Travel Time Prediction Models for Major Arterial Road in Baghdad City using Manufactured GPS device

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Abstract. Travel time on arterials can be rotten into two components, free flow travel time and delay. That's where the difference between the observed travel time and travel time of free flow, the delay can be calculated. Which is one of the most important roadways Metrics for Traffic. Estimation of travel time and measurement of reliability are critical issues for improving the efficiency of traffic network operations and safety. The purpose of this review is to estimate overall travel time and to analyse the collected data and also to estimate the travel time through predicting model for total delay of signalized intersections. In addition, utilizing a more convenient method and tools to reflect and to achieve a more practical model of delay time for the selected urban arterial in Baghdad city. Global Positioning System (GPS) receivers have an ability to reliably measure intersection delay in terms of (deceleration delay, stopped delay, and acceleration delay). In addition to measuring the travel time for each link along the streets specified for this study (Al-Karada Kharidge street). 50 test runs were collected from GPS-equipped instrumented vehicle at off peak and peak hours of the day for each direction for selected street in this study. So, the required data collection period for two months was from December 2019 to February 2020 were identified to study the complete travel time variations and travel delay times for each link and each intersection along the identified arterial street. The field data were collected for the selected of Al-Karada Kharidge street the Baghdad University intersection to Mohamed al-Qasim intersection.

Keywords: Delay, Travel Time, predicted model

1. Introduction
Travel time considered among the basic characteristics used in transportation planning, management, and traffic operation. There are many factors that affect travel time including the behaviour of drivers, traffic characteristics, geometric characteristics of corridor in urban areas. When considering traffic characteristics, the referred characteristics are traffic volume and density under interrupted flow condition. When considering geometric characteristics, the referred characteristics are roadway width, number of lanes, lane width, type of intersection, and type of traffic control device at intersections [10]. Although
travel time has been studied and understood heavily by traffic engineers, planners, and road users but it is difficult during the planning and operational analysis [5], The definition of travel is the period of time that the driver takes from trip start to trip finish, the spatial reach of this trip will be an intersection, an urban link, or a segment or a route. Different studied and researches were conducted to model the travel by of means of time series data that extracted from GPS [11]. A travel time prediction model at intersection with traffic signal has been developed by [6] via Seasonal Auto Regressive Integrated Moving Average (SARIMA) modelling approach with data extracted from Bluetooth. In addition, researches have been conducted to predict the real time of bus arrival with take into consideration delay explicitly by applying Kalman Filtering using GPS probe vehicle technique [7]. The travel time of urban arterial in urban city played a vital role in measuring the performance of traffic system. The methods of measurement for acceleration and deceleration rates vary from study to another based on the aims of study and availability of the technology. Low sampling rate is the main dilemma of the recent studies and this resulted from the limitations in data collection technology. The acceleration rate can be calculated from the differences in travel time between two stations or the distance between them. The difficulty of this approach is that someone could not specify where and when drivers stopped their acceleration process or initiated their deceleration process [9]. A study conducted by [8] using GPS test vehicles technique in order to measure the max value of the acceleration rate for passenger cars and trucks on a specified road, the results of this study showed that data extracted from GPS have a high resolution of speed data and adequate to use for calculating the acceleration rates. [1] developed three prediction models for travel time for three selected links of Palestine street in Baghdad using data that was collected from field using GPS device. The three developed models showed adequacy and reliability compared to the observed data based on statistical tests results [1]. The variation of headway time was studied by [2] for the Palestine street and the results of this study showed that the probability density distribution (PDF) function of the selected links had shifted to the right and peak increases for link.1 higher than link.2. Finally, a travel delay model was developed by [3] in order to predict the total delay that occurred at intersections with traffic signal, the results of this study showed that delay model can provide fairly precise estimation of the actual values of control delay. [4] The use of GIS is an important advance in predicting potential road conditions that will allow highway engineering and agencies to comply with future plans, so this model provided the sharing of information technologies that represent GIS with pavement management systems.

