Journal of Engineering and Sustainable Development
http://jeasd.uomustansiriyah.edu.iq/index.php
https://doi.org/10.31272/jeasd.25.5.2

Vol. 25, No. 05, September 2021
ISSN 2520-0917

GIS-BASED ANALYSIS ACCESSIBILITY TO DESTINATIONS BASED ON PUBLIC TRANSPORT

*Ayah A. Hussein[1] Noor M. Asmael[1]

1) Highway and Transportation Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

Received 27/3/2021 ***Accepted in revised form 28/5/2021*** ***Published 1/9/2021***

Abstract: Baghdad city depended on the private auto in transport and this led to great problems with increasing congestion and traffic problems. Existing public transport suffers from poor accessibility to opportunities which is considered the main existing problem. The local agency decided to construct Baghdad Elevated Train as one of the keys to solve this problem and decrease congestion. This study aims to discuss the changes that the installing of the planned train line could make, by using the Geographical Information System (GIS) to model the transportation networks (sidewalks, public transport network, and the planned elevated train) for two scenarios, first for the current public transport network and second for the long-term situation of the adding of the planned train, furthermore, to find the coverage area for each station and determine the population can be served for each station depending on the census of the zones for the year 2020. The modeled network databases were used to create the closest facility between the centroid of the 43 zones and the selected facilities (Commercial, Educational, Governmental, and Hospitals). The results revealed that the additional service of the train reduced the travel time between Al-Sadr City to four destinations selected for the mentioned facilities by the following percentages (62%, 40%, 46%, and 65%) respectively. Moreover, the population coverage stated that stations 8, 9, and 10 are the most populated.

Keywords: *Accessibility, Public Transport, GIS, Elevated Train.*

1. Introduction

Accessibility can be defined as an easement or people's ability to use services and to reach their destinations for different opportunities (goods, services, activities, and facilities) or as Baradaran & Ramjerdi define it the connectivity state [1,2]. The traffic congestion phenomenon is a reflection of the people who prefer to use private cars as an essential mode of transport to destination [3], which is noted in Baghdad city as large numbers of individuals prefer the private auto and lately, it mostly becomes the main mode used. Also, the public transport service suffers from a lack of infrastructure, which in turn leads to increase travel time and the cost of operating vehicles, and many other adverse effects which all lead to a decrease the accessibility in the city [4]. A study in London showed that the accessibility by using private autos is the least cost mode, however, the other planned public transport modes can effectively reduce the cost and provide more sustainable transport alternatives [5]. Others took the effect of energy efficiency into considerations which in turn showed that public transport would achieve sustainable transport more than private transport [6]. As a global issue, many authors were interested in study accessibility in many aspects and it all started with Hansen, who made an empirical study depending on the gravity model presents an operational definition, and

*Corresponding Author: edma008@uomustansiriyah.edu.iq

proposes a method to measure the accessibility patterns within metropolitan areas [7]. The accessibility measurement to various services is based on travel time or distance, the access to hospitals is frequently studied based on travel time calculations because it's usually emergency calls [8-11], others cared about studying the accessibility depending on distance especially to shops and cultural facilities [12]. Due to their importance in achieving sustainable less harmful effects on the environment the public transport modes have been widely studied by many researchers [13-19]. Most of the studies were based on GIS platforms to assess the accessibility, as it copes smoothly between the interchanges of the same or different transportation modes [20]. Others used it to measure the potential accessibility by different modes to different destinations [21]. Mavoa et al. measured different accessibility achieved by public transport mode for 17 different destination types [22]. Also, it can be noticed in [23] that the authors used the application in designing a spatiotemporal model to discover the changes could a sustainable transport mode make on the interaction between accessibility and land use before and after installing it. Due to the congested traffic situation in Baghdad city, (Baghdad Elevated Train) is one of the main solutions is to be conducted to overcome this problem, therefore this study aims to evaluate the impacts of this project on the accessibility potentials in this area by examining the time changes between the two situations before and after installing the train.

This paper is organized into six sections, the introduction defines the accessibility and refers to the previous related studies, next to a definition of the study area, then the collected data and the Network building, next to the methodology of the paper, then the illustration of the results, and finally the conclusion of the study.

2. Study Area

The study area is in Baghdad city the capital of Iraq divided by the Tigris river into two sections, containing 43 zones, 26 zones are located in Al-Risafa city and 17 zones located in Al-Karkh city which are surrounding the central line elevated train of 16 km long with 12 stations (see Image 1) the data needed are followed in the next section.

