Journal of Engineering and Sustainable Development
http://jeasd.uomustansiriyah.edu.iq/index.php
https://doi.org/10.31272/jeasd.25.5.1

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

TRAVEL TIME RELIABILITY INDICES FOR URBAN ROUTES IN BAGHDAD CITY

***Estabraq F. Alattar[1]** **Zainab A. alkaissi[1]** **Ali J. Kadem[1]**

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

Received 4/1/2021 ***Accepted in revised form 3/3/2021*** ***Published 1/9/2021***

Abstract: Reliability is one of the main metrics of transport system efficiency and quality of service. For both travelers and transport management organizations, the high variance of road travel times has become a problem. Reliability has been identified as one of the main areas of interest of the Strategic Highway Research Plan II. In order to evaluate congestion and unexpected changes in travel time, reliability metrics are increasingly used. GPS devices provide for exact assessment of travel time for each connection along the routes used for this research. (14 Ramadan arterial street, Al-Karada arterial street and Damascus arterial street). A GPS-equipped instrumented car was used to gather 50 test runs at peak and off peak times. At peak and off peak hours, 50 test runs were obtained using a GPS-equipped instrumented car. Raising the buffer time index results in inferior conditions for reliability. A buffer index of AL- Karada street was created about 53% and 30% for Damascus street and finally for 14 Ramadan street which present a 29% buffer index for north direction. As for its southern direction 14 Ramadan street created a buffer index of about 65% and 33% for AL- Karada street and finally for Damascus street which present a 29% buffer index. In addition, travel time index for (14 Ramadan street, AL-Karada street and Damascus street) respectively is about 2.8 %, 3.3% and 2.6% for north direction, as for its southern direction the travel time index is obtained for (14 Ramadan street, AL- Karada street and Damascus street) respectively were a 3%,3.7%, and 2.5%. Finally, the 95% percentile travel time for observed three selected routes in this study, the extra delay was felt on each route (1627, 2212, and 1192) sec. for (14 Ramadan street, AL- Karada street and Damascus street) for north direction, as for its southern direction the extra delay that perceived on each route (2221, 2132, and 975) sec. for (14 Ramadan street, AL- Karada street and Damascus street) respectively.

Keywords: *Reliability, travel time index, buffer index, 95% percentile travel time, Manufactured device GPS, travel time*

1. Introduction

The urban arterial time was a significant element in calculating the transport infrastructure in the urban city. [1]. Travel Time Efficiency is one of the success indicators when evaluating a facilities, a road corridor, or a road segment. Measures like on-time performance or % failure can be used to assess the number of trips that fail or excel in meeting a pre-determined performance standard, which might be expressed based on a target minimum speed or travel duration.Drivers are normally aware of and prepared for everyday congestion, but unexpected congestion caused by unforeseen events such as changes in demand, weather, accidents, work zones, and special events is usually unforeseeable. [13]. The reliability of travel time is important for many users of the transport system, whether they be truck drivers, transit passengers, cargo shippers, or even air travelers. Personal and

**Corresponding Author*: estabraq.alattar@yahoo.com

business travelers value reliability because it helps them use their time appropriately. Since reliability is so important for users of the transport system, transport planners and decision-makers should regard travel time reliability as a key predictor of quality. The value of travel time efficiency is known by traffic experts as it better quantifies the advantages of traffic control and operating practices than simple averages. [8]. In assessing congestion and unpredictable variations in travel time, reliability measures are increasingly used. [11]. The 95th travel time percentile and the Buffer Index (BI) and Preparation Time Index (PTI) were known as travel time reliability performance metrics. The basis for the development of these indexes is the distribution of travel time and an analytical methodology. Journey time reliable analysis is necessary explain why there is a difference in travel time and aid in transportation system administration. [3]. Over there several previous studies on travel time reliability analysis and predicted modeling are illustrated in table (1). Nowadays using a satellite navigation system such as GPS technique (Global Positioning System) is considered the most advanced and accurate method to calculate the travel time. The United States Air Force has been developed this navigation system in cooperation with the United States Government and became an internationally used system. This system provides a GPS receiver with the geographical location and time information anywhere on or near Earth. The US launched the GPS project. Defense Department for US Military Use in 1973. It became fully operational in 1995, though only 24 satellites were used. [7]. The use of GIS has made significant progress in forecasting future road conditions, allowing road engineers and authorities to work together on plans [2].

Table 1. Summary of earlier studies on the analysis of Travel Time Reliability and predicted modeling

Author (Year)	Study Area	Reliability measures	Modeling predicted or travel time distribution
Schroeder et al.(2013)[14]	Durham	Travel time index	FREEVAL HCM model
Hojati et al. (2016)[9]	Queensland, Australia	Extra buffer time index	Tobit model
Wang et al. (2017)[15]	Seattle, WA, US	Coefficient of variation	Maximum likelihood method; K-means analysis
Alkaissi, Z. A. (2017)[1]	Iraq, Baghdad	buffer time index, Travel time index, 95th percentile travel time	Travel Time Prediction
Chen et al. (2018)[6]	Beijing, China	Coefficient of variation, buffer time index	Weibull, exponential, lognormal, and normal distribution testing
Chen, Z., & Fan, W. (2019)[4]	North Carolina at Charlotte, United States	Planning time index	A time series model
Chen, Z., & Fan, W. D.(2020)[5]	North Carolina at Charlotte, United States	planning time index	Weibull, Gamma, Burr and Lognormal testing

2. Methodology

The purpose of this study is to predict over-all trip time for each link of the three selected arterial streets of Baghdad, these three roads are essential roadways in Baghdad, linking the CBD with important commercial, industry, and elevated residential areas. They're also a common alternative to driving on the highway. The dramatic shift creates future strain on the development and attraction of daily trips. Buffer index, buffer time, and 95 percentile trip time are some of the most reliable indicators, were

estimated. In order to ensure that 95% arrive on time at the end trip of the track, the buffer index reflects the additional buffer time that most passengers apply to their average travel time while planning trips. This additional time is added for any unforeseen delay to account for [8]. The research of journey times reliable can aid in the understanding of travel time disparities and the development of transportation systems. The 80th or 85th or other percentiles may also become the basics of researchers. The SHRP 2 suggested the use of 80-percent travel times in place of the 95-percentile trip, as it considered activities leading towards the 80th percentile journey time to be more normal events and more likely to be more typical events that are more likely to be influenced by organizational initiatives such as transportation infrastructure development [13]. The main goals are:

- Estimation of travel time for each link of the three selected major arterial streets in Baghdad city (14 Ramadan arterial street, Al-Karada arterial street, and Damascus arterial street). using a test-car technique of a GPS device.