2. Research Objective

The purpose of this research is to approximate the distribution analysis and overall travel time using measured total delay estimate for signalized intersections for major arterial street in Baghdad city which are considered this route one of the most important routs join the central business district (CBD) with main commercial, industrial and high density residential zones. This is also a popular alternative to expressway. dramatic change that produces potential pressure on daily trip generation and attraction. A statistical method is needed to model travel time distribution on which reliability indices measurements including buffer index, buffer time and 95% percentile travel time were developed based on.

3. Study Area

The study area has Al-Karada Kharidge street arterial urban street within CBD area in Baghdad city. The distances along the route were calculated depended on measurements of the GPS that equipped in the vehicle. This route connects the central business district (CBD) with major commercial, industrial and high-density residential zones. Al-Karada Kharidge street is among the most important arterial streets in the governorate of Baghdad Most surrounding area of mix Land-use (residential, commercial, and industrial). A very variable path where most of the traffic is controlled through by police man instead of traffic lights, with a bus corridor included along the road. It connects two vital areas between Al Jadriyah zone and the Baladayat zone, that start from the Baghdad University intersection to Mohamed al-Qasim intersection. That is located east of Baghdad, the carriageway had four lanes in total with two lanes each direction and divided by physical median. The length of the path each direction is (7.213 km), this street consists of eight links as shown in table (1), and also consist of nine intersections.
Table 1. Details of Al-Karada Kharidge Street (North Direction)

| Intersections              | Links   | Description of Links                                      | Length of Link (for Links) |
|---------------------------|---------|----------------------------------------------------------|----------------------------|
| Baghdad University        | Link 1  | Start from Baghdad University intersection to Kamal Junblat square | 1.510 km                   |
| Kamal Junblat square      | Link 2  | start from Kamal Junblat square to Al-Hurya intersection   | 509 m                      |
| Al-Hurya intersection     | Link 3  | Start from Al-Hurya intersection to Al-Masbah intersection | 2.525 km                   |
| Al-Masbah intersection    | Link 4  | start from Al-Masbah intersection to Aqba Bin Nafi intersection | 527 m                      |
| Aqba Bin Nafi intersection| Link 5  | start from Aqba Bin Nafi intersection to Al-Tahariyat square | 450 m                      |
| Al-Tahariyat square       | Link 6  | Start from Al-Tahariyat square to Abdel kader El Djezairi square | 397 m                      |
| Abdel kader El Djezairi square | Link 7 | Start from Abdel kader El Djezairi square to Al-Senaha intersection | 340 m                      |
| Al-Senaha intersection    | Link 8  | Start from Al-Senaha intersection to Mohamed Al-Qasim intersection | 465 m                      |
| Mohamed Al-Qasim intersection | ------ | -------------------------------------------------------- |---------------------------|

4. Data Collection and Application

The field data are collected for the identified (Al-Karada Kharidge street) in this research the required data collection period for two months was from December 2019 to February 2020 at the off-peak and peak of the evening and morning periods. During good weather, all needed traffic data are gathered because adverse weather conditions can cause variations in the usual pattern of traffic flow. The GPS device (TELTONIKA GPS, FMA 202, As for his commercial name wenk GPS, wenk 122) a local manufactured GPS consisting of a GPS device and a control button connected to the device via a cable as shown in figure (1). Where data were collected in this study through it. The developed methodology depends on using test car technique with GPS equipment. The data collection equipment turns on and off automatically with the vehicle ignition. The benefit of the control button is to control the points that are taken by the device as the methodology of this study requires taking the start point and end points of the link to calculate the travel time spent by the vehicle in this link, in addition to Measurement of delay at intersections by Four readings which are taken at intersections respectively along the route and in the reverse direction. These readings are used to compute (deceleration, stopping, and acceleration) time. Sometimes, at some intersections there is no stopping occur so that when you press the control button a point will be recorded showing the location of the vehicle, i.e. coordinates, the time that the point was taken and the actual speed. figure (1) shows the GPS device used in this study and a screenshot of the field data measurement that is sent from the GPS device to the server and with the account user name and password, the data is obtained that includes date, location, speed and time of measurement. distances along roads were calculated based on measured point locations from GPS.
5. Results and Discussions

