Identification and analysis of spatial access disparities related to primary healthcare in Batna City, Algeria

Ahmed Akakba, Belkacem Lahmar

University of Batna 2, Institute of Earth and Universe Science, Department of Geography and spatial planning, Batna

Abstract

The issue of spatial disparities, such as accessibility to healthcare, is considered a crucial focus in planning and public service and one of the most pressing concerns for policymakers and planners in Batna City, Algeria. The territory suffers from uncontrolled urban dynamics, structural urban policy problems and environmental issues. This research paper used the two-step floating catchment area (2SFCA) method to measure the potential spatial healthcare accessibility of people living within Batna City by applying three threshold travel distances of the catchment area. Functional accessibility was measured based on the facility-to-population ratio, which provides a good overview of the level of the city's accessibility quality. The data used in this paper were gathered from official census district reports and the local health department. These data were converted and re-optimized to be compatible with the geographical information systems (GIS) approach applied. We found that the optimal threshold distance that offers balanced results between the spatial accessibility score and other ratios recommended by the World Health Organization (WHO) was between 1,000 and 1,500 meters. The central census districts were found to have a higher access score than the rest of the city; most census districts that do not have accessibility (12% of the population) to healthcare facilities are concentrated in the south-western part of Batna City.

Correspondence: Belkacem Lahmar, University of Batna 2, Institute of Earth and Universe Science, Department of Geography and spatial planning, Batna, Algeria. E-mail: b.lahmar@univ-batna2.dz

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Introduction

Despite the decentralization of the National Health System (NHS) and the dualism of public and private healthcare (Oufriha, 2006a), the Algerian health system still comprises several structural problems, such as random health facility distribution compared to the population distribution, financial problems and the difficulty in adapting to rapidly spreading and contagious diseases, such as the recent pandemic challenge (Bouyoucef Barr, 2013, 2015; Chachoua, 2014).

In order to fit the requirements of the local issues and perform better strategies and reactions against diseases, it is necessary to make healthcare facilities accessible to all. This can be done by optimizing the spatial distribution of new healthcare facilities based on the "proximity of public service" principle as defined by Evans *et al.* (2013) and used by Universal Access (2023) and the World Health Organization (WHO) (2013, 2023) for estimating physical accessibility. Indeed, ensuring equal access to healthcare and provision of human resources (physicians, nurses and related medical staff) is considered one of the primary Sustainable Development Goals (SDGs) of the United Nations (UN) (Griggs *et al.*, 2013; UN, 2015; United Nations Development Programme, UNDP, 2015).

Several local studies on the Algeria healthcare system's organization, quality and efficiency affirm that citizens are not satisfied with the NHS (Benachenhou *et al.*, 2011; Bensafi & El Houari, 2017), but the policymakers argue that NHS has significant investments (Fouad, 2006a, 2006b; Oufriha, 1993; Oufriha, 2006a, 2006b). However, one of the most important emerging topics (*i.e.* accessibility) has not been discussed in depth by researchers and academics in Algeria. Healthcare accessibility can be defined as the level of ease and comfort of personal reach of a facility from people's residences. It may refer to spatial or physical accessibility affected by factors, such as geographical location and travel distance as well as non-spatial parameters, e.g., socioeconomic status, health status, financial status, perception of health, etc. (Evans *et al.*, 2013; Jonsson *et al.*, 2018; Swaminathan *et al.*, 2018; Nemet & Bailey, 2000). Furthermore, access to healthcare is considered to be of crucial importance for the health of a population (Kanuganti *et al.*, 2016). In this context, the two most significant factors influencing access to healthcare in Algeria are spatial supply and demand (Luo & Wang, 2003; Luo, 2004; Aissaoui, 2016a). In addition, several studies confirm that non-spatial determinant factors should also be included when assessing healthcare quality (Bouledroua, 2010; Aissaoui, 2016a, 2016b).

Information on concepts, methods and challenges related to the measurement of accessibility are discussed in depth by Guagliardo (2004), Higgs (2004), Yang *et al.* (2006), Apparicio *et al.* (2008) and Askari *et al.* (2016), especially with respect to healthcare where several factors inevitably affect access, such as: i) Spatial factors, *e.g.*, supply and demand locations, transport cost, distance or travel time; ii) Non-spatial factors, *e.g.*, socioeconomic variables of population, educational attainment and cultural factors; and iii) Transportation quality, *e.g.*, accessibility to healthcare by public transport, including the number of transit stops as mentioned by Sharma and Patil (2021). In this connection, they also discuss the impact of the social vulnerability index (SVI) and indicators included when using principal component analysis (PCA).

Accessibility and proximity are the principal keys to providing good public service; therefore a healthcare system that meets the requirements of availability and affordability would be useless without spatial accessibility provided equally to all. The most frequently used acceptability technique is the two-step floating catchment area (2SFCA) (Shah *et al.*, 2016; Lin *et al.*, 2018; Naylor *et al.*, 2019; Khashoggi & Murad, 2021), which represents a multimodal relative spatial access assessment approach. It was subsequently developed into an appropriate method for measuring spatial accessibility, considering supply and demand jointly (Luo & Wang, 2003; Luo & Qi, 2009, 2009; Luo *et al.*, 2018). The main advantage of this method is that it offers measurement of accessibility at both spatial and functional levels. The spatial level considers the threshold distances between the health demand and the location of healthcare facilities, whereas the functional level relies on ratios. Regarding our aim to measure the spatial accessibility in Batna City, the main questions were: i) What is the best method to measure accessibility spatially and functionally? ii) What are the factors affecting healthcare accessibility in Batna City? iii) What districts are less-served (due to low accessibility? iv) What districts are the most accessible ones? v) Is it possible to reduce spatial inequality?

