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Travel Time Reliability Analysis in Three Different Routes in Baghdad City

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Abstract

Travel time reliability is defined as the degree of certainty and predictability of travel time on a transportation system. Reliable transportation systems provide some guarantees to reach a particular destination within a reasonable time in harmony with the expected time. In this study data collection process on the specified paths was carried out through the test vehicle equipped with GPS (moving vehicle technology) device. The Statistical Package program(SPSS) was used to analyse the total travel time of each link on the three selected routes and the estimated speeds based on GPS field data collected during 50 running trials in the south and north directions during morning and evening hours. The results of buffer time indexes for three routes are presented for each route from Bayaa to Bab Almuadam to illustrate changing structure of the reliability during the peak period. Extra delays with regard to free flow travel time are observed on route 1, 2, and 3 in terms of 95% percentile travel time about 52, 38, and 41%, respectively.

Keywords: Reliability measurement, travel time, buffer index

1. Introduction

The travel time in urban city plays an essential role in measuring the performance of traffic transportation system. This study aims to estimate the total travel time, analyse the collected data, in addition to estimate the travel time reliability. Travel time reliability is important for passengers, transit passengers, shippers and other road users because it allows them to make better decisions regarding the use of their time. For example, shipping companies require predictable travel times to deliver goods and services on time. The concern is not only that the travel time is excessive due to rush hour congestion (i.e., reduced traffic of required level) but also it may be unpredictable as a function of time or part of the route [1]. Hence, recently, the analysis of transportation projects with regard to the evaluation of the reliability of travel time is of great interest. Some international research projects have also been guidance on how an agency can embed value of reliability (VOR) in the cost-benefit analysis when making project investment decisions related to reducing congestion. The transportation system was specified by [2] as the most important lifeline in the event of natural disasters such as the earthquakes, floods, hurricanes, etc [12]. Restoration of other lifelines (such as water supply, electric power system, sewage system, communication and many more) in the event of a disaster can only be possible if there is a solid and effectively available transportation networks. If vehicles cannot move to places needed, the transportation system would only hinder the recovery process economically and cause to increase death tolls. A reliable transportation system must also be considered every day disturbances. Actual travel requirements vary over time due to its nature, therefore contribute to the uncertainty of travel times. With

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increasing time value attributed to its importance, big loss may be incurred by drivers due to unexpected schedule of their travels. The transportation system will provide a competitive advantage in the global economy as the importance of the reliability of the transportation system gets higher.

2. Materials and Method

In this study, the data collection process begins when the test vehicle is equipped with GPS. The tool is consisting of a GPS device and a control button connected to the device via a cable, as shown in Figure 1. Travel time data was obtained from WENK GPS at 10-second intervals from (7–9 a.m.) and (1-3 p.m.) peak hours the morning and evening periods for each route. In this way, the trip time for each link is determined based on the data from the station. The concern has been paid to obtain data during good weather due to the fact that the bad weather may cause undesired disturbance in the estimated travel times. The statistics on travel time was estimated for a single day (January 1st, 2021 to February 28th, 2021). Data were obtained and analysed for all the week-days, except for the holidays and weekends. Present data form a single report for two directions north and south to each route. The free flow speed (FFS) of the selected street was collected by field measurement during normal traffic conditions without any fluctuations. The coordinate data is extracted from the GPS traffic devices logged into a server that is accessed using the username and password registered by engineers in the local company, and the data were pulled and saved in Excel files. Before collecting field data by a GPS device, several important steps must be taken consisting of: preparing a test vehicle, determining travel time routes, creating a framework with instructions for the driver (data collector), determining the necessary sample size depend on conducting an experiment study. The coordinates of all intersections on each route represented obtained through the test position for Moving-Vehicle Method [11]. While the first intersection in terms of the movement direction represents the start point, the next following intersection represents the end of the link until the finishing point of route for both north and south direction (go & return).

The free flow speed was obtained from field measurement during the free flow conditions for each link of the specified arterial streets. However, length (km) of each link was calculated by driving the vehicle in free-flow conditions in order to obtain the most accurate measurement. In addition, it should be noted that the free flow speed must not exceed the speed limit.

