Evaluation the Level of Service of Signalized Intersection: Al-Amreia Intersection as a Case Study

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Abstract. One of the main element in the network is the intersection which consider as the critical points because there are many conflict in this element. The capability and quality of operation of an intersection was assessed to provide a better understanding of the network's traffic efficiency. In Baghdad city, the capital of/Iraq the majority of the intersections are operated under the congestion status and with level of service F, therefore theses intersection are consider as high spot point of delay in the network of Baghdad city. In this study we selected Al-Ameria signalized intersection as a case study to represent the delay problem in the intersections in Baghdad. The intersection is located in the west of Bagdad city, this intersection realizes a huge traffic, and there are a lot of tourist attractions near to the study area. The aim of this research is to enhance traffic operations, improve the level of service and decrease the delay in Al-Ameria signalized intersection by examine four suggested alternative. Special teams with a special tools are collected traffic and geometric data for the intersection. HCS 2010 program are used in this study to measure the delay and evaluate the level of service in each approach and for the hall of the intersection. The result of this study show that the intersection is operated under the breakdown condition with level of service F for all approaches. The results highlighted that the fourth alternative is the best suitable suggestion to enhance the level of service for the intersection. The fourth alternative recommended to construct a flyover from the North bound towards the South bound the level of service improve from F to C for the base year and for the target year.

Keywords: Signalized intersection · Delay · Level of service · HCS

1 Introduction

The intersection can be consider as one of the significant part of the network due to the conflict that will be happened at this point and may be leads to many problems such as traffic congestion, traffic accidents. According to Eastern Asia Society for Transportation Studies, there are two types of intersections grade and grade separated. At the same time

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the intersections can be classified as signalized and unsignalized due to the type of control [1]. Traffic capacity, the key items that are used to determine traffic activity in the intersection are the volume to capability ratio, deviation, and quality of service [2]. The capacity of intersection can be defined as the maximum number vehicles that can move through a given section during one hour under the dominant conditions, the capacity for the intersection is measured for the lane group (for all lanes in the approach) [3]. The volume to capacity ratio refer to the degree of saturation of the intersection which refer to the ability of the intersection to operate the traffic demand under best condition. Any intersection with volume to capacity ratio less than 0.85 is consider as an ideal condition for the intersection and the traffic volume for this intersection will not expected any congestion and delay. On the other hand, any intersection with volume to capacity ratio more than 1.0, the intersection will operate with unstable condition and the traffic volume in the intersection will expected more delay and there will be queuing in all approaches [4]. Delay can be consider as an adequate indicator to assess the traffic operation for the intersection [5]. Based on the HCM 2010 the delay can be define as the "the additional travel time experienced by a driver, passenger, or pedestrian". The delay of the intersection can be classified into: uniform delay, incremental delay and initial queue delay [2].

The average control delay can be calculated according to the Eq. 1:

$$\mathrm{d} = \mathrm{d}_1 + \mathrm{d}_2 + \mathrm{d}_3 \tag{1}$$

Where:
d_1: is uniform control delay,
d_2: is incremental delay, and.
d_3: is initial queue delay.
The uniform control delay is:

$$d_1 = \frac{0.5C(1 - g/C)^2}{1 - [min(1, X)g/C]} \tag{2}$$

Where
C: is cycle length in seconds and g is the lane group's efficient green period (second).
X: represents the lane group's v/c ratio.
The incremental latency is as follows:

$$d_2 = 900T\left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8KIX}{cT}}\right] \tag{3}$$

Where:
T: analysis period duration (hour),
K: signal controller mode-dependent delay adjustment factor,
I: upstream filtering/metering adjustment factor.
c: lane group potential (veh/hr),
X: lane group v/c ratio.

The initial queue delay is:

$$d_3 = \frac{3600}{vT}\left(t_A \frac{Q_b+Q_e-Q_{eo}}{2} + \frac{Q_e^2+Q_{eo}^2}{2c_A} - \frac{Q_b^2}{2c_A}\right)$$

$$Q_e = Q_b + t_A(v - c_A)$$

$$\text{If } v \geq c_A \text{ then: } Q_{eo} = T(v - c_A) \quad (4)$$

$$t_A = T$$

$$\text{If } v < c_A \text{ then: } \begin{array}{c} Q_{e0} = 0.0 \cdot veh \\ t_A = Q_b/(c_A - v) \leq T \end{array}$$

Where:
T: is the analysis period's time in hours,
v: the request flow rate in vehicles per hour, and.
tA: is the adjustment period for unmet demand during the analysis period (hour),
cA: average potential of lane category (veh/h),
Qb: denotes the initial queue at the start of the analysis period (veh),
Qe: denotes the initial queue at the end of the analysis period (veh),
Qeo: denotes the initial queue at the end of the analysis period when cA > cA and Qb = 0.0 (veh).