5.1 Trajectories of Travel Time and Analysis of Vehicle Speed Profile

Control delay is known as the delay owing to the activity of traffic signs at signalized intersections. Control delay is just a portion of the overall delay. The total delay at intersection can be defined as the sum of three components. In this research, the components of total delay at signalized intersections are (deceleration, stopping, and acceleration time) along the Al-Karada Kharidge arterial street was measured from (the Baghdad University intersection to Mohamed al-Qasim intersection) dependent on GPS data collected on during the weeks in January and February 2020 during 100 trial runs in the north direction and south direction at non-peak and peak periods. figures (2) and (3) demonstrations the profile of speed along the Al-Karada Kharidge street for each direction. The free flow speed for each link is specified in the table (1), That reflects speed limit in Al- Karada Kharidge street. the trajectories of travel time along Al-Karada Kharidge street present in the figures (4) and (5). The total travel time varied, for each direction, as shown in table (2). Figure (6) shows the delay Component Proportions: (Acceleration, Stopped and Deceleration) delay time at Allqaa intersection for each direction.

Figure 1. The manufactured device GPS and data measurement

Figure 2. Profile of Speed Along Al-Karada Kharidge Street (North Trend) at Evening Non- Peak Hour.
Figure 3. Profile of Speed Along Al-Karada Kharidge Street (North Trend) at Morning Peak Hour.

Figure 4. Profile of Travel Time Along Al-Karada Kharidge Street (North Trend) at Evening Peak Hour
Figure 5. Profile of Travel Time Along Al-Karada Kharidge Street (South Trend) at Morning Non-Peak Hour

Table 2. Total Travel Time for the Sample Test Run Selected (Al-Karada Kharidge street)

| Street Name     | Direction Type | Travel Time (Morning Period) | Travel Time (Evening Period) |
|-----------------|----------------|-------------------------------|------------------------------|
|                 |                | At Peak (mm:ss)                | At off Peak (mm:ss)          | At Peak (mm:ss) | At off Peak (mm:ss) |
| Al-Karada       | North direction| 30:36 to 33:23 (mm:ss)        | 17:09 to 22:18 (mm:ss)      | 38:33 to 41:15 (mm:ss) | 15:04 to 20:29 (mm:ss) |
| Kharidge street | South direction| 35:32 to 43:53 (mm:ss)        | 17:25 to 20:33 (mm:ss)      | 31:39 to 32:44 (mm:ss) | 21:40 to 23:55 (mm:ss) |
Figure 6. Delay Component Proportions: (Acceleration, Stopped and Deceleration) delay time for 50 Trial Runs during Peak and Non-Peak Hours at Aqba Bin Nafi Intersection 100% (a) for North Direction (b) for South Direction
5.2 Analysis of Travel Time for links

Delay for each street is a delay at intersections with traffic lights and delays for links as delays in intersections (deceleration delay, acceleration delay, stopping delay) are showed in the figure (6). As for the delay of the links is lost due to delay congestion in links, it is note in the figures (7) and (8) the travel time and the delay for 50 tests run of Link 4 in the north and south direction, respectively, in addition, Maximum travel time and delay time for links respectively at north direction presented in the table (3).