Figure 1. The manufactured device GPS

2.1. Route number 1

Figure 2 illustrates the general lay out for links with available intersections. For route 1, the sample size taken was 50 runs for the total number of runs, divided into 25 runs for each direction. The route consists of eleven links for the north and south direction and the related data is shared as can be seen Table 1, Table 2 for both south and north directions. Figure 3 depicts the route.

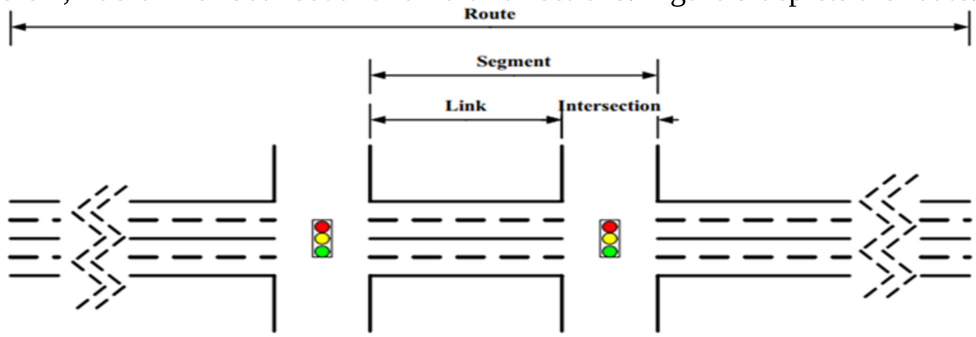

Figure 2. Scheme overview and basic elements of a standard urban route [4]

Table 1. Route 1 north direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bayaa Sq.	…	33.266022 - 44.336543	…
2	Saydiaa - Bayaa Intersection	60	33.258149 - 44.341235	1.4
3	Addarwesh In.	40	33.235311 - 44.345189	3.0
4	Doraa Expressway	100	33.237172 - 44.371493	6.6
5	Alkarrada Exit	60	33.247738 - 44.416491	4.7
6	Baghdad University	40	33.293190 - 44.453884	2.3
7	Mohammed Alqasim	60	33.303230 - 44.467921	9.5
8	Alshaab Stadium	60	33.321249 - 44.434697	2.0
9	Neurology Hospital	40	33.334523 - 44.419203	5.0
10	Almustansirya	60	33.359142 - 44.394094	2.0
11	Art College	40	33.355409 - 44.383792	1.0
12	Bab Almuaddam	40	33.348769 - 44.385141	0.75

Table 2. Route 1 south direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bab al muaddam	40	33.348769 - 44.385141	0.75
2	Art College	40	33.355409 - 44.383792	1.0
3	Almustansirya	60	33.359142 - 44.394094	2.0
4	Neurology Hospital	40	33.334523 - 44.419203	5.0
5	Alshaab Stadium	60	33.321249 - 44.434697	2.0
6	Mohammed Alqasim	60	33.303230 - 44.467921	9.5
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12	Bayaa Sq.	…	33.266022 - 44.336543	…