These questions can be answered through the following hypothesis: firstly, the most accessible district is the central one because, historically, all facilities and public services are located in the centre of the city, with planned and structured districts added later. Secondly, the factors that affect accessibility in Batna City are the location of the facilities centres and the spatial distribution of the population. Methodologically, the method fits our aims because it is possible not only to measure the spatial inequality in access to public healthcare facilities in Batna City, but also the functional deficit of the local healthcare system based on the population-to-health facility ratio (PTR). Importantly, our study did not include public transport or any vehicle transport.

Materials and Methods

Study area

Batna City, located in the eastern region of Algeria (Figure 1), has experienced uncontrolled urban growths since its foundation in 1844 (Chibani, 2015). Spatially, the urban sprawl exceeds its administrative boundaries; however, this study realized within the urban space, excludes the metropolitan part and the new urban extensions due to unreliable data regarding demographic census and health data. From a demographical aspect, the city counted 301,708 inhabitants in 2012; by the end of 2023, the estimated 400,000 inhabitants (Direction de la Programmation et du Suivi Budgétaire, 2017) were divided into 315 small units representing census districts. However, the distribution of the population within the study area is heterogeneous. Two patterns can be recognized: i) A high-density zone with collective housing planned by the local authority to solve the housing problems. The directional distribution (1st standard deviation) confirms that the central census districts have a high population density (the longitude and latitude of the central district are 6.172874 E and 35.54369 N, respectively). ii) A low-density zone (less than 951 inhabitants per census district) represents new urban extensions of individual houses with inadequate infrastructure and poor public facilities, which result in a functional imbalance in public services, including the quality of healthcare service.

The city is situated in a high-temperature zone (+39°C in summer), with moderate precipitation and a low slope (3%-5%), which increases the vulnerability of epidemic transmitted diseases. In addition to the recent COVID-19 pandemic, Bendib *et al.* (2016) and Issam & Said (2017) indicate that 48.9% of the total area of Batna is highly vulnerable to *Leishmania* spp. The NHS healthcare strategy since 2007 relies on ensuring primary healthcare, focusing on optimizing public service coverage, promoting accessibility and reclassifying the healthcare facilities into four categories

Table 1. Summary of data collected.

Dataset	Data type	Description	Data format
Population	Spatial Attribute	Census district boundaries Census data at the level of census districts: numbers of population extract from official census data	Polygon Excel table
Healthcare facilities	Spatial Attribute	Healthcare centre locations Name and location address, available resources, served population and covered census district (after executing 2SFCA analysis) etc.	Point Excel table
Road network (based on OpenStreetMap)	Spatial Attribute	Road centre line Road identification, name, type, length	Line Excel table

(Direction de Santé et de Population Wilaya de Batna, 2017): specialized healthcare centres as a regional scale service, hospitals that serve the population within a city; and two sub-types of primary healthcare categories, i.e. treatment rooms and multi-service clinics. The city of Batna has a total of thirteen proximity healthcare facilities divided into two categories (Figure 1): i) Treatment rooms: represent the lowest level in the NHS, offer essential services (*e.g.,* vaccination, health examination, and maternal and child care), limited to a few physicians, and their availability is limited to 8 hours per day; it is for small areas geographically and serves a low number of populations. ii) Multi-service clinic: represent the 2nd level; it offers some advanced services with more physicians and extra resources like dentists and biological analyst compared to the treatment room. Availability of services is 12 hours per day and, in some cases 24/24 hours.

In this research paper, we cover primary health care only (multi-service clinics and treatment rooms) because in practice, both categories perform the same tasks and the same role in providing healthcare to citizens and demands (regardless of the available resources); in addition, its unable to differentiate and distinguish between actual service area (neighbourhood, urban sector) of treatment rooms and multi-service clinics.

Requirements, collection and data preparation

The 2SFCA method was executed by GIS technology using ArcGIS (ESRI, Redlands, CA, USA) to calculate spatial accessibility scores by considering the catchment area based on the threshold distance or related spatial factors. To achieve the purpose of this study, we used the following data (Table 1): i) Healthcare facilities locations; ii) Population census districts; and iii) The road network.

The data gathered from various sources, including those only available in paper format, were entered into the GIS through digitization. Census districts and related data were collected from Batna's general census of population and housing report and represented as a polygon layer within the GIS software. Addresses of the healthcare facilities in Batna City were identified through Google Maps and in the field using a global positioning (GPS) instrument. Those data were later geo-coded and represented as points. The data on related healthcare facilities was collected from the local (Batna Province) health department as an Excel table. The road network and related attribute data were downloaded from OpenStreetMap.

Network analysis of distance

Table 2 highlights the threshold distances and their corresponding walking travel time in minutes.

The potential service area was determined using the ArcMap GIS network analyst subroutine as this deals with routing and transport issues by providing the accurate location to detect the closest facility to the demand (Comber *et al.*, 2011). Assuming that

Table 2. Threshold distances and their corresponding walking travel times.

Travel distance (meter)	Equivalent travel time (minute)
600	7-10
1,000	12-15
1,500	20-30

