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GIS Based Network Analysis for Optimum Path for Tourist Places: A Case Study of Al Ula, Saudi Arabia

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Abstract: ***Al Ula area, located in the north-west of the Saudi Arabia Kingdom is an ancient oasis in a desert valley preserved by time. it is an archaeological and cultural jewel in the heart of Saudi Arabia. Al Ula area has a potential as a new tourism attraction within its historical sites. ArcGIS network analysis provides to build the most efficient travel route, generating travel directions, locating the closest facility and defining service area based on travel time and distance and the tourism importance of the route which will help an opportunity in development of tourism. Using GIS technology, it is possible to visit different tourist sites effectively with a deliberate decision. The present study aims to explore the GIS based network analysis in defining the optimal route and services area. Hotels, hospitals, Fuel station, restaurant …etc. were located in Al Ula area for tourist destination. Route analysis capabilities of GIS are done on the basis of estimation travelling time and distance through network. It is shown that using GIS in routing help a powerful ability for network analysis, management of shortest route and closest facility analysis which benefits users to provide optimum planning for tourism.***

Keywords: Al Ula, Tourism, Travel Route, Closest Facility and optimal Route

1. Introduction

Tourism is a movement of people from one place to various other places for recreation, leisure, exploration, health, religious and many other aspects [1].

According to the United Nations World Tourism Organization (UNWTO), "tourism comprises the activities of persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited" [2].

The tourism industry makes a vital contribution toward the national economy. According to one report, prior to the Covid-19 pandemic, tourism accounted for 1 in 4 of all new jobs created across the world, 10.6% of all global jobs (334 million), and 10.4% of global GDP (9.2 trillion).

In 2020, the tourism sector suffered a loss of almost 4.5 trillion, to reach 4.7 trillion [3]. When the epidemic in China is alleviated, all regions should take full advantage of their tourism resources. For tourism enterprises, it is important to provide reasonable tourist routes and different types of scenic spots to attract more tourists and enhance the charm and popularity of scenic spots [4]. The development of tourism should be resumed to avoid greater losses.

Through time there has been a huge development in information technology recently. In addition, GIS has been commonly used in different fields such as tourism activities [5].

A network is a set of linear features that are interconnected in GIS. Common examples of networks include highways, railways, city streets, rivers, transportation routes (e.g., transit, school buses, garbage collection, and mail delivery), and utility distribution systems (e.g., electricity, telephone, water supply, and sewage). Collectively, these networks form the infrastructure of modern society. They provide the means for the movement of people and goods, the delivery of services, the flow of resources and energy, as well as the communication of information [6-7].

GIS is an important tool in tourism planning [8] it contributes to Developing special applications that serve tourism in its modern concept; So far these systems have not been used effectively in Al Ula Governorate.

The main objective of this research is to demonstrate the ability of GIS in development of tourism industry process and tourism planning operations in Al Ula governorate.

In this research GIS will be used to build an effective system that improves tourism planning,starting from the construction of a database containing features associated with the tourist operation like restaurants, hotels, religious and archaeological monuments... etc., in Al Ula governorate.

Then the evaluation of each touristic places, thus creating a new tool within the GIS environment that employs the previous touristic places to weight the road network in tourist terms, that is, determining the tourist weight of each route of the road network you use within the network analysis in the ArcGIS program.

In addition to the above, we will be recognized Network Analyst applications and its role in the tourism planning process will be, such as identifying service areas or identifying the Closest Facility.

2. Description of Study Area and Data

2.1 Description of Study Area

Al Ula is a region covering 22,561 km2, making it almost as large as Belgium. it is one of the cities of the Kingdom of Saudi Arabia, located in the north-west of the Kingdom. Its capital, Al Ula City, is located in the Wadi al-Qura valley, 1,100 km north of Riyadh, 725 km from Mecca and 375 km from Medina. The shores of the Red Sea are approximately 200 km west of Al Ula **Figure 1**.

It belongs to the Al Medina region. It is approximately 300 kilometers north from the center of Al Medina region and it represent the capital of Al Ula governorate **Figure 1**. Human settlement is about 4,000 years old and it is one of the most important tourist destinations in Saudi Arabia.

Al Ula is an ancient oasis in a desert valley preserved by time. With breathtaking UNESCO World Heritage Sites such as Hegra and an impressive site that holds the Guinness World Record.

The Maraya Concert Hall is an archaeological and cultural jewel in the heart of Saudi Arabia. Packed with stunning natural wonders such as the sandstone monolith that is the Elephant Rock and Jabal Ikmah, 'the open-air library' of the city, Al Ula is where you can enjoy gorgeous natural scenery, admire stunning displays of human creativity, and indulge in authentic Arabian hospitality.

The topography of the Al-Ula area is mountainous in general **Figure 2**, it is an extension of Al Hejaz mountains in the south. The aspects of the surface of the province varies between mountains, plateau blocks, spacious plains and rivers, isolated hills and dunes.

2.2 Archaeological Sites

Al Ula governorate contains many tourist areas that attract tourists both from within and outside the country, which in turn contains many important tourist attractions.