- Estimation of total travel time of the three selected major arterial streets in Baghdad city (14 Ramadan arterial street, Al-Karada arterial street, and Damascus arterial street). using a test-car technique of a GPS device.
- The free flow velocity of each link was measured by driving the vehicle under free-flow conditions to obtain the most accurate measurement. Also, the free flow velocity should not exceed the velocity limit. And by the free flow velocity and the length of each link, the free flow time was calculated.
- Estimated the reliability indices for the three major arterials (14 Ramadan arterial street, Al-Karada arterial street, and Damascus arterial street) and for each link in these routs: Buffer time index, travel time index, and 95% percentile travel time.

3. Study Area

Within Baghdad's central business district, there are three arterial urban streets in the study area. The central business district (CBD) is connected to the main industrial, commercial and high-density residential areas by these roads. They also serve as the common alternatives to motorway routes. The three selected arterials were classified based on the comprehensive study classification of the city of Baghdad (Scott Wilson Kirkpatrick & partners) obtained from the Amanat al Assima-Design Department, a section as shown in figure (1) below, and the streets were classified as follows:

- Path number 1: 14 Ramadan street: Principal Distributor TSO1
- Path number 2: Al-Karada street: Principal Distributor TSO1
- Path number 3: Damascus street: Principal Distributor TSO1

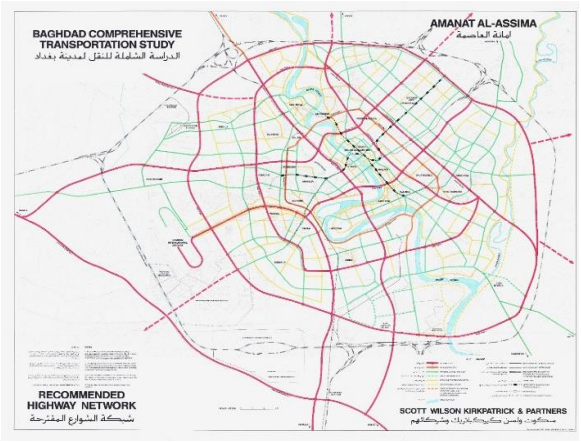

Figure 1. Map of Baghdad Roads (Amanat AL-Assima)

- Route number1: 14 Ramadan road is one of Baghdad's most significant arterial roads. The majority of the surrounding regions are made up of different Land-use combinations, including residential and

commercial sectors, as well as a bus corridor that connects two important places, Mansour and Adhamiya, that start from Dhari square to Arab Auctioneer square. The first is in the direction (north direction) of Arab Auctioneer square and the second is in the direction (south direction) of Dhari square. That is located northwest of the Iraqi capital, there are four lanes in each direction (North and South) and two lanes for each direction. For two directions, the route length is (7.926 km). The sample size that was taken for his street was one hundred runs in total. Divided into fifty runs for each direction. The route consists of six links and also consists of nine intersections for the north and south directions as shown in figure (2). The maps are based on the (WGS) 1984 datum and map projection zone 38 north of (UTM) map. Street lengths were calculated using data from the GPS device installed in the vehicle.

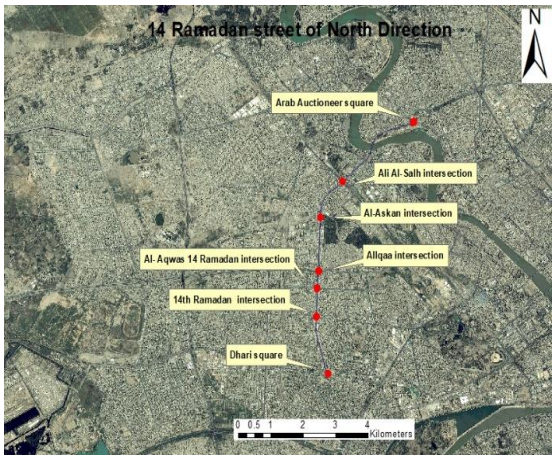

Figure 2. The Selected Intersections Along 14 Ramadan Street (Urban Arterial)

- Route number 2: Al-Karada road is one of the most significant major arterial roads in the governorate of Baghdad. An extremely changeable path where policeman manage the majority of the traffic rather than traffic signals, with a bus corridor, including along the road. It joins two dynamic areas, which start (from the Baghdad University to Mohamed al-Qasim intersection). That is located east of the capital, there were four lanes in all, two in each direction. For two directions, the route length is (7.213 km), there are eight connections in this route, and also consist of nine intersections for the north and south direction as shown in figure (3).

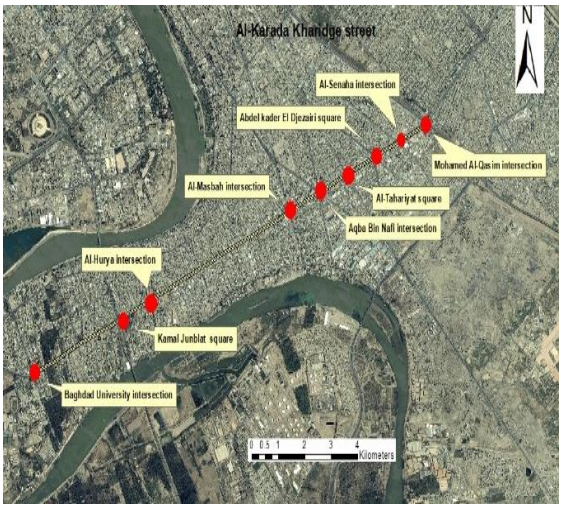

Figure 3. The Selected Intersections Along Al-Karada Street (Urban Arterial)

- Route number 3: Damascus road is one of the most significant arterial roads in the city of Baghdad, the areas surrounding the street have a various land uses; commercial, residential, and high-intensity for the pedestrians, especially in the northern and southern Al-Allawi garage, as the specified street joins two dynamic areas amid Al-Yarmuk and Bab Al-Muadham starting from the Eagles square to Talaea intersection. It is located southeast of the Iraqi capital; there are four lanes in all, two in each direction. For the north direction the route length is (6.350 km) with seven intersections, and consists of six links as shown in figure (4). For the south direction, the route length is (5.470 km) with six intersections and also consists of five links. as shown in figure (5).