Table 3. Maximum Travel Time and Delay Time for Each Link at Al-Karada Kharidge street (North Direction)

| Links of Al-Karada Kharidge Street | Maximum Travel Time of Link (sec) | Maximum Delay Time of Link (sec) | Delay Percentile of Travel Time (%) |
|------------------------------------|-----------------------------------|----------------------------------|-------------------------------------|
| Link. 1                            | 1259 sec                          | 1168.4 sec                      | 93 %                                |
| Link. 2                            | 301 sec                           | 270.46 sec                      | 90 %                                |
| Link. 3                            | 732 sec                           | 580.5 sec                       | 79 %                                |
| Link. 4                            | 436 sec                           | 404.38 sec                      | 93 %                                |
| Link. 5                            | 182 sec                           | 155 sec                         | 85 %                                |
| Link. 6                            | 678 sec                           | 654.18 sec                      | 96 %                                |
| Link. 7                            | 345 sec                           | 324.6 sec                       | 94 %                                |
| Link. 8                            | 190 sec                           | 162.1 sec                       | 85 %                                |

5.2.1 Spatial analysis of Al-Karada Kharidge Street. The total delay of the rout is the link delay in addition to the delay of the intersections with the traffic light. In addition, it is noted through table (4) that the average delay that occurs in the link is more than the average delay that occurs at the intersections with a traffic signal because the deceleration delay and the stopping delay are parts of the components of the total delay of the intersections whose events occur in the delay of the link. As for the delay that occurs in the start of link as a result of vehicles stopping at the side of the road, or as a result of some vehicles U-turn, pedestrians crossing or changing lines, it is less than the total delay at the signalized intersection however the delay of the link increases at the downstream intersection. Finally, it is noticed stopping delay is the major part of
total delay at intersection and link, so it should be noted that Link 1 and Link 3 are the ones that cause the greatest delay on Al-Karada Kharidge street in the north direction, depending on the average total delay at intersections and average travel time of links. Identify travel time information and delay time information on Al-Karada Kharidge Street Using an ArcGIS 10.2 program. The figure (9) shows a geographical map on which Al-Karada Kharidge Street is specified in the northern direction and on which the average travel time is specified for each link, as the red link indicates the most crowded link and causes a delay along the corridor is link 3. In addition, to the gradation of colors according to the average travel times. As this map is based on the date of the World Geodetic System 1984 and the projection region 38 north of the Universal Transverse Mercator (UTM) map.

Table 4. Maximum Total Travel Time and Delay Time for Al-Karada Kharidge Street (North Direction)

| No. of Links | Average Travel Time of Link (sec) | Max. Travel Time of Link (sec) | Total Delay at Intersection or Square Max.(sec) | Average(sec) |
|--------------|----------------------------------|-------------------------------|-----------------------------------------------|--------------|
| Link. 1      | 316                              | 1259                          | 1415                                          | 267          |
| Link. 2      | 128                              | 301                           | 257                                           | 138          |
| Link. 3      | 418                              | 732                           | 578                                           | 244          |
| Link. 4      | 194                              | 436                           | 450                                           | 208          |
| Link. 5      | 73                               | 182                           | 43                                            | 20           |
| Link. 6      | 64                               | 678                           | 211                                           | 48           |
| Link. 7      | 66                               | 345                           | 208                                           | 33           |
| Link. 8      | 57                               | 190                           | 26                                            | 14           |

Figure 9. Graded Map of Average Travel Time of Links for Al-Karada Kharidge Street (North Direction)
5.3 Model Development of travel time

A regression model was used to predict the total travel time of corridor as a dependent variable along Al-Karada Kharidge arterial route by use the (SPSS version 24 statistical software). The independent explanation parameter included the total delay at signalised intersections (deceleration, stopping and acceleration) delay time, travel time of links and delay of links obtained from field data collected over 100 test runs using test car equipped GPS device as explained earlier to study the travel time variance behaviour on the links that have substantial variation and multimodal form due to the delay at the signalled intersection and impedance due to the traffic jam at links at the peak and off peak hour. A normal distribution is applied and fitted for the field data. The graphical representation of histogram with normal curve for travel time distributions are shown in figure (10) for total travel time of corridor (TTOC), total delay at intersections (TDAI), delay of link (DOL) and travel time of links (TTOL) in this research. The travel time distribution is fitted to normal for (TTOC, TDAI, DOL and TTOL). Based on normality test for Shapiro-Wilk column in table (5).

