# Evaluation of Traffic Flow Along Arterial Street in Ramadi City
# تقييم الجريان المروري على امتداد طريق شرياني في مدينة الرمادي

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**Abstract :**

The increase in traffic volumes along urban arterial is one of the important problems that makes difficulties in the operation management and movement then leads to traffic congestion in these facilities.

The present paper was dealing with the objectives of evaluation of the level of service along the 17th July arterial in Ramadi city, and use many improvement strategies to overcome the traffic operation problems. To achieve these objectives, the study was comprised of two stages. First stage was related to data collection by field survey where, the arterial street has two unsignalized intersections and traffic volume data were collected manually during 15-minute interval for each intersection of the arterial for both directions WestBound (WB) & EastBound (EB).Second stage included the analysis and evaluation of the arterial street with two cases. In the first case, the arterial was analyzed as street with unsignalized intersections (existing conditions). The arterial street was evaluated by computing its level of service based on the travel time and travel speed data which were measured by license plate method, while in the second case, the arterial was analyzed as street with signalized intersections therefore, Highway Capacity Software 2000 ( HCS 2000 ) program was used to evaluate the level of service for the arterial street. To improve its performance, three scenarios were proposed and applied theoretically. Accordingly, the level of service was improved from E to C for both directions (WB & EB).

**الخلاصة:**

أن الزيادة في الحجوم المرورية على امتداد الطرق الشريانية في المناطق الحضرية تكون واحدة من المشاكل المهمة والتي تجعل هنالك صعوبات في أدارة تشغيل المرور والحركة وبالتالي تؤدي إلى الازدحام المروري في هذه المناطق .
أن البحث الحالي تعامل مع أهداف تقيم مستوى الخدمة على امتداد طريق 17 تموز في مدينة الرمادي وكذلك استخدام عدد من التحسينات للسيطرة على مشاكل التشغيل المروري . لانجاز هذه الأهداف فأن الدراسة الحالية شملت مرحلتين . المرحلة الأولى تتعلق بجمع البيانات بواسطة المسح الميداني على الطريق الشرياني , وحيث أن الطريق يحتوي على تقاطعيين بدون أشارة ضوئية وكذلك بيانات الحجوم المرورية تم جمعها يدويا خلال كل 15 دقيقة لكل تقاطع من تقاطعات الطريق الشرياني لكلا الاتجاهين ( الغرب والشرق ). أما المرحلة الثانية فقد تضمنت التحليل والتقييم للطريق الشرياني بحالتين . الحالة الأولى كانت بتحليل الطريق الشرياني كطريق تعمل كل تقاطعاته بدون أشارة ضوئية ( الظروف الموجودة ) ثم تقييم الطريق بواسطة مستوى الخدمة بالاعتماد على بيانات وقت الانتقال وسرعة الانتقال للمركبات والتي تم قياسها بواسطة طريقة ( license plate ) . أما المرحلة الثانية فكانت بتحليل الطريق الشرياني كطريق تعمل تقاطعاته بالإشارة الضوئية لهذا تم استخدام البرنامج الحاسوبي ( HCS 2000 ) لتقييم مستوى الخدمة للطريق . لتحسين أداء الطريق فان ثلاثة مقترحات يتم تطبيقها نظريا وطبقا لهذا فان مستوى الخدمة قد تحسن من المستوى ( E ) إلى المستوى ( C ) لكلا الاتجاهين (الغرب والشرق ).

## Introduction

The primary function of arterial streets is to serve major through traffic movements with a high level of mobility and provide limited land access. Arterial streets carry the highest traffic volumes and serve the longer internal and external trips as well as intra-area travel between city centers. Traffic flow on arterial streets is influenced by roadside friction, interaction among vehicle, and effect of traffic signals. All of these definitely affect the capacity and level of service of the arterial streets. Capacity of the arterial streets is generally considered by the capacity of signalized intersection along those arterial streets[4]. Roadside friction along the arterial streets is characterized by number of access alongside the arterial, land use type, pedestrian activity, parking space and street geometry. There are several basic engineering parameters affecting the performance of arterial streets such as travel time, traffic volume, free-flow speed and stopped delay [4]. The delays and speeds changes caused by traffic signal operation considerably reduce the quality of traffic flow on arterial streets.