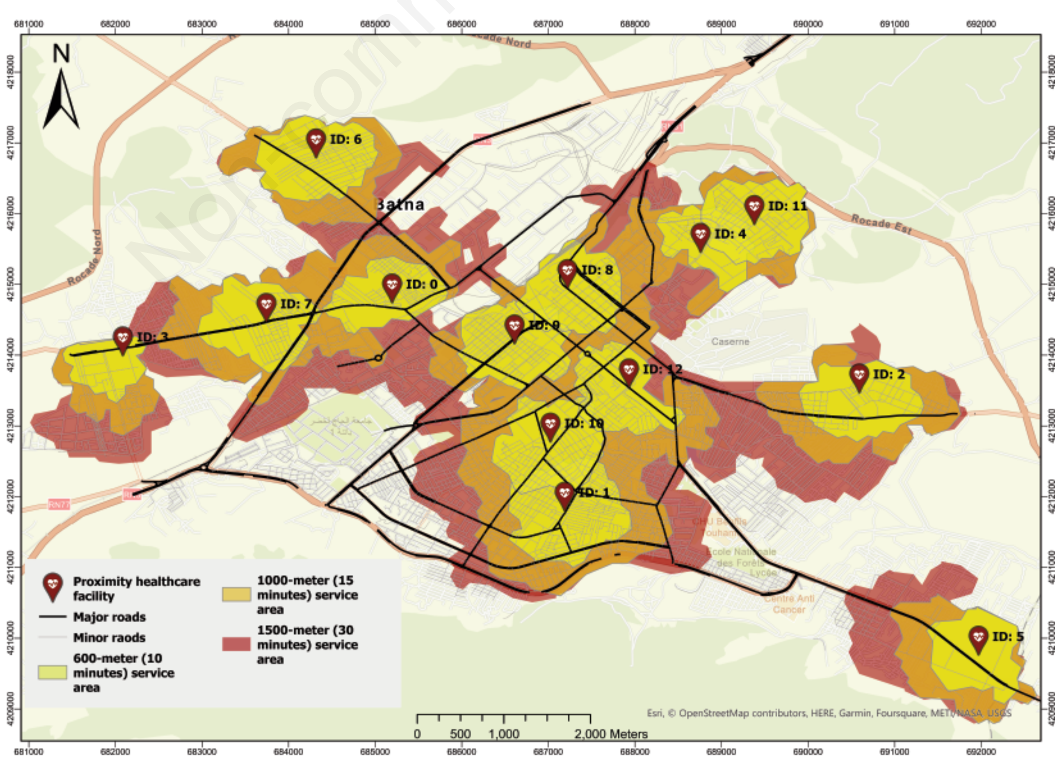


Figure 1. Service areas based on travel threshold distances.

every facility serves the residents only and that the population prefers to access the nearest facility, the service area of each facility was made up of the residents living closer to that facility than any other (Figure 2).

The 2SFCA method

The service area, or influence area, is determined based on the threshold distance that a health centre can serve. The quality of service provided by a health centre depends on the infrastructure available and the quality of physicians and their availability. The 2SFCA catches the area twice as it concerns both population demand and the health care supply. We calculated the proportion of the population served by each health centre within the service area following Luo and Qi (2009). Step 1 gives the health centre to the population ratio (R_j):

$$R_j = \frac{HC_J}{\sum_{\{k\in(d_{jk}\leq d0)\}} Pk} \quad \text{(Eq.1)}$$

where *HC* represents the health centre; *j* its location; HC_j; the number of facilities at location *j* (the supply capacity); *P* the population habitation; *k* their locations; d_0 the travel threshold (service area catchment); d_{jk} the travel distance between *k* and *j*; d_{ij} the travel distance between *i* and *j*; P_k the population at location *k* whose centroid falls within the catchment; and R_j the health care to population ratio within the catchment area in question.

Step 2 gives the accessibility index of the population (A^F_i) at a given location *i* to health care:

$$A_i^F = \sum_{\{j\in(dij\leq d0)\}} R_j \quad \text{(Eq.2)}$$

This means that we first searched for all the population habitations within the threshold travel distance from a given health centre and in the same way sought all possible closest facilities for the population within the travel distance within its catchment area as explained in detail in Figure 3.

Spatial autocorrelation statistics for accessibility

Moran's *I* is a well-known statistical analysis of spatial autocorrelation, which is produced based on both feature locations and feature values simultaneously. It evaluates whether the pattern expressed is clustered, dispersed or random.

Results

The results of measuring spatial accessibility are shown in Figure 4 based on the accessibility index score and the population-to-facility ratio at the three different distance levels investigated.

Spatial accessibility ranks

The 600-meter level

The results of measuring accessibility at this threshold covered 45.4% of the total surface area of the city (census district), which directly reflects an unbalanced outcome, with 59.0% of the total served population (*i.e.* 176,234 inhabitants) classified as underserved. Additionally, 38.4% of the population (*i.e.* 114,843 inhabitants) within 134 census districts could only access one healthcare facility, with an accessibility score of 0.98073. In comparison, 2.7% of the population (*i.e.* 7,925 inhabitants) within only nine census districts could access two healthcare centres, with an accessibility score of 2.56556 (Table 3). However, no significant spatial

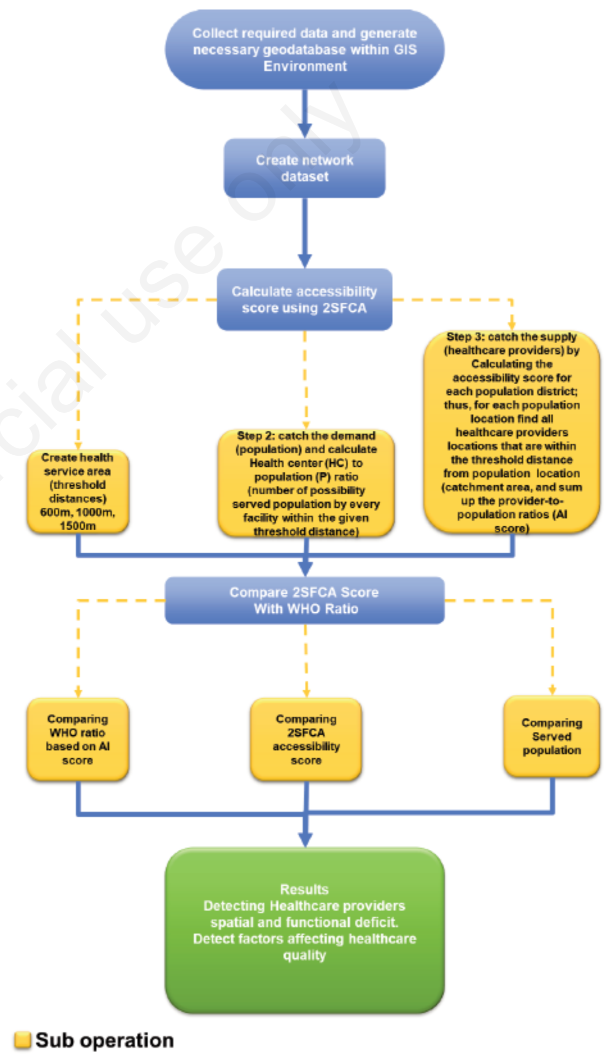


Figure 2. The 2SFCA processing workflow.