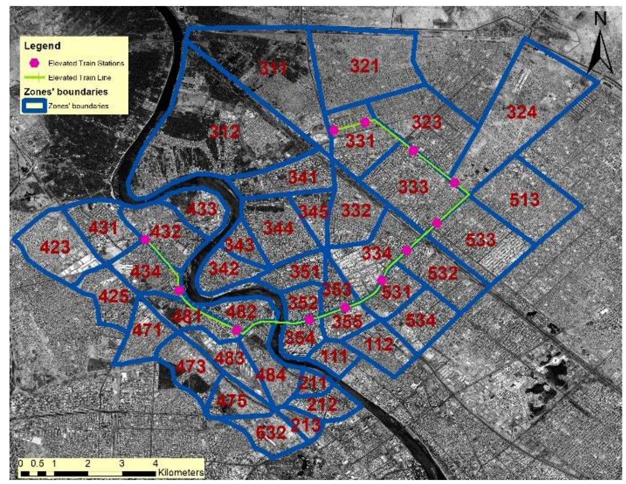


Image 1. The Study Area

3. Data Collection and Network Building

3.1. Data Collection

The public transport network routes in the study area have been collected based on a reconnaissance survey for the public transport vehicles passing through the same direction of the elevated train, and the data concerned each route were surveyed depending on Ride Check Technique (see Fig. A.1), which is a technique that provides all information about passenger volumes through the route, determines the dwell times at each stop station and the running time per route segment [24,25]. Furthermore, characteristics of the public transport vehicle such as speed, time, and direction were collected by using the mobile application (Tracks Pro).

3.2. Network Building

In the context of meeting the objectives of this study, the data collected has been built-in ArcGIS software to accomplish the work as follows:

a- The collected information about the public transit network is used to draw the routes in GIS; since the current public transit in Baghdad doesn't have a uniform distribution of the network stops (it depends on the passengers' demand to stop at their destinations), a 500m interval has been chosen between each stop and a 40 km/hr is chosen as the speed of the Public Transport vehicles, a route model has been created in GIS to connect between these stops' stations by using the network database created by using the main streets network, moreover, Fig.1, shows the poor service of the public transport network in comparison with the streets network in the selected area.

b- The sidewalks network layer is also drawn in ArcGIS Map software, a speed of 4 km/hr was adopted as the walking speed of the pedestrians [19], and by using equation 1 the walking time has been measured,

$$Tw = (Lkm/Vw) * 60 \quad (1)$$

Where T_w is the time of walking in minutes, L_{km} is the length of the road in km, and V_w is the walking speed (4 km/hr).

c- Baghdad elevated train layout, speed (50 km/hr) and stations' locations were provided by the General Company for Iraqi Railways (IRR), (see Fig. 2).

The facilities' locations have been obtained by the author with the GPS instrument, see Figs. (3-6), the methodology is as mentioned in the next section.

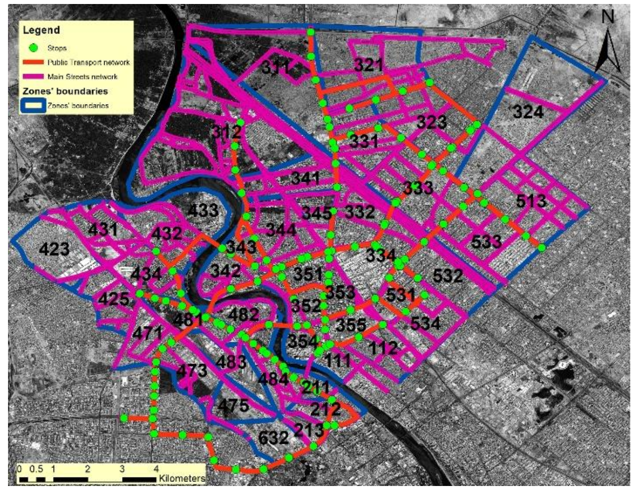


Figure 1. The public transport network in the study area

Figure 2. Baghdad Elevated Train line layout (source: The General Company for Iraqi Railways IRR)

