Application of GIS to assess the accessibility of urban streets in Baghdad city

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Abstract. Accessibility has an important impact on shaping human activity patterns on all of the spatial scales. This study presented an evaluation of accessibility levels with private to commercial centers for three selected routes in Baghdad city. The study involved more than 45 days transport survey for private vehicles in Baghdad city using Global Positioning System (GPS) probe for recording indicators of traffic performance. Gravity model was used to measure accessibility index as an implementation of GIS-based model by using link geography and the spatial boundary of analysis in order to build route networks at three routes in Baghdad City, Bayaa intersection - Bab Al-Muatham intersection (Route 1), Bayaa intersection - Bab Al-Muatham intersection (Route 2) and 14 Ramadan Street - Bab Al-Muatham intersection (Route 3). It was found that Route 1 has the high accessibility index with 0.67 in compare with Route 2 and 3 (0.58 and 0.59), respectively. The reason that Route 1 had the highest accessibility index due to the high access point and low traffic volume as compared with the other two routes.

1. Introduction

There are numerous accessibility definitions in literature; none-the-less, a general accessibility definition by Kumagi & Wachs [1] is ease (or difficulty) opportunities (for example, employment) or services for the purpose of reaching a location. The accessibility captures efforts that are necessary for overcoming spatial separation of 2 locations, and typically reflects utility (such as the travelling from the home to a job) related to the travelling between those locations [2–4]. Van Wee & Geurs [5] provided a complete review of the measures of accessibility, however, the most generalized accessibility formulation, A, of the location, i, has been presented by Koenig [6]:

\[ A_j = \sum_i O_j f(C_{ij}) \]  

Where Oj represents opportunities (activity or utility) to be obtained from the travelling to a location j, Cij represents time, cost or distance, of the travel from point i to point j, and f(C_{ij}) represents function that ensures that accessibility is increased with the decrease of travel cost between 2 locations [7]. Which is why, fundamental to the understanding of the accessibility is the travel cost between the source and the destination. Such cost, or impedance, may be measured in several ways. The simplest one of the
measures is Euclidian distance between a pair of points which has been usually utilized in earlier analyses [8,9].

AlKaissi (2017) presented an estimation of the total travel time and distribution analyses for 3 chosen routes in Palestine Arterial Street in Baghdad: Al-Mawwall to Bab Al-Muatham intersections, Bab Al-Muatham to Al-Sakhr Intersections, and Al-Sakhr to Beirut Intersections. The results of the buffer time index in conditions of worse reliability. Different predicted model for the 3 studied Palestine street routes were developed according to the field data that have been obtained [10].

Antwi et al. (2020) presented research that presents a comparison of the prediction of the travel time and levels of accessibility with the public and private transports en route to the commercial centres. Antwi’s study includes a 21-day transportation survey for the public shuttles and private cars in Oforikrom district with the use of the GPS probe for recording trace performance indicators to be analysed in the environment of the GIS. The study results showed on a map the accessibility degree via modes, and comparative line plot of the travel time with the public as well as the private transportations. The research had shown that the private cars in district perform generally more sufficient in comparison with the public shuttles on the travel time and accessibility level. The execution of this study had shown that convergence of choice of the transportation mode and dynamics of the travel time has been vital for the policy-makers in the implementation of a variety of the transportation modes and commuters to select a mode with low cost of accessibility [11].

Which is why, the translation of the accessibility concept to a practical planning tool stems from the requirement for the powerful approaches to help the decision makers and planners in dealing with the urban and transport management and providing better evaluations of impacts of various schemes (or set of the schemes) that have been advanced by the policies of transportation and land-use.

2. Objective of the Research

The primary aim of the present study is developing a comprehensive accessibility index model for the selected routes. The aim of this study can be done by achieving the accessibility level for every segment of the network via ArcGIS v. 10.4.1.