The archaeological sites will be the main tourist attraction of Al Ula. The county has exceptional sites related to pre-Islamic heritage. Among them, Hegra (Al-Hijr-Madain Salih, [9], offers great potential as a tourist attraction. Its attractiveness is mainly related to the monumental dimension of its tombs, its historical link with the Route of Incense [10] and the visibility that the Nabbatean civilization achieved, in the world tourist imaginary thanks to nearby Petra (Jordan). The rest of the heritage in the area (like many other archaeological sites in the world) faces notable difficulties of interpretation at a tourist level, which reduces its ability to attract visitors. The archaeological heritage is not (easily) readable for average and not-initiated visitors. It needs interpretation, much adaptation, signage and ideally a visit supported by explanations made by experienced professional guides. The most important of these touristic sites are:

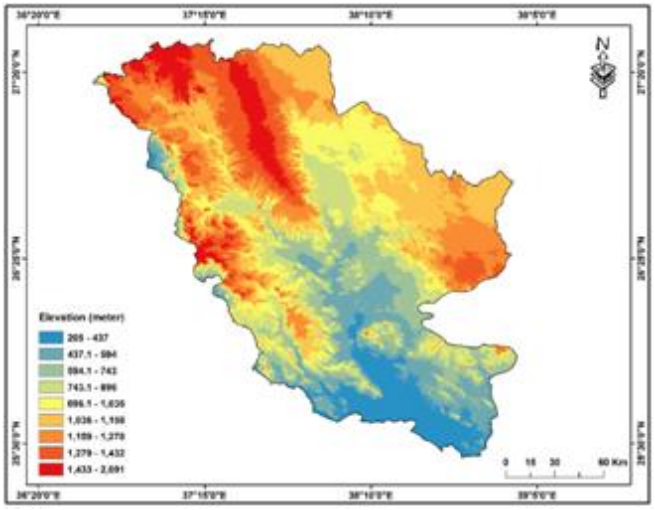


Figure 1: Location map of study area

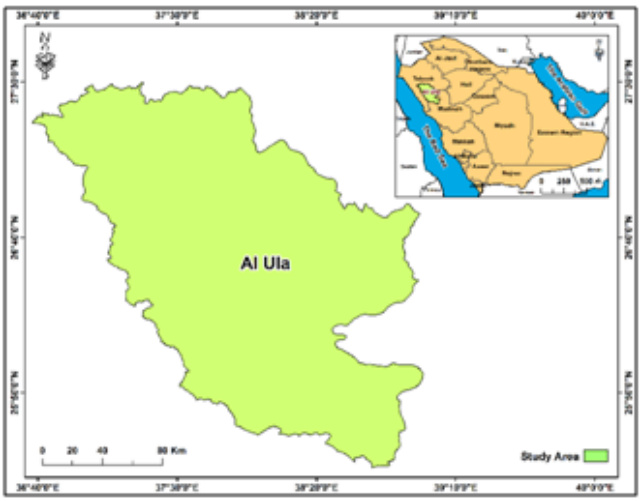


Figure 2: The Digital Elevation Model of Al Ula

"HegraMadain Saleh"
is the collective title of the cities in which the Nabetean Kingdom once had one of its two most powerful center of trade, culture and education. It was also the home of the people of Thamud. Madain Saleh was the second wealthiest and most powerful city governed by the ancient Nabataeans. This ancient metropolis is buried between rocky cliffs and encircled by a mighty ring of sandy mountains. This ancient city has been made mention of in the Hol Qur'an as "al-Hijr" which is in reference to the stone comings and mountain dwellings in which the people of Thamud resided.

Today this ancient civilization ruins lay somewhere the modern region of al-Ula governorate which is a subdivision of the city of al-Madinah, in the kingdom of Saudi Arabia.

In its antiquity, Madain Saleh was an important center of culture, trade and learning for the mighty Nabataean civilization, the only other city that was more important to them was Petra, in modern day Jordan.

Madain Saleh dates back to as early as the first two centuries BCE when the glorious rule of the Nabataean state was at its height. The region fell into decline following Roman conquests in 106 CE however the region continued to serve

as an important location for cultural and intellectual exchange up until the 4th century CE.

Today the cities of Saleh as seldom visited by Muslim tourists as its ancient carvings and artefacts conceal a macabre and morbid history.

Apart from its impressive stone monuments and striking carvings, the ancient city is also home to a vast necropolis there are many tombs still visible there, it is also believed to be the site for the ruins of the people of Thamud, following their annihilation.

The region fell into decline following Roman conquests in 106 CE however the region continued to serve as an important location for cultural and intellectual exchange up until the 4th century CE.

According to sound Islamic sources, Prophet Muhammad instructed his companions to hurry while passing through the ruins and not to drink the water from its well subsequently-local tourism to this region is restricted and very limited as Muslims are not encouraged to visits these sites.