The level of service (LOS) at any section of the arterial street has a significant effect on the over-all operating performance of that arterial street thus, improvement of the level of service at each section usually results in an improvement of the over-all operating of the arterial street [2]. Improvement of the effectiveness of the traffic control parameters would contribute to reduce the congestion and to relief those conditions that impede the flow of traffic along the arterial. In order to obtain an effective operation of traffic along the arterial, elements that play a role in traffic operation should be considered. These elements include geometric condition (e.g., number and width of lanes, spacing between intersections) and regulatory measures (e.g., traffic signals and parking control) [5].

## Methodology

This methodology provides the framework for the evaluation of arterial streets. If field data on travel times are available, this framework can be used to determine the street's level of service ( LOS ). Also, the direct measurement of the travel speed along an arterial street can provide an accurate estimate of LOS

Figure (1) illustrates the basic method for determining LOS on an arterial street. The analyst should be able to investigate the effect of signal spacing, street classification , and traffic flow on LOS. The methodology uses the signalized intersection for the traffic lane group, By redefining the lane arrangement ( e.g , presence or absence of left –turn lanes, number of lanes ) the analyst can influence which traffic flow is in the through-traffic lane group as well as the capacity of the lane group. This redefinition, in turn, influences the street LOS by changing the intersection evaluation and possibly the street classification [3].