Table 3. Data for the 600-meter threshold distance.

Close facilities (no.)	Frequency (no. of districts)	Population (no.)	Population (%)	Facility ratio (per person)	Accessibility score
0	172	176,234	59.0	0	0
1	134	114,843	38.4	0.0871	0.98073
2	9	7,925	2.7	2.5237	2.56556

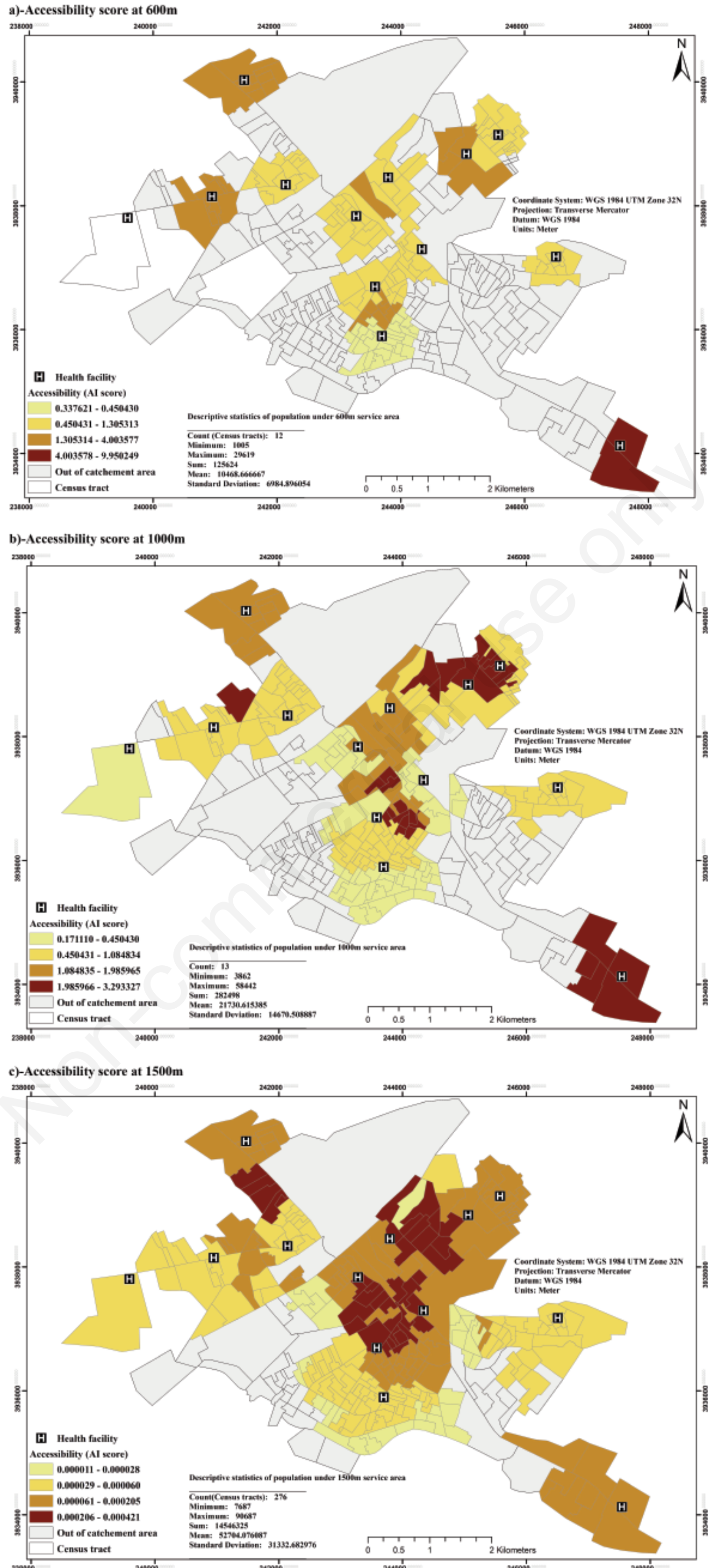


Figure 3. The calculated spatial accessibility score of primary healthcare facilities.

result was confirmed (Figure 4a). Thus, all healthcare facilities cover a low number of populations compared to the Algerian theoretical guide of public service and facilities (Figures 1 and 5), while the ID 12 health centre is currently out of service and inaccessible. Statistically, 41.1% of the population finds itself above the average of 0.95118. Since it can be assumed that most of the population can travel 600 meters to achieve the requested healthcare service, this level does not present a real impediment.

The 1,000-meter level

The results of this threshold covered 69.2% of the census districts (Table 4), representing 62.2% of the population (*i.e.* 186,772 inhabitants). In the same context, 41.3% of the population was found to have accessibility to one health facility (*i.e.* 123,765 inhabitants) with an accessibility score of 0.61995, and 19.4% (*i.e.* 58,197 inhabitants) to have accessibility to two healthcare facilities with an accessibility score of 1.35544. In comparison, 1.6% of the population (*i.e.* 4,810 inhabitants) within twelve census districts could access three healthcare facilities with an accessibility score of 2.5. At a 1000-meter threshold distance, the total served population increased to 62.2% compared to the 600-meter threshold distance. This means that 37.7% of the population is uncovered from the spatial point of view. Concentrated in the Southwest of Batna City, this part of the population has no healthcare accessibility, so the accessibility score is 0 (Figure 4b). In comparison, 60.9% of the population can access one healthcare facility in the Northeast and the city centre with an accessibility score of 0.9845, compared to the average of 0.9512.