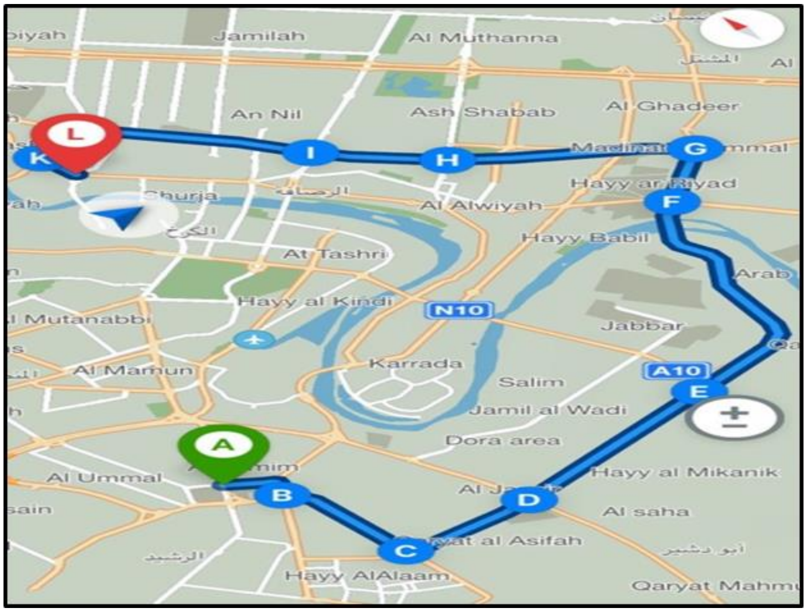


Figure 3. Route 1 with the selected intersections of north and south directions

2.2. Route number 2

The route 2 consisting of ten links for the north and south direction is illustrated in Figure 4. Table 3 and Table 4 give the data regarding the coordinates and lengths of the links on the route.

Figure 4. Route 2 with the selected intersections of north and south directions

Table 3. Route 2 north direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bayaa Sq.	…..	33.266022 - 44.336543	……
2	Um Altubol	60	33.285215 - 44.346748	2.41
3	Qahtan Sq.	40	33.291398 - 44.350088	0.8
4	Alnusur Sq.	40	33.301866 - 44.356623	1.28
5	Baghdad Gallery	60	33.314801 - 44.366000	1.77
6	Alawee	60	33.321692 - 44.380468	1.6
7	Iraqi museum	40	33.325344 - 44.383909	0.48
8	Yafa st.	40	33.317049 - 44.393231	1.28
9	Liberation Sq.	40	33.327113 - 44.407958	1.77
10	Wathba Sq.	40	33.336586 - 44.400361	1.44
11	Bab Almuaddam Sq.	40	33.348769 - 44.385141	1.93

Table 4. Route 2 south direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bab Almuaddam Sq.	40	33.348769 - 44.385141	1.93
2	Wathba Sq.	40	33.336586 - 44.400361	1.44
3	Liberation Sq.	40	33.327113 - 44.407958	1.77
4	Yafa st.	40	33.317049 - 44.393231	1.28
5	Iraqi museum	40	33.325344 - 44.383909	0.48
6	Alawee	60	33.321692 - 44.380468	1.6
7	Baghdad Gallery	60	33.314801 - 44.366000	1.77
8	Alnusur Sq.	40	33.301866 - 44.356623	1.28
9	Qahtan Sq.	40	33.291398 - 44.350088	0.8
10	Um Altubol	60	33.285215 - 44.346748	2.41
11	Bayaa Sq.	…..	33.266022 - 44.336543	…..

2.3. Route number 3

The route 3 consisting of eleven links for the north and south direction is illustrated in Figure 5. Table 5 and Table 6 give the data regarding the coordinates and lengths of the links.

Figure 5. Route 3 with the selected intersections of north and south directions

Table 5. Route 3 north direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bayaa Sq.	…..	33.266022 - 44.336543	….
2	Um Altubol	60	33.285215 - 44.346748	2.41
3	Qahtan Sq.	40	33.291398 - 44.350088	0.8
4	Jorden Sq.	40	33.305017 - 44.334803	2.25
5	Sayed Alhaleeb	40	33.304480 - 44.340882	0.64
6	Almansur	60	33.318282 - 44.338243	1.6
7	Alleqaa Sq.	60	33.329260 - 44.338810	1.28
8	Adamya Bridge	60	33.350730 - 44.345478	2.57
9	Almuthanna airport	100	33.341168 - 44.355747	1.44
10	Utaifeya	60	33.350445 - 44.362790	1.44
11	Sarafiaa bridge	60	33.355134 - 44.383456	1.6
12	Bab almuddam	40	33.348769 - 44.385141	0.8

Table 6. Route 3 south direction

link	Intersections	Free-flow speed km/hr	location	Length of links km
1	Bab almuddam	40	33.348769 - 44.385141	0.8
2	Sarafiaa bridge	60	33.355134 - 44.383456	1.6
3	Utaifeya	60	33.350445 - 44.362790	1.44
4	Almuthanna airport	100	33.341168 - 44.355747	1.44
5	Adamya Bridge	60	33.350730 - 44.345478	2.57
6	Alleqaa Sq.	60	33.329260 - 44.338810	1.28
7	Almansur	60	33.318282 - 44.338243	1.6
8	Sayed Alhaleeb	40	33.304480 - 44.340882	0.64
9	Jorden Sq.	40	33.305017 - 44.334803	2.25
10	Qahtan Sq.	40	33.291398 - 44.350088	0.8
11	Um Altubol	60	33.285215 - 44.346748	2.41
12	Bayaa Sq.	….	33.266022 - 44.336543	….