![Figure 10. Normal Travel Time Distributions for AL-Karada Kharidge Street](image-url)
Linear regression technique was done to get the best relations between total travel time of corridor (TTOC) and total delay at intersections (TDAI), delay of link (DOL) and travel time of links (TTOL) by using data from measurements in the field. There were two forms (single variable and multi-variable) of regression analysis used. regression analysis results for Dependant parameter total travel time of corridor (TTOC), and Independent Explanatory Variables: total delay at intersections (TDAI), delay of link (DOL) and travel time of links (TTOL). In a step - wise regression linear method, these variables were added. In this step, the total delay at intersections (TDAI), delay of link (DOL) and travel time of links (TTOL) were incoming in the regression model, and incoming the (TTOL) value gives a modified $R^2$ of 0.997. Details of the developed regression models are shown in tables (6) & (7). From these tables, it was found that in all models, the resulting coefficients of determination ($R^2$) are considered to be good and comparable to that found in other studies. At 95%, they are also found to be significant level of confidence as the significance of statistic $F < 0.001$. It has also been noticed that the travel time of links (TTOL) has the highest $t$-value of all independent variables. Thus, the travel time of links (TTOL) is considered to be the most significant independent variable and has the most contribution in all models.

### Table 5. Test of Normality for Travel Time Distribution

|         | Kolmogorov-Smirnov<sup>a</sup> | Shapiro-Wilk |
|---------|---------------------------------|--------------|
|         | Statistic df Sig. | Statistic df Sig. |
| TTOC    | .058 85 .200* | .973 85 .071     |
| TTOL    | .057 85 .200* | .973 85 .074     |
| TDAI    | .077 85 .200* | .971 85 .051     |
| DOL     | .057 85 .200* | .974 85 .078     |

* This is a lower bound of the true sig.

<sup>a</sup> Lilliefors Sig. Correction

### Table 6. The Summary of Predicated Single and Multiple Variable models

| Model                  | Change Statistics |            |            |            |            |
|------------------------|-------------------|------------|------------|------------|------------|
|                        | R Square Change   | F Change   | df1 | df2 | Sig. F Change |
| 1 (single)             | .997              | 28551.673  | 1   | 83  | .000        |
| 2 (Multi-variables)    | .997              | 14308.610  | 2   | 82  | .000        |
| 3 (Multi-variables)    | .997              | 9459.684   | 3   | 81  | .000        |

<sup>a</sup> Forecasters: (Constant), TTOL
<sup>b</sup> Forecasters: (Constant), TTOL, TDAI
<sup>c</sup> Forecasters: (Constant), TTOL, TDAI, DOL
Table 7. regression analysis results for Dependant Parameters TTOC and Independent Parameters; (TTOL, TDAI, DOL)

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. | Collinearity Statistics |
|-------|-----------------------------|---------------------------|---|------|------------------------|
|       | B                           | Std. Error                | Beta |       | Tolerance | VIF |
| (Constant) | 77.452 | 7.921 | 9.778 | .000 |          |     |
| 1     | TTOL                      | 1.029 | .006 | .999 | 168.972 | .000 | 1.000 | 1.000 |
| (Constant) | 99.236 | 21.502 | 4.615 | .000 |          |     |
| 2     | TTOL                      | .951 | .072 | .923 | 13.307 | .000 | .007 | 138.146 |
|       | TDAI                      | .085 | .078 | .076 | 1.090 | .279 | .007 | 138.146 |
| (Constant) | 209.735 | 197.553 | 1.062 | .292 |          |     |
| 3     | TTOL                      | .678 | .491 | .658 | 1.380 | .171 | .000 | 6466.547 |
|       | TDAI                      | .078 | .079 | .070 | .992 | .324 | .007 | 141.124 |
|       | DOL                       | .280 | .497 | .271 | .563 | .575 | .000 | 6605.952 |

Details of correlation coefficients analysis between total travel time of corridor (TTOC) and travel time of links (TTOL), total delay at intersections (TDAI) and delay of link (DOL) are shown in table (8). From that table, it could be noted TTOL, DOL have the highest correlation with TTOC. Generally, the signs of the correlation coefficients are in the expected direction, meaning that the total travel time of corridor (TTOC) tends to increase as the travel time of links (TTOL), total delay at intersections (TDAI) and delay of link (DOL) increase.