The accessibility score reflects the reality that the city's centre is more accessible to health services (actually, the Algerian cities centres are always more accessible). The 1,000-meter threshold distance is balanced between the travel distance and the served population. Thus, the 1000-meter service area represents an acceptable distance as most of the population can travel and find the supply (healthcare) within this distance. As a result, 65.1% of the total census tracts has at least one health centre within a 1000-meter distance and in the same context, we found that people in 13 census tracts can access three health centres within the same distance (Figure 6). The 2SFCA histogram and distribution are explained in Figure 7. The service area of 1,000 meters is acceptable since most of the population can travel this distance (12-15 minutes) to achieve the requested healthcare. It deserves to be

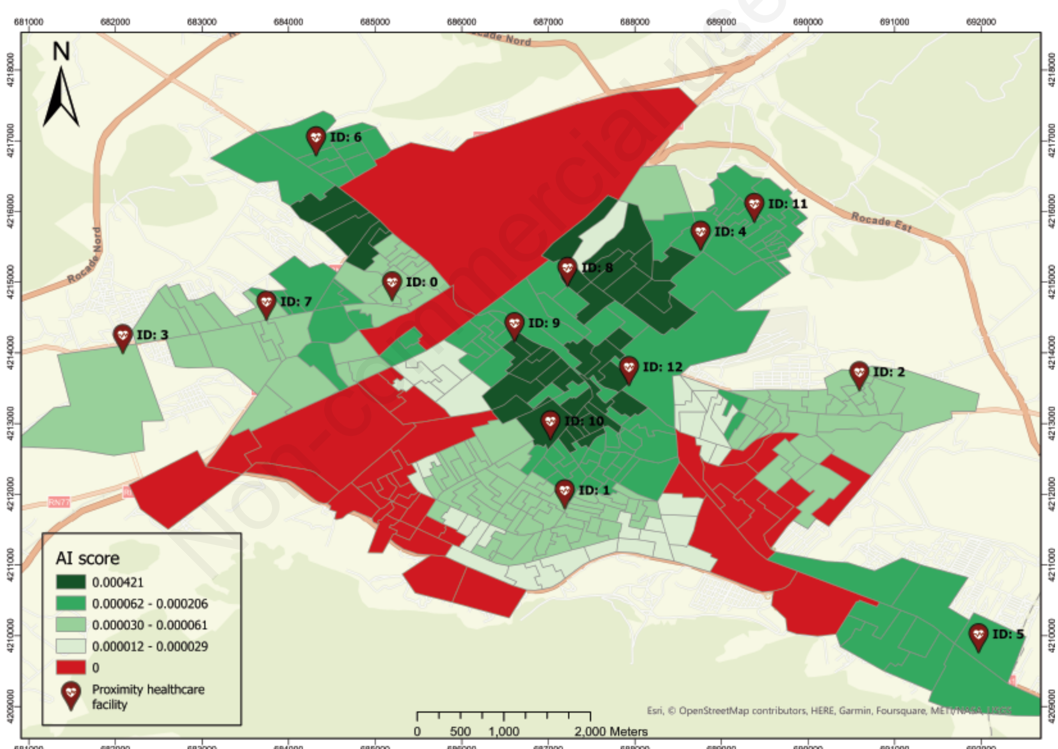


Figure 4. The accessibility score in Batna City based on the 2SFCA method.

Table 4. Data for the 1,000-meter threshold distance.

Close facilities (no.)	Frequency (no. of districts)	Population (no.)	Population (%)	Facility ratio (per person)	Accessibility score
0	98	112,926	37.7	0.0000	0
1	138	123,765	41.3	0.0808	0.61995
2	67	58,197	19.4	0.3437	1.35544
3	12	4,810	1.6	6.2370	2.50306

emphasized that the accessibility score of 62.2% of the population is above the average of 0.9512 in addition to the acceptable population/facility ratio.

The 1,500-meter level

This service area was large, covering 87.6% of the total census districts and 88.2% of the total number of inhabitants. The total underserved population decreased to 12.0% because of increasing travel time. However, the accessibility score (Table 5) is below the average (compared to other distance thresholds) due to the limited number of healthcare facilities. Now, 71.0% of the population can access more than one healthcare facility, reflecting the population-to-facility ratio. However, from the spatial point of view, 12.0% of the population was found to be uncovered. Concentrated in south-western Batna City (Figure 4c), the people in this area do not have any healthcare accessibility, so the score is 0.

In comparison, 55.2% of the population could access at least one healthcare facility in the Northeast and the central census districts with an score of 0.6553. This result is significant and confirms the results seen in the 1,000-meter analysis section. Thus, the population within the central and northern parts of Batna City has better access compared to those living in the south-western and southern areas. The 2SFCA histogram and distribution are explained in Figure 8.