3. Study Area

In this study, three routes have been selected in Baghdad city which meet all the characteristics of traffic condition, arterial roads urban streets (arterials and collectors) where the traffic is assumed to be always in heavy traffic condition. Bayaa intersection - Bab Al-Muatham intersection (highway route), Bayaa intersection - Bab Al-Muatham intersection (downtown route) and 14 Ramadan Street - Bab Al-Muatham intersection. These routes are heavily urbanized and commercialized containing many restaurants and shopping venues. Numerous signalized and unsignalized access points exist along the facility ranging from private driveways to large Mall entrances. All the selected routes are shown in Figures 1 to 3.
Figure 1. Overall map of route 1 - Bayaa intersection - Bab Al-Muatham intersection (highway route)

Figure 2. Overall map of route 2 - Bayaa intersection - Bab Al-Muatham intersection (downtown route)
4. Data collection method
Travel time data was obtained from WENK GPS at 10-second intervals from (7–9 AM) and (1-3 PM) for each route between 7–9 AM and (1-3 PM). Every 5 minutes, the data from the station was used to determine the trip time for each segment based on the data from the station. The statistics on travel time was calculated for a single day (January 1st, 2021 to February 28th, 2021). Data were collected and analyzed for all week-days, except the public holidays and weekends, and were then combined to form a single report. Tables 1, 2, and 3 each provide a sample data sheet, which can be downloaded.

![Figure 3. Overall map of route 3 - 14 Ramadan Street - Bab Al-Muatham intersection](image)

| Weekday  | Avg. Travel time (AM) mm:ss | Avg. Travel time (PM) hh:mm:ss | Avg. Stops (AM) | Avg. Stops (PM) |
|----------|-----------------------------|--------------------------------|----------------|-----------------|
| Sunday   | 46:25                        | 56:23                          | 19             | 12              |
| Monday   | 59:06                        | 1:04:51                        | 21             | 17              |
| Tuesday  | 34:50                        | 1:11:02                        | 7              | 26              |
| Wednesday| 58:20                        | 1:01:14                        | 5              | 20              |
| Thursday | 41:15                        | 1:08:37                        | 8              | 18              |
Table 2. Travel survey data for the private vehicles in working days for Route 2

| Weekday      | Avg. Travel time (AM) (mm:ss) | Avg. Travel time (PM) (hh:mm:ss) | Avg. Stops (AM) | Avg. Stops (PM) |
|--------------|-------------------------------|---------------------------------|-----------------|-----------------|
| Sunday       | 33:15                         | 26:17                           | 13              | 18              |
| Monday       | 24:40                         | 37:24                           | 24              | 17              |
| Tuesday      | 18:59                         | 31:49                           | 9               | 15              |
| Wednesday    | 18:34                         | 29:22                           | 5               | 19              |
| Thursday     | 18:37                         | 19:30                           | 3               | 13              |

Table 3. Travel survey data for private vehicles in working days for Route 3

| Weekday      | Avg. Travel time (AM) (mm:ss) | Avg. Travel time (PM) (mm:ss) | Avg. Stops (AM) | Avg. Stops (PM) |
|--------------|-------------------------------|-------------------------------|-----------------|-----------------|
| Sunday       | 85:00                         | 89:00                         | 17              | 15              |
| Monday       | 88:00                         | 95:00                         | 18              | 12              |
| Tuesday      | 74:00                         | 75:00                         | 20              | 16              |
| Wednesday    | 66:00                         | 63:00                         | 23              | 17              |
| Thursday     | 54:00                         | 77:00                         | 16              | 25              |

5. Measurement of Accessibility

A measurement of accessibility can be defined as estimation of the ease at which certain locations of interest may be accessed. A considerable number of the approaches of accessibility measurement were advancement with time, and different review articles are focused upon certain measurement or application types [12–15]. While the reliability of the travel time is defined as the dependability or consistency in the travel times, as it has been measured from day-to-day and/or over various times throughout the day [16].