3. Moving Vehicle Technique Method

Since the late 1920s, vehicle testing technology has been used to collect travel time data. This method traditionally involves the use of a data collection method in which the analyst monitors the accumulated driving time at predetermined checkpoints along the route. This data is converted into travel time, speed, and delay for each segment along the survey street. This sample size is more than sufficient than the suggested sample size recommended in the Travel Time Data Collection Handbook shown in Table 7 [5]. Moreover, the vehicle-moving method technique involves steering the test vehicle by an observer in the flow of traffic to collect the required data during the day. The device is installed through the car's lighter to obtain power when the car is running. The data collection process begins when the GPS-equipped test vehicle reaches the specified route to get clear and concise results. The most important features and trends in the results should be described and interpreted.

Table 7. Demonstrative sample size of test vehicle on arterial street [5]

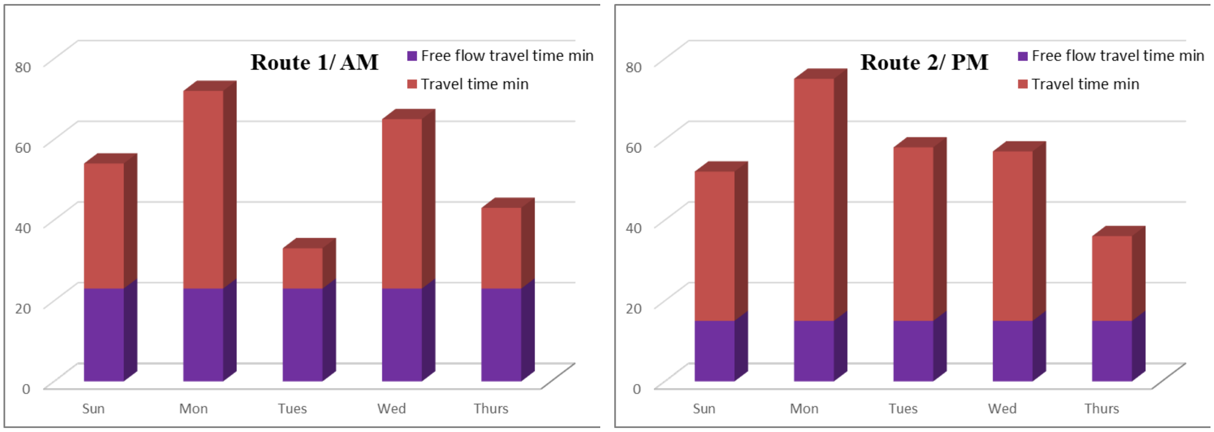
Traffic Signal Density (Signals per mile)	Average Coefficient of Variation (%)	Sample Sizes		
		90% Confidence, ± 10 % Error	95% Confidence, ± 10 % Error	95% Confidence, ± 5 % Error
Less than 3	9	5	6	15
3 to 6	12	6	8	25
Greater than 6	15	9	12	37

3.1. Data Processing

The well-known statistical package SPSS program is the most widely used statistical data analysis software in many fields such as engineering, economics, medicine, social sciences, etc., and is available in the majority of higher education institutions worldwide. Various simple and complex statistical analyses can be performed, starting with descriptive statistics to modelling. This does not necessarily mean that it is a much "better" package than any of the other options available [6]. Overall, travel times are much higher than free travel time [10] for all routes as shown in Table 8. The peak hours of the morning and evening periods of all three routes are summarized shows that the car takes more time to arrival during morning hours on Monday. Route 1 with the longest distance has the maximum average travel time 72min, during evening hours. The maximum average travel time is, on the other hand, 99min recorded on Tuesday. As for route 2, average travel time during morning and evening are moderate: while the maximum is 60min on Sunday recorded during morning time, it is 75min on Monday afternoon. The average travel time on route 3 for morning and evening times are recorded as 56min and 79 min on Monday respectively. Although the free flow travel time is equal for Monday and Tuesday during morning and evening time it should be mentioned that road condition differs through the day and over the days of the week.

