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URBAN TRAFFIC INCIDENT MANAGEMENT, USING NETWORK ANALYSIS TO IMPROVE THE EVACUATION TIME TO HEALTHCARE FACILITIES

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Summary

The city of Biskra is ranked the second city in Algeria with the highest traffic accident rate. There are multiple causes of accidents that derive from the diversity of traffic. In addition, its geographical location as a crossroads between the northeast and the south of Algeria is a major factor. Biskra is also considered a commercial and industrial city that receives daily large flows of travellers and merchandise.

Traffic accidents are a complex problems that is dealt with in several approaches. In this research, from a geographical point of view, we will contribute to improve the trajectory of intervention and evacuation. Therefore, this research paper aims to create a geodatabase including the road network with associated entities to carry out spatiotemporal analyses and evaluate the service area of health facilities in terms of the nearest path.

This paper uses GIS tools for evacuation to the public hospital employing a Network Analyst. This study may serve as a decision-making aid for the local authorities of this city in terms of evacuation and intervention in the event of a road accident. It provides real-time information on the location of the accident and the nearest path along with an estimated time.

The outputs of these analyses can determine a map of accessibility, which allows for training in order to improve the real-time evacuation. As a result, this approach will lead to the reduction of evacuation time by less than 10 minutes, and thus leading to a decrease in the number of fatalities.

Keywords

road accidents • network analysis • health facilities • evacuation time • Biskra

1. Introduction

The city of Biskra, as it is geographically a gateway to the desert, and due to its economic position as an industrial and tourist centre, has become an attractive city for daily flows because it contains a number of fundamental institutions for the region, such as the university, the industrial zone, the activity zone, tourist resorts...etc. Transportation and its systems are an accurate measure and a fitting indicator of the level of the

development and growth of states and peoples [Kadri et al. 2022]. Therefore, decision-makers in the city of Biskra must, on the one hand, work on road safety and minimize the causes of accidents, and on the other hand, improve intervention and evacuation operations.

More than 20,000 vehicles enter the city of Biskra every day, resulting in an increase in the number of accidents to 1759 in 2022, with an average of 4 interventions per day [DPSB 2021]. Most of the accidents occur in the industrial and areas of heavy traffic, as well as on the national roads and on the city's road network, especially during rush hours when there is traffic congestion on the three bridges that connect the eastern side with the rest of the city. The intervention and evacuation process in the event of an accident in the Algerian cities follows the emergency plan, which is designed in a traditional way and takes more time. Therefore, the intervention process is ineffective in many cases.

In this paper, we aim to develop a digital approach and manage geographic information using GIS in order to improve the performance of the emergency plan by examining the spatial distribution of healthcare facilities and identifying the quickest evacuation route for transporting victims to hospitals.

The purpose of applying GIS is to replace traditional maps and plans with modern applications and tools. Consequently, the use of network and spatial analysis to develop interactive maps will allow rapid updating of data and intervention itinerary. Conversely, according to Dubois-Maury and Chaline [1994] risk intervention is important by preventing the background of design of cities and contributing enormously to the modification of the urban area.

2. Study area

Biskra lies in southeastern Algeria and due to its geographical location it serves as an crucial crossroad linking the north and south of the country. The city is located at an intersection of several important roads, including: National Road number 03 (RN03), connecting the north of Algeria with the cities in the desert. Biskra has a dry climate with high temperatures, over +40°C in the summer, with minimal precipitation that does not exceed 250 mm/year.