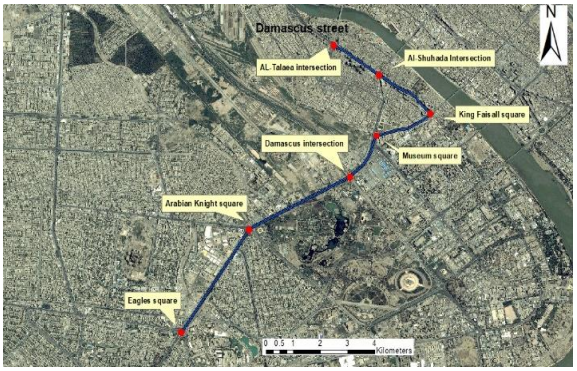

Figure 4. Damascus Street (Urban Arterial) with the Selected intersections for North Direction

Figure 5. Damascus Street (Urban Arterial) with the Selected intersections for South Direction

4. Data Collection and Application

For a selected three arterial streets, the field data is collected (14 Ramadan arterial street, Al-Karada arterial street, and Damascus arterial street). So that the period of is continued for six months from October 2019 to March 2020 at the peak and off-peak of the morning and evening periods. During the good weather, all of the needed data was obtained, because adverse weather circumstances may reason variation in the normal traffic flow. The device (TELTONIKA GPS, wenk 122), as shown in figure (6), is a locally produced GPS comprising of a GPS unit and a controlling key linked to the device through a wire., was used for data measurements in this research. The established methodology used is based on the use of GPS technology and vehicle testing. As the vehicle starts, the data collection equipment is turned on and off. Because the technique of this study necessitates capturing the starting and ending spots for each link in the specified route to measure the travel time that the car spends in each link, the control button provides a way for the user to operate the device, as well as taking the starting and ending points of the route to measure the total time the car spends in This route. The GPS device utilized in this research is shown in Figure (6), and the data received contains the date, position, velocity, and measurement time. The length of the tracks was computed using GPS coordinates. Free flow velocity was obtained from field measurement during free-flow conditions for each of the identified arterial streets.

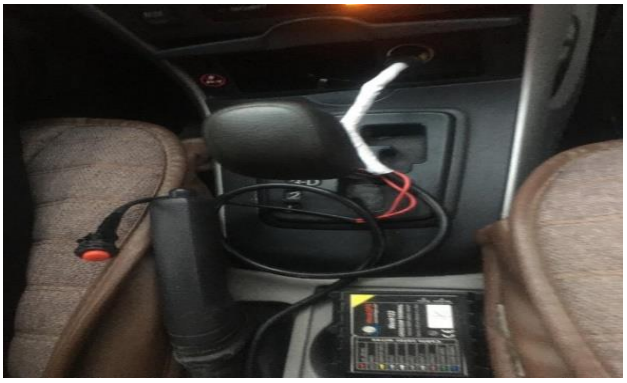

Figure 6. The Manufactured Device GPS

5. Reliability Measurement

5.1. Reliability Measurement for 14 Ramadan Street

Buffer time index measure is explained as [4]:

$$\textbf{Buffer Index (\%)} = \frac{95th\ percentile\ travel\ time - Average\ travel\ time\ (\text{sec})}{Average\ travel\ time\ (\text{sec})} \quad (1)$$

The buffer time index is expressed as a percentage and its value increases as reliability get worse. This demonstrated that the reliability of travel time was worse with a higher percentage of buffer time for links (5,3,4,6,1, and 2) respectively for the north direction, also for the south direction that the reliability gets worst for (6,2,1,4,3, and 5) as shown in tables

(2) & (3). The buffer indicates reflects the extra buffer time that most passengers apply to their average travel time to guarantee ensure arrival while planning trips. This additional time is added to account for any unforeseen delay. So it will be a buffer time (355, 160, 158, 188, 198, and 104) sec, for links (from 1 to 8) respectively for north direction, also for the south direction it will be a buffer time (440,287,335,68,151, and 80) sec, it is obtained for each link based on the average travel time. To ensure that 95% arrive at the end trip of the track on time, for a link (from 1 to 6), that means the buffer time index shown in figure 7 (a) and 7 (b) is added to the average travel time for each link.

Table 2. Measurement of Links Reliability Along 14 Ramadan Street (North Direction)

Reliability Measurement			
Links of 14 Ramadan street	Buffer Time Index (%)	Travel Time Index (%)	95% Percentile Travel Time (sec)
Link. 1	76 %	2.9 %	457 sec
Link. 2	72 %	3.3 %	248 sec
Link. 3	98 %	6.4 %	322 sec
Link. 4	89 %	2.1 %	336 sec
Link. 5	138 %	3.5 %	612 sec
Link. 6	81 %	2.1 %	419 sec

Table 3. Measurement of Links Reliability Along 14 Ramadan Street (South Direction)

Reliability Measurement			
95% Percentile Travel Time (sec)	Travel Time Index (%)	Buffer Time Index (%)	Links of 14 Ramadan street
666 sec	3.1 %	101 %	Link. 1
526 sec	3.3 %	120 %	Link. 2
401 sec	3 %	60 %	Link. 3
160 sec	3.6 %	74 %	Link. 4
220 sec	3.2 %	57 %	Link. 5
697 sec	2.8 %	172 %	Link. 6

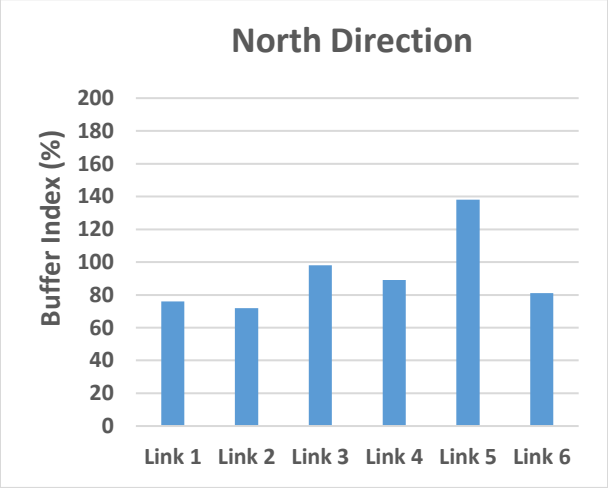

Figure 7 (a). Buffer Time Index for Links (from 1 to 6)

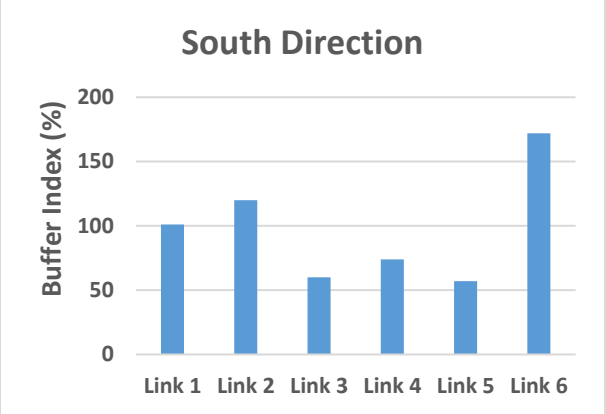

Figure 7 (b). Buffer Time Index for Links (from 1 to 6).

Travel time index measure is explained as [12]:

$$\textbf{Travel Time Index (\%)} = \frac{\textit{Average Travel Time}}{\textit{Free Flow Time}} \quad (2)$$

The travel time index, compromises the average additional time required during peak time than periods of free time. The additional time is applied to the free travel time to achieve the necessary average travel time to traverse the listed links during the peak period, as illustrated in figure 8 (a) and 8 (b). travel time index value for Links (from 1 to 6) is shown in tables (2) & (3) for both directions (north and south) direction. Rising the index of travel time more than 1.0, meaning that it takes about a longer travel time (290, 330, 640, 210, 350, and 210) that free travel time of the corridor for north

direction and (310, 330, 300, 360, 320, and 280) for south direction with the higher travel time index for Link (3) for north directions and link (4) for south direction. This means that a higher travel time index extremely congested conditions, which means worse reliability.