Table 8. Total average travel time and free flow travel time in minutes for all routes am- pm

Route Time	Weekdays min					Free flow travel time min
	Sun	Mon	Tues	Wed	Thurs	
Route 1/AM	54	72	33	65	43	23
Route 1/PM	73	94	99	88	82	23
Route 2/AM	60	48	30	28	27	15
Route 2/PM	52	75	58	57	36	15
Route 3/AM	54	56	44	46	28	19
Route 3/PM	70	79	79	75	51	19



a) b)

Figure 6. Average travel time and free flow travel time in minutes for a) Route 1/am and b) Route 2/pm

3.2. Estimation of Travel Time Reliability

The Standard deviation (SD) can be defined as a measure utilized for the quantification of the variation amount in the dataset. The SD can be used for the quantification of the reliability of the travel time. This measure is not utilized quite often, due to the fact that it is not that easy for the common people to understand the reliability of the travel time from the values of the SD which may be represented in Eq (1).

$$SD = \frac{\sum(\text{Travel time on specific segment} - \text{Average travel time for certain dataset})^2}{\text{Total datasets number}} \quad (1)$$

The variation of the percent represents normalized SD. It is a ratio of SD to mean traveling time. This measurement has been considered to be beneficial in the case of the comparison of the variation degree amongst the variety of the data-sets as in Eq (2).

$$\text{Percent Variability} = \frac{SD}{\text{Average travel time}} * 100 \quad (2)$$

The 95th or 90th percentile travel time represents simplest approach for measuring the reliability of the traveling time. It is an estimation of how bad the delay of the traffic will be on certain routes. The users of the road can understand how bad the traffic could be and then accordingly plan their trips when they know 90-th or 95-th percentile travel times, which are usually measured in minutes [7].

Buffer time (BI) represents extra time (also referred to as the time cushion) that the travellers have to add to their mean traveling time in the case of planning the trips for the purpose of ensuring the on-time arrival. The buffer time may be represented by Eq (3).

$$\text{Buffer Time Index} = \frac{\text{95−th percentile travle time−Average travel time}}{\text{Average travel time in minutes}} \quad (3)$$

Travel Time Index (TTI) represents a ratio of the mean traveling time over the whole year to the travel time at the cases of the free-flow and may be represented by Eq (4).

$$\text{Travel Time Index} = \frac{\text{Avg.travel time}}{\text{Free flow travel time}} \quad (4)$$

The index of the planning time (PTI) can be described as the amount of the total time that the traveller must allow in order to ensure the arrival on-time. The calculation of the planning time index can be represented by Eq (5).

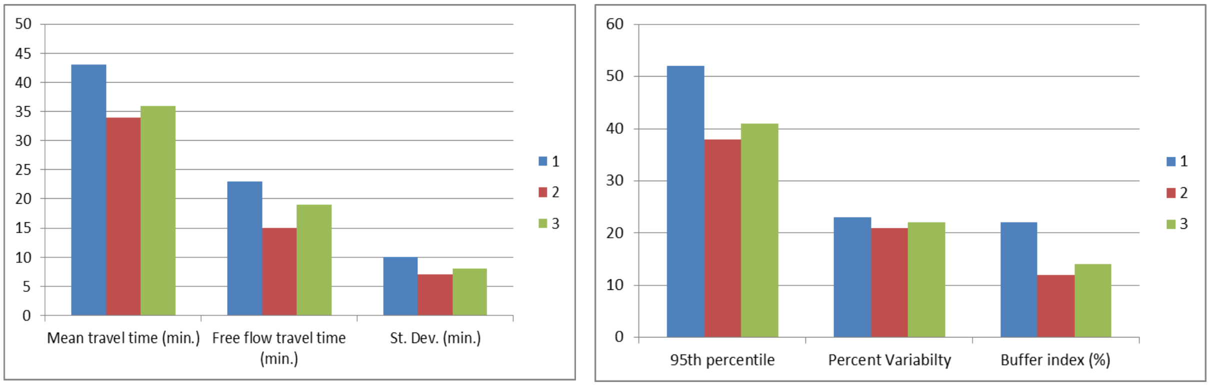
$$\text{Planning Time Index} = \frac{\text{95 percentile travle time}}{\text{Free flow travel time}} \quad (5)$$