Some of the more notable tombs and ruins that have been preserved to this day are historic sites such as:

''Jabl al Ahmar''
Which is an outcrop in the South Eastern part of Madain Saleh and encompasses numerous tombs of which three contain ancient drawings dating to between CE 16 and CE 61.

But besides its tombs and burial chambers, the city also contains an important historic site:

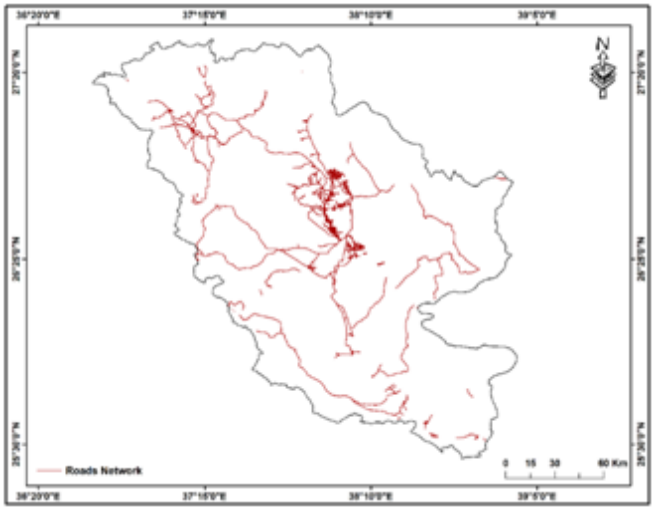
''Diwan court''
Which is comprised of three stone benches used for sacred ceremonial feasts. The court has a very large entrance leading towards an open space where a larger feast could have been hosted but the Diwan was consecrated specifically for religious gatherings, it was a rectangular rock chamber.
From the Diwan we can trace a narrow passageway known as:

"Al-Siq"
It is about 40m wide and runs between two rock faces lined with a number of altars Al-Siq also has jagged cliff walls along its rocky passage leading to **"Jabal Ithlib"** which is heavily adorned by carvings in honour of the ancient Nabatean deities with surviving ancient rock carving still visible of camels and traders.

Surprisingly, the ancient monuments and constructions of the Nabateans remain as magnificent and sturdy as they would have been thousands of years ago.

One such monument is the **Castal Bint Maiden**, which is the largest tomb currently sta Palace of the in Madain Saleh its portal is visibly raised above ground and an ancient inscription plaque can be seen on the entrance of its doorway. The monument contains a row of facades that provides a panoramic view of the ancient city.

A more ancient and historic site is:



"Qasr al-Sanea"
Which is believed to have been one of the very first tombs carved in the region serving as an archetype for Nabataean architectural style tombs. Despite being one of the most antiquated tombs in the city, it is also one of the most well preserved containing a great monument, with five stepped crow-steps and an inscription above its entrance.

The bodies of its dead inhabitants were stored into various compartments inside the structure. During Ottoman rule in Madinah, between 1744 and 1757, a fort was built in Madain Saleh on the orders of the Ottoman governor of Damascus As'ad Pasha al-Azm-who ordered for the provision of a water tank which was replenished by a large well-built inside the fort. The site served as a one-day stop for Hajj pilgrims where they could purchase goods such as dates, lemons and oranges this (stop-over) became part of a series of fortifications built by the Ottomans to protect the pilgrimage route to Mecca.

2.3 Data

In this paper, **Figure 3** represent the work-flow with three stages begins with collecting data **Table 1**and building a geodatabase, then using Model builder to build a tourist road weighing tool. The network topology and the network dataset were built. Finally, the network analysis has been used in the to determine optimum path for tourist places and to analyze services area and closest facility in Al Ula.

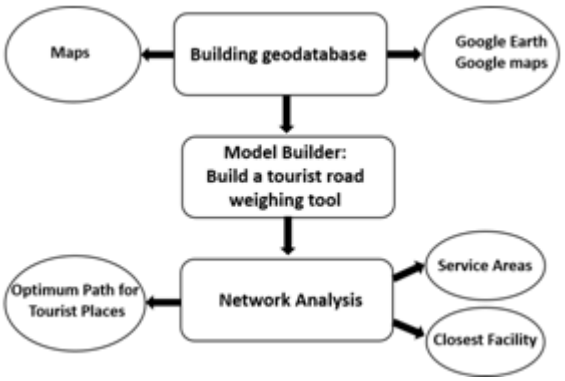


Figure 3: workflow

Table 1: Data used in the study

Data	*Sources*
Al Ula base map	Al Ula Municipality
Al Ula Road network shapefile	Satellite images
Tourist places	Collected by GPS
Public services (facilities)	General Department of Urban Planning in the Al Ula Municipality

3. Methodology

3.1 Creation of geodata base

To create GeoDatabase, following data has been used:

- Al Ula base map.
- Al Ula Road network shapefile: The road network was captured from satellite images (Google Earth) after geo-referencing by four control points. **Figure 4**.
- Shapefile of tourist places: GPS was used to collect the coordinates of the existing tourist places **Figure 5**.The attributes table included essential parameters such as value of importance of touristic site.
- •Hotels, airport, bus terminal as well as public services like hospitals, restaurant, coffee, Market, fuel station, ATM…, the attributes table included essential parameters such as value of importance of facilities. The attributes data of the road networks were obtained from the General Department of Urban Planning in the Al Ula Municipality **Figure 6**.