Table 8. Correlation Coefficients between TTOC and TTOL, TDAI, DOL

| Pearson Correlation | TTOC | TTOL | TDAI | DOL |
|---------------------|------|------|------|-----|
|                      |      | .999 | .995 | .999 |
|                      | TTOC |      | .996 | 1.000 |
|                      | TTOL | .999 |      | .996 |
|                      | TDAI | .996 | .996 |     |
|                      | DOL  | .996 | .996 | 1.000 |
| Sig. (1-tailed)      |      |      |      |     |
|                      | TTOC | .000 | .000 | .000 |
|                      | TTOL | .000 | .000 | .000 |
|                      | TDAI | .000 | .000 | .000 |
|                      | DOL  | .000 | .000 | .000 |
|                      | TTOC | 85   | 85   | 85   |
|                      | TTOL | 85   | 85   | 85   |
|                      | TDAI | 85   | 85   | 85   |
|                      | DOL  | 85   | 85   | 85   |

A total travel time of corridor (TTOC) model was developed using regression technique, which is a set of statistical operations to forecast the relations amongst particular field variables in this study, that is, travel
time of links (TTOL), total delay at intersections (TDAI), and delay of link (DOL).

\[ \text{TTOC} = 77.452 + 1.029 \times \text{TTOL} \]  

(1)

Where

TTOC: Total travel time of corridor
TTOL: Travel time of link

5.3.1 Validation of Modeling. The greatest appropriate for the estimated travel time model for the field travel time value for the AL-Karada Kharidge arterial street model studied. The validation of the travel time model from field data seen between predicted travel time and actual travel time. In order to complete the validation process, additional data was measured and not used in the model building. And to construct a general model with reasonable performance, an 80 percent data splitting technique was used. The accuracy of fit for the projected model and field data was then checked using a chi-square test, as seen below.

Goodness of Fit:

\[ N. = 25, \text{ degree of freedom}=24, \text{ sig. level } \alpha = 0.05 \]

| Predicted Models | \(z^2\) | \(z_{\text{critical}}\) |
|------------------|--------|----------------------|
| AL-Karada Kharidge Street | 7.689 | 36.415 |

The predicted travel time model can be concluded to represent the overall travel time of the actual field values of the corridor. This is because there are no major variations, as \(z^2 < z_{\text{critical}}\), between the forecasted model and the field data observed.

6. Conclusions

1- Intersection delay and link delay are the two delays that cause delays in travel in arterial streets as intersection delay is a result of delayed deceleration, stopping and acceleration. As for the delay of the link, it can arise as a result of the large flow on the link after passing the source intersection and the driver trying to accelerate and return to the vehicle's actual speed. It can also arise as a result of the Due to part of the total delay that occurs at the downstream intersection, which is the deceleration delay as well as the stopping delay which are considered as an overlapping delay between delay of link and delay of intersection.

2- Where it was noticed that the total delay of the intersections constitutes the largest part of the delay of the arterial street, due to the delay of stopping, which constitutes the largest The component of the overall delay at intersection (deceleration, stopping and acceleration) delay.

3- The travel time model thus developed is \(\text{TTOC} = 77.452 + 1.029 \times \text{TTOL}\), this estimated travel time model will provide a reasonably reliable estimation of the real field values for the total corridor travel time.

4- The GPS device is an efficient successfully field device to calculate the travel time for each link along the lane in addition to measuring the intersection delay accurately, and it consists of (deceleration, stop, and acceleration) delay at peak and off-peak hour.
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