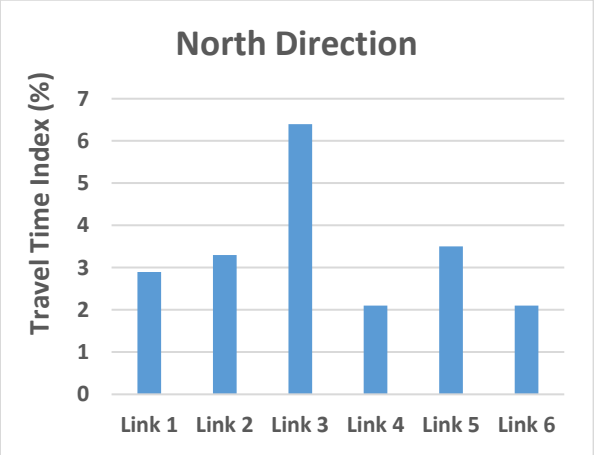

Figure 8 (a). Travel Time Index Results for Links (from 1to 6)

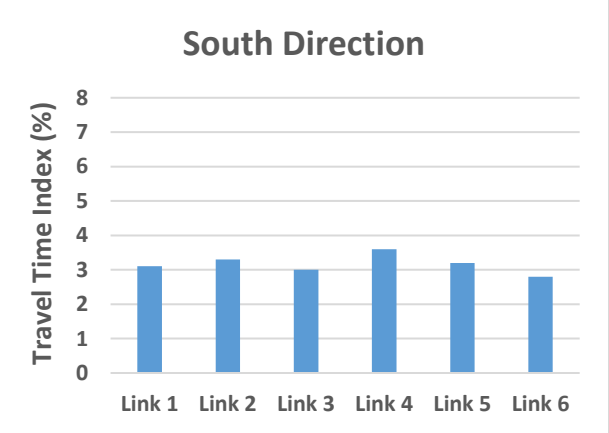

Figure 8 (b). Travel Time Index Results for Links (from 1to 6)

This 95 percent travel time metric is used to calculate very long travel times, calculating the time that travelers need to plan in order to reach the expected arrival time. It is sometimes named time for planning. The National Cooperative Highway Research Program (NCHRP) suggests it as the easiest travel time efficiency measure [10]. Figures 9 (a) and 9 (b) indicate the 95% percentile travel time that poses the extra delay perceived on each link as shown in tables (2) & (3) for both directions (north and south) direction. The link (5) of north direction and link (6) of south direction had the maximum 95 percent travel time values.

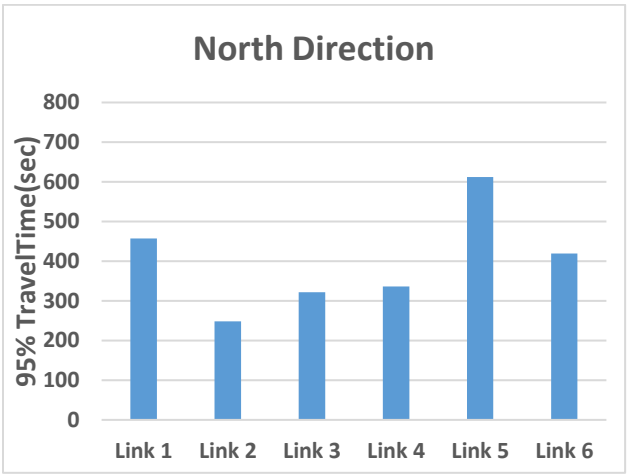

Figure 9 (a). 95% Travel Time Results for Links (from 1to 6)

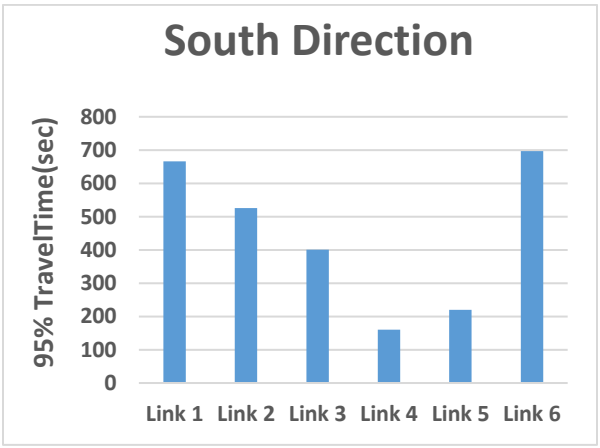

Figure 9 (b). 95% Travel Time Results for Links (from 1to 6)

5.2. Reliability Measurement for AL-Karada Street

Buffer time index measure is explained as shown in equation (1). Figures 10 (a) and (b) demonstrates the reliability measure of the buffer index from link (1) to (8) for AL-Karada arterial street. These indicated that the reliability of travel time was worse the higher the percentage of the link buffer time indicator for

links (1,4,7,5,8,2,6, and 3) respectively for north direction, also for a south direction that the reliability gets worst for (8,4,7,6,2,5,1 and 3) as shown in tables (4) & (5). The buffer index reflects the added buffer time that most passengers apply to their mean travel time to guarantee safeguard arrival while planning trips. This additional time is included to accommodate for any unforeseen delay. So it will be a buffer time of (448,83,192,182,59,35,55,46) sec, for links (from 1 to 8) respectively for north direction, also for the south direction it will be a buffer time of (24,54,6,250,80,244,54,217) sec, it is obtained for each link on the basis of the mean travel time to safeguard that 95% arrive at the end trip of the track on time, for a link (from 1 to 8), that means the buffer time index is added to the average travel time for each link.

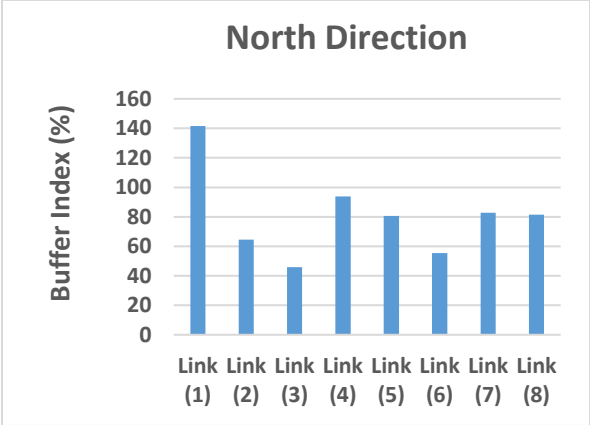

Figure 10 (a). Buffer Time Index for Links (from 1 to 8)