Figure 6 Shows that the spatial distribution of different services such as hospitals hotels, coffee, restaurant, airport, bus terminal, police stations through a route network which is also known as service allocation analysis. With the help of this analysis, the efficiency of these services in terms of time and distance may be analyses the actual service area of different facilities or whether these facilities are enough for that area, if not then how much it required.

3.2 Creating the Network

Network analysis can powerfully model realistic network conditions. Network analysis can be used to analyze problems such as vehicle routing, closest facility, and service area, by giving the data of roadways and cost attributes [11-12]. Network analysis can be used to calculate the access in terms of travel time and evaluate accessibility against certain criteria [13].

In our study the network data set was created **Figure 4**, and the attributes table included essential parameters such as (distance (m), speed (km/h), road direction, road name, and type. An average speed of 40 km/h has been set for secondary roads, 50 km/h for main roads and 80 km/h for motorways. Arrival time and return time were calculated based on speed and distance in minutes.

The Road network, tourist places, facilities were considered for network analysis for touristic purposes. this analysis was based upon the impedance. Impedance is a cost attribute of road network. It may be time or length which can be chosen by the user. Analysis was carried on the basis of estimated travel time and distance (time and length as impedance).

The network analyst provides a range of field selection options that we want as a cost. For example, if we enter the time as a cost, the route between the two points will be selected based in the shortest period of time. If we chose the distance as a cost factor the shortest route will be chosen up between the two points.

but what if we want to choose the road with the most important in tourist terms, for example, we want to connect two points with the most important road in tourist terms That is the route that passes near the largest number of tourist attractions and facilities, in this case, a weight is added to the roads network to take into account the historical sites and facilities surrounding roads in the identification of the route between two points. So, we must weigh these roads by tourist attractions and facilities that are adjacent to them. To weighted this network, a weighting tool has been built using the Model Builder within the ArcGIS software **Figure 7**.

3.3 Building a weighting tool of Network

The idea of this weighting tool is to surround all tourist attractions and facilities by buffers and then find the intersection of these buffers with the road network. After, the assessment of each tourist attractions, that has been entered when building the database, is taken and given to the road with which it intersects. so that the road is overloaded with the buffer that surround tourist attractions will be taken a different value according to the assessment of these tourist attractions. This tool will help the tourist planner to choose a route with a greater tourist weight and learn about the tourist attractions that have been involved in weighing the road network when he moves between tourist places.