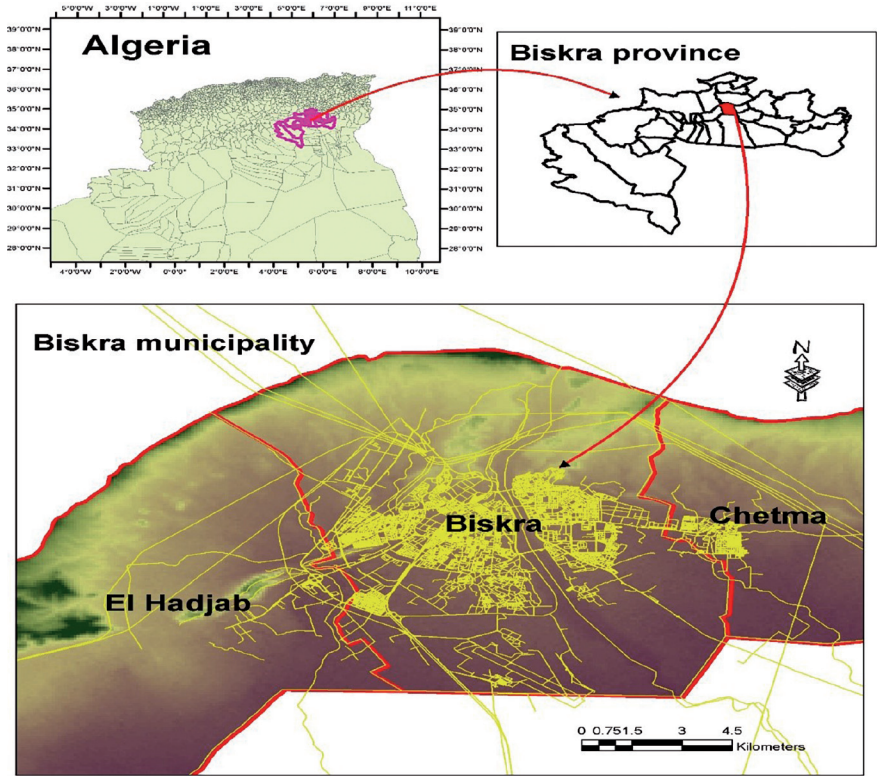
The municipality of Biskra extends over an area of 127.70 km², 400 km south-east of the capital, Algiers, between 5°0'00" east longitude and 34°0'00" north latitude. Its administrative boundaries are limited by the communes of Branis and Djemorah to the north, Chetma and Sidi-Okba to the east, Elhadjeb to the west, and Oumache to the south. The city's population is 244773 (Fig. 1) [Saker et al. 2018].

3. Materials and methods

For the purpose of improving the transportation of patients and traffic accident victims in the city of Biskra, we adopted the following approach:

- Creation of a streets network dataset of Biskra city,

- Analysis of the service area for time intervals of 5 to 25 minutes from the hospital,
- Spatial join between catchment areas and health facilities,
- Statistical summary of healthcare facilities available within 5 to 25 minute radius from the hospital.



Source: Authors own study

Fig. 1. Geography of the study area

In order to assess the spatial arrangement of healthcare facilities in the city of Biskra in relation to the Bachir Ben Nacre Hospital, we will perform a spatial service area analysis covering these facilities. This analysis will be executed with GIS software and its extension GIS Network Analyst.

3.1. GIS and health geography

A Geographical Information System (GIS), especially together with network analysis, offers a number of analyses that can be used in health geography. This research paper utilises these analyses in order to improve the service and reduce the evacuation time to

the hospital by creating a geodatabase, that provides the necessary geographical information in real-time.

Urbanism and regional planning organize the human activities based on distances, surfaces and neighbourhoods. Other information is related to the landscape, objects and their form [Souquière 1994]. GIS supports health geographers with a range of methods (quantitative, qualitative, and spatial analysis) to investigate 'who gets what, where, and why' with respect to both illness and healthcare [Cromley and McLafferty 2011]. Public health is a growing field that is increasingly using GIS [Briney 2014]. Inequality in such factors as income and access to high-quality healthcare determines where healthcare development should be focused, making GIS a crucial element in public health research. GIS provides analytical tools for health geography and epidemiological research wherein geography plays an important role. For example, Higgs [2004] compared different approaches to measuring access to healthcare services, while Apparicio et al. [2008] compared five approaches for conceptualising and measuring the geographical accessibility of services and facilities in residential areas. These studies found that measurements of the geographical accessibility of urban health services might vary depending on the selected distance type and aggregation method. Several methods have been used to assess and quantify geographic accessibility to healthcare facilities, either by measuring the distance from the nearest health facility [Lin et al. 2018, Lu et al. 2018, Nemet and Bailey 2000], or using gravity models. Methods of spatial analysis offer tools to describe and understand the spatial organisation of healthcare, examining the relationship between health outcomes and access to improve healthcare delivery. GIS as a computer-based system supports the integration and analysis of geographically referenced data. It has the ability to process, store and retrieve collected data if necessary, and analyse and display data as maps. This enables the visualization of patterns and generating of new ideas [Cromley 2003].