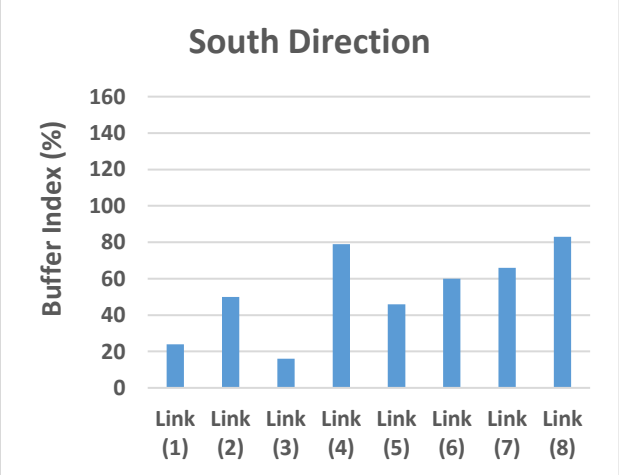

Figure 10 (b). Buffer Time Index for Links (from 1 to 8)

Table 4. Measurement of Links Reliability Along AL-Karada Street (North Direction)

Reliability Measurement			
Links of AL-Karada Kharidge Street	Buffer Time Index (%)	Travel Time Index (%)	95% Percentile Travel Time (sec)
Link 1	142 %	3.5 %	763 sec
Link 2	65 %	4.2 %	211 sec
Link 3	46 %	2.8 %	610 sec
Link 4	94 %	6.1 %	375 sec
Link 5	81 %	2.7 %	132 sec
Link 6	55 %	2.7 %	100 sec
Link 7	83 %	3.2 %	121 sec
Link 8	81 %	2.1 %	104 sec
Route	53 %	16 %	2212 sec

Table 5. Measurement of Links Reliability Along AL-Karada Street (south Direction)

Reliability Measurement			
Links of AL-Karada Street	Buffer Time Index (%)	Travel Time Index (%)	95% Percentile Travel Time (sec)
Link 1	24 %	3.6 %	126 sec
Link 2	50 %	5.3 %	162 sec
Link 3	16 %	1.7 %	47 sec
Link 4	79 %	11.7 %	566 sec
Link 5	46 %	5.5 %	255 sec
Link 6	60 %	2.7 %	651 sec
Link 7	66 %	2.7 %	136 sec
Link 8	83 %	2.9 %	480 sec
Route	33 %	37 %	2132 sec

Figure 11(a) and 11 (b) indicates the 95% percentile travel time that poses the extra delay perceived on each link as shown in table (4) & (5) for both directions (north and south) direction. Link (1) in the north direction and link (6) in the south direction had the maximum 95 percent travel time values.

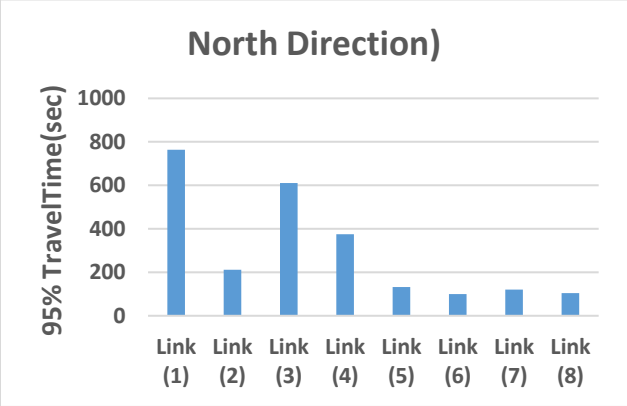

Figure 11 (a). 95% Percentile Travel Time Results for Links (from 1 to 8)

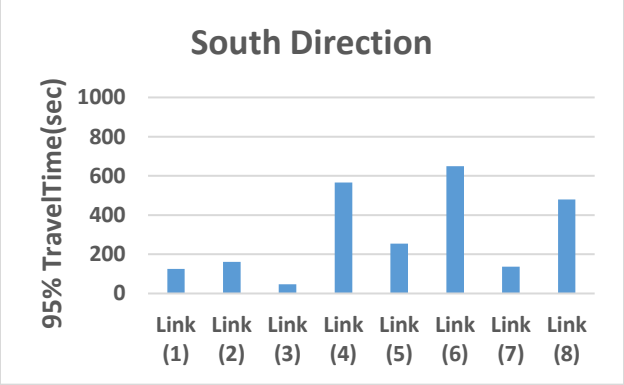

Figure 11 (b). 95% Percentile Travel Time Results for Links (from 1 to 8)

The travel time indicator, which is computed by dividing the average trip time by the free flow time for each link and per street as shown in equation (2), the travel time index shows the average extra time obligatory through peak time as opposed to periods of free flow traffic, as illustrated in figure 12 (a) and 12 (b). Travel time index value for Links (from 1 to 8) is shown in tables (4) & (5) for both directions (north and south) direction. Increasing the travel time index greater than 1.0 means that it takes roughly (350, 420,280,610,270,270,320, and 210) second longer than that of free travel time of the corridor for north direction and (360, 530, 170, 117, 550, 270, 270, and 290) for south direction. The largest difference in travel time index was observed for both directions of Link (4). This means that a higher travel time index shows congested conditions, which means worse reliability.

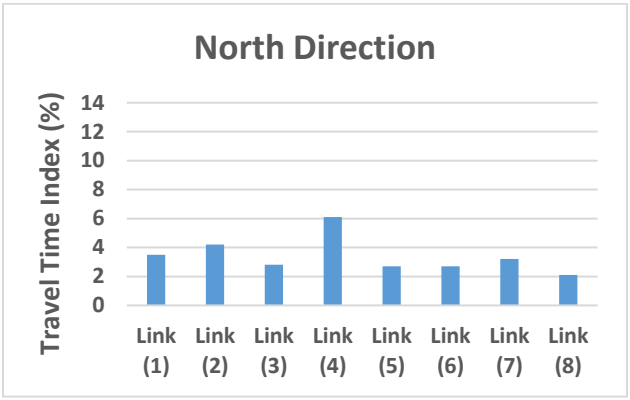

Figure 12 (a). Travel Time Index Results for Links (from 1to 8)

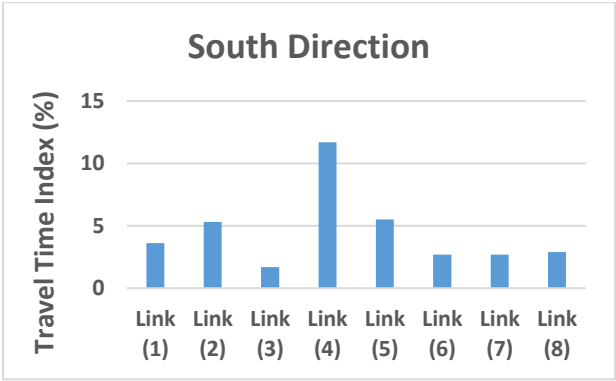

Figure 12 (b). Travel Time Index Results for Links (from 1to 8)

5.3. Reliability Measurement for Damascus Street

Buffer time index measure is explained as shown in equation (1). figure 13 (a) and 13 (b) demonstrates the reliability measure of the link's buffer time index (1) to (6) for north direction and for link (1) to (5) for south direction along Damascus arterial street. The buffer time index is expressed as a percentage and its value increases as reliability gets worse. These showed that the reliability of links (1,2,3,5,6,

and 4) in the north direction deteriorates., also for a south direction that the reliability gets worst for (4,3,2,1 and 5) as shown in tables (6) & (7). The buffer index reflects the added buffer time that most passengers apply to their average travel time to guarantee on-time arrival while planning trips. This additional time is extra to account for any unforeseen delay. So it will be a buffer time (167,162,62,63,37, and 36) sec, for links (from 1 to 6) respectively for north direction, also for the south direction it will be a buffer time (144,142,12,23, and 22) sec, it is obtained for each link on the basis of the average travel time. To safeguard that 95%, arrive at the destination of the arterial corridor on time, that means additional buffer time is given from the average value.