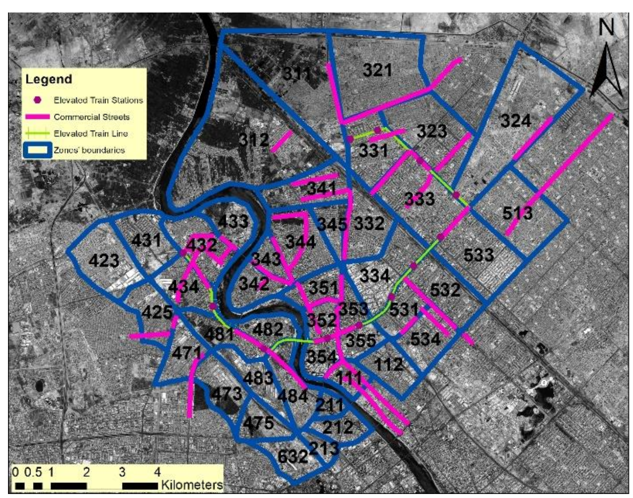


Figure 3. The commercial facilities locations in the study area

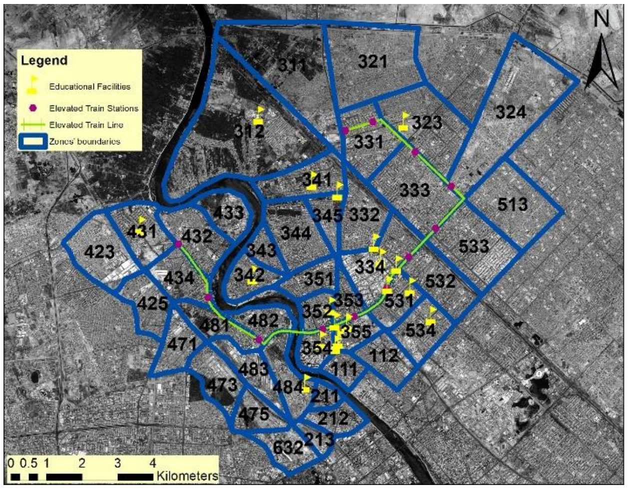


Figure 4. The educational facilities locations in the study area

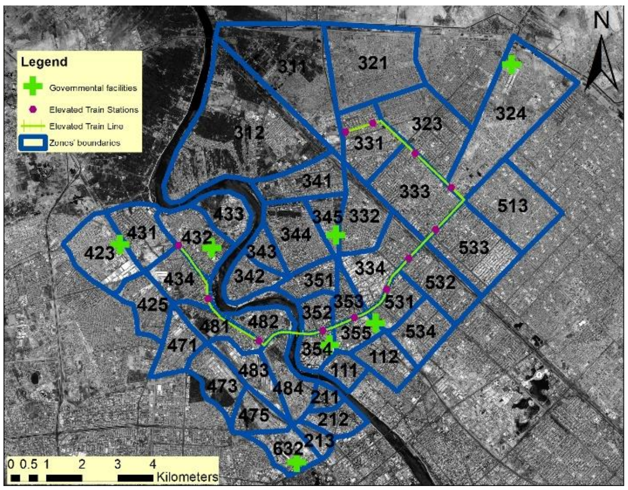


Figure 5. The governmental facilities locations in the study area

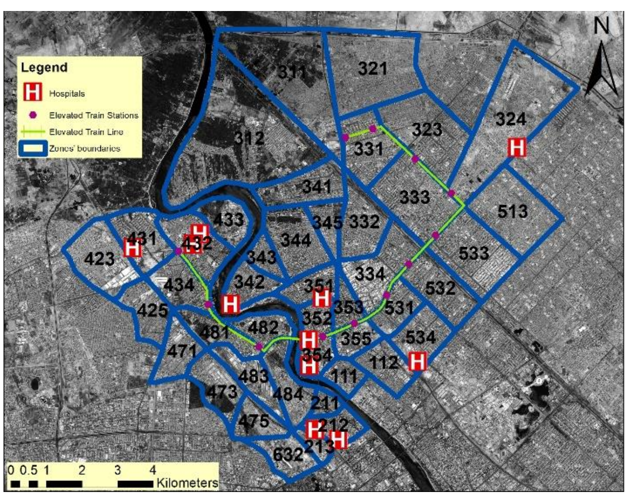


Figure 6. The hospitals' locations in the study area

4. Methodology

The modeling network has been used to measure the accessibility in the area for two scenarios, first one is about the current public transport network and the second one is for the long-term plan of installing the elevated train line.

- ***The travel time difference for the selected zones***

Two zones have been chosen (533 and 513) which are located in (Jamila as a commercial region and Al-Sadr City as one of the most populated regions in the city) respectively, the modeled network has been used to create the closest path from the 43 zones to all facilities in the study area, which are (7 governmental destinations, 40 commercial destinations, 11 hospital destinations, and 19 educational destinations). For each facility 5 locations have been selected to show the impact of the elevated train line on the travel time (this process has been done by using the GIS Technique Closest Facility).

- ***The accessibility measurement***

The created network database has also been used to create the closest path from the centroids of the 43 zone of the study area to each facility to find the accumulated time of walking and using the current PT network for the first scenario and the walking, public transit and the elevated train for the second scenario from the origins to the selected destination; (this process has also been done by using the GIS Technique Closest Facility). To measure the accessibility one facility has been chosen in the area as a destination as follows (Mustansiriyah District, Hay Al-Waziryah, Al- Kadhimiya District, and Hay Ur) for (education, commercial, governmental, and a hospital facility) respectively. The accessibility is measured according to Hansen's equation, as follows:

$$Aj = \sum aj \ * \ f(Cij) \quad (2)$$

Where, (A_j) is the accessibility potential for the people in each origin zone, (aj) is the size of opportunities of destination zone j, and f(c_{ij}) is an impedance function. The larger and the closer opportunities are the more they contribute to accessibility [26].

The impedance function has been found by several methods [27], however, the negative exponential functional method has been used more than the others in many studies [26] and it is to be used in this study, according to equation 3 [18]:

$$As\ f(Cij) \ = \ e - \beta.Cij \quad (3)$$

Where, C_{ij} is the cost of travel between zone i and j (the travel time has been chosen as a travel cost in this study) and β is a parameter stating the sensitivity to travel cost and its value ranges between (0-1), it can change the effect of travel time and determine the weight of activity opportunities, a value of 0.1 has been chosen for β [18].

- ***The coverage of the elevated train stations***

Another network database was created, however, this time the sidewalks layer has been used as an input layer to build it and then calculate the service area that can be provided for 1 km for each station which is considered as the distance that the pedestrians can walk; moreover, this area has been used to assess the population served for each station, results are in the next section.

5. Results

Once all the process completed the following results have been revealed The Tables (1 to 8) show the travel time from the zones in (Jamila and Al-Sadr City) to the selected zones for each case before and after installing the elevated train and show the difference between the two cases for all facilities, i.e., show the impacts of the train on the travel time for each facility. It can be noted that the travel time has been reduced which in turn improves the accessibility between the zones and the selected facilities.