3.2. Conceptual data model

The reality of an urban area can be represented by a geographical database describing all the objects or phenomena of that area, as well as the relationships between these objects. This model of reality is in fact a schematization of the real world. Moreover, as with maps, the description of objects in databases is closely linked to the scale of representation at which one is working. Every database reflects a specific model of reality. A conceptual data model is a representation of the data necessary for an information system [Lamine 2015]. It highlights the characteristics of entities, their attributes, the associations and the constraints between these entities for a given domain. A formalism includes a set of representation rules allowing the formulation of a model graphically. It includes a number of basic concepts for expressing a model [Gilles 2009]. In this context, we opted for the conceptual entity-association model extended to the main concepts of the object-oriented approach. This formalism also makes it possible to model the spatial-temporal applications. One of its major objectives is to ensure the

orthogonal relationship between the modelling of data structures and modelling of spatiality and temporality, resulting in a model both simple and powerful [Parent et al. 2012]. We applied topological rules to verify the interconnection and non-overlapping nature of spatial data, see diagram (Fig. 2).

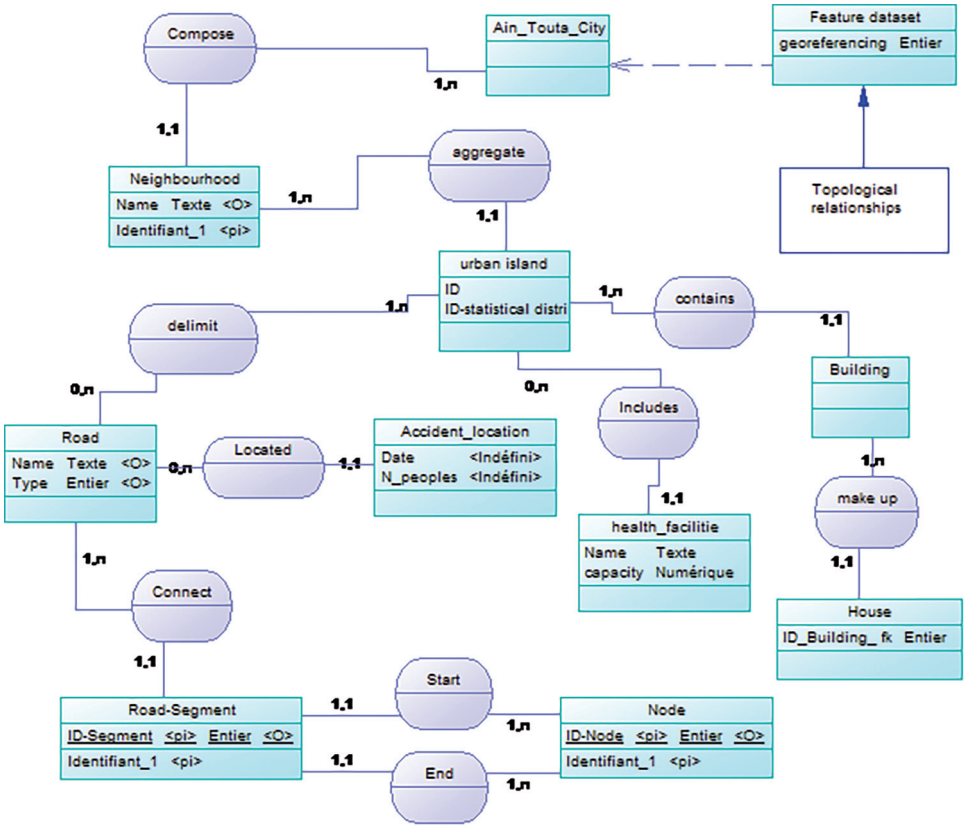


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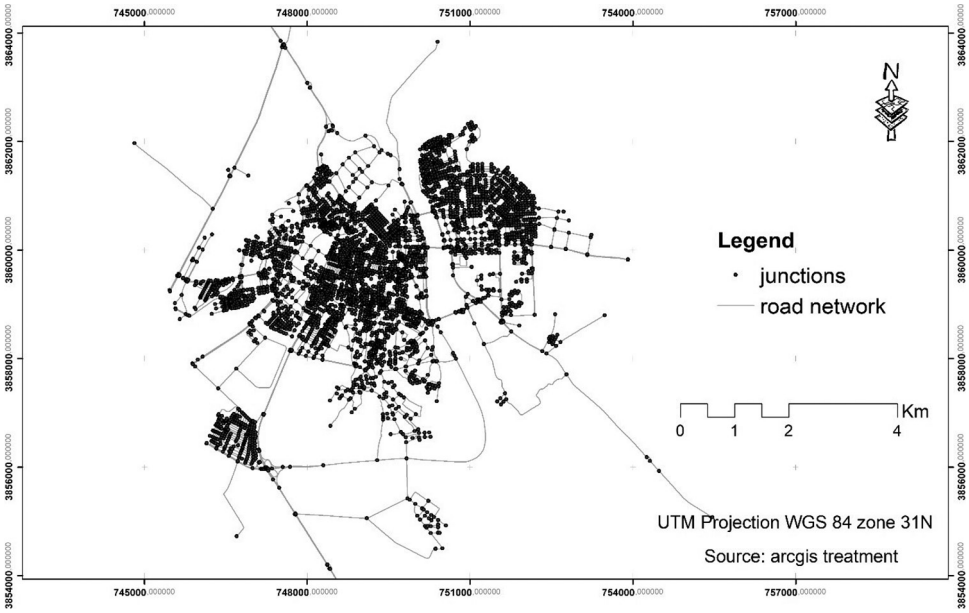
Fig. 2. Conceptual data model

3.3. GIS network analysis extension

The Arc GIS Network Analyst extension allows the analysis of a transport network, based on a polyline layer representing the roads. The fundamental objective of this extension is to find routes from a set of origin points to a set of destination points [Lacroix 2013]. The extension also makes it possible to integrate characteristics of a road network such as one-way roads, roundabouts, and waiting times at traffic lights. In addition, it reduces the computation of both travel distances and related costs such as distance-time (Map 1).



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Map 1. Road Network dataset of Biskra city

3.4. Create network datasets

Network datasets are collections of feature classes that are interconnected. They are formed based on three types of sources:

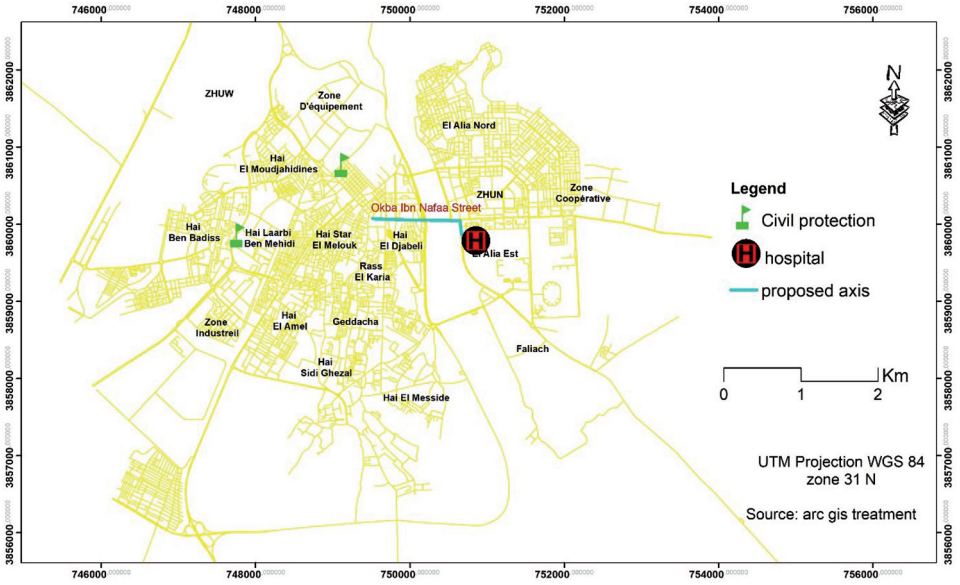
1. 'section' entities (such as street axes),
2. 'junction' features (point feature classes containing track level crossings railways for example),
3. 'turning' entities (which make it possible to model transport).

