Optimizing the Traffic Operation System of 14th-Ramadhan Signalized Intersection in Baghdad City using HCS Technique

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Abstract. The purposes of the study are assessing the current level of service (LOS) at the 14th-Ramadhan signalized intersection in CBD area of Al-Mansoor district in Baghdad city and increasing the improvement of the traffic operation system by investigating appropriate proposals to increase the traffic capacity of this facility. Data of traffic flow collected using Tally mark method by many observers. Evaluation of the current intersection is to be taken in consideration using HCS Technique (2010), also existing and proposal layouts are displayed using AutoCAD (2017). The results showed that the selected traffic facility are currently suffered from serious lowering in service level causing forced conditions (LOS "F"). Thus, most important considerations should be considered for developing in the LOS by proposing many solutions. In summary, the study is proposed to execute the overpass structure (Grade Separation Bridge) along 14th-Ramadhan street from southbound to northbound directions and vice versa (two lanes in each direction) considering the third proposal (P3). By using HCS2010, the LOS will be changed from F to B assuming that it is expected to continue at higher traffic performance for approximately at least 15 year later

1. Introduction

Intersection in an urban highway networks has an influencing on the traffic performance of the system. In general, two main types of intersections called at agencies of the Eastern Asia Society for highway Studies, at-grade and grade separated intersections. Traffic volume may be priority type, uncontrolled or controlled by signals. At the last type different directions of vehicles participate the same area of the intersection and traffic volume is separated by the time. Because of participating the same movement area, traffic moves such as stop and go situation [1].

As related to Estabraq [2], the objective of this study include the analysis and evaluation LOS of Maysaloon and AL-Bayda’a intersections in Baghdad city. The location of both of them lies in an area with a heavy traffic flow in case there are many attractive locations near to it. The traffic, signal and geometrical data gathered manually to estimate the traffic distribution in many directions. HCS technique was used for the demands of analysing the traffic flow. It showed that the best proposal which is considered to be carryout, is to build a flyover joins the Maysaloun intersection with AL-Bayda’a squares in the direction of Al-Doraa expressway.

On the other hand, the objectives of other study include the analysis, assessing level of service and traffic operation of Al-Abassy intersection in the CBD of Fallojah city. The required flow and geometrical design data collected by some engineers to assess the distribution of traffic in different directions. HCS version 2000 is used for the demands of traffic flow analysis. It suggest of
constructing flyover along new street in the direction of Al-Kamalyat intersection for the mentioned intersections is necessary to enhance LOS at Al-Abassy intersection [3].

2. Theoretical Background

According to Rogers [4], the intersection is used to control conflicting and merging stream points of traffic that minimize the delay time by choosing the geometrical parameters that enhance the vehicle movements in intersection. Delay

Traffic Capacity considered as the lanes number, width for each lane and grades. Intersection flow-to-capacity (v/c) ratio referred to as degree of flow saturation, represents the adequacy of an intersection to be suitable for flow demand. The ratio lesser than 85% mean that enough capacity is available and vehicles are not expected for effectiveness delays and queues. When it closest to 100%, flow will be in critical case, conditions of queuing will be occurred [5].

Delay is important parameters which to be used in measuring the operation performance of an intersection. It considered as a factor which is contains three conditions including of the decelerating to a stop delay, the stopping delay and the accelerating delay after stopping. From all cases the delay is called a as a control delay [6].

Equation (1), (2) and (3) are presented to compute the control delay as shown blow:

\[
d = d_1 \cdot (PF) + d_2 + d_3
\]

\[
d_1 = \frac{(1-\left(\frac{g}{c}\right)^2) \cdot c}{2 \left(1-\left(\frac{\min(1,X) \cdot g}{c}\right)\right)}
\]

\[
d_2 = 900 \cdot T \cdot (X - 1) + \sqrt{(X - 1)^2 + \frac{8 \cdot k \cdot T \cdot X}{c \cdot T}}
\]

Where:

"d" is "control delay (s/veh)"
"d_1" is "uniform delay (s/veh)"
"d_2" is "incremental delay (s/veh)"
"d_3" is "initial queue delay (s/veh)"
"PF" is "progression adjustment factor"
"X" is "v/c ratio for the lane group (also called saturation degree)"
"C" is "cycle length (s)"
"c" is "capacity of lane group (veh/h)"
"g" is "effective green time for lane group (s)"
"T" is "duration of analysis period (h)"
"k" is "incremental delay adjustment for the actuated control"; and
"I" is "incremental delay adjustment for the filtering or metering by upstream Signals".