To evaluate the quality of the any part in the transportation network the traffic engineers used the term level of service (LOS) which is represented the delay that occur in the traffic stream that used this part of the network [6]. According to HCM 2010 the LOS can be defined as "a quantitative stratification of a performance measure or measures that represent the quality of service". The LOS of intersection can be classified into six level centered on the normal intersection delay from A to F The LOS for a signalized intersection is shown in Table 1.

Table 1. LOS criteria for signalized intersection [2]

LOS	Average delay sec/veh
A	≤10
B	10–20
C	20–35
D	35–55
E	55–80
F	More than 80

2 Previous Studies

The HCS software has been used in several studies to evaluate and improve the LOS for signalized intersections in various Iraqi cities. HCS 2000 was used to assess the

Al-Thawra signalized intersection in Al-Hilla district, Iraq. The intersection operates with a 263.7 s/veh F LOS delay. The analysis proposed building a flyover to boost the LOS; as a result, the LOS would be C with a latency of 22.8 s/veh [7]. Karim used HCS 2000 in 2011 to assess the Al-Quds signalized intersection in Baghdad, Iraq. With an average delay of 328.7 s per vehicle, the intersection was found to fit with LOS F. By inserting one lane for each approach, the intersection's LOS improves to C, with an average delay of 34.6 s per vehicle [8]. Another research used HCS 2000 to assess the AL-Mustansiriyah Intersection in Baghdad, Iraq. The best idea for improving the LOS in this intersection was to construct a flyover between Al-Mustansiriyah University Street and Al-Talibia Street, according to the study [9]. In addition, the LOS for the AL-Kafa'at signalized intersection in AL-kut district, Iraq, is evaluated using HCS 2000. The current LOS for this intersection is F, with an average delay of 102.8 s per vehicle; but, according to this report, adding more lanes for the right turn would increase the LOS to D, with an average delay of 38.1 s per vehicle [10]. HCS 2010 was used to test the LOS for the Al-Furqan intersection in Al-Fallujah district, Iraq. The operational review for this intersection indicates that the intersection operates at LOS F with an average delay of 105.2 s per vehicle. This study recommended that traffic from the west bound be avoided in order to increase the LOS from C, which has an average pause of 34.5 s per vehicle [11].

3 Objectives of the Study

The main objectives in this study are:

- Establish the peak hour for Al-Amreia intersection, which is consider as the highest traffic volume in all approaches.
- Evaluate the current LOS at the Al-Amreia intersection with both approaches.
- Suggestion different proposals to improve the LOS at Al-Amreia intersection.
- Evaluation the LOS for all suggested proposals for all approaches at Al-Amreia intersection.
- Selections the best propsal to improve the LOS at Al-Amreia intersection for the base and target year

4 Study Area

Baghdad is the capital of Iraq; it considers as one of the congested cities in the world because the huge number of vehicles that using the network in this city especially after 2003. All intersections in Baghdad city are operated under breakdown condition with LOS F. For this reason, one of the congested intersection are selected in this study. Al-Amreia intersection is selected as a case study for these reasons:

- Al-Amreia intersection connects the traffic volume that are coming from the West provinces to Baghdad city.
- This intersection has high traffic volumes in all approaches

- There are many attraction locations (residential, educational and commercial) close to the study area.

Figure 1 represented Al-Amreia intersection and the boundary area of the selected intersection study.