To measure accessibility and ensure data fluidity in the geographic database of this study, the road network dataset was built by connecting road segments and nodes in both directions, thus linking accident locations with healthcare facilities.

4. Results and discussions

Biskra city is divided into two parts by a natural barrier formed by oued Sidi Zarzour If there is an accident in the northwest and southwest of the city, the evacuation route to the hospital will cross three bridges, taking up to 15 minutes. The lanes selected have a high saturation rate and a high likelihood of accidents. The results obtained indicate the axis of Okba Ibn Nafaa Street as the longest axis, as it consists of two sides. We are going to focus our intervention on both sides of the axis of Okba Ibn Nafaa Street, since

our database indicates that they record the greatest number of accidents and have the highest saturation rate (Map 2).



Source: Authors' own study

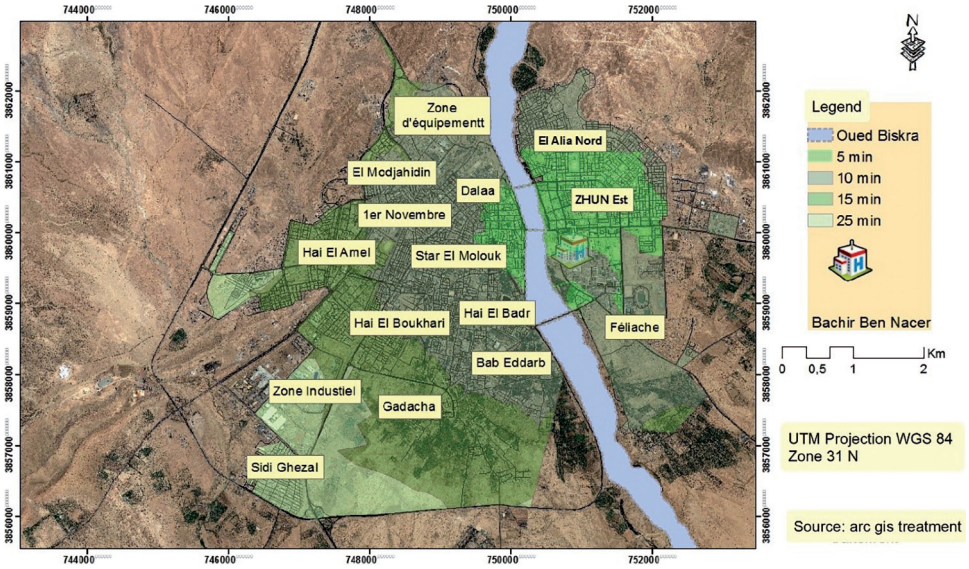
Map 2. The main proposed axis for evacuation

4.1. Service area analysis

A service area is a region that includes all the streets within a defined impedance. In this study, catchment areas ranging from 5 to 25 minutes between Bachir Ben Nacer Hospital and the city of Biskra were generated (average speed: 25 km/h).

4.2. Spatial join

A spatial join involves matching records from the join layer to the target layer based on a spatial relationship, followed by copying over to an output feature class. During processing, when a match is determined, a new record is added to the output feature class, including the shape and attributes of the target layer, as well as the matched attributes of the joined layer. The geometry types of the input layers as well as the chosen matching option define the spatial relationship. In this study, the spatial join allowed the transfer of attributes from the service area class to the healthcare facility feature class (Map 3), based on their spatial relationships (spatial overlap). Thus, it will be possible to specify the accessibility of healthcare facilities in different service areas.