4. Results and Discussion

For all intersections from Bayaa to Bab Almuadam buffer index values obtained as 22%, 12% and 14% for Route1, Route 2 and Route 3 respectively. This states that the reliability gets worst for Route 1 during the peak period. However extra delay is observed on Route 1, 2, and 3 in terms of 95-th percentile travel time as 52, 38, 41 respectively. Higher value of 95-th percentile travel time obtained for route 1 expresses that the Route 1 is the longest one requiring more time to pass and each link may be subject to multiple condition. More reliable route is Route 2 because it has high travel time and planning time index as 2.27, 2.53, respectively. All the results for three routes regarding travel time reliability measurement are shown in Table 9 and Figure 7.

Table 9 . Travel time reliability measurement

Routes	Mean travel time (min.)	Free flow travel time (min.)	SD (min.)	95^{th} percentile	Percent Variability	Buffer index (%)	Planning Time Index	Travel Time Index
1	43	23	10	52	23	22	2.26	1.87
2	34	15	7	38	21	12	2.53	2.27
3	36	19	8	41	22	14	2.16	1.89



a) b)

Figure 7. Travel time reliability measurements

The effect of different links on reliability varies in an urban transport network due to their different locations across the entire network and the rate of different traffic sharing. Consequently, various changes in reliability present the essential way to improve the reliability of the entire network by facilitating the primary links in the network.

In conjunction with complex network theory and traffic load, there are proposes for assessing the significance of a transportation network which can identify the main links and combine the total and partial importance of nodes in the network. It overcomes current issues of the complexity of deleting nodes, calculates the number of nodes, and simplifies calculation of the reliability of the transportation network connection. As traffic is a dynamic process, the random variation of the transportation network should be taken into account and further discussion must be carried out for a more reasonable evaluation method for the links [12].

Conclusions

The reliability analysis aims to calculate the impact of travel time fluctuations on reliability measurement and then to produce extra arrival time at a real cost. It is also necessary for increasing safety, ensuring the quality for road users, and producing minimum delays for their trips. In addition, it's a perfect indicator to improve the overall system management and operations [9]. In this study, three different routes in Baghdad were investigated in terms of their travel time reliability performances. The mean travel times for those three routes were obtained as 43,34,36 minutes, respectively. While the buffer time indexes were calculated as 22,12,14 minutes, 95-th percentile travel times were found as 52,38,41 respectively. Federal Highway Administration (FHWA) defines the travel time reliability as consistency or dependability in travel time as measure from day to day and across different times of the day [13]. The 95th percentile travel time,Buffer Index (BI) and Planning Time Index (PTI) are considered as performance indicators for travel time reliability. Travel time distribution and empirical based approach are the base for development of these indices. Study of travel time reliability can help in understanding the variation in travel time and aid in developing strategies for transportation system management. Reliability indices extracted for each link of the three arterial routes in this study may be used by the professionals of transportation department or practicing designers of Baghdad city. Furthermore, delay components obtained can help traffic engineers and planners to stimulate the level of service at intersections.

Unreliability in transportation network arises from two different sources: capacity and flow variation. Excessive flow and degraded capacity both lead to higher travel time, which decreases transportation network reliability. In reality, these variations are uncertain and cannot be treated deterministically. Uncertainty in link capacities, in the parameters of the link travel time function, in travel demands and in route choice models will be included in the further research concept of this study being carried out. In the field of future research;
• reliability analysis of the impact of speed and travel time fluctuations on public transport
• assessment of the discomfort of congestion for private vehicles
will be looked at to get more realistic model.

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