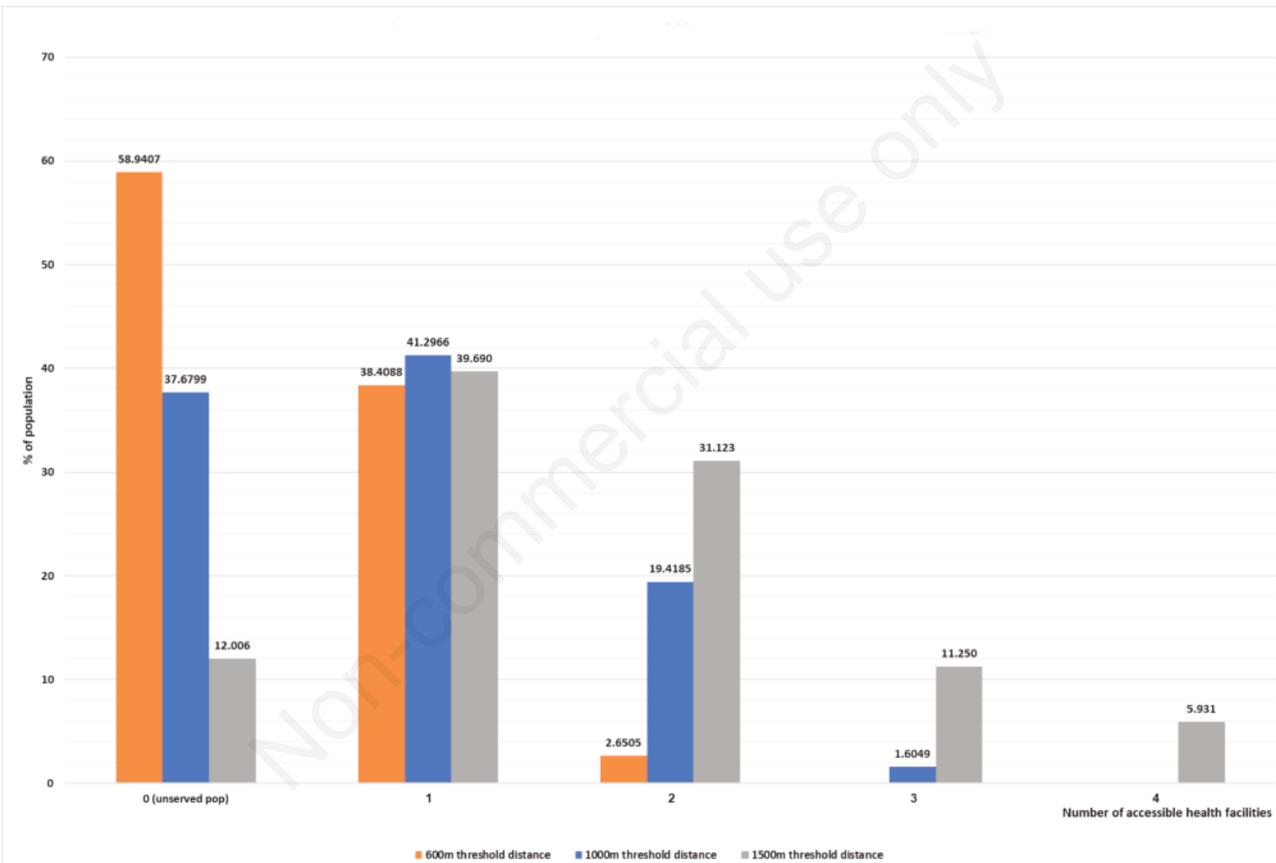


Figure 5. Access to healthcare facilities for the different distances by percentage of the population.

Table 5. Data for the 1,500-meter threshold distance.

Close facilities (no.)	Frequency (no. of districts)	Population (no.)	Population (%)	Facility ratio (per person)	Accessibility score
0	39	35,985	12.006	0.0000	0
1	107	118,962	39.690	0.0841	0.51085
2	101	93,282	31.123	0.2144	0.67069
3	45	33,720	11.250	0.8897	1.16267
4	23	17,776	5.931	2.2502	1.37759

Population to facility ratio

The ratios were compared with the Algerian theoretical guide of public service and facilities (10,000 – 12,000 inhabitants for treatment room, and 30,000-40,000 inhabitants per multi-service clinic). It is worth mentioning that the number of populations served by each centre is a sub-result (Figure 9). Naturally, the greater the threshold distance, the greater the number of demands by default taking into account the existence of more than one available health centre (Figure 6). As a general result, we can confirm that due to the spatial distribution of the population, some healthcare facilities did not reach the maximum capacity (*i.e.* those with less than 10000 – 12000 inhabitants for the treatment rooms and those in the 30,000-40,000-inhabitant group per multi-service clinic); in contrast, other facilities were found to be suffering from overload. Statistically, the spatial autocorrelation of the accessibility score based on Moran's *I* was found to be 0.52, Z-score 20.95 and p=0 (Figure 10).

Discussion

Providing equal spatial access to healthcare has become crucial, especially with the population's demands growth; in other words, a healthcare system that meets the requirements of availability and affordability will be useless if the spatial accessibility to healthcare is not provided to all equally. Hence, this study sought to identify and analyze spatial disparities in access to healthcare facilities in Batna City using the 2SFCA method.

The analysis presented here indicates remarkable disparities in the spatial accessibility to healthcare centres within Batna City. While health services cover the central and northern districts, the peripheral districts are less well served. Naturally, the difference in the number of healthcare centres available within the catchments and the spatial distribution of the population contributed to creating disparities in access to the facilities. Our study confirms the previous report by Lahmar *et al.* (2021) that most of the population (about 70%) can access at least one healthcare facility within 30 minutes, while citizens who live in southern and south-western Batna travel might have to travel as far as 1,700 m to reach the closest health facility. On the other hand, from a functional viewpoint, the previous study found that the suburban areas offer a bet-