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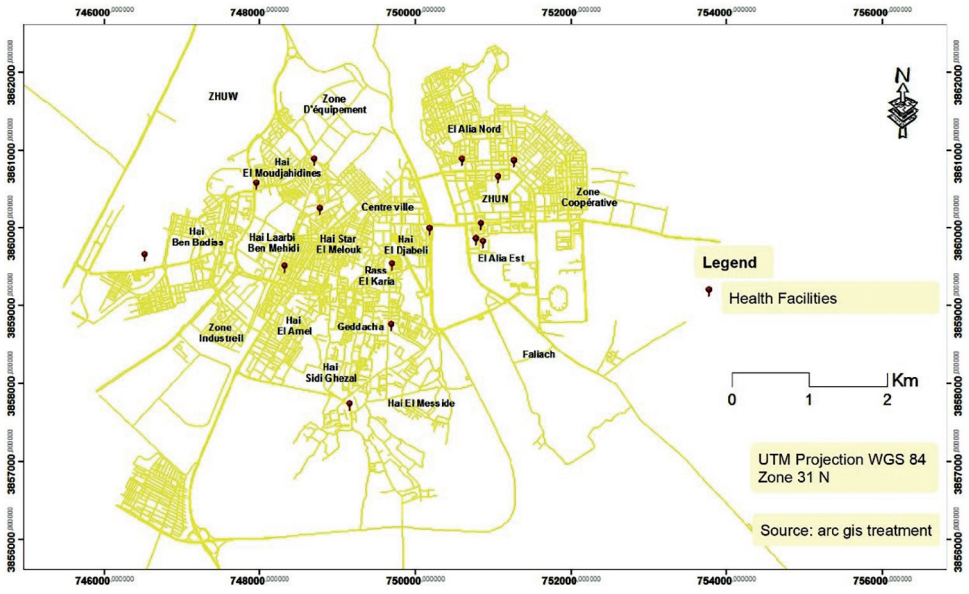
Map 3. Service area of Bachir Ben Nacer Hospital from 5 to 25 min



Source: Authors' own study

Map 4. Healthcare facilities in the city of Biskra

Public healthcare facilities are legal entities with administrative and financial autonomy that are subject to state control. They provide diagnosis, monitoring and treatment for sick, injured or pregnant individuals [Le panorama des establissments de santé 2011].

4.3. Analysis of nearest evacuation routes

This research paper aims to analyze and identify the nearest evacuation routes from various healthcare facilites in Biskra City, considering time distances of 5, 10, and 15 minutes, from which there can be a prompt intervention at the site of the accident. To accomplish this, we propose the creation of dedicated routes for ambulances to follow during the evacuation process. The analysis is conducted using Geographic Information Systems (GIS) with a particular emphasis on two healthcare facilities in Biskra City.

The proposed evacuation routes will be optimized to bypass traffic congestion and other obstructions. This includes factoring in unconventional routes, such as navigating through areas without traffic regulations or even driving counter to usual traffic flow. The findings and proposed routes are presented in Figures 3, 4, and 5.

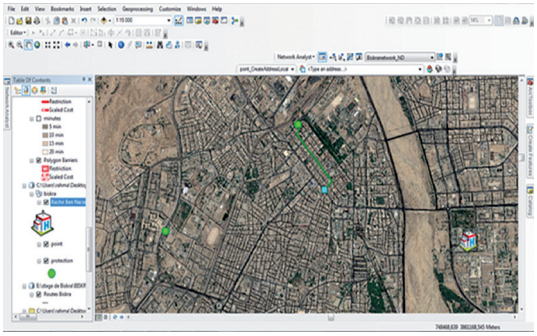


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Fig. 3. The nearest evacuation route (5 minutes) (a)

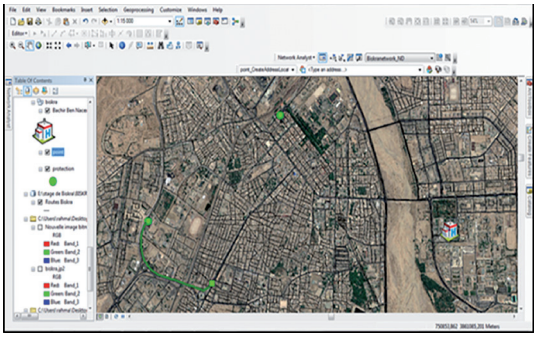

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Fig. 4. The nearest evacuation route (10 minutes) (b)