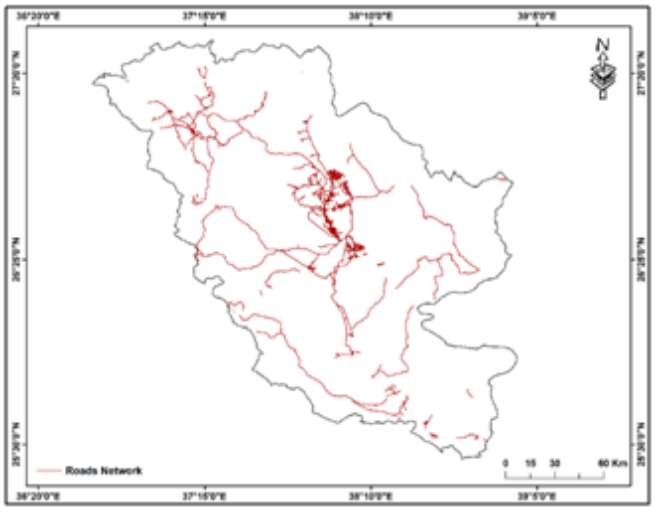


Figure 4: Roads network in the study area

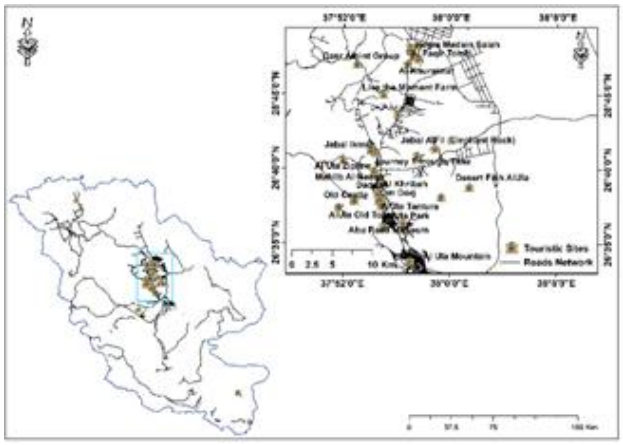


Figure 5: Tourist places in the study area

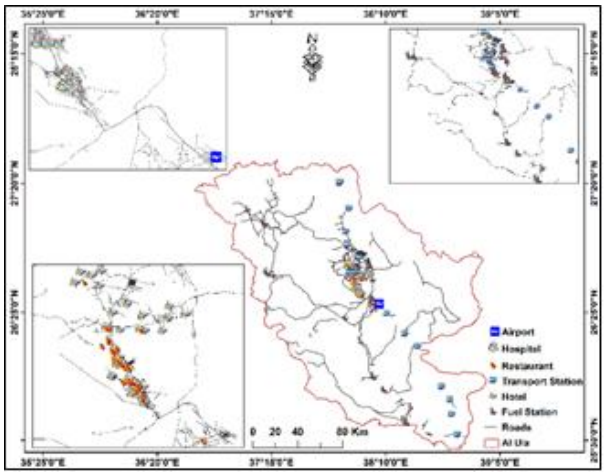


Figure 6: Facilities in the study area

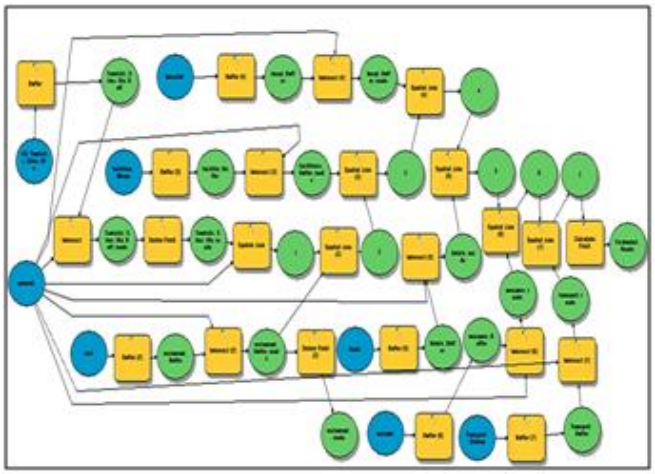


Figure 7: Model Builder for building a weighting tool

4. Results and Discussion

Determine the best tourist route:

We will determine the best tourist route according to the following third case:

1) If we choose time as cost factor.
2) If we choose distance as cost factor.
3) If we choose the tourist weight of the road as a cost factor.

Analysis of the best tourist route will be made between AlUla Mountain and Hegra Madain Salah

- Identification of service area
- Find closest facility

4.1 Choose time as a cost factor

The purpose of choosing this barrier (time), it's getting the track shorter by activating the **Time Start** option and setting distance with meter. Then we identify **Impedance** which is the obstacle or the most important factor when analyzing the tourist route, the Minutes field in this case is used and the unit is seconds.

Figure 8 shows how time is chosen as a cost factor when analyzing.

After the setting process is completed, the analysis process can be started by using the **Solve** option of the network analyst toolbar and the shorter route will appear between the two chosen location (Al Ula Mountain to Hegra Madain Salah). **Figure 9**shows the shorter time tourist route and **Figure 10**shows the sub-directions of the shorter time tourist route.

