Tactical dashboards aid analysts and line-of-business managers analyze historical data and visualize trends to gain deeper understanding.

3- Operational dashboards benefit operations staff understand events, projects, or assets by monitoring their status in real time.

4- Informational dashboards help organizations inform and engage their audiences through community outreach.

Figure 1 above shows an example of COVID-19 Operational Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU).

Figure 2 The Libya's main cities map

IV. COVID-19 PANDEMIC IN LIBYA

As shown in Figure 2 below, Libya is located in the north of Africa between longitude 9^{o} west and 25^{o} east and latitude 18^{o} south and 33^{o} north. It extends from the Mediterranean coast in the north to the Sahara in north with an area of approximately 1.759 million km^{2} where more than 90% of the total land area is desert or semi-desert. It is bounded on the eastern side by Egypt, on the west by Tunisia and Algeria and on the south by Chad, Niger, and Sudan. According to the last Census done by the Bureau of Statistics and Census (BSC) in Libya the total population of Libya is around 7 million people. The population density varies widely from one area to another.

According to the United Nations Human Settlements Programme (UN-Habitat), Libya's urban population is

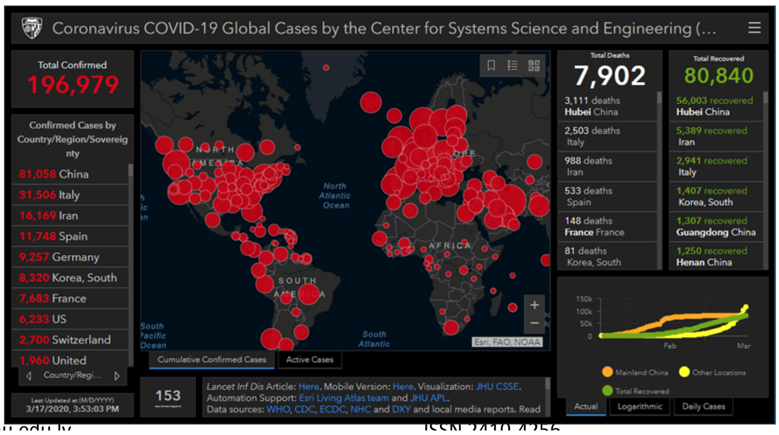


Figure 1. COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)

growing rapidly, urbanization rates in Libya have risen steadily to 79% percent in 2016. Today about 85% of the total population live in urban areas in major cities including Tripoli, Zawayah, Misurata, Benghazi and Bayda. However, the increase in population will result in a number of major challenges in the country including the provision of health care facilities around a wide country. Older adults and people of any age with underlying medical conditions become to be at higher risk for developing severe illness from the pandemic than their younger and less medically compromised counterparts. There are several diseases which make up a substantial proportion of health conditions and contributing causes in deaths involving COVID-19; for example, Cardiovascular conditions, respiratory complications, and diabetes diseases [19]. Figure 2 above shows a map of the main cites of Libya.

With a massive impact, a very rapid spread and had reached more than 20 municipalities and 30 cities in Libya, it was necessary to have a faster information technology tool to perform spatial analysis. Not only for epidemic prevention and control, but also to determine the spatial allocation of health resources and detection of vulnerability areas.

As abovementioned in sections two and three, a large and growing body of literature has emphasized the importance role of GIS tools in the assessment of the scale of the pandemics in general, and COVID-19 pandemic in specific, from a geographical perspective. Because the pandemics have a geographical nature of distribution, GIS can provide a better understanding of the spatial distribution, better manage the COVID-19 infection, and effectively analysis its impacts. In addition, several spatial data related to COVID-19 can be extracted such as the locations of COVID-19 cases, which can be considered as a type of spatial object which has a spatial dimension or attribute data and can be mapped by a GIS tool.

In order to propose a methodology to create a spatial data visualization dashboard to monitor COVID-19 development in any country, this study will create an ESRI ArcGIS dashboard to monitor COVID-19 development in Libya. Next section will present the stages of the methodology and the dashboard.