For the Governmental facility Table 1, states that the travel time has been reduced by 14% from Jamila (533) to Bab Al- Muaatham (355), 38% to Al-Hurriyah (423), 25% to Al-Kadhimiya (432), 11% to Bab Al-Muaatham (354), and 30% to Al-Aameryah (632). Table 2, shows the travel time changing from Al-Sadr City (513) to the same zones. As it has been reduced by (36%, 46%, 35%, 30%, and 37%) respectively.

For the Commercial facilities, Table 3, shows the travel time has been reduced from Jamila to Adhamiyah (342) by 54%, 26% to Al-Kadhimiya (432), 27% to (425) Al-Kadhimiya, 51% to Bab Al-Muaatham (354), and 22% to Hay Al-Jumhuriah. The travel time has been reduced from Al-Sadr City to the same zones by (62%, 35%, 33%, 63%, and 37%) respectively, see Table 4.

For the Hospitals in the area the travel time is reduced by 37% from Jamila to Adhamiyah (342), 24% to Al-Kadhimiya (432), 19% to Al-Hurriyah (431), 10% to Haifa Street (212), and 54% to Bab Al-Muaatham (354), see Table 5. Table 6, clarifies that the travel time is reduced by (47%, 33%, 27%, 22%, and 65%) from Al-Sadr City to the same selected zones respectively.

For the Educational facilities, Table 7, states the travel time has been reduced by 3% from Jamila to Bab Al- Muaatham (355), 2% to Bab Al-Muaatham (354), 22% to Al-Hurriyah (431), 9% to Adhamiyah (312), and 27% to Haifa Street (484). Also, the travel time has been reduced by

(27%, 22%, 31%, 22%, and 40%) from Al-Sadr City to the same selected zones, see Table 8.

Figs. (7 to 14) show the accessibility change between the two scenarios from the 43 origins of the study area zones to the selected destination of each facility. It can be seen that the adding of the elevated train has efficiently increased the accessibility of people in the zones of the study area to the desired destinations for different purposes, as the population accessibility has been increased.

Fig. 7 shows the accessibility status for the first case, and Fig.8 shows the accessibility difference after adding the train line. Both represent the commercial destination located in Hay Al-Waziryah (zone 353), which has been increased according to the results showed in Fig. 8 in zones (513, 553, 553 534, 531, etc.).

Figs. 9& 10 illustrate the accessibility situation of the two scenarios for the educational purpose which is located in Al- Mustansiriyah district (zone 531). The accessibility of the people has been increased (see Fig.10) in zones (513, 345, 334, 343, etc.).

For the governmental destination located in Al-Kadhimiya District (zone 432), Figs. 11& 12 show the population accessibility and state the difference between the two cases. As it has been increased in zones like (513, 532, 531, 534, etc.), see Fig.12.

- Finally, the population accessibility has been increased from zones like (311, 343, 342, 111, etc.) to the hospital destination selected located in Hay Ur (zone 324). As the comparison between the two cases is clearly illustrated in Figs. 13 & 14.

Fig. 15, illustrates the coverage area for each station of the elevated train, Table 9 and Fig. 16, clearly show the population served for each station. It’s revealed that stations 8, 9, and 10 are serving more people than the others as they are located in the most populated districts in Baghdad. The conclusion of the study is followed in the next section.

Table 1. The travel time from zone (533) (Minutes) Governmental facilities

Zone No.	T.T Case1	T.T Case2	Difference%
355	74.90	64.18	14
423	186.12	115.27	38
432	171.94	128.23	25
354	95.12	84.43	11
632	230.85	162.29	30

Table 2. The travel time from zone (513) (Minutes) Governmental facilities

Zone No.	T.T Case1	T.T Case2	Difference%
355	96.82	61.82	36
423	208.04	112.92	46
432	193.86	125.87	35
354	117.04	82.07	30
632	252.78	159.93	37

Table 3. The travel time from zone (533) (Minutes) Commercial facilities

Zone No.	T.T Case1	T.T Case2	Difference%
342	136.65	63.28	54
432	171.40	127.69	26
425	264.24	193.40	27
354	86.52	42.72	51
111	107.04	83.06	22

Table 4. The travel time from zone (513) (Minutes) Commercial facilities

Zone No.	T.T Case1	T.T Case2	Difference%
342	158.58	60.92	62
432	193.33	125.33	35
425	286.17	191.04	33
354	108.45	40.36	63
111	128.96	80.70	37

Table 5. The travel time from zone (533) (Minutes) Hospitals

Zone No.	T.T Case1	T.T Case2	Difference%
342	140.93	88.19	37
432	181.61	137.90	24
431	226.82	183.11	19
212	162.43	146.10	10
354	94.72	43.42	54

Table 6. The travel time from zone (513) (Minutes) Hospitals

Zone No.	T.T Case1	T.T Case2	Difference%
342	162.86	85.83	47
432	203.54	135.54	33
431	248.74	180.75	27
212	184.36	143.74	22
354	116.64	41.06	65

Table 7. The travel time from zone (533) (Minutes) Educational facilities

Zone No.	T.T Case1	T.T Case2	Difference%
355	78.93	76.44	3
354	94.97	93.39	2
431	196.61	152.90	22
312	147.49	134.48	9
484	118.27	86.49	27