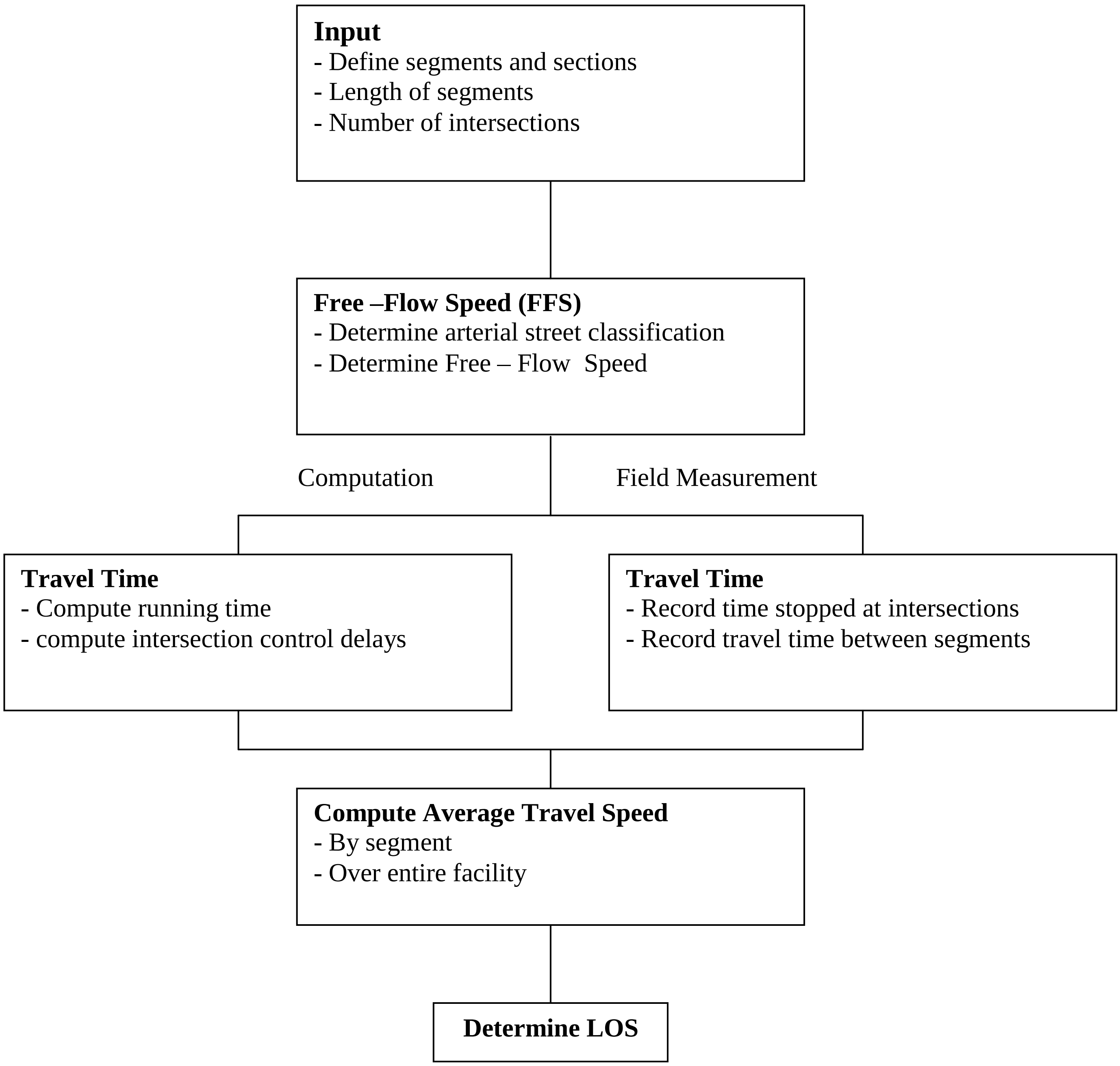



**Figure (1) : Arterial Street Methodology [3].**

## Study Area

The 17th July arterial is considered as one of the important streets in Ramadi city which it suffer from high traffic volumes along the day especially at peak periods. This arterial is divided into three lanes in each direction Westbound and Eastbound where the one of three lanes is used as on-street parking by the vehicles at most of time.

It consists of two unsignalized intersections and one rotary where the intersections are located at the start and end of the arterial street. The total length of the 17th July arterial is 2405 m, for the study purpose it is divided into three sections in each direction. Figure (2) shows satellite Image of 17th July arterial.


**Figure (2) : Satellite Image of 17th July Arterial .**

## Arterial Segment

At the start of the analysis, it is useful to define the location and length of the arterial street to be considered. All relevant physical, signal, and traffic data should be identified. Consideration should be given to the extent of the arterial street, generally at least 1 mi is necessary in down town areas and 2 mi in other areas and to whether additional segments should be included [3].

The segment is the basic unit of the analysis, it is one directional distance from one signalized intersections to the next. The length of segment is used with free flow speed ( FFS ) and arterial classification to calculate the running time per mile in arterial segment. Figure (3) shows the segment between the intersection no.1 and the intersection no.2 for Westbound and Eastbound directions.

## Geometric Data Collection

The geometric design of highway facilities deals with the proportioning of the physical elements of highway therefore, data regarding of these physical features of 17$^{th}$ July arterial are collected. These data include the following :

1- Distance between the intersections and other elements of the 17$^{th}$ July arterial such as rotary and minor streets.
2- Locations of the on-street parking.
3- Number of approach lanes at each intersection and major road.
4- Lane width.