V. THE PROPOSED METHODOLOGY

Based on the ArcGIS dashboards requirements, this study has proposed a methodology to develop a strategic plane for mapping the COVID-19 pandemic and monitoring COVID-19 cases in Libya to support the Libyan government institutions in controlling its spreads and evolution. The research design involves the following research process steps::

1- Understanding the COVID-19 disease situation
2- Creating the effected cases map.
3- Creating the spread of the COVID-19 map
4- Creating the vulnerable populations areas map
5- Creating the location and capacity of Hospitals map
6- Linking the COVID-19 disease situation with the geographical maps

These process steps are illustrated in Figure 3 below:

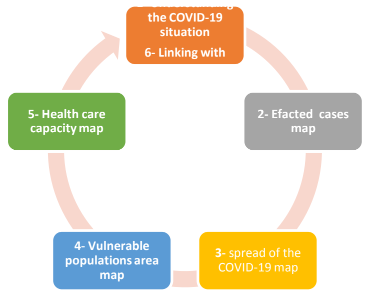


Figure 3 Research Process

A. Tools and Technologies used

In this study, the ArcGIS Pro (v2.8), ArcGIS Online and its Operations Dashboard will be utilized. In addition, the ArcGIS Survey123 tool is manipulated to collect the COVID-19 data which is among the ArcGIS Online tools that can be applied for digital fieldwork. ArcGIS Survey123 tool stands out as a field dedicated application for gathering, analyzing, and reporting data and can be used flexibly on smart devices and computers with or without available internet connection in the field of data collecting. ArcGIS Survey123 tool is developed by ESRI, which can be installed on any smartphone, and available in any online application store, and can communicate directly with ArcGIS online through the internet. This tool is a part of the Esri Geospatial portal and can coordinated with Esri's ArcGIS cloud, making it fully compatible with both ArcGIS Desktop and ArcGIS Online. Furthermore, Survey123 is useful for collecting survey data in various types including texts, numbers, pictures, and locations [20]. Figure 4 below shows an example of data collected by ArcGIS Survey123 tool.

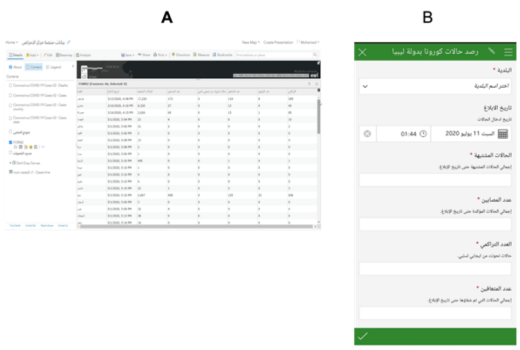


Figure 4 (A) (B) Shows field survey information and data type for generating a survey form and image of the Survey123 application on the smartphone

The World Geodetic System 84 (WGS84) converter tool is used to re-project the spatial layers to be compatible with the international projection system, Global Positioning System (GPS). The WGS84 is standard for GPS to be used as its reference coordinate system. WGS84 converter tool consists of a reference ellipsoid, a standard coordinate system, altitude data, and a geoid [21], [22].

The methods applied in this study are including statistical charts and hotspot analysis embedded in the ArcGIS Pro (v2.8). The next section will provide the phases of the proposed methodology.

B. Methodology Phases:

These phases are synthesized according to the requirements of developing ArcGIS dashboards the aforementioned steps of the research process and depicted in figure ##. These phases are presented below:

Phase 1: Collecting the Base Maps

The first phase reflects the collection of all the necessary base maps that needed to support the system, like national borders and cities' locations. Creating base maps are the essential information for building any GIS or geo-visualization system.

Phase 2: Collecting the Spatial Data

By using the ArcGIS Survey123 tool, the spatial data has been collected and datasets or geodatabases have been managed. The spatial information consists of a series of information that called layers, which can be presented as a table or a user-view. It is the geo-location data of discovered and confirmed cases, quarantined cases, and recovered cases. The output of the ArcGIS Survey123 tool is shapefiles of COVID-19 disease information.

According to the Libyan National Center for Disease Control (LNCDC), the cumulative number Coronavirus Cases in Libya until the 16th of October 2022, 507024 cases, the deaths number is 6437 people, the recovered cases number is 500547 people and the active cases number is only 40 people.

Table 1 , Table 2 and Table 3 below present samples of the collected data of some Libyan cities as an example.

Table 1. A sample numbers of Coronavirus active cases in a sample Libyan's cities on sample dates.

Active	**22/06/2020**	**23/06/2020**	**24/06/2020**	**25/06/2020**	**26/06/2020**	**27/06/2020**	**28/06/2020**	**29/06/2020**	**30/06/2020**
Benghazi	0	1	0	3	1	3	3	0	0
Sabha	8	4	5	5	10	10	23	35	14
Tripoli	9	9	8	10	2	0	4	3	5
Misurata	4	6	6	0	0	0	1	0	1

Table 2. A sample numbers of Coronavirus recovered cases in a sample Libyan's cities on sample dates.