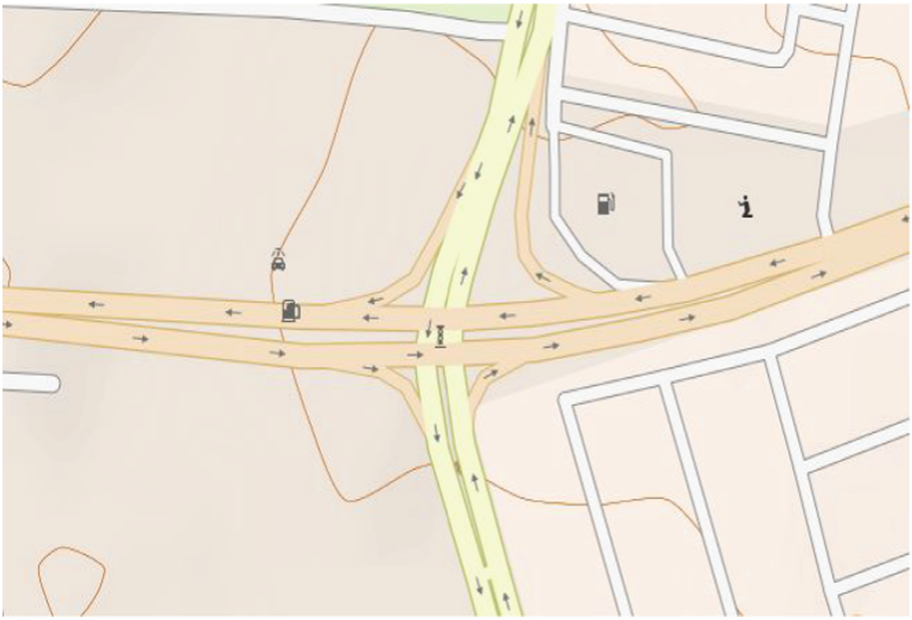

Fig. 1. Satellite image for Al-Amreia intersection in Bagdad city, Iraq [open street]

5 Methodology

To obtain the LOS for Al-Amreia intersection this study will follow the methodology that describe in HCM 2010. Figure 2 shows the main steps that must be follow to obtain the LOS which is the primary output.

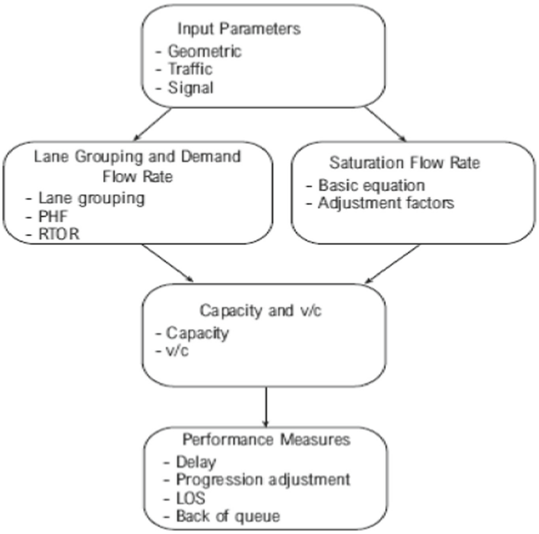

Fig. 2. Signalized intersection methodology

6 Data Collection

To evaluate the traffic operation at Al-Amreia intersection in terms of LOS a field data survey is made by special teams these data including traffic and geometric data. The measurements of these data are made manually on working days (Monday to Thursday) at January 2021 to spot the peak hours.

6.1 Traffic Volumes

Traffic data survey is made for Al-Amreia intersection at the workdays from (6:00 am to 7:00 pm) during the 2^{nd} week on January 2021, the traffic volume is counted in each approach for the three movement (left, through and right) and the highest number of traffic volume during the survey time was highlighted as peak hour. The traffic volume flow is classified into two categories:

- Passenger vehicles: Any vehicle contains four tires only.
- Heavy vehicles: Any vehicle contains more than four tires.

Table 2 shows the traffic volume at Al-Amreia intersection for each approach according to their movement form (6:00 am to 7:00 pm).

While Table 3 shows the Heavy vehicles percentage at Al-Amreia intersection.