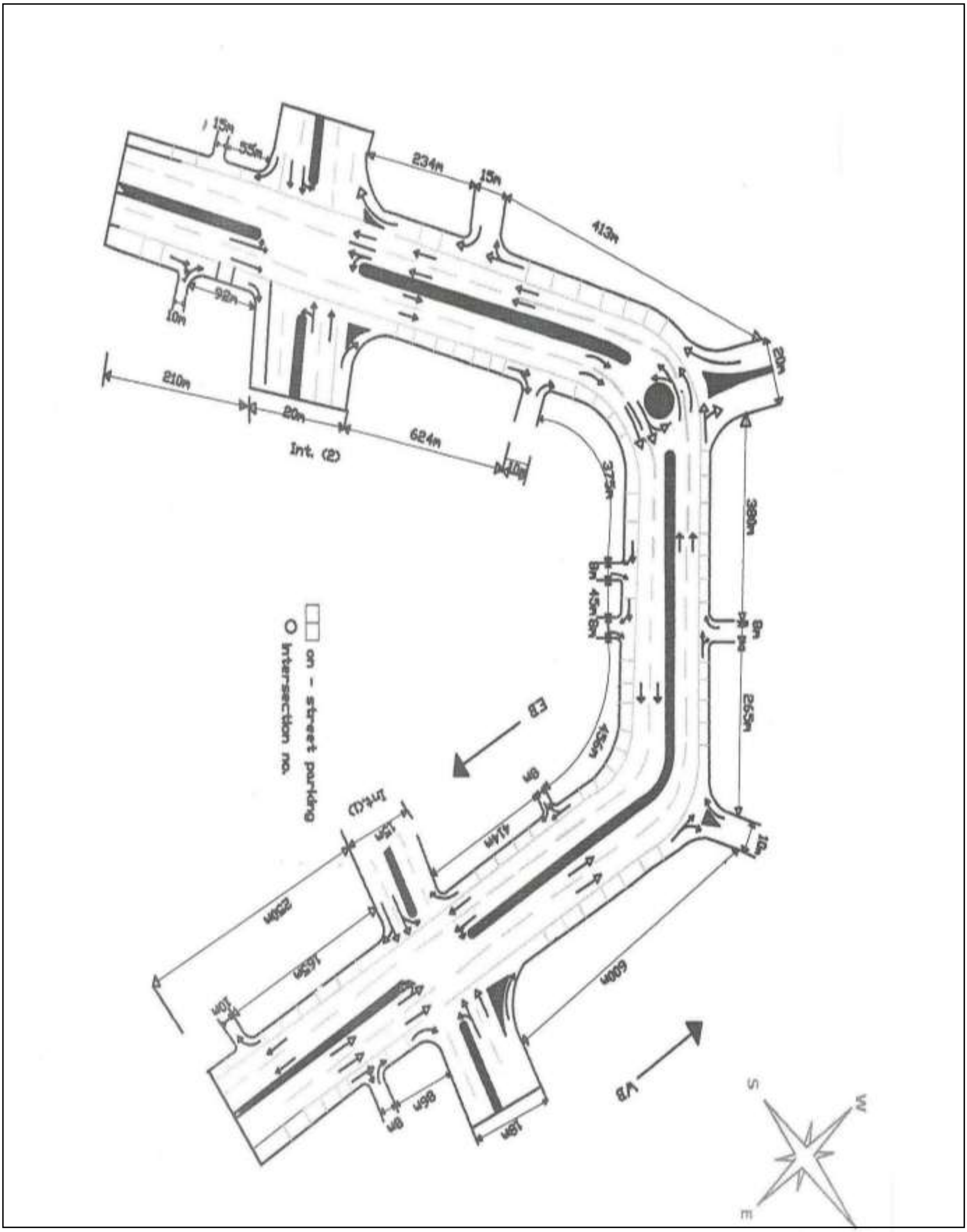


Figure (3) : Existing 17th July Arterial Geometric Conditions.

## License – Plate Method

License – Plate Method is used to measure the travel time and then the travel speed is calculated for the selected arterial street with unsignalized intersection. This method requires observers be positioned at the beginning and end of the test section. Each observer records the last three or four digits of the license plate of each car that passes, together with the time at which the car passes.
The times of arrival at the beginning and at the end of the test section for each license plate is recorded. The difference between these times is the traveling time of each vehicle [1]. The average traveling time on the test section was then calculated as the mean of produced values. A sample size of 53 license number matches is considered to obtain the travel time. The average travel speed is computed by the following equation :

$$St = \frac{n*L}{\sum ti} * \frac{3600}{1000}$$

Where :
St = average travel speed (kph) .
n = number of license matches .
L = length of test section (m) .
ti = record travel time (sec) .

## Traffic Volume Data

The traffic volume at the arterial street was estimate, by counting the hourly traffic volume for (11) hours from (7:00 a.m to 6:00 p.m) during work day and clear weather. The periods of volume counting were divided into 15 minute intervals. Table (1) shows the traffic volume at the $17^{th}$ July arterial. The distribution of the traffic flow along $17^{th}$ July arterial for both directions (WB & EB ) is summarized in figures (4 & 5 ).

## Highway Capacity Sofware 2000 (HCS 2000) computer program data

The evaluation of the level of service (LOS) of the arterial street requires input data concerning the arterial sections, free-flow speed, arterial classification, and the arterial intersections delay. Appendix (A ) describes these required data.