Delay is the principal factor which is used to evaluate the timing of traffic signals and estimating the (LOS) required at the intersections as expressed in Table 1. Furthermore, it is an important key which is computed due to including stopping decelerating delay, the stopped time delay and accelerating delay after stopping. It can be estimated in many methods, the most commonly recommended one is controlled delay that contain delays due to stopping, approaching and period of travel as that analyzed by the HCS technique [4].
### Table 1. Type of LOS depended on delay [7]

| Delay (veh/sec) | LOS |
|-----------------|-----|
| "d ≤ 10"        | "A" |
| "10 < d ≤ 20"   | "B" |
| "20 < d ≤ 35"   | "C" |
| "35 < d ≤ 55"   | "D" |
| "55 < d ≤ 80"   | "E" |
| "80 < d"        | "F" |

3. **Study Purposes and Goals**

The main goals of the present study are estimating the traffic operation performance in 14th-Ramadhan intersection in Al-Mansoor district in Baghdad city. This can be evaluated by estimating the current LOS at the study area with the choice of the best possible engineering solutions to provide a suitable flow movement of vehicles at the present and future target time.

4. **Area of Study**

14th-Ramadhan signalized intersection is an important area which is lies in Al-Karkh Side of Baghdad city (capital of Iraq) near to the city centre. The geographic coordination of the intersection is illustrated in Figure 1. It joined four articulated approaches which are (14th-Ramadhan street from southbound to northbound direction and vice versa, Al-Andules street from the westbound direction and Abu Jaafar street from the eastbound direction).

![Figure 1. Google Map layout of the Current Al-Mansoor Intersection.](image)

5. **Methodology and Data Collection**

The procedure steps of the study methodology are illustrated in diagram as shown in Figure 2. All requirements containing geometrical and flow data were collected manually by a specialized engineering observers.
5.1. Data of Geometrical Design and Signal Operation

The number of lanes for each of the four approaches of the intersection was measured by a specialized engineering team. In addition, due to the inactivation of traffic signals, the largest green cycle of the four approaches was measured manually and adopted in the preliminary analysis as shown in Table 2.

Table 2. Geometrical and Signal Operation Data.

| Direction     | Approach                | Number of lanes | Movement | Width (m) | Green time (Sec) | Amber Time (Sec) |
|---------------|-------------------------|-----------------|----------|-----------|------------------|------------------|
| North         | From Al-Mansour Intersection | 1, 4, -        | L, TH    | 3         | 132              | 0                |
| South         | From AL-Liqaa Intersection | 2, 2, -        | L, TH    | 3         | 72               | 0                |
| East          | From AL-Andules street     | 1, 3, -        | L, TH    | 3         | 158              | 0                |
| West          | From Abu Jaafar street     | 3, 3, -        | L, TH    | 3         | 297              | 0                |

5.2. Data of Traffic Flow

The flow of traffic were collected manually using Tally Marks method. Vehicles have been classified into (small size including pc and mini buses) and (large size). All data collected in January, 2019 for
(three time/day) during the week excluding the formal and informal holidays. Based on questionnaires’ estimations, [7:00-9:00 AM, 1:00-3:00 and 5:00-7:00 PM] had been taken in consideration to collect the traffic flow in this study. In addition, heavy vehicles Hv (%) consisting of buses and trucks as shown in equation (4) as well as peak hourly factor (PHF) are expressed in Tables 3, 4, 5 and 6 based on each 15 min/hr, where:

\[
Hv (\%) = \frac{\text{Number of Trucks and Buses}}{\text{Total Number of PC and Heavy Vehicles}} \times 100\% \tag{4}
\]

\[
PHF = \frac{\text{Total Flow at an Hour}}{4 \times V_{\text{Max of (15 minutes)}}} \tag{5}
\]

Where: "\(V_{\text{Max of (15 minutes)}}\)" is "the traffic flow at the peak 15 minutes".