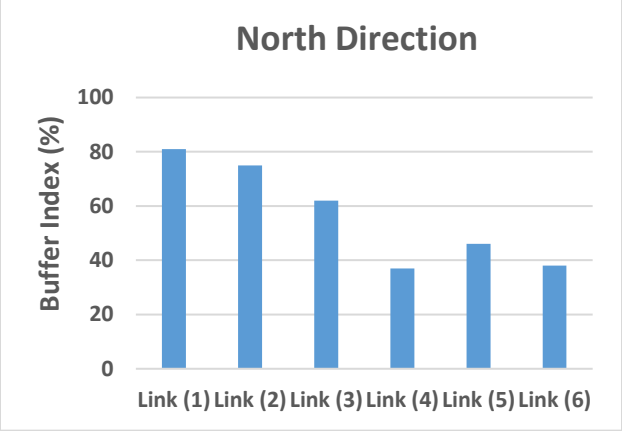

Figure 13 (a). Buffer Time Index for Links (from 1 to 6)

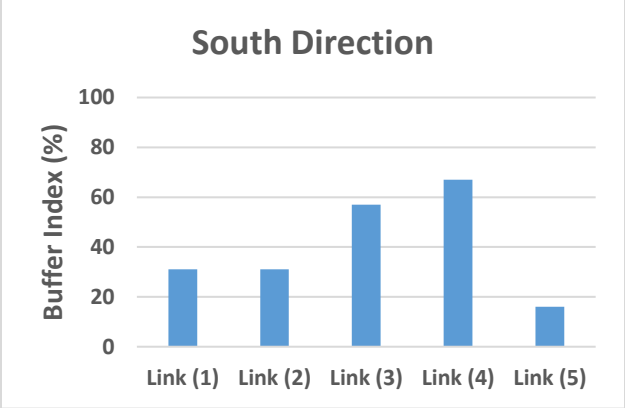

Figure 13 (b). Buffer Time Index for Links (from 1 to 5).

Table 6. Measurement of Links Reliability Along Damascus Street (North Direction)

Reliability Measurement			
Links of Damascus Street	Buffer Time Index (%)	Travel Time Index (%)	95% Percentile Travel Time (sec)
Link. 1	81 %	2.8 %	373 sec
Link. 2	75 %	2.4 %	377 sec
Link. 3	62 %	2.4 %	161 sec
Link. 4	37 %	2.2 %	132 sec
Link. 5	46 %	2.7 %	199 sec
Link. 6	38 %	4.1 %	135 sec

Table 7. Measurement of Links Reliability Along Damascus Street (South Direction)

Reliability Measurement			
Links of Damascus Street	Buffer Time Index (%)	Travel Time Index (%)	95% Percentile Travel Time (sec)
Link 1	31 %	2.1 %	99 sec
Link 2	31 %	2 %	54 sec
Link 3	57 %	3.6 %	390 sec
Link 4	67 %	2.4 %	359 sec
Link 5	16 %	1.9 %	158 sec

The travel time index, compromises the average additional time required during peak time than periods of free time as shown in equation (2), The additional time is applied to the free travel time to achieve the necessary average travel time to traverse the listed links during the peak period, as illustrated in figure 14 (a) and 14 (b). The travel time index value for Links is shown in Tables (6) & (7) for both directions (north and south) direction. Rising the index of travel time more than 1.0, meaning that it takes about a longer travel time (280, 240,240,220,270, and 410) second longer than that of free travel time of the corridor for north direction and (210, 200, 360, 240, and 190) for south direction with the upper travel time index for Link (6) for north

directions and link (3) for south direction. This means that a higher travel time index shows congested conditions, which means worse reliability.

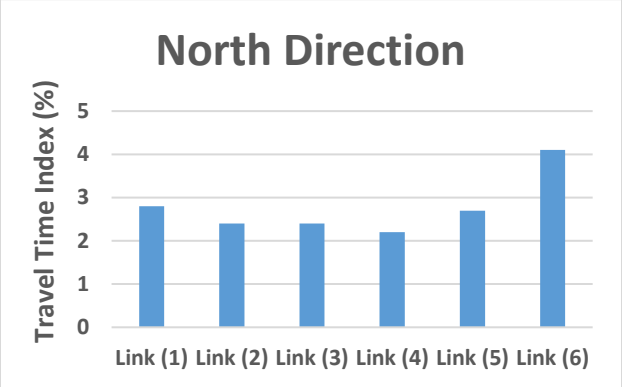

Figure 14 (a). Travel Time Index Results for Links (from 1 to 6).

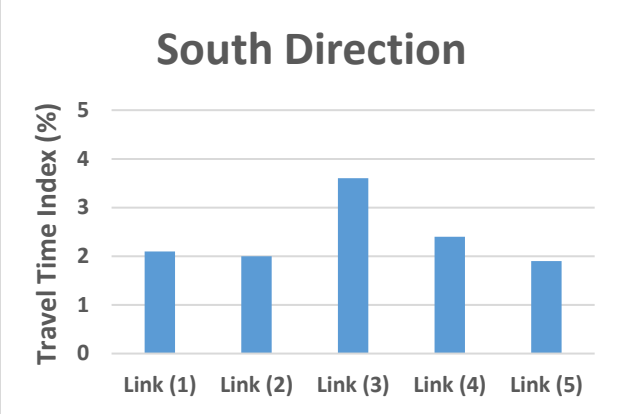

Figure 14 (b). Travel Time Index Results for Links (from 1 to 5).

Figure 15 (a) and 15 (b) indicates the 95% percentile travel time that poses the extra delay perceived on each link as shown in table (6) & (7) for both directions (north and south) direction. Link (2) of north direction and link (3) of south direction had the maximum 95 percent travel time values.

.