Table 8. The travel time from zone (513) (Minutes) Educational facilities

Zone No.	T.T Case1	T.T Case2	Difference%
355	100.85	74.08	27
354	116.89	91.03	22
431	218.54	150.54	31
312	169.41	132.12	22
484	140.20	84.13	40

Table 9. The population can be served for each elevated train station

Station No.	Population	Station No.	Population
Station #1	260876	Station #7	408424
Station #2	282498	Station #8	526821
Station #3	161060	Station #9	738153
Station #4	209992	Station #10	432520
Station #5	109431	Station #11	327252
Station #6	164337	Station #12	370610

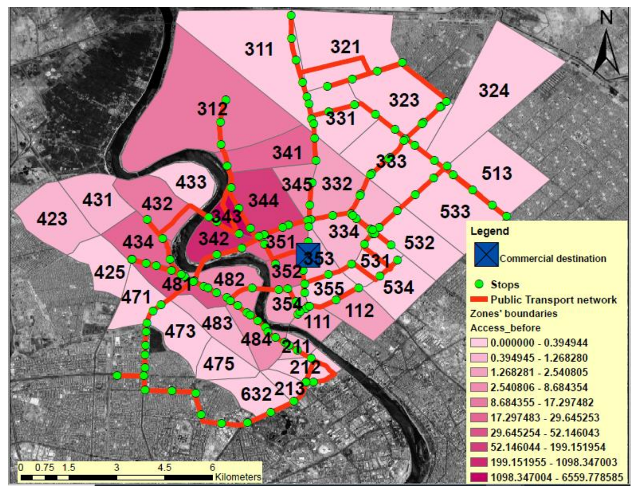


Figure 7. The accessibility to the commercial destination for the first scenario

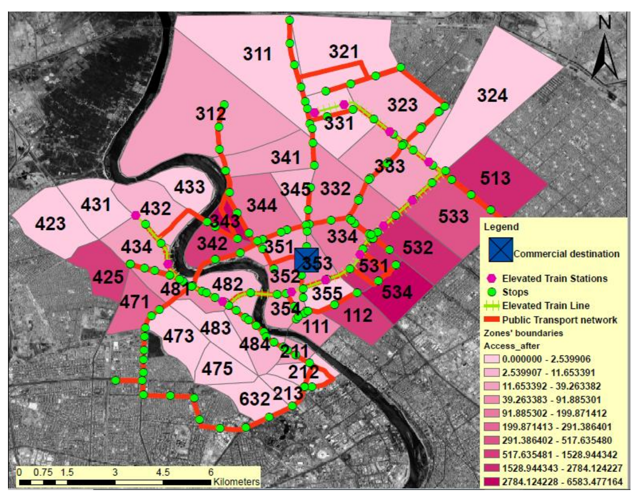


Figure 8. The accessibility to the commercial destination for the second scenario

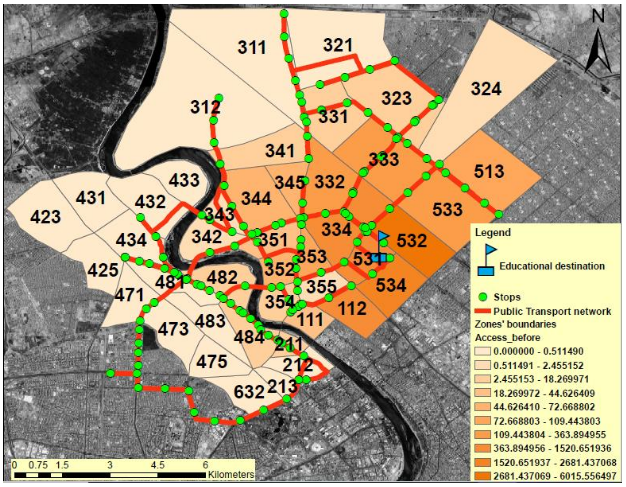


Figure 9. The accessibility to the educational destination for the first scenario

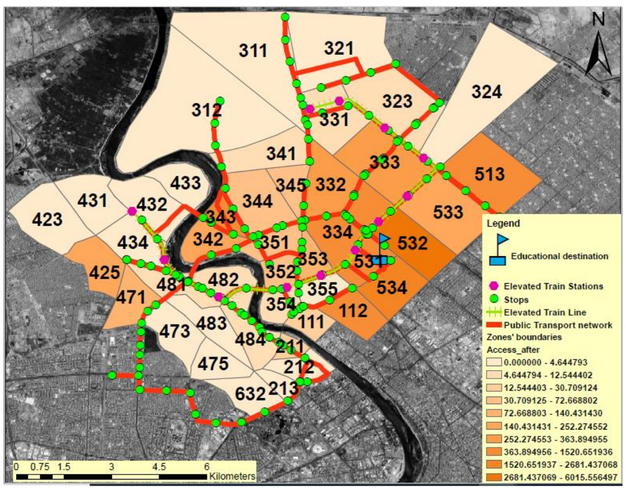


Figure 10. The accessibility to the educational destination for the second scenario