Recovered	**22/06/2020**	**23/06/2020**	**24/06/2020**	**25/06/2020**	**26/06/2020**	**27/06/2020**	**28/06/2020**	**29/06/2020**	**30/06/2020**
Benghazi						0		1	0
Sabha						28	8	1	2
Tripoli	13	16	6	2	2	1	3	2	1
Misurata						0	2	0	0

Table 3. A sample numbers of Coronavirus death cases in sample Libyan's cities on sample dates.

Death	**22/06/2020**	**23/06/2020**	**24/06/2020**	**25/06/2020**	**26/06/2020**	**27/06/2020**	**28/06/2020**	**29/06/2020**	**30/06/2020**
Benghazi									
Sabha	3	3	1	2			2	1	1
Tripoli		1	0						
Misurata			0				1		

Phase 3: Importing the collected Spatial Data to ArcGIS Pro.

By importing the shapefiles datasets to ArcGIS Pro, the spatial layers have been created to develop the COVID-10 dashboard. Each of these layers contains attribute data which is either raw data such as topographic or satellite data or thematic data such as health services, quarantined centers, and other health services.

Phase 4: Linking the collected Spatial Data with international projection system

Re-projecting the layers to the international projection system GPS by using WGS84 tool, this will help in compatibility with field collected data. The layers can be stacked to show the relationship between them. The process of linking the attribute data with the spatial coordinates of the map is known as Geocoding

Phase 5: Building the operational dashboard by using ArcGIS online

ArcGIS online used to build the operational dashboard by building all the base maps and populate them to the web maps that can be part of the final operational dashboard (real time data).

Phase 6: Linking the dashboard to the Libyan National Center for Disease Control (LNCDC)

The developed dashboards are linked to the Libyan National Center for Disease Control (LNCDC) web portal to support decision makers, researchers, and other interested parties.

(up) shows the flow of the proposed methodology phases.

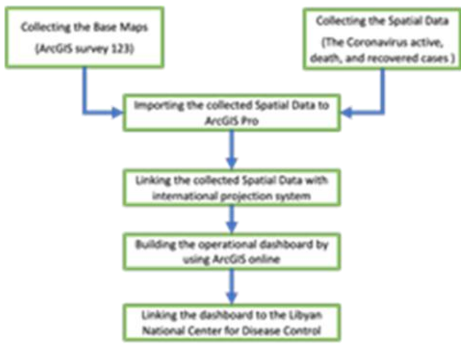


Figure 5 Process of ArcGIS dashboard for COVID-19 monitoring.

VI. THE CHALLENGES OF EMPLOYING THE GIS TOOLS IN LIBYA

There are several challenges and constraints which make the application of a GIS tools in this project is a very time-consuming process. Some Examples of these challenges that we have faced are:

1- Infrastructure constraints:

GIS tools in general and ArcGIS tool in specific require stable power supplies and communication (Internet). In Libya, there is a complicated issues related to power supplies in Libya in addition to that there are several which are not covered by communication and internet. These issues make almost impossible to launch appropriate conditions for data collection in some regions which are too far away from main city centers.

2- Cost constraints, tools and labors:

There are many commercial licensed GIS tools, ArcGIS from ESRI is one of them. Comparing to the free and open-source GIS tools, the commercial licensed GIS tools provide a full support in case those tools face any issue. In fact, the availability of local GIS tools expertise is curial in reducing the cost of supporting and maintaining these tools. However, getting licensed GIS tools in Libya is not easy because of Libya's complex political and financial situation.

Because of the forementioned challenge of the cost and availability of low-cost GIS tools and expertise labors for those tools, there are almost no available skilled labors who can use the GIS tools effectively in collecting pandemic data.

Furthermore, the detailed base maps are not available, therefore, we have to make maps and update them which are costly and time-consuming activity. Usually, this activity requires establishing field surveys to cover the whole area with at least a detailed topographical map. It is important to know the most important information which is influencing decision making in the official organizations.