**Table 3. Collection Data From Al-Mansour Intersection.**

| Details | From 7:00 | 8:00 | 1:00 | 2:00 | 5:00 | 6:00 |
|---------|-----------|------|------|------|------|------|
| Time Interval | A.M. | P.M. | P.M. | P.M. | P.M. | P.M. |
| R (pc/h) | 325 | 231 | 119 | 100 | 422 | 363 |
| R\(_{HV}\) (v/h) | 0 | 5 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 2.11 | 0 | 0 | 0 | 0 |
| PHF | 0.77 | 0.75 | 0.70 | 0.64 | 0.88 | 0.91 |
| TH (pc/h) | 113 | 95 | 266 | 239 | 338 | 266 |
| TH\(_{HV}\) (v/h) | 0 | 0 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 0 | 0 | 0 | 0 | 0 |
| PHF | 0.74 | 0.76 | 0.95 | 0.84 | 0.92 | 0.74 |
| L (pc/h) | 52 | 35 | 36 | 33 | 48 | 47 |
| L\(_{HV}\) (v/h) | 0 | 0 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 0 | 0 | 0 | 0 | 0 |
| PHF | 0.77 | 0.80 | 0.75 | 0.75 | 0.70 | 0.69 |

**Table 4. Collection Data From Abu Jaafar Street.**

| Details | From 7:00 | 8:00 | 1:00 | 2:00 | 5:00 | 6:00 |
|---------|-----------|------|------|------|------|------|
| Time Interval | A.M. | P.M. | P.M. | P.M. | P.M. | P.M. |
| R (pc/h) | 78 | 53 | 112 | 69 | 202 | 103 |
| R\(_{HV}\) (v/h) | 0 | 0 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 0 | 0 | 0 | 0 | 0 |
| PHF | 0.75 | 0.79 | 0.76 | 0.69 | 0.83 | 0.83 |
| TH (pc/h) | 97 | 81 | 71 | 77 | 440 | 291 |
| TH\(_{HV}\) (v/h) | 0 | 0 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 0 | 0 | 0 | 0 | 0 |
| PHF | 0.81 | 0.86 | 0.66 | 0.74 | 0.86 | 0.66 |
| L (pc/h) | 564 | 519 | 547 | 387 | 467 | 324 |
| L\(_{HV}\) (v/h) | 0 | 0 | 0 | 0 | 0 | 0 |
| Hv (%) | 0 | 0 | 0 | 0 | 0 | 0 |
| PHF | 0.75 | 0.75 | 0.89 | 0.9 | 0.86 | 0.84 |

**Total Flow**
### Table 5. Collection Data From AL-Liqaa Intersection.

| Details         | Time (hour) |
|-----------------|-------------|
| From 7:00       | 8:00        |
| To 8:00         | 9:00        |
| 1:00            | 2:00        |
| 5:00            | 6:00        |
| 7:00            | 8:00        |
| Time Interval   | A.M.        | P.M.        | P.M.        |
| R (pc/h)        | 90          | 116         | 192         | 187         | 54          | 47          |
| $R_{HV}$ (v/h)  | 0           | 0           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0           | 0           | 0           | 0           | 0           |
| PHF             | 0.68        | 0.69        | 0.72        | 0.73        | 0.45        | 0.59        |
| TH (pc/h)       | 446         | 251         | 244         | 162         | 112         | 65          |
| $TH_{HV}$ (v/h)| 0           | 0           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0           | 0           | 0           | 0           | 0           |
| PHF             | 0.64        | 0.81        | 0.80        | 0.75        | 0.82        | 0.77        |
| L (pc/h)        | 95          | 74          | 108         | 71          | 104         | 84          |
| $L_{HV}$ (v/h)  | 0           | 0           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0           | 0           | 0           | 0           | 0           |
| PHF             | 0.79        | 0.69        | 0.79        | 0.59        | 0.79        | 0.84        |