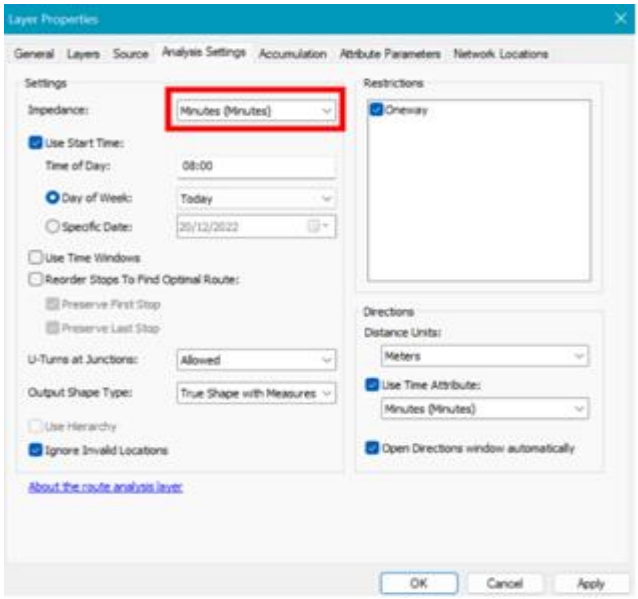


Figure 8: Time is chosen as a cost factor

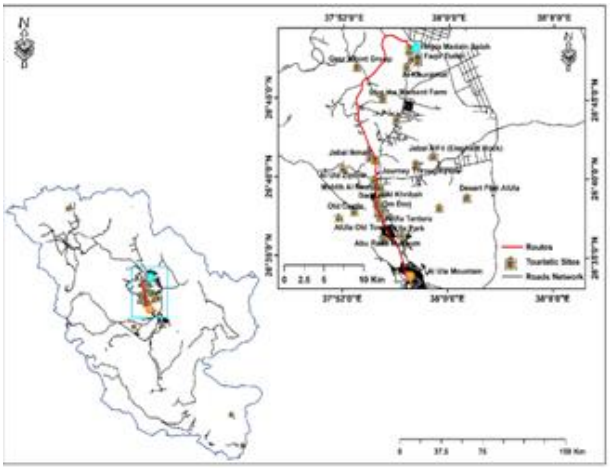


Figure 9: The shorter time route between Al Ula Mountain to Hegra Madain Salah

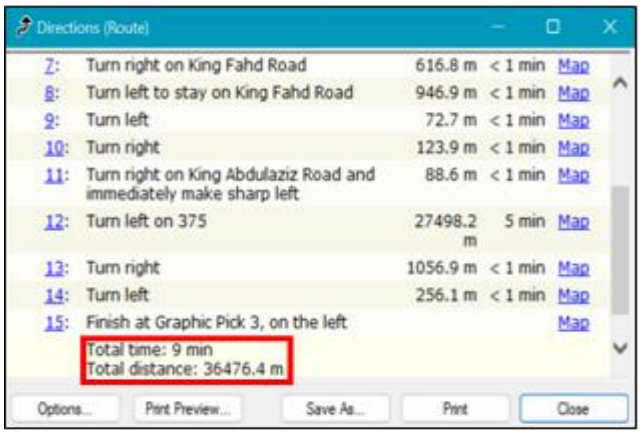


Figure 10: The sub-directions of the shorter time tourist route

4.2 Choose distance as a factor of cost

At this stage the shortest route will be chosen between the two locations. The **Figure 11**shows how to determine distance as a cost factor parameter in network analysis.

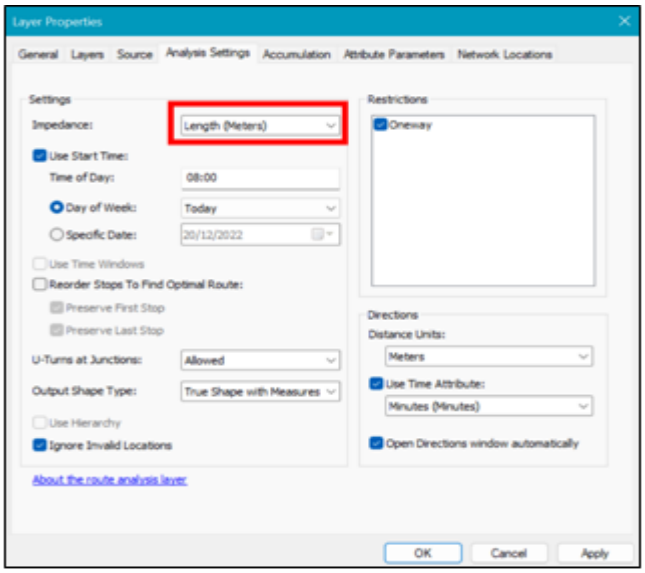


Figure 11: Distance is chosen as a cost factor

4.3 Choose tourist weighted roads as a factor of cost

In this case, the road with the greatest tourist weight will be selected to link the tourist attractions that will be visited.**Figure14**shows how to introduce tourist weight as a cost when analyzing the track.

In this case the shortest distance or less time will not be chosen but the field named "evaluation_cost" that contain weight of road will be chosen.

Figure15 shows the tourist weighted route between Al Ula Mountain to Hegra Madain Salah.

Figure 16 shows the sub-directions of the tourist weighted route.