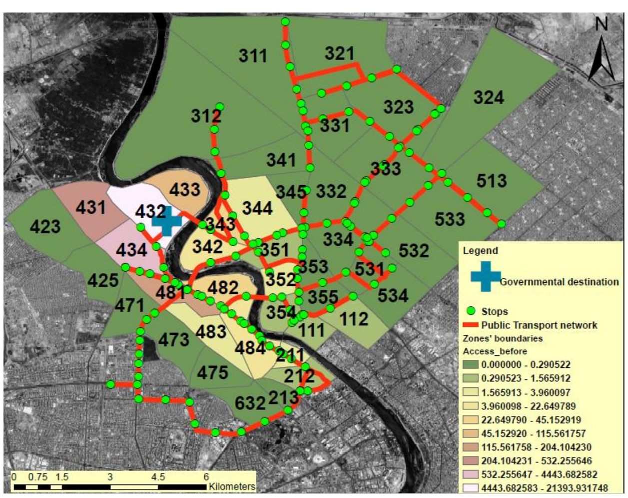


Figure 11. The accessibility to the governmental destination for the first scenario

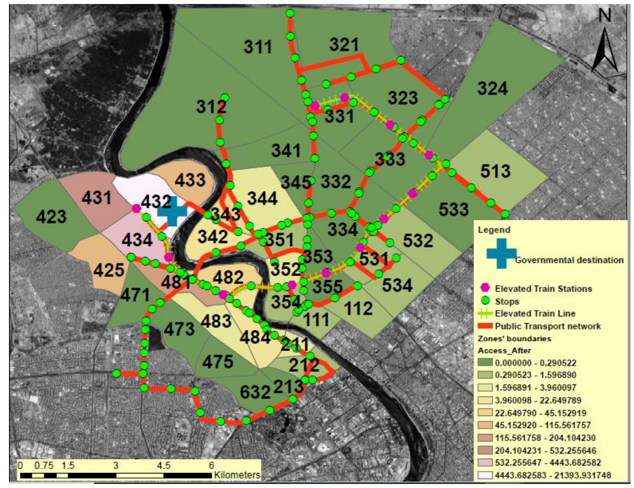


Figure 12. The accessibility to the governmental destination for the second scenario