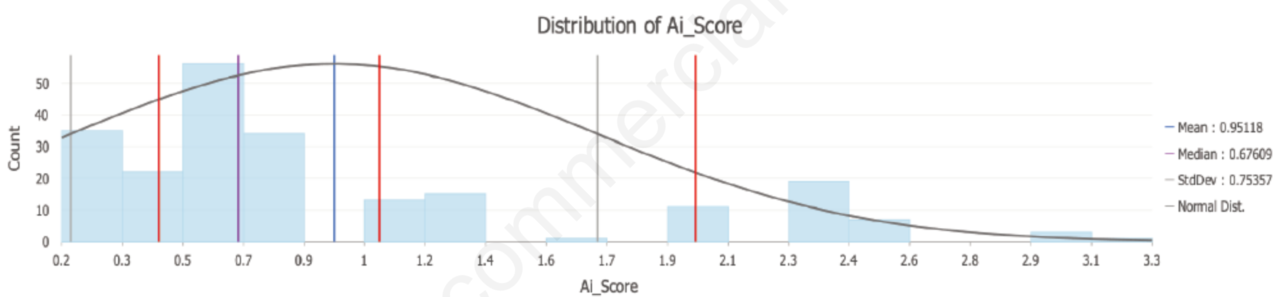


Figure 6. The 1,000-meter accessibility score histogram based on 2SFCA. Districts with a score of 0 were excluded from the results. The *vertical*, red lines are the classification breaks.

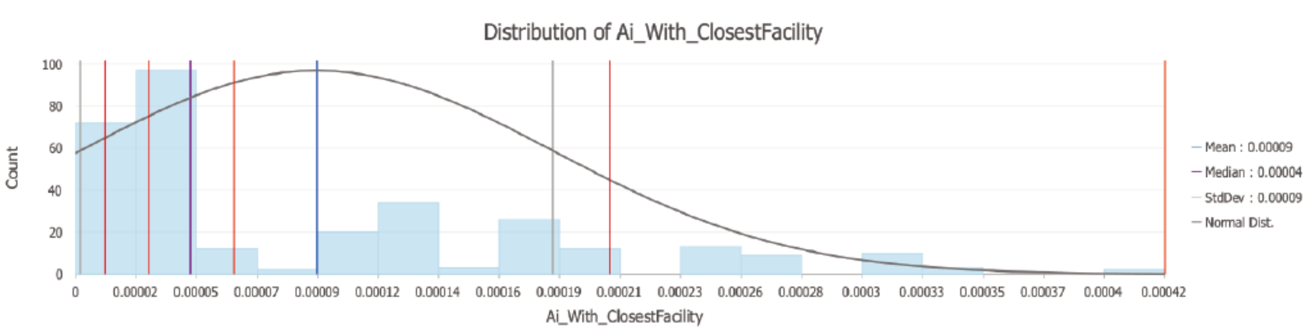


Figure 7. The 1,500-meter accessibility score histogram based on 2SFCA. Districts with a 0 scores were excluded from the results. The vertical, red lines are the classification breaks.

ter quality of healthcare service (based on population to facility ratio) compared to our results. The contrast between results and the previous study (Lahmar *et al.*, 2021) can be explained by the latter's reliance on the ratio of the number of people per health facility within the same district, without considering health centres in adjacent sectors. Also, the spatial distribution of the population affects these results. Another factor is the use of the geographic divisions as units, which generally are much larger than the census districts, therefore, give less detail than studies based on the census district which we used in this study.

Previous gaps were covered using a 2SFCA method that relies on measuring the number of people served by each healthcare centre in a pre-determined service area and, in return, calculating the number of health centres that each citizen can access within a predefined travel distance. It is further essential that investigations consider integrating spatial and non-spatial factors to identify and assess spatial disparities in access to healthcare more accurately.

The measure comparing the spatial relationships between the supply (healthcare facilities) and demand (population within the census district) across the urban area reflects the higher provider-to-population ratio. Firstly, the lowest score was zero, representing districts with no accessibility (red part in Figure 5), which was obtained by 35 districts, representing 35,985 people concentrated in the peripheral southern and south-western parts of the city, which means that they do not have sufficient accessibility because they are beyond 1,500-meter distance (*i.e.* 30-min travel time) to access at least one healthcare facility. It was an expected result. These less-served areas represent 11.1% of the total census districts, including about 12.0% of the population, with a score of 0.000421. The score reflects the low provider-to-population ratios. Secondly, the higher the score of spatial accessibility, the more excellent the opportunity to access services (Figure 5), which was obtained by 39 census districts representing 88.2% of the populations concentrated in the central and northern parts of the city. Also, the spatial accessibility score increases if the supply is greater than the demand; in contrast, the score decreases if the demand is higher than the supply, regardless of the distance between the demand and supply. Figure10 confirms the previous results. Based on Moran's *I*, we confirmed the main hypothesis of this research paper, whereas a significant relationship among the accessibility score, and district's location in Batna City.

Limitations

This study assumed that all patients will travel on foot and not use public transport or vehicles, which must be considered in the future. It would also be preferable not to merge treatment rooms and multi-service clinics because they are different categories with different workforce objectives assigned to each category in the NHS (functional and geographical). Further, we used the population-to-health facility ratio and the number of health facilities per 10,000 population to identify underserved areas. Those ratios allowed us to make comparisons within and between the census