3- Data Collection and Management challenges

The only official source of information about coronavirus infections, deaths, recoveries in Libya is the LNCDC. This center works on a national level by using its subdivision around Libya. It publishes related information on its website and daily reports on its Facebook page. Referring to previous infrastructure constraints, LNCDC has encountered many challenges to collect coronavirus data in time. In addition, the collected data are not digital nor structured data reports. The released reports at the beginning of the spread of the pandemic in Libya were neither accurate nor detailed, for example:

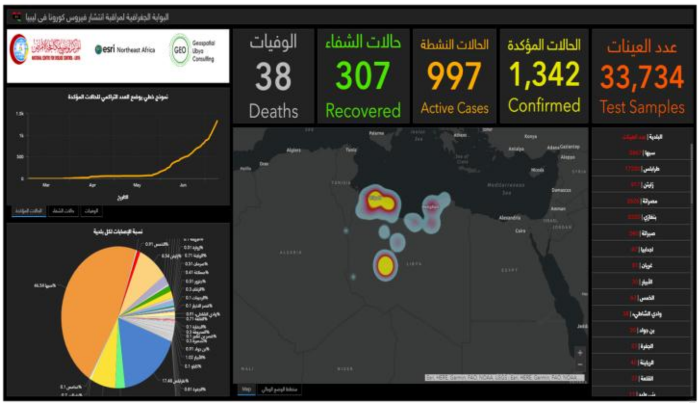


Figure 6 The final form of the geographical portal (GIS Dashboard) to monitor the COVID-19 pandemic in Libya.

- They have not included the estimated evolution size of the epidemic in Libya and its impact in terms of mortality or other information such as the availability and the circumstanc of healthcare facilities around Libya.
- There is a lot of disagreements between the announced reports of the corona virus disease cases between the LNCDC and some branches in Libyan cities in terms of the number of cases and the names of the regions that these cases are belong to.
- There was a huge delay of announcing the infected cases recovery. In some regions, they have never announced the infected cases recovery. In other regions, they announced the infected cases recovery without announcing the infection of those cases.

VII. RESULTS AND DISCUSSION

The study describes the geographical distribution of the COVID-19 in Libya, in order to provide an effective tool in improving data sharing and real-time information to support critical decision-making and can be used as an effective tool for supporting non-pharmaceutical mitigation measures in the fight against the pandemic response. The use of the ArcGIS dashboard tool in the COVID-19 response in Libya significantly guided and supported the active case search team to easily identify areas to be visited by the team in order to promptly detect, test, and isolate cases towards control and eventual containment of the pandemic, thereby reducing the risk of transmission of the virus.

The number of cumulative cases is the daily sum of all confirmed cases from March 25th to June 25th, 2020.

The regional distribution of COVID-19 is quite obvious, with significant spatial agglomeration. The southern region of Sabha had the largest number of cases, followed by the western region in Tripoli and Misrata then the eastern region in Benghazi. In other cities, such as Gharyan, Zlitan, Surman, Nalout, Ghat, and Jufra, the number of cases ranged from 50 to 200.

The collected geospatial information is delivered to GIS to create a dashboard to utilize, quick access, and manipulate that information. The GIS dashboard of the geographic distribution of the cumulative cases of COVID-19 reported in Libya is shown in Figure 6 above.

The advantage of using GIS is that it maps the many different locations of the country and other facilities with humans on a dashboard, which supports better monitoring and surveillance. Also, the ArcGIS dashboard gives detailed information with respect to disease forecasting, outbreak prediction of outbreaks, identification of disease clusters or hotspots, and evaluating different strategies to prevent the spread of infectious diseases.

For example, the geospatial information can be visualized in linear graphs, bars or doughnut graphs, as shown in figures below. Figure 7 depicts the linear curves of the number of the active, recovered and death cases of covid-19 during the time of pandemic. Figure 8 shows the bar chart of the number of the active, recovered, death cases of covid-19 in the Libyan cities during the pandemic. Figure 9 presents a doughnut chart for the total number of cases of covid-19 as distributed in the Libyan cities.

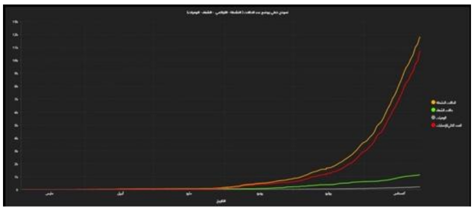


Figure 7 The linear curves of the active, recovered, death cases of covid-19 during the pandemic

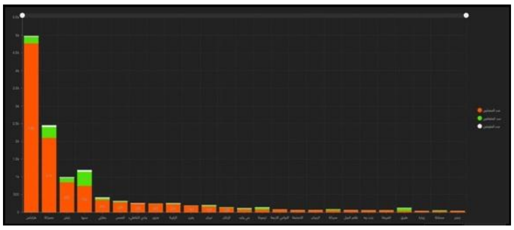
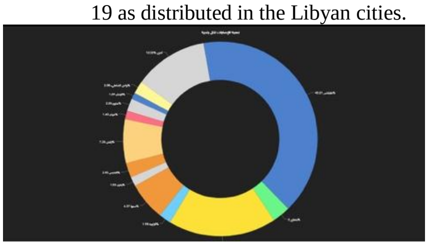


Figure 8 The bar chart of the number of the active, recovered, death cases of covid 19 in the Libyan cities during the pandemic

Figure 9 The doughnut chart presents the total number of cases of covid 19 as distributed in the Libyan cities.