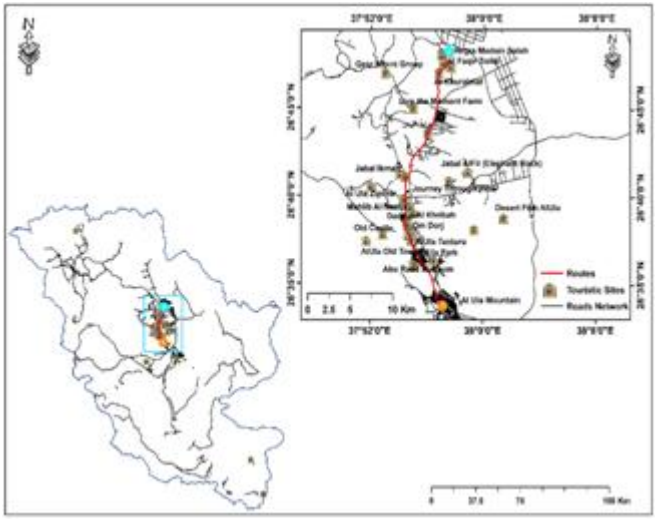


Figure 12: The shorter route between Al Ula Mountain to HegraMadain Salah

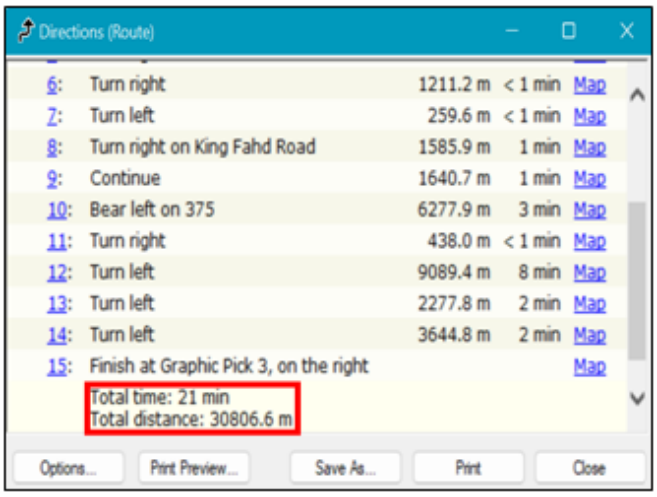


Figure 13: The sub-directions of the shorter tourist route

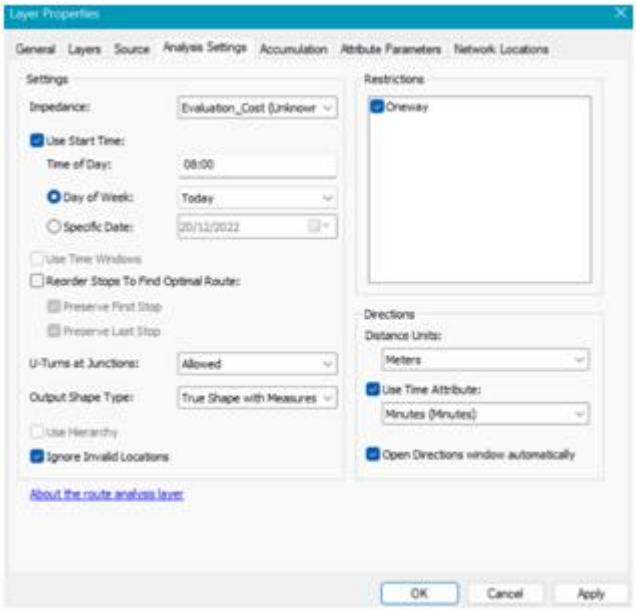


Figure 14: Weight is chosen as a cost factor

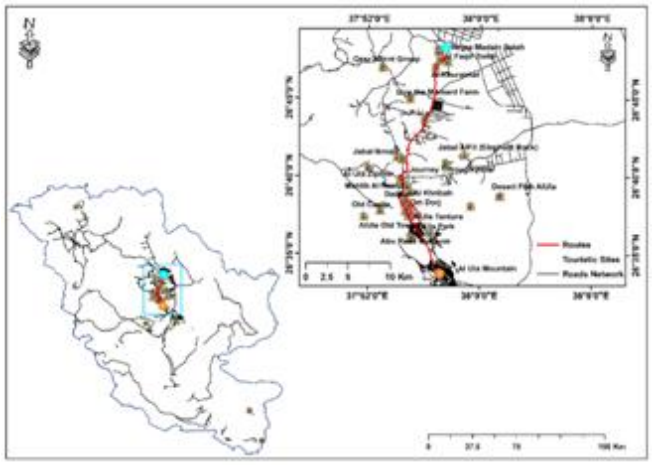


Figure 15: The important tourist route between Al Ula Mountain to Hegra Madain Salah

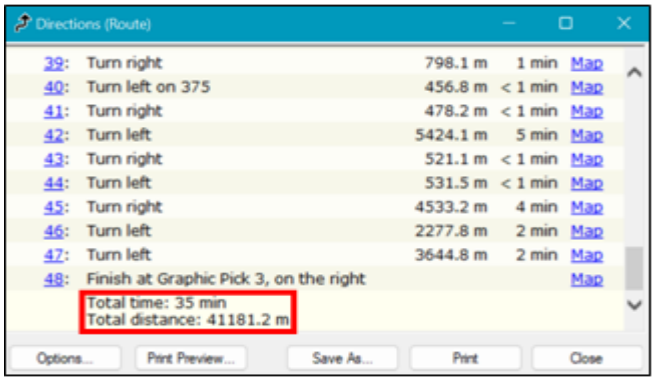


Figure 16: The sub-directions of the important tourist route

Table 2: Tourist routes according the selected impedance

Number of tracks	Cost factor	Time (minute)	Distance (meter)	weight of roads
1	Time	9	36476.4	199
2	Distance	21	30806.6	176
3	tourist weight	35	41181.2	253

It is therefore logical that the time required for tourists to travel this route is greater than the time required on the first track (less time), and the distance travelled is greater than the distance travelled on track two (shortest distance).

4.4 Identification of services area

In many of the previous studies, the service areas were produced by creating buffer zones from a particular point [14, 15]. Accessibility always needs to be determined by travel time and road length [16]. The tourism planning process and the tourism industry include many services center that provide facilities for tourists or services while they are present, such as hospitals, police stations, banks and others. The tourist must therefore know the whereabouts of these centers or of the nearest center in the area in which they are located. The network analyst provides several analyses that help us to provide the previous requirements.

In this research service areas will be applied to fuel station in the study area as an example. Service Analysis was conducted based on distance **Figure 17** and time **Figure 18** is a cost attribute chosen as impedance.