### Table 6. Collection Data From Al-Andules Street.

| Details         | Time (hour) |
|-----------------|-------------|
| From 7:00       | 8:00        |
| To 8:00         | 9:00        |
| 1:00            | 2:00        |
| 5:00            | 6:00        |
| 7:00            | 8:00        |
| Time Interval   | A.M.        | P.M.        | P.M.        |
| R (pc/h)        | 49          | 77          | 64          | 80          | 101         | 122         |
| $R_{HV}$ (v/h)  | 0           | 0           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0           | 0           | 0           | 0           | 0           |
| PHF             | 0.79        | 0.81        | 0.76        | 0.85        | 0.86        | 0.88        |
| TH (pc/h)       | 50          | 71          | 72          | 66          | 89          | 206         |
| $TH_{HV}$ (v/h)| 0           | 0           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0           | 0           | 0           | 0           | 0           |
| PHF             | 0.80        | 0.85        | 0.86        | 0.83        | 0.89        | 0.76        |
| L (pc/h)        | 120         | 155         | 91          | 86          | 145         | 100         |
| $L_{HV}$ (v/h)  | 0           | 1           | 0           | 0           | 0           | 0           |
| Hv (%)          | 0           | 0.70        | 0           | 0           | 0           | 0           |
| PHF             | 0.77        | 0.82        | 0.80        | 0.88        | 0.88        | 0.86        |

### 6. Analysis and Discussion of Data

Data excel sheet is used for analysing the flow distribution to know the peak flow at one hour. Accordingly, an hour of [5:00-6:00 PM] experienced to be the hour of peak flow. The traffic flow that met inside intersection from all approaches during this hour was 1743 vph notifying that this traffic in veh/hr units equal to that in pc/hr because of zero percent of heavy vehicles in that hour as shown in Figure 3.
Figure 3. Traffic Flows at 14th-Ramadhan Signalized Intersection.

6.1. Evaluation and Optimization of the Current Design and New Proposals
Assessment the traffic flow data for the current conditions using HCS technique is presented in appendix A, Figures A1 and A2. Geometrical design using AutoCAD program is displayed in appendix B, Figure B1. The details of analysis summarized in Table 7 which result in (LOS F).

| Details                                      | Proposal No. | Cycle Length (sec) | No. of Phases | Amber Time (sec) | LOS | Delay (sec/veh) |
|----------------------------------------------|--------------|--------------------|---------------|------------------|-----|-----------------|
| Existing Design                              | -            | 659                | 4             | -                | F   | 177.9           |
| Optimizing of Existing Design (Change in Signals Timing only) | P1           | 70                 | 4             | 4                | C   | 27.6            |
| Change in Geometric features and Signals Timing | P2           | 90                 | 4             | 4                | D   | 38.1            |
| Change in Geometric features and Signals Timing | P3           | 70                 | 3             | 4                | B   | 18.8            |

The first proposal (P1) is suggested to optimize the current data as presented in appendix A, Figures A3 and A4. Geometrical layout is displayed in appendix B, Figure B1 too. The details of analysis summarized in Table 7 which result in (LOS C), so this proposal give a little improving in LOS which leads to consider another option of alternatives.

Two alternatives related to changing in geometrical design and signal timing were considered: the first one assumed to be the second proposal (P2) which is suggest of constructing overpass (grade separation bridge) along centerline of the two directions (2 lanes per direction) from southbound to the northbound and vice versa. Traffic analysis summarized in Table 7 and all details illustrated in appendix A, Figures A5 and A6. Geometrical design is displayed in appendix B, Figure B2. Despite the cost of construction the carry out of this proposal will not improve in flow performance where the LOS is D; therefore, another option of alternatives has been considered.
The third proposal (P3) is also suggested as in (P2), but the only difference is that the traffic signal system has changed from four-phase to three-phase. Traffic analysis summarized in Table 7 and all details illustrated in appendix A, Figures A7 and A8. Geometrical design is displayed in appendix B, Figure B3. In contrary to what is in (P3) if compared to the (P2) that the HCS results will raise the level of service to the LOS B for the same reasons mentioned earlier.

6.2. Analyzing of Future Flow Demand
HCS technique is used to analyze the future data to find a target year based on P3 with experienced “2%” annual rate of traffic growth. The results as shown in Figure A9 show that this intersection would be received a high flow capacity (arriving to saturation condition) for not less than 14 years later.

7. Conclusions
In summary, for improving the serviceability of intersection and minimize the time of stopping, the study is proposed to execute the overpass structure (Grade Separation Bridge) along 14th-Ramadhan street from southbound to northbound directions and vice versa (two lanes in each direction) considering the third proposal (P3). By using HCS2010, the LOS will be changed from F to B assuming that it is expected to continue at higher traffic performance for approximately at least 15 years later.