Table 2. One-hour traffic level at the Al-Amreia intersection for both approaches

Time (hr)	EB (Al-Khadra)			WB (Abu Ghareeb)			NB (Al-Ghazalia)			SB (Al-Amreia)		
	RT	TH	LT	RT	TH	LT	RT	TH	LT	RT	TH	LT
6–7 am	150	250	120	50	240	55	30	220	400	110	200	50
7–8 am	250	520	442	32	320	92	30	230	490	170	320	120
8–9 am	240	540	480	36	280	180	25	232	480	240	320	240
9-10 am	260	400	616	28	320	184	24	344	300	160	260	60
10–11 am	260	432	640	12	160	100	28	268	420	140	172	80
11–12 pm	256	380	800	28	408	200	20	400	548	184	304	56
12–1 pm	560	360	624	80	620	304	32	356	524	152	428	120
1–2 pm	360	320	480	84	440	320	40	488	500	180	400	152
2–3 pm	600	316	908	100	584	300	60	660	664	240	756	120
3–4 pm	465	250	682	82	456	250	74	582	574	272	290	78
4–5 pm	240	200	660	60	360	160	60	400	528	240	240	48
5–6 pm	120	256	408	70	278	160	32	288	273	220	400	55
6–7 pm	88	200	256	65	220	130	25	320	389	250	534	53

Table 3. Heavy vehicles percentage at Al-Amreia intersection.

Approach	% Heavy vehicles
EB (Al-Khadra)	7
WB (Abu Ghareeb)	12
NB (Al-Ghazalia)	9
SB (Al-Amreia)	6

6.2 Saturation Flow Rate

One of the main effective parameter on the capacity of intersection is the saturation flow rate. To calculate this parameter for Al-Amreia intersection. The software HCS 2010 is employed. The calculated saturation flow for each approach at Al-Amreia intersection is shown in Table 4.

6.3 Existing Geometric Design

It is important to determine the number of lanes and the direction of each movement when evaluating the quality of operation (LOS) at the Al-Amreia intersection. Figure 3 illustrates the intersection's current geometric layout.

Table 4. Saturation flow rate calculated at Al-Amreia intersection.

Approach	Movement	Saturation flow rate (vphg)
EB (Al-Khadra)	RT	1615
	TH	5187
	LT	1805
WB (Abu Ghareeb)	RT	1733
	TH	5033
	LT	1723
NB (Al- Ghazalia)	RT	1499
	TH	5123
	LT	1902
SB (Al-Amreia)	RT	1644
	TH	4944
	LT	1899

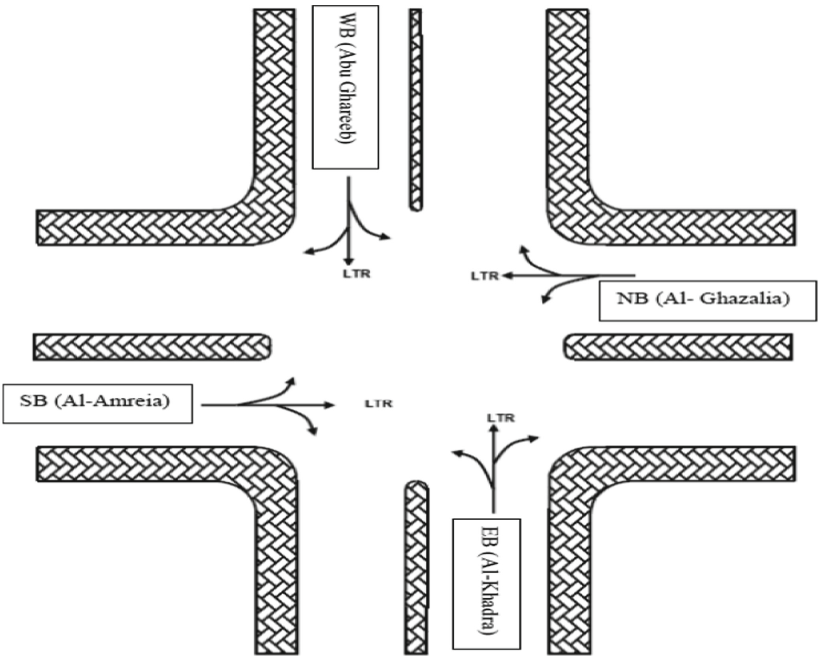

Fig. 3. Existing geometric design of Al-Amreia intersection

7 Analysis and Results

7.1 Peak Hour Volumes

The following findings were drawn from the site inspection and traffic analysis:

- The peak hour at the Al-Amreia intersection is between 2:00 and 3:00 p.m. At this hour, the overall traffic volume at the Al-Amreia intersection was 5038 pc/h (see Fig. 4).