Choose distance as impedance in determining service area:

The map in **Figure 17** shows three service area polygons which calculated for each fuel station in a service area for amenities based on travel distance, with a buffer of 2000,1500,1000 meters. The blue color means a sufficient number of amenities are available in this area. The area has less availability of amenities for tourism and new more amenities are required. These service areas show how accessibility varies with impedance.

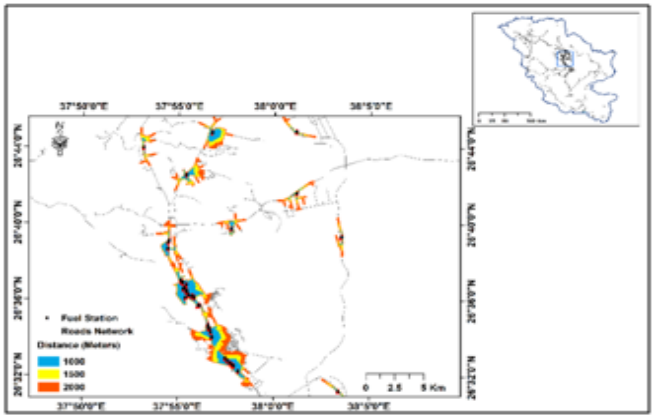


Figure 17: Service area for different fuel station based on travel distance

Choose time as an impedance in determining service area:

The map in **Figure 18** shows three service area polygons which calculated for each fuel station in a service area for amenities based on travel time, with a buffer of 2, 3, 4minutes. The green color means a sufficient number of amenities are available in this area. The area has less availability of amenities for tourism and new more amenities are required. These service areas show how accessibility varies with impedance.

4.5 Closest Facility analysis

The closest facilities analysis finds the closest facilities that can be reached based on travel time or on travel distance, in our case, closest hospitals to hotels based on travel time which determine the user to locate the specified location. The map **Figure 19** represented closest hospitals to the hotel in the study area.

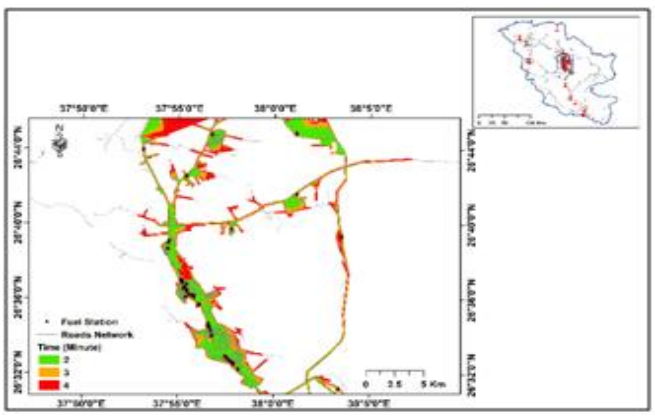


Figure 18: Service area for different fuel station based on travel time

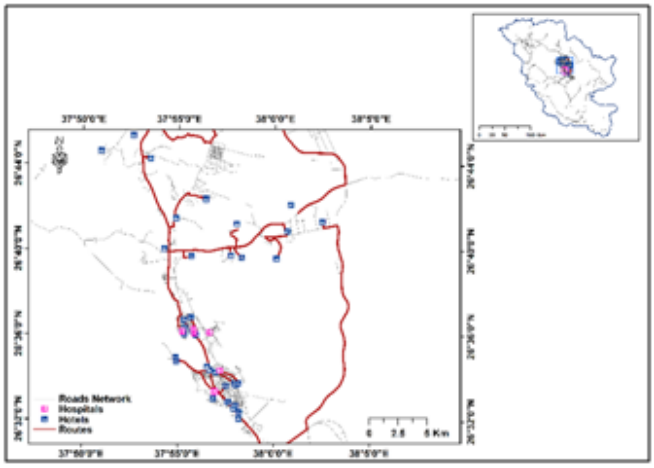


Figure 19: Closest hospitals from hotels based on travel time

5. Conclusion

A spatial database has been built for Al Ula governorate, which includes tourist attractions and the road network. It is a basis that can be adopted for use by specialists or non-specialists and help decision makers to take the right decisions, and can be updated periodically as desired.

A tool was developed using Model Builder within the ArcGIS program, to weigh roads within Al Ula governorate depending on the tourist attractions surrounding it. We selected two locations (from Al Ula Mountain to Madain Salah) and we analyzed the best tourist route. We have found that a tourist route with greater tourist weight requires more time and distance than the other two tracks because it takes time and distance as cost factors when analyzing. after analysis we found significant and obvious differences in the times and distances between the tracks. the results were by time and distance as cost factor and then the tourist weight in order as follows 9 minutes, 21 minutes, 35 minutes (For time), for distance 36476.4m, 30806.6m, 41181.2m.

In addition to the above, we have identified the service areas for each hospital in Al Ula on the basis of either time or distance, i.e., the identification of the ways in which we can reach each hospital according to the restrictions we have put in place, as the availability of hospitals and medical centers helps in the development of the tourism industry process.

The nearest hospitals to each hotel have been located in the study area, taking into account impedances that may be time or distance.

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