VIII. CONCLUSION AND FURTHER WORKS

This paper presents a GIS dashboard for the Libyan government's health care organizations. The role of this dashboard is assisting the COVID-19 Libyan confrontation team to monitor and track the local COVID-19 pandemic. Through this study, the importance of GIS tools is highlighted in monitoring and controlling the outbreak of epidemic diseases in general. The importance of monitoring and controlling the outbreak of epidemic diseases is stemming from the fact that spread of such diseases is directly related to the nature of the geographical distribution of the population.

Two leading GIS software packages are presented, which are QGIS and ArcGIS. The first is open source, and the second is commercially licensed. Since this work originally emanates from a project implemented for the benefit of a government institution, we chose the second software package to implement the required system because it is commercially licensed, which means that full support is available for it in case of any technical problem.

The ArcGIS dashboard is the typical starting point for the GIS dashboard development using the ArcGIS package. A raw data can be feed to the dashboard to be displayed later in other formats such as charts or interactive maps that are easy to be understood. Users can then take advantage of that information through the following procedures:

- Monitoring for the purpose of understanding events,
- Publishing and media for the purpose of community awareness, and
- Scientific data analysis for the purpose of making strategic decisions.

In addition, a general methodology is produced for developing the ArcGIS dashboard for monitoring COVID-19 cases in Libya to support Libyan government institutions in making appropriate strategic decisions to control the spread of the epidemic. The proposed methodology consists of six phases, starting from maps and other basic-data collection, and ending with connecting the final product (dashboard in this case) to the customer. For each of these phases, the ArcGIS tool has been used to accomplish the task of that particular phase. The purpose of developing this methodology was to form a core for a future project that aims to create an integrated framework for developing any monitoring GIS, such as traffic control, road accident control, agricultural pests, and price control systems.

The authors of this study have reviewed several challenges and obstacles they have encountered during the development of this particular GIS dashboard. They shared this experience because they believe it is beneficial for a researcher in this field to be aware of this list in advance.

The health care services providers are the main source for the required spatial data that will be utilized to create GIS dashboards to monitor and control pandemic spreading over the Libyan local communities. However, unless the Libyan government adopts the GIS frameworks, the authors of this study believe that monitoring and controlling pandemic spreading in Libya will not be attained. Continued efforts are needed to make the health care spatial data more accessible to the department of information and documentation of the Libyan National Center for Disease Control (LNCDC). As a result, the authors of this study recommend two important changes which need to be made to meet the prerequisites of GIS frameworks.

The first recommendation is improving the cooperation and coordination frameworks among health care facilities providers and other governmental institutions. This improvement will aid in producing, maintaining, exchanging, and using spatial information for building and managing Libyan health care spatial data infrastructure systems. For example, the cooperation and coordination between LNCDC and the Libyan Bureau of Statistics and Census (BSC), will assist building databases for the census data and healthcare facilities data that will raise the accuracy of the collected Health Care spatial-temporal data to address the challenges of COVID-19 modelling.

The second recommendation is creating a GIS management office within the department of the documentation and information of LNCDC. This office should be close to municipal authorities to collect, produce, maintain, and exchange spatial information and oversee the progress of deploying GIS dashboard applications for LNCDC. Another responsibility of this office could be developing a GIS infrastructure strategic plan to understand the spatial-temporal dynamics of COVID-19 and the scope of disease outbreak within the whole country.

Further research is required to better understand the roll of spatial data in particular community activities, detecting changes, identifying tendencies, assessing risks, outlining possible outcomes, and preventing losses. Spatial analysis refers to studying entities by examining, assessing, evaluating, and modeling spatial data features such as locations, attributes, and relationships that reveal data's geometric or geographic properties. It uses a variety of computational models, analytical techniques, and algorithmic approaches such as statistical techniques, Machine Learning algorithms and Deep Learning algorithms to assimilate geographic information and define its suitability for a target system.

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