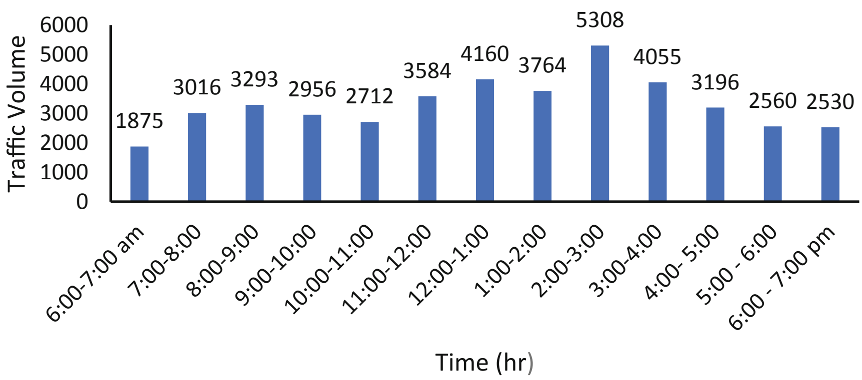

Fig. 4. Distribution of traffic volume at Al-Amreia intersection from 6:00 a.m to 7:00 p.m.

7.2 Peak Hour Factor (PHF)

According to HCM 2010, the PHF can be described as the ratio of total volume to the hour's maximum 15-min rate of flow. The following table summarizes the PHF values for both routes to the Al-Amreia intersection (Table 5).

7.3 Existing LOS

To assess the current LOS HSC 2010 software, it is implemented. The LOS at the base year was determined to be LOS (F), as seen in Table 6.

Table 5. Peak hour factor at Al-Amreia intersection.

Approach	Movement	PHF
EB	RT	0.88
	TH	0.91
	LT	0.89
WB	RT	0.95
	TH	0.94
	LT	0.87
NB	RT	0.88
	TH	0.95
	LT	0.87
SB	RT	0.90
	TH	0.93
	LT	0.91

Table 6. Existing LOS at Al-Amreia intersection

Approach	Average delay sec/veh	LOS
EB (Al-Khadra)	216.3	F
WB (Abu Ghareeb)	102.4	F
NB (Al-Ghazalia)	128.6	F
SB (Al-Amreia)	107.3	F
Intersection	138.7	F

8 Proposals Design Alternative

8.1 First Proposal: Change the Cycle Length and Green Time for All Approaches

The first proposal that will be adopted it to change the cycle length form 90 s to 120 s. In addition, it will increase the green time for the congested direction approaches (EB (Al-Khadra) and SB (Al-Amreia)) in the intersection, it is found from the results shown in Table 7 that the change the cycle length and green time for all, the intersection became operational as a result of these methods (LOS F). As a result, this plan is not recommended for operational improvement, and another one must be adopted.

8.2 Second Proposal: Increase Number of Lanes

The second plan to enhance the intersection's LOS proposed increasing the amount of lanes on both approaches by removing parking in the approach lanes. It is found from the

Table 7. LOS at Al-Amreia intersection within first proposal

Approach	Average delay sec/veh	LOS
EB (Al-Khadra)	172.2	F
WB (Abu Ghareeb)	92.4	F
NB (Al-Ghazalia)	89.3	F
SB (Al-Amreia)	91.8	F
Intersection	111.4	F

results shown in Table 8 that the increase the number of operation lanes at all approaches caused the intersection to work (LOS F). As a result, this plan is not recommended for operational improvement, and another one must be adopted.

Table 8. LOS at Al-Amreia intersection within second proposal

Approach	Average Delay sec/veh	LOS
EB (Al-Khadra)	145.7	F
WB (Abu Ghareeb)	83.7	F
NB (Al- Ghazalia)	75.6	E
SB (Al-Amreia)	81.8	F
Intersection	96.7	F

8.3 Third Proposal: Underground from East Bound Towards West Bound

The third proposal to improve the LOS for the intersection suggested to increase the number of lanes in all approaches by eliminating the parking in the execution of underground along EB (Al-Khadra) towards WB (Abu Ghareeb). It is found from the results shown in Table 8 that the increase the number of operation lanes at all approaches made the intersection operate on (LOS D). Therefore, this proposal is not recommended to improve the operation and it is necessary to adopt another proposal (Table 9).