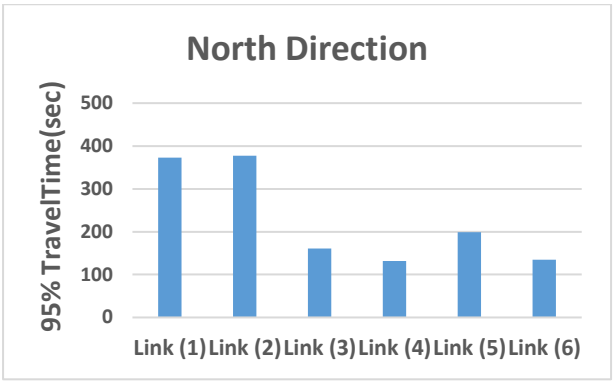

Figure 15 (a). 95% Percentile Travel Time Results for Links (from 1 to 6).

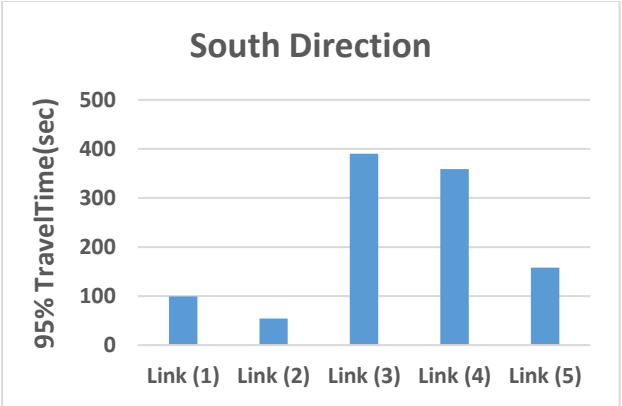

Figure 15 (b) 95% Percentile Travel Time Results for Links (from 1 to 5).

Figures 16 (a) and 16 (b) presented the reliability measurement for the Index for the three selected streets in this study in terms of the buffer time index for 14 Ramadan street, AL-Karada street, and Damascus street for two directions. Raising the buffer time index results in bad conditions for reliability. AL- Karada street manufactured a buffer index of about 53% and 30% for Damascus street and finally for 14 Ramadan street which presents a 29% buffer index for the north direction. These illustrated that the reliability gets worst for (Karada street, Damascus street, and 14 Ramadan street) respectively. Also buffer time of (364, 765, and 274) second for (14 Ramadan street, AL-Karada street, and Damascus street) respectively is got using the mean travel time for each route. That means extra (364, 765, and 274) sec. As for its southern direction 14 Ramadan street

manufactured a buffer index of about 65% and 33% for AL- Karada street and finally for Damascus street which presents a 29% buffer index. These showed that the reliability decline for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. Also buffer time of (877, 527, and 219) sec. for (14 Ramadan street, AL- Karada street, and Damascus street) respectively is got using the mean trip time for each route.

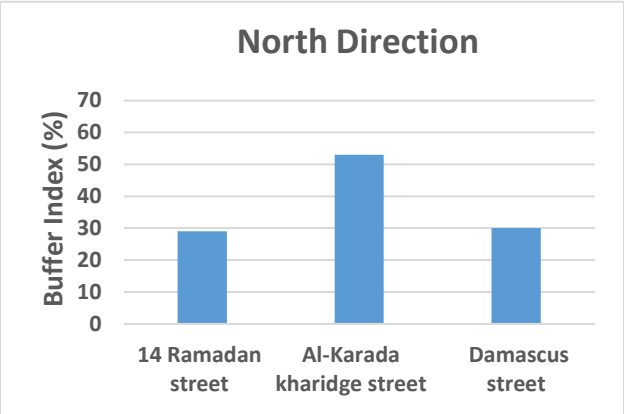

Figure 16 (a). Buffer Time Index of Three Routes arterials.

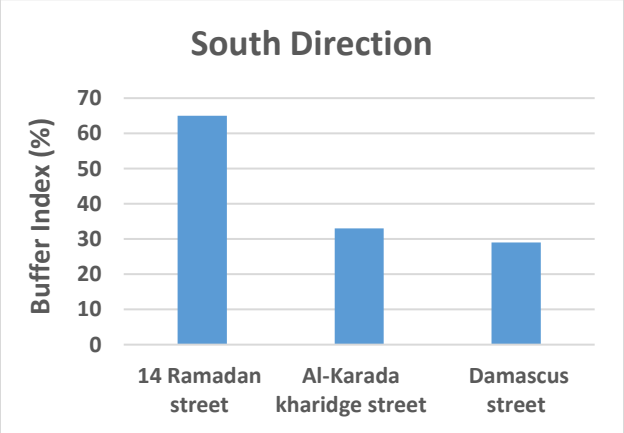

Figure 16 (b). Buffer Time Index of Three Routes arterials.

Figures 17 (a) and 17 (b) depicts the travel time index, which represents the mean trip time separated by the free-flow time for the three selected streets in this study. A 2.8 %, 3.3%, and 2.6% TTI is obtained for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. It increaces the index of travel time more than 1.0 meaning that it takes approximately 280, 330 and 260 percent of free travel time for the three routes respectively. The highly congested conditions were shown by this. As for its southern direction, the travel time index is obtained for (14 Ramadan street, AL-Karada street, and Damascus street) respectively is a 3%,3.7%, and 2.5%. Rising the index of travel time is more than 1.0, meaning that it takes about a longer travel time 300, 370 and 250 respectively percent of free travel time.

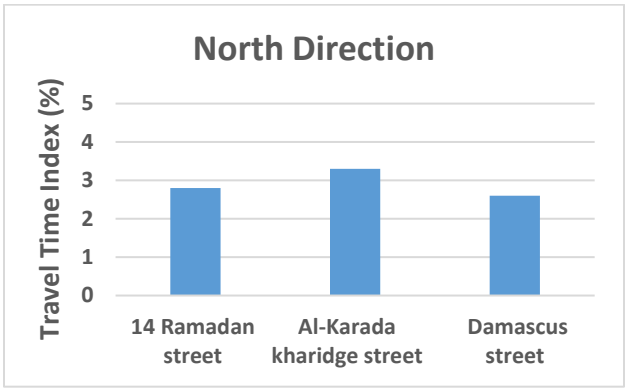

Figure 17 (a). Travel Time Index (%) of Three Routes arterials.

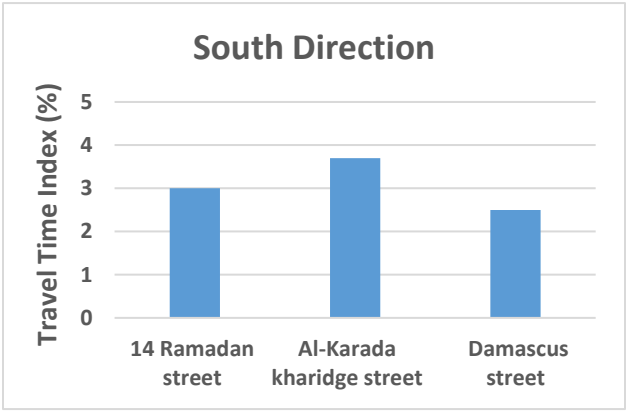

Figure 17 (b). Travel Time Index (%) of Three Routes arterials.