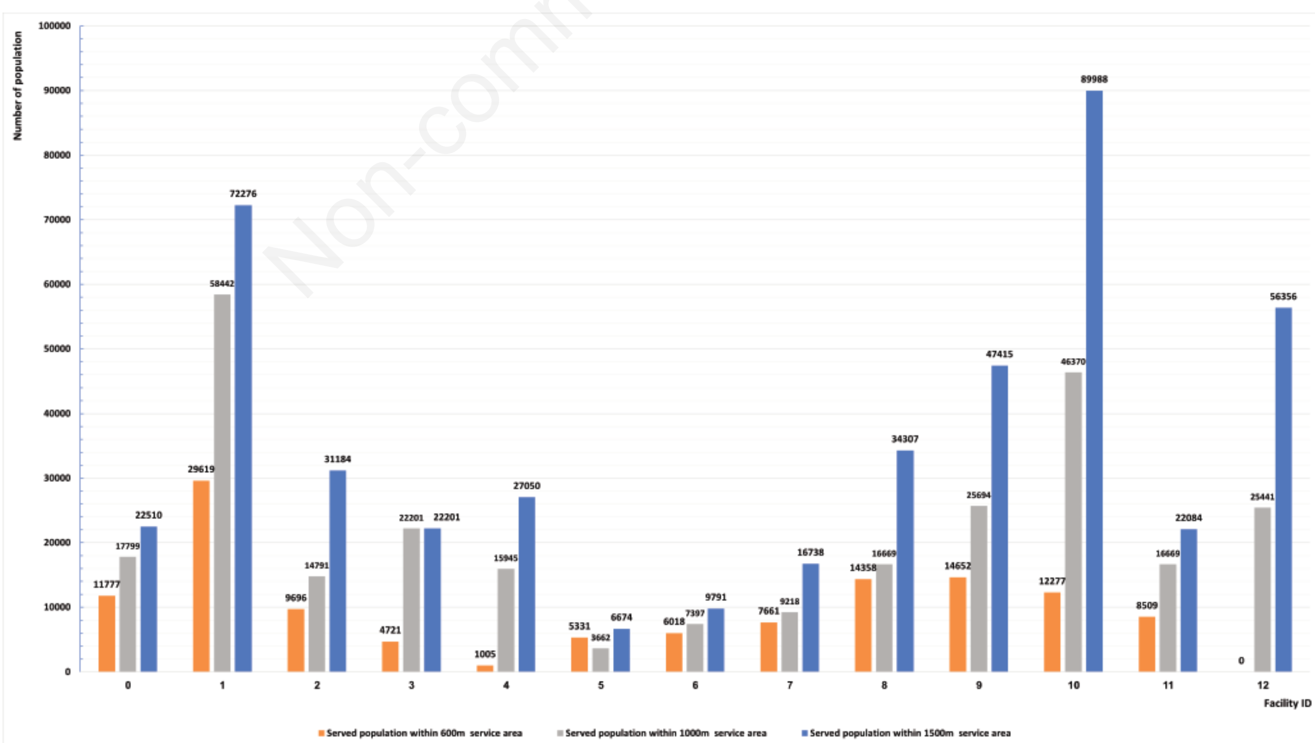


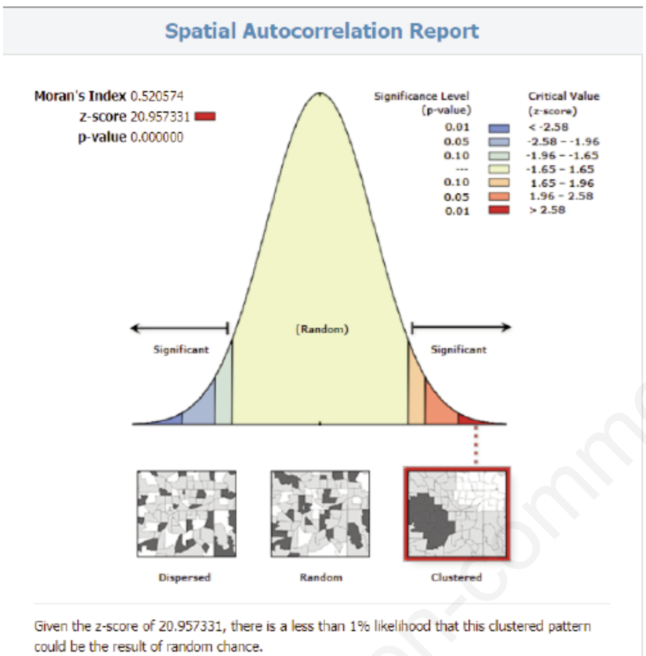
Figure 8. Population to facility ratio for the different distances investigated.

tracts in Batna, but better health care ratios may be available, which could have given even more in-depth details. Finally, this study only covered the healthcare centres in Batna City according to the available data and the schedule for preparing this study; however, it is needed to bring forth a comprehensive conception of the reality of the complete healthcare system.

Conclusions

The spatial accessibility of primary health in Batna is affected by three main factors: i) Number of health facilities (the number of health centres is insufficient, especially if we consider measuring the spatial accessibility of the treatment room and multi-service clinic together, ii) travel distance, iii) policymakers' decision and iv) population distribution. The results showed that 88.2% of the Batna population have access to healthcare centres. However, with disparate levels of accessibility, most of those are concentrated in the central and northern districts of the city. In contrast, the rest of the population is classified as underserved as they would need to travel more than 1,500 meters (*i.e.* 30 minutes) to access a healthcare facility. Those are concentrated in the south-western and southern parts of the city.

Finally, the results indicate that the number of healthcare centres is sufficient compared to the Algerian guide of the facility in Batna. This is not entirely true and the output from this study (and others) should be considered as reference for decision-makers when developing the sectoral healthcare plans. Allocation of new healthcare centres supported by reduced spatial disparities in access to healthcare, prioritization and reinforcement of the workforce in the less-served districts would result in reduced travel distances, optimized healthcare coverage and improved quality.



Global Moran's I Summary

Moran's Index	0.520574
Expected Index	-0.003185
Variance	0.000625
z-score	20.957331
p-value	0.000000

Dataset Information

Input Feature Class:	AI Score
Input Field:	CENSUS_1500.AI_SCORE
Conceptualization:	INVERSE_DISTANCE_SQUARED
Distance Method:	EUCLIDEAN
Row Standardization:	True
Distance Threshold:	1043.0783 Meters
Weights Matrix File:	None
Selection Set:	False

Figure 9. Spatial autocorrelation of the accessibility score using Global Moran's index.

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