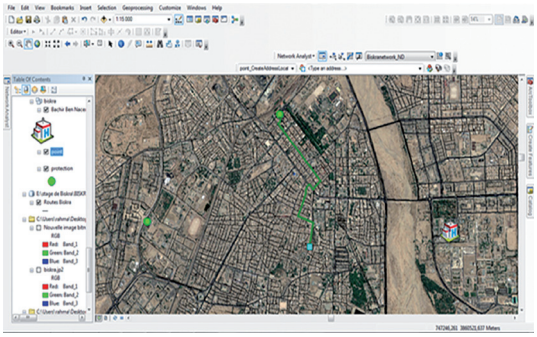

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Fig. 5. The nearest evacuation route (15 minutes) (c)

4.4. Road map generation

- Road Map can be displays in Arc Map after generating a route.
- Road Map displays the direction and the time required, in addition as well as the length of each route.

Based on the findings of the research, we propose an evacuation route to the central hospital taking into account the following factors:

- Bypass traffic lights by driving in the opposite direction to expedite the evacuation process.
- Choose the route nearest to the ambulance leading towards Okba Ibn Nafaa Street to ensure a swift evacuation.

The paths of evacuation operations and the locations of accidents are stored in the geographic database in the form of a new layer (output), which contains spatial and temporal data that can be relied upon for studying road security in the city.

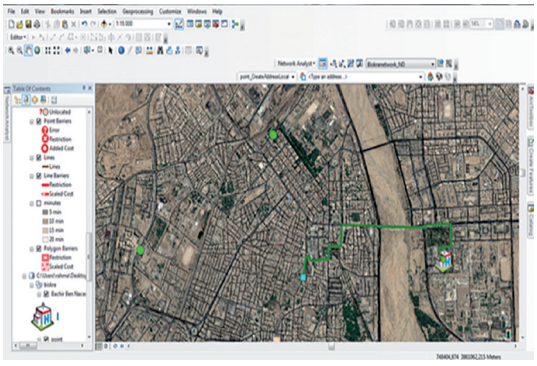

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Fig. 6. The nearest evacuation route (15 minutes) (a)

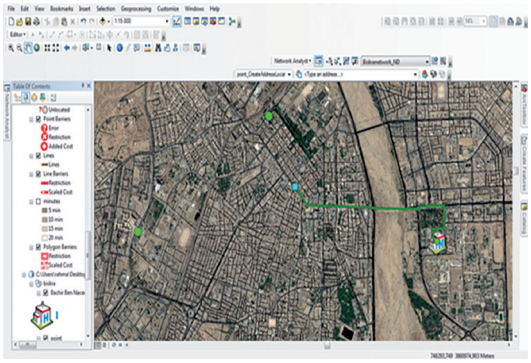

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Fig. 7. The nearest evacuation route (10 minutes) (b)

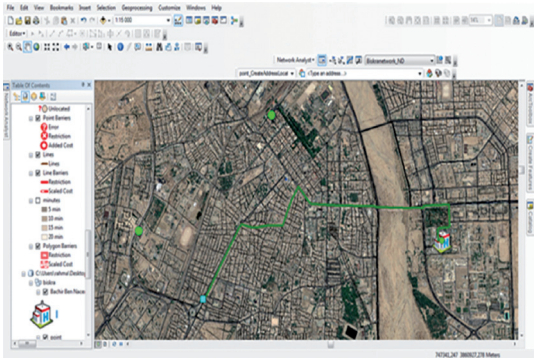

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Fig. 8. The nearest evacuation route (25 minutes) (c)

5. Conclusion

Using geographic information systems in territorial planning, an intervention and evacuation system has been developed to reduce response time and optimize itineraries in the event of accidents. An interactive map displays an accident site along with the nearest route from healthcare facilities to accident sites and then to the central hospital. If the central hospital's capacity is full, the system will provides alternative options by identifying other nearby healthcare facilities.