Figures 18 (a) and 18 (b) shows the 95% percentile travel time of (1627, 2212, and 1192) sec. for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. The upper

value for 95% travel time is achieved for AL-Karada street for north direction. As for its southern direction the extra delay that is perceived on each route (2221, 2132, and 975) sec. for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. 14 Ramadan street had the maximum 95 percent travel time values.

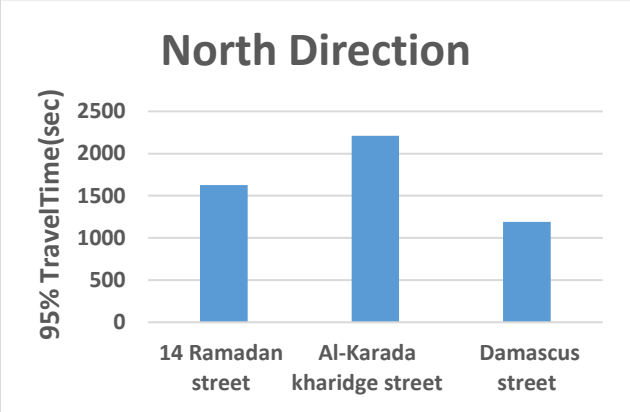

Figure 18 (a). 95% Travel Time (sec) of Three Routes arterials for Both Direction.

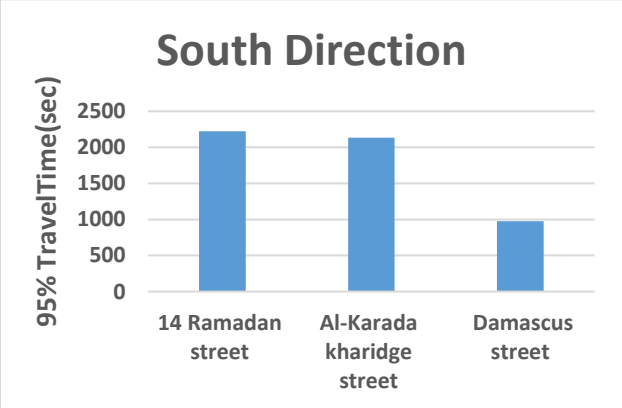

Figure 18 (b). 95% Travel Time (sec) of Three Routes arterials for Both Direction.

6. Conclusions

1- The findings of the buffer time index have been analyzed under less reliable settings. AL- Karada street produced a buffer index of about 53% and 30% for Damascus street and finally for 14 Ramadan street which presents a 29% buffer index for the north direction. These illustrated that the reliability gets worst for (Karada street, Damascus street, and 14 Ramadan street) respectively. Also buffer time of (364, 765, and 274) sec. for (14 Ramadan street, AL-Karada street, and Damascus street) respectively is obtained founded on average travel time for each route. As for its southern direction 14 Ramadan street manufactured a buffer index of about 65% and 33% for AL- Karada street and finally for Damascus street which presents a 29% buffer index. These illustrated that the reliability gets worst for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. Also buffer time of (877, 527, and 219) sec. for (14 Ramadan street, AL- Karada street, and Damascus street) respectively was obtained based on mean travel time for each route.

2- The 95% percentile travel time for observed three selected routes in this study presented the maximum delay perceived on each route (1627, 2212, and 1192) sec. for (14 Ramadan street, AL- Karada street, and Damascus street) respectively. AL- Karada street for north direction had the maximum 95 percent travel time values. As for its southern direction the extra delay that is perceived on each route (2221, 2132, and 975) sec. for (14 Ramadan street, AL-Karada street, and Damascus street) respectively. 14 Ramadan street had the maximum 95 percent travel time values.

3- Travel time index for (14 Ramadan street, AL- Karada street, and Damascus street) respectively is about 2.8 %, 3.3%, and 2.6% for north direction, as for its southern direction the travel time index is obtained for (14 Ramadan street, AL- Karada street and Damascus street) respectively is a 3%,3.7%, and 2.5%.

Conflict of interest

The authors undertake not to cause any conflict of interest in the publishing of this article with any person or with the competent authorities.

7. References

1. Alkaissi, Z. A. (2017). *"Travel Time Prediction Models and Reliability Indices for Palestine Urban Road in Baghdad City"*, Al-Khwarizmi Engineering Journal, Vol.13, No. 3, pp:120-130.
2. Al-Mansoori, T., Abdalkadhum, A., Al-Husainy, A. A. (2020*)." GIS Enhanced Pavement Management System: A Case Study in Iraq"*. Journal of Engineering Science and Technology Vol. 15, No. 4: 2639 – 2648.
3. 3.Chen, C., Zwet, E.V., Varaiya, P., Skabardonis, A. (2003). *" Travel Time Reliability as a Measure of Service"*, Leiden University Medical Centre, University of California, Berkeley.
4. Chen, Z., & Fan, W. (2019). *"Data analytics approach for travel time reliability pattern analysis and prediction"*. Journal of Modern Transportation, 27(4), 250-265.
5. Chen, Z., & Fan, W. D. (2020). *" Analyzing travel time distribution based on different travel time reliability patterns using probe vehicle data"*. International Journal of Transportation Science and Technology, 9(1), 64-75.
6. Chen P, Tong R, Lu G, Wang Y (2018) *"Exploring travel time distribution and variability patterns using probe vehicle data"*: case study in Beijing. J Adv Trans 3747632
7. D. O. D. USA, (2008). *" Global Positioning System Standard Positioning Service - SPS Service, "*.
8. Federal Highway Administration. (2005): *" Traffic congestion and reliability: Trends and advanced strategies for congestion mitigation"*. Cambridge Systematic Inc. and Texas Transportation Institute, College Station, TX.
9. Hojati AT, Ferreira L, Washington S, Charles P, Shobeirinejad A(2016) *" Modelling the impact of traffic incidents on travel time reliability"*. Transp Res C Emerg 65:49–60
10. National Cooperative Highway Research Program (NCHRP). (2008), NCHRP Report 618: *" Cost-effective performance measure for travel time delay, variation, and reliability. "*Washington, DC: Transportation Research Board.
11. Ning WU, Geistefeldt, J. (2016)." *Modeling Travel Time For Reliability Analysis In A Freeway Network "* "Ruhr-University Bochum, Germany
12. Pankaj, A. (2019). *" A Comprehensive Study On The Estimation Of Freeway Travel Time Index And The Effect Of Traffic Data Quality"*, The University of Wisconsin-Milwaukee.
13. Systematics, C., & National Research Council. (2013). *"Analytical procedures for determining the impacts of reliability mitigation strategies".* Transportation Research Board.
14. Schroeder B, Rouphail N, Aghdashi S (2013) *" Deterministic framework and methodology for evaluating travel time reliability on freeway facilities"*. Transp Res Rec 2396:61–70
15. Wang Z, Goodchild A, McCormack E (2017) *" A methodology for forecasting freeway travel time reliability using GPS data"*. Transp Res Proc 25:842–852.