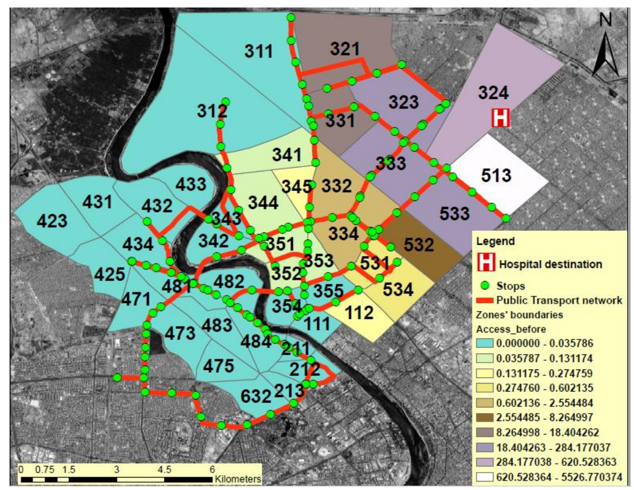


Figure 13. The accessibility to the hospital destination for the first scenario

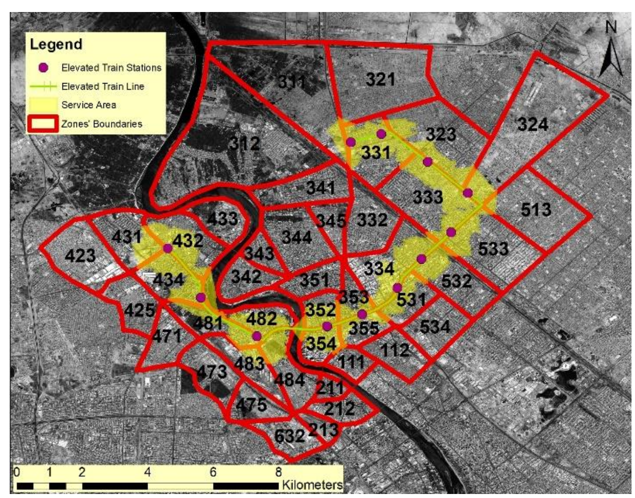


Figure 14. The accessibility to the hospital destination for the second scenario

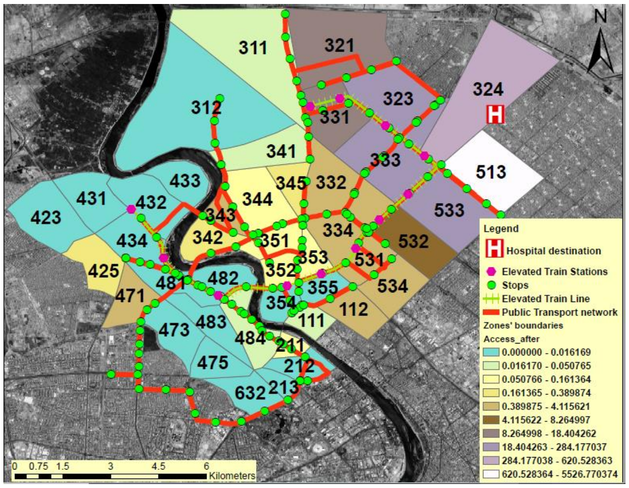


Figure 15. The coverage of each station of the elevated train

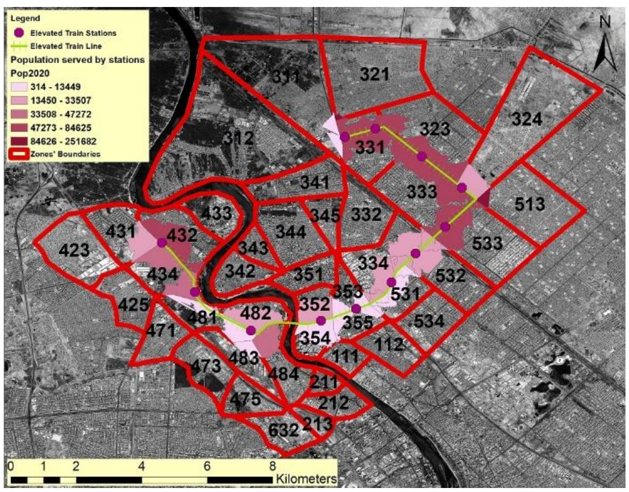


Figure 16. Population served for each station of the elevated train

6. Conclusion

Referring to the objectives of this study the results showed that the intended project of the elevated train has reduced the travel time between (Jamila and Al-Sadr City) to the selected zones as mentioned above, which in turn improves the accessibility. Also, it can be noted the planned train enhances the population accessibility from different zones in the study area to the selected destinations for different purposes (education, commercial, governmental, and a hospital). Furthermore, the elevated train stations are to be located to serve populated regions in the capital Baghdad. Such as Sadr City, Jamila, and Al-Shaab. Stations No.1 and 2 are located in Al- Kadhimiya district which is considered as one of the most important districts in Al-Karkh city as it contains a commercial center, religious tourism, educational and governmental institutions, thus, this station will serve different travel purposes of passengers.

Acknowledgment

Thanks go to the highway and transportation department, college of engineering, Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad – Iraq, for the support to implement the research.

Conflict of interest

The authors declare no conflict of interest in publication of this research.

Abbreviations

T. T	Travel Time
PT	Public Transport

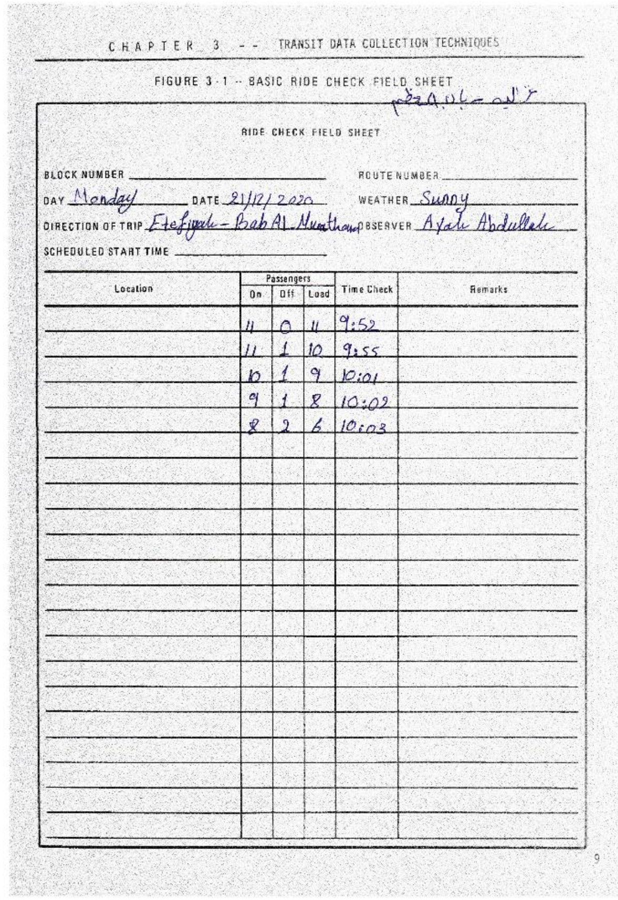
7. References

1. Litman, T. (2003). *Measuring Transportation: Traffic, Mobility and Accessibility*. ITE Journal, 73, 28-32.
2. Baradaran, S. & ramjerdi, F. (2001). *Performance of accessibility measures in Europe*. Journal of Transportation Statistics, 4, 31-48.
3. Christodoulou, A. and Christidis, P. (2020). *Evaluating congestion in urban areas: The case of Seville*. J Transp Geogr.
4. Asmael, N. M. and Alkawaaz, N. G. (2019). *The Influence Change of Private Car Ownership on Patterns of Mode Choice in Baghdad city*. IOP Conf. Series: Materials Science and Engineering 518, 022025.