It was decided that the functionality of transit-enabled network would be utilized to determine the accessibility of city's employment prospects through public transportation. The prospective accessibility metric used in this study will be based on a gravity model and will be location-based [8]. A certain time and origin location's accessibility value equals the summation of attractiveness of all socioeconomic possibilities that are divided by the corresponding travel impedance which is related to those opportunities at that time and location. The equation that was employed, as well as a schematic that shows the gravity model, are shown in Figure 4. According to the accessibility formula, the accessibility at a starting point I (Ai) equals the total of attractiveness at each opportunity (i.e. supply location) j divided by the trip time with transit from starting point to the opportunity j (tij).
The index of accessibility can be defined as a number stating the ease of the traveling from one area to the other around it through including the travel barriers (i.e. distance and time) parameters and travel traction parameters to the zones of destination. In the present work, the travel barriers have been represented by total travel time value with total running time value through the route on road network. Whereas the parameter of travel attraction is distribution of the travel with the destination matrix. After the analysis of the travel time and the running time, and calculation of the index of accessibility through the division of travel time by the running time according to the equation of the Gravity Model [17].

\[ A_i = \frac{t_i}{r_{ii}} + \sum_{j \neq i} \frac{t_{ij}}{r_{ij}}, \quad i \neq j, \quad A_i \leq 1.0 \]  

Where \( A_i \) is accessibility index with parameter \( t \) to be selected as travel time and \( r \) to be the running time of each individual segment at each route.

6. Implementation of GIS-Based Model
The accessibility analysis was measured as follows:
1) The model's spatial geography has been characterized based on the analysis link geography and spatial boundary.
2) Build Route networks
   a) Building spatial networks in the GIS software
   b) Calculating length of every route from the geometry.
   c) Divide every route length by relevant speed of the travel for the purpose of obtaining travel time for every one of the links.
3) Calculate the location of the centroid and utilize it for defining the Origin, and Destination of the zone \( i \).
4) Calculating the access distance, \( d_{oa} \), and the related traveling time from the beginning to the end of the segment, (Figure 5).
Figure 5. Depiction of the journey from the origin $i$ to the destination $j$ (research work).

Figure 6 illustrates geographic extent of road-based (private vehicle travel) networks as implemented in Baghdad case study. Figure 6 illustrates a sample of OpenStreetMap cycle network that has been constructed for the present research, which demonstrates network density in the urban area and the number of the potential travel routes to be evaluated. The computation of the distance of the network, $d$, utilized in the above calculation for all routes.

7. Results and Discussions
Theoretically may be interrupted that the increase of the index of accessibility, the trip will be easier to travel and vice versa. The lower the index of the index accessibility indicated a poor accessibility of trips to access their activity location.
As shown in Table 4, the highest index is in the segment between Bayaa intersection and Al-Hamid Mosque intersection, and Junction of the University of Technology to Rusafa Sector Hospital segment; this indicated that the area was highly accessible; the distance between the area and other locations is very short; the road network in that area is larger and more supportive. While the average accessibility index of Route 1 is 0.67. Figure 7 shows the accessibility index graph for Route 1.

| Locations                      | Travel time (sec.) | Running Time (sec.) | Accessibility Index |
|--------------------------------|--------------------|--------------------|---------------------|
| Youth intersection             | 33                 | 21                 | 0.64                |
| Al-Hamid Mosque                | 152                | 128                | 0.84                |
| The 7th Brigade HQ             | 114                | 94                 | 0.82                |
| Tabarek Rahman Mosque          | 310                | 221                | 0.71                |
| Al Qasim Road intersection     | 561                | 404                | 0.72                |
| Junction of the University of Technology | 294            | 194                | 0.66                |
| Rusafa Sector Hospital         | 89                 | 72                 | 0.81                |
| Neurological System Hospital   | 131                | 99                 | 0.76                |
| Al-Mustansiriya Hospital       | 313                | 253                | 0.81                |
| Turkish embassy                | 381                | 82                 | 0.22                |
| alkhulafa' Intersection        | 421                | 181                | 0.43                |
| **Average**                    |                    |                    | **0.67**            |