8. Recommendations
- Analyzing the LOS of intersection using SIDRA 5.1 technique.
- Using video camera as an automatically method for accounting the traffic flow instead of Tally marks method.

9. Acknowledgment
The authors gratitude FUC and KUS; and the engineers Abdullah R A, Omar J M, Nadia R G and Maysam M R for accomplishing this paper.

10. Appendices

10.1. Appendix A

| SIGNALIZED INTERSECTION SUMMARY |
|----------------------------------|
| Eastbound | Westbound | Northbound | Southbound |
| L | T | R | L | T | R | L | T | R | L | T | R |
| No. Lanes | 1 | 2 | 0 | 3 | 3 | 0 | 1 | 4 | 0 | 2 | 2 | 0 |
| Location | L | T | L | L | L | L | L | L | L | L | L | L |
| Volume | 145 | 440 | 467 | 440 | 40 | 330 | 194 | 112 |
| Lane Width | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |

| Duration | 0.25 |
| Area Type: CBD or Serious |
| Signal Operations |
| Phase Combination | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| BD | Left | P | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Right | P | Right | P | Right | P | Right | P | Right | P |
| Thru | 5 | 6 | 7 | 8 | 5 | 6 | 7 | 8 |

| Green | 156.0 | 297.0 | 132.0 | 72.0 |
| Yellow | 0.0 | 0.0 | 0.0 | 0.0 |
| All Red | 0.0 | 0.0 | 0.0 | 0.0 |

Figure A1. HCS details of geometrical, flows and phases data of an existing design before optimization.
**Figure A2.** HCS outputs of the current design before optimization.

**Figure A3.** HCS details of geometrical, flows and phases data of the current design (proposal P1).

**Figure A4.** HCS outputs of an existing design (proposal P1).
Figure A5. HCS outputs of geometrical, flows and phases data of the proposal P2.

Figure A6. HCS outputs of the proposal P2.

Figure A7. HCS outputs of geometrical, flows and phases data of the proposal P3.
### Intersection Performance Summary

| Approx/Lane Group | Lane Capacity | Adj Sat Flow Rate (s) | v/c G/C | Lane Group | Approach |
|-------------------|---------------|----------------------|---------|------------|----------|
| Eastbound L        | 316           | 1483                 | 0.52    | 0.21       | 30.5 C   |
|                    | T             | 913                  | 0.43    | 0.21       | 25.3 C   |
| Westbound L        | 1749          | 4087                 | 0.31    | 0.43       | 13.6 B   |
|                    | T             | 1843                 | 0.28    | 0.43       | 13.3 B   |
| Northbound L       | 568           | 3058                 | 0.12    | 0.19       | 24.2 C   |
| Southbound L       | 568           | 3058                 | 0.23    | 0.19       | 25.2 C   |

Intersection Delay = 18.8 (sec/veh) Intersecion LOS = B

**Figure A8. HCS outputs of the proposal P3.**

| Approx/Lane Group | Lane Capacity | Adj Sat Flow Rate (s) | v/c G/C | Lane Group | Approach |
|-------------------|---------------|----------------------|---------|------------|----------|
| Eastbound L        | 316           | 1483                 | 1.48    | 0.21       | 251.7 F   |
|                    | T             | 913                  | 1.22    | 0.21       | 137.5 F   |
| Westbound L        | 1749          | 4087                 | 0.69    | 0.43       | 25.3 C    |
|                    | T             | 1843                 | 0.79    | 0.43       | 20.0 C    |
| Northbound L       | 568           | 3058                 | 0.34    | 0.19       | 26.4 C    |
| Southbound L       | 568           | 3058                 | 0.65    | 0.19       | 32.2 C    |

Intersection Delay = 70.4 (sec/veh) Intersection LOS = E

**Figure A9. HCS outputs of the proposal P3 for the future time.**
10.2. Appendix B

Figure B1. Geometrical design and lanes distribution details of the current features before and after optimization (proposal P1).
Figure B2. Details of geometrical design and lanes distribution of the proposal P2.
Figure B3. Details of geometrical design and lanes distribution of the proposal P3.

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