8.4 Fourth Proposal: Fly Over from North Bound Towards South Bound

The fourth proposal is to execute a flyover that connects NB (Al- Ghazalia) towards SB (Al-Amreia), while the intersection is kept operating with four legs. It is clear from the results that were shown in Table 10 that the LOS was (C). Also the execution of this proposal will not make any improvement on the LOS, therefore; the fourth proposal was adopted.

Table 9. LOS at Al-Amreia intersection within third proposal

Approach	Average delay sec/veh	LOS
EB (Al-Khadra)	30.7	C
WB (Abu Ghareeb)	29.1	C
NB (Al-Ghazalia)	53.7	D
SB (Al-Amreia)	49.7	D
Intersection	40.8	D

Table 10. LOS at Al-Amreia intersection within third proposal

Approach	Average delay sec/veh	LOS
EB (Al-Khadra)	34.3	C
WB (Abu Ghareeb)	27.5	C
NB (Al-Ghazalia)	20.5	C
SB (Al-Amreia)	21.2	C
Intersection	25.9	C

9 Analysis of Forecasted Traffic Data

The HCS software is used to analyze forecasted data (after 20 years at a 2% annual growth rate) through power, pause, and LOS calculations for all approaches and the entire intersection. For the intended year. According to the data gathered, the LOS in the target year would be LOS (C), as seen in Table 11.

Table 11. LOS at Al-Amreia intersection within third proposal

Approach	Average delay sec/veh	LOS
EB (Al-Khadra)	46.0	D
WB (Abu Ghareeb)	30.5	C
NB (Al-Ghazalia)	22.3	C
SB (Al-Amreia)	26.3	C
Intersection	31.3	C

10 Conclusions

From the results that obtained from the analysis for Al-Amreia intersection it can be concluded that the existing LOS F with average delay 138.7 s/veh. The study suggested four proposals to improve the LOS for the intersection, it is concluded that the fourth proposal which is construct a flyover from NB (Al-Ghazalia) towards SB (Al-Amreia), the proposal reflects the best solution to improve the LOS for the intersection on base and target year. The intersection will operate at C LOS with average delay 25.9 s/veh for base year, while for target year the intersection will operate at C LOS with average delay 31.3 s/veh.

References

1. Kidwai, F.A., Karim, M.R., Ibrahim, M.R.: Traffic flow analysis of digital count down signalized urban intersection. In: Proceedings of the Eastern Asia Society for Transportation Studies, vol. 5, pp. 1301–1308 (2005)
2. Manual, Highway Capacity: HCM2010, Transportation Research Board, National Research Council, Washington, DC (2010)
3. Khisty, C.J., Kent Lall, B.: Transportation engineering. Pearson Education India (2016)
4. Garber, N.J., Hoel, L.A.: Traffic and highway engineering. Cengage Learning (2014)
5. Zheng, Y., Hua, X., Wang, W., Xiao, J., Li, D.: Analysis of a signalized intersection with dynamic use of the left-turn lane for opposite through traffic. Sustainability **12**(18), 7530 (2020)
6. Tüydeş-Yaman, H.: Estimation of Level of Service at Signalized Intersections around the Proposed Health Campus in Etlik Ankara (2014)
7. Al-Ubaidy, A.M., Al-Azzawi, Z.T., Dawood, N.: Evaluation the performance of Al-Thawra at-grade intersection using the HCS2000 computer package. Eng. Tech. J. **28**, 15 (2010)
8. Karim, Q.S: Evaluation and improving of Al-Quds intersection in Baghdad city. Eng. Dev. J. **15**(2) (2011)
9. Jasim, I.F.: Improvement of traffic capacity for AL-Mustainsiriyah intersection in Baghdad City. Al-Qadisiyah J. Eng. Sci. **5**(3) (2012)
10. Khalaf, A.Z., Hamodi, H., Riyadh, M.: Analysis of traffic operation for AL-Kafa'at signalized intersection in Al-Kut City. J. Eng. Dev. Eng. Tech. J. **33** (2015)
11. Alwani, K.H.M.: Improving capacity and traffic operation for Al-Furqan intersection at Al-Fallujah City (Iraq). In: Scientific and Technical Conference Transport Systems Theory and Practice, pp. 27–38. Springer, Cham (2019).