As shown in Table 5, the highest index is in the segment between Qahtan square and Yarmouk Hospital, and Arabian Knight square and Karkh Rotary, indicating that the area was very accessible because the distance between the two locations was very short, and the road network in that area was larger and more supportive, with shopping centers, government centers, health facilities, and other amenities. While the average accessibility index of Route 2 was 0.58. Figure 8 shows the accessibility index graph for Route 2.
Table 5. Accessibility index for Route 2

| Locations             | Travel time (sec.) | Running Time (sec.) | Accessibility Index |
|-----------------------|--------------------|--------------------|--------------------|
| Bayaa Court           | 250                | 85                 | 0.64               |
| Qahtan Sq.            | 613                | 130                | 0.84               |
| Yarmouk Hospital      | 24                 | 22                 | 0.82               |
| Eagles Sq.            | 122                | 75                 | 0.71               |
| Baghdad Mall          | 125                | 99                 | 0.72               |
| Arabian Knight Sq.    | 155                | 71                 | 0.66               |
| Karkh Rotary          | 63                 | 59                 | 0.81               |
| Damascus Sq.          | 246                | 156                | 0.76               |
| Alawi Station         | 50                 | 26                 | 0.81               |
| King Faisal I Intersec| 243                | 98                 | 0.22               |
| Tourism Ministry      | 117                | 70                 | 0.43               |
| **Average**           |                    |                    | **0.58**           |

Figure 8. Accessibility Index for Route 2

As indicated in Table 6, the segment between Eagles Square and Mr. Milk Intersection had the highest index, indicating that the region was extremely accessible. The distance between the two areas was quite short, and the road network in that region was larger and more supporting, with shopping centers,
government centers, health facilities, and other amenities. The lowest index was in the segment between Al-Sarrafia Bridge Intersection and Bab Al-Muazam Intersection due to the fact that the access to the area was difficult due to a network of roads which are less supporting, the travel time and distance were quite lengthy, and the facilities were lacking. Route 3 had an average accessibility index of 0.59. Figure 9 shows the accessibility index graph for Route 3.

**Table 6. Accessibility index for Route 3**

| Locations                      | Travel time (sec.) | Running Time (sec.) | Accessibility Index |
|--------------------------------|--------------------|---------------------|---------------------|
| Bayaa Court                    | 230                | 90                  | 0.64                |
| Qahtan Sq.                     | 610                | 180                 | 0.84                |
| Yarmouk Hospital               | 65                 | 45                  | 0.82                |
| Eagles Sq.                     | 140                | 90                  | 0.71                |
| Mr. Milk Intersection          | 185                | 175                 | 0.72                |
| 14th Ramadhan Intersection     | 260                | 210                 | 0.66                |
| Al-Liqaa Intersection          | 190                | 120                 | 0.81                |
| 14th Ramadhan Bridge           | 85                 | 50                  | 0.76                |
| Al-Muthana Airport Intersection| 120                | 90                  | 0.81                |
| Al-Sarrafia Bridge Intersection| 280                | 120                 | 0.22                |
| Bab Al-Muazam Intersection     | 310                | 110                 | 0.43                |
| **Average**                    |                    |                     | **0.59**            |

Figures 10 and 11 represent the accessibility index legends on all selected three routes. The figure presented that Route 1 had the highest accessibility index values which indicates that the route was extremely accessible. While Route 2 had the lowest accessibility index value which indicates also that the route was less accessible.
8. Conclusions
This paper proposed gravity model as accessibility measurement of spatial elements on urban scales that include neighbourhoods and communities on a basis of a data-set via GPS device. The measurements provided easy understands and calculations. A model that overcomes some limitations of the indices of accessibility through the partial encompassing of multi-dimensional aspect of the issues of accessibility.
estimation via GIS as an implementation of GIS-based model by using link geography and the spatial boundary of analysis in order to build route networks. Gravity model was used to measure accessibility index at three routes in Baghdad City, Bayaa intersection - Bab Al-Muatham intersection (Route 1), Bayaa intersection - Bab Al-Muatham intersection (Route 2) and 14 Ramadan Street - Bab Al-Muatham intersection (Route 3). It was found that Route 1 has the high accessibility index with 0.67 in compare with Route 2 and 3 (0.58 and 0.59), respectively. The reason that Route 1 has the highest accessibility index was due to high access point and low traffic in compare with the other two routes.

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