The data collection on traffic in the city of Biskra offers a comprehensive understanding of the current traffic conditions across various roads. This data forms a basis for creating a traffic dataset within the geographic information system (GIS). The quantity and quality of this geodatabase determines the scope and dependability of possible analyses. The GIS provides efficient and rapid solutions, outpacing traditional plans and maps, presenting a valuable resource for decision-makers in Biskra.

For healthcare transport providers, utilizing geographical information can facilitate the management of patient transfers operations by taking into account such factors as, service areas, traffic conditions, and infrastructure disruptions (i.e. road closures). As a result, the Geographic Information System simplifies the process of improving the routes by considering factors such as the shortest distance and car specifications. Ultimately, the use of GIS as an advanced approach enables local authorities to issue realistic and updated reports and regular evaluations of the urban area, providing a dependable instrument for effective decision-making.

References

Apparicio P., Abdelmajid M., Riva M., Shearmur R. 2008. Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. International Journal of Health Geographics, 7(1), 7. https://doi.org/10. 1186/1476-072X-7-7.

Briney A. 2014. Overview of public health and GIS. GIS Lounge. Retrieved August, 4, 2019. https://www.gis lounge.com/overview-public-health-gis/.

Cromley E.K. 2003. GIS and Disease. Annual Review of Public Health, 24, 7.

Cromley E.K., McLafferty S.L. 2011. GIS and public health (2nd ed.). Guilford Press, New York.

Dubois-Maury J., Chaline C. 1994. The city and its dangers: prevention and management of natural, social and technological risks. Edition Masson. Paris.

Gilles R. 2009. Conception de bases de données avec UML. Édition Presses de l'Université du Québec.

Higgs G. 2004. A literature review of the use of GIS-based measures of access to health care services. Health Services and Outcomes Research Methodology, 5(2), 119–139. https://doi.org/10.1007/s10742-005-4304-7.

Kadri D., Kkhalfallah B. 2022. Impact of urban expansion on urban transport in the city, study case: city of Bordj Bou Arreridj, Algeria. Analele Universităţii din Oradea, Seria Geografie, 32(1), 6–10. https://doi.org/10.30892/auog.321106-877.

Lacroix P. 2013. Contributions of GIS to Efficient Mine Action. Thèse de doctorat, Université de Genève.

Lamine B.M., Mahdi K. 2015. La mobilité motorisée dans la ville de Batna, étude de la répartition spatiale des établissements de santé vis-à-vis du CHU, BSGLg, 64, 83–92.

Le panorama des établissements de santé. 2011. Paris Nadine Gautier (eds.).

Lin Y., Wimberly M.C., Da Rosa P., Hoover J., Athas W.F. 2018. Geographic access to radiation therapy facilities and disparities of early-stage breast cancer treatment. Geospatial Health. https://doi.org/10.4081/gh. 2018.622.

Lu H., Zhang X., Holt J.B., Kanny D., Croft J.B. 2018. Quantifying spatial accessibility in public health practice and research: An application to on-premise alcohol outlets, United States, 2013. International Journal of Health Geographics, 17(1), 23. https://doi.org/10.1186/s12942- 018-0143-y.

Monographie of Direction Planning and Budget Follow-up, Biskra Province. 2021.

Nemet G.F., Bailey A.J. 2000. Distance and health care utilization among the rural elderly. Social Science and Medicine, 50(9), 1197–1208. https://doi.org/10.1016/ s0277-9536(99)00365-2.

Parent C., Spaccapietra S., Zimányi E., Donini P., Plazanet C., Vangenot C., Rognon N., Crausaz P.A. 2012. MADS, modèle conceptuel spatio-temporel. Dantoada, p1.

Saker A., Hadda D., Mahdi K. 2018. Geomatics approach for urban extension management caught between planning tools and reality on the ground. Case of the district of Biskra (Algeria). Analele Universităţii din Oradea, Seria Geografie. Article no. 282102-771.

Souquière P. 1994. La carte électronique: Définitions et principes. Bulletin du comité Français de Cartographie, 139, 47–60.

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