5. Ford, A. C, Barr, S. L., Dawson, R. J., James P., (2015). *Accessibility Analysis Using GIS: Assessing Sustainable Transport in London.* J. Geo-Inf., 4, pp. 124-149.
6. Kwok, R. C. W., Yeh, A. G. O., (2004). *The use of modal accessibility gap as an indicator for sustainable transport development.* Environment and Planning A, 36, pp. 921- 936.
7. Hansen, WG (1959). *How accessibility shape land use.* J Am Inst Plann. 25, pp.73-76.
8. McGrail, M. R. (2012). *Spatial accessibility of primary health care utilising the two step floating catchment area method: An assessment of recent improvements.* International Journal of Health Geographics 11, 50.
9. Nicholl, J., West, J., Goodacre, S., & Turner, J., (2007). *The relationship between distance to hospital and patient mortality in emergencies: An observational study*. Emergency Medicine Journal, 249, pp. 665‑668.
10. Pilkington, H., Prunet, C., Blondel, B., Charreire, H., Combier, E., Le Vaillant, M., Amat-Roze, J. M., and Zeitlin, J (2017). *Travel time to hospital for childbirth: Comparing calculated versus reported travel times in France.* Maternal and Child Health Journal.
11. Ahmed, S., Adams, A. M., Islam R., Hasan, S. M., and Panciera, R. (2017). *Impact of traffic variability on geographic accessibility to 24/7 emergency healthcare for the urban poor: A GIS study in Dhaka, Bangladesh.* PLoS One, 14(9), Article e0222488.
12. Ghosh-Dastidar, B., et al. (2014) *Distance to store, food prices, and obesity in urban food deserts*. American Journal of Preventive Medicine 475, pp. 587‑595.
13. Litman, T. (2003). *Integrating public health objectives in transportation decision making* Am J Health Promot 18, pp. 103-108.
14. Fuglsang, M., Hansen, H. S. and Münier, B. (2011). *Accessibility Analysis and Modelling in Public Transport Networks – A Raster Based Approach.* LNCS 6782, pp. 207-224
15. Jun, C., Kwon, J. H., Choi, Y. and Lee, I. (2007) *An Alternative Measure of Public Transport Accessibility Based on Space Syntax.* LNAI 4413, pp. 281-291.
16. Wu, B. and Hine, J. (2003). *A PTAL approach to measuring changes in bus service accessibility*. Transport Policy 10, pp. 307-320.
17. Yigitcanlar, T., Sipe, N., Evansr, E. and Pitot, M. (2007). *A GIS-based land use and public transport accessibility indexing model*. Australian Planner 44, pp. 30-37.
18. Karou, S. and Hull, A. (2014). *Accessibility modelling: predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh.* UK. J Transp Geogr 35, pp. 1-11
19. Bilek, M. and Amireche, L. (2017). *GIS-Based Prediction of Metro-Line Impact on Accessibility in Public Transport by Modelling Travel Time: A Case Study of North-Western Zone of Algiers, Algeria.* J Remote Sensing & GIS, 6, PP. 2469-4134.
20. O'sullivan, D., Morrison, A. and Shearer, J., (2000). *Using desktop GIS for the investigation of accessibility by public transport: an isochrone approach.* Int. j. Geogr. Info. science, 14, No. 1, pp. 85-104.

21. Liu, S. and Zhu, X. (2004). *An integrated GIS approach to accessibility analysis*. Trans. GIS 8, pp. 45- 62.
22. Mavoa, S., Witten, K., Mccreanor, T. and O'sullivan, D. (2012). *GIS based destination accessibility via public transit and walking in Auckland, New Zealand.* J Transp Geogr 20, pp. 15-22.
23. Demirel, H., Korkutan, M., Shoman, W. and Alganci, U. (2017). *Geographic Information System (GIS) based accessibility analysis for highway transportation.* Sigma J Eng & Nat Sci 8 (4), pp. 339-344
24. UMTA (1985). *Review of Transit Data Collection Techniques.* Office of Methods and Support Urban Mass Transportation Administration, Washington, D.C. 20590. chapter 3 pp. 7
25. Asmael, N. and Waheed, M (2018). *Demand estimation of bus as a public transport based on gravity model.* MATEC Web of Conf. Vol. 162, pp. 01038 EDP Sciences
26. Handy, S. L. and Niemeier, D. A. (1997). *Measuring accessibility: an exploration of issues and alternatives.* Environ. Plan. A 29, pp. 1175-1194
27. Geurs, K. T. & Ritsema van Eck, J. R. (2001) *Accessibility measures: Review and applications, Evaluation of accessibility impacts of land use transport scenarios, and related social and economic impacts*. Rivm, Utrecht university.

Appendix – A



CHAPTER 3 -- TRANSIT DATA COLLECTION TECHNIQUES

FIGURE 3-1 -- BASIC RIDE CHECK FIELD SHEET

RIDE CHECK FIELD SHEET

BLOCK NUMBER ________ ROUTE NUMBER ________

DAY Monday DATE 21/12/2020 WEATHER Sunny

DIRECTION OF TRIP Etefiyah – Bab Al-Muatham OBSERVER Ayah Abdullah

SCHEDULED START TIME ________

Location	Passengers			Time Check	Remarks
	On	Off	Load		
	11	0	11	9:52	
	11	1	10	9:55	
	10	1	9	10:01	
	9	1	8	10:02	
	8	2	6	10:03	

9

Figure A.1. Ride Check field sheet