Table ( 1 ): Traffic Volume at 17th July Arterial from 7:00 A.M. to 6:00 P.M

| Time | Traffic (WB) V/15min. | Traffic (EB) V/15min. | Time | Traffic (WB) V/15min. | Traffic (EB) V/15min. |
|---|---|---|---|---|---|
| 7:00-7:15 | 195 | 150 | 2:15-2:30 | 225 | 255 |
| 7:15-7:30 | 210 | 160 | 2:30-2:45 | 219 | 248 |
| 7:30-7:45 | 270 | 180 | 2:45-3:00 | 212 | 235 |
| 7:45-8:00 | 281 | 190 | 3:00-3:15 | 210 | 210 |
| 8:00-8:15 | 322 | 220 | 3:15-3:30 | 196 | 208 |
| 8:15-8:30 | 318 | 215 | 3:30-3:45 | 191 | 205 |
| 8:30-8:45 | 320 | 207 | 3:45-4:00 | 187 | 201 |
| 8:45-9:00 | 315 | 209 | 4:00-4:15 | 180 | 199 |
| 9:00-9:15 | 280 | 195 | 4:15-4:30 | 175 | 195 |
| 9:15-9:30 | 275 | 192 | 4:30-4:45 | 173 | 193 |
| 9:30-9:45 | 279 | 190 | 4:45-5:00 | 171 | 192 |
| 9:45-10:00 | 286 | 188 | 5:00-5:15 | 168 | 191 |
| 10:00-10:15 | 280 | 190 | 5:15-5:30 | 160 | 185 |
| 10:15-10:30 | 275 | 186 | 5:30-5:45 | 155 | 180 |
| 10:30-10:45 | 265 | 184 | 5:45-6:00 | 140 | 177 |
| 10:45-11:00 | 255 | 181 | | | |
| 11:00-11:15 | 215 | 185 | | | |
| 11:15-11:30 | 217 | 181 | | | |
| 11:30-11:45 | 198 | 185 | | | |
| 11:45-12:00 | 196 | 187 | | | |
| 12:00-12:15 | 190 | 189 | | | |
| 12:15-12:30 | 188 | 191 | | | |
| 12:30-12:45 | 195 | 193 | | | |
| 12:45-1:00 | 190 | 196 | | | |
| 1:00-1:15 | 201 | 200 | | | |
| 1:15-1:30 | 205 | 205 | | | |
| 1:30-1:45 | 210 | 215 | | | |
| 1;45-2:00 | 232 | 265 | | | |
| 2:00-2:15 | 228 | 260 | | | |

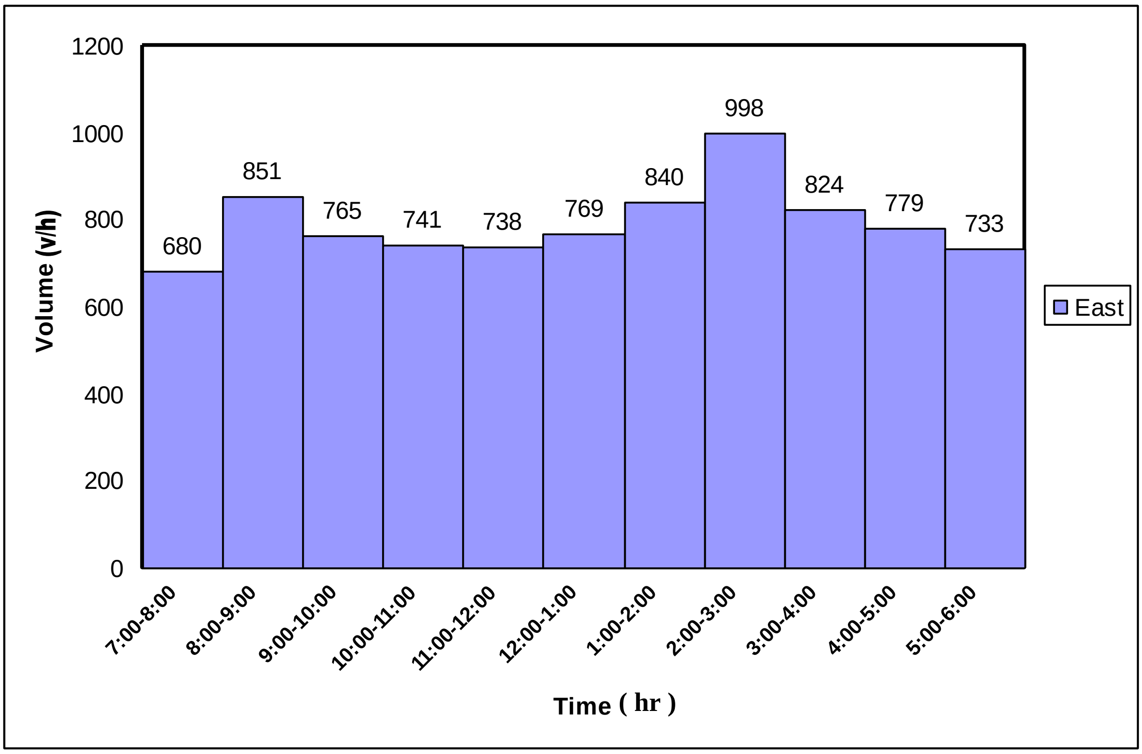



Figure ( 4 ):Distribution of Traffic Flow at 17th July Arterial ( EB ) from 7:00 A.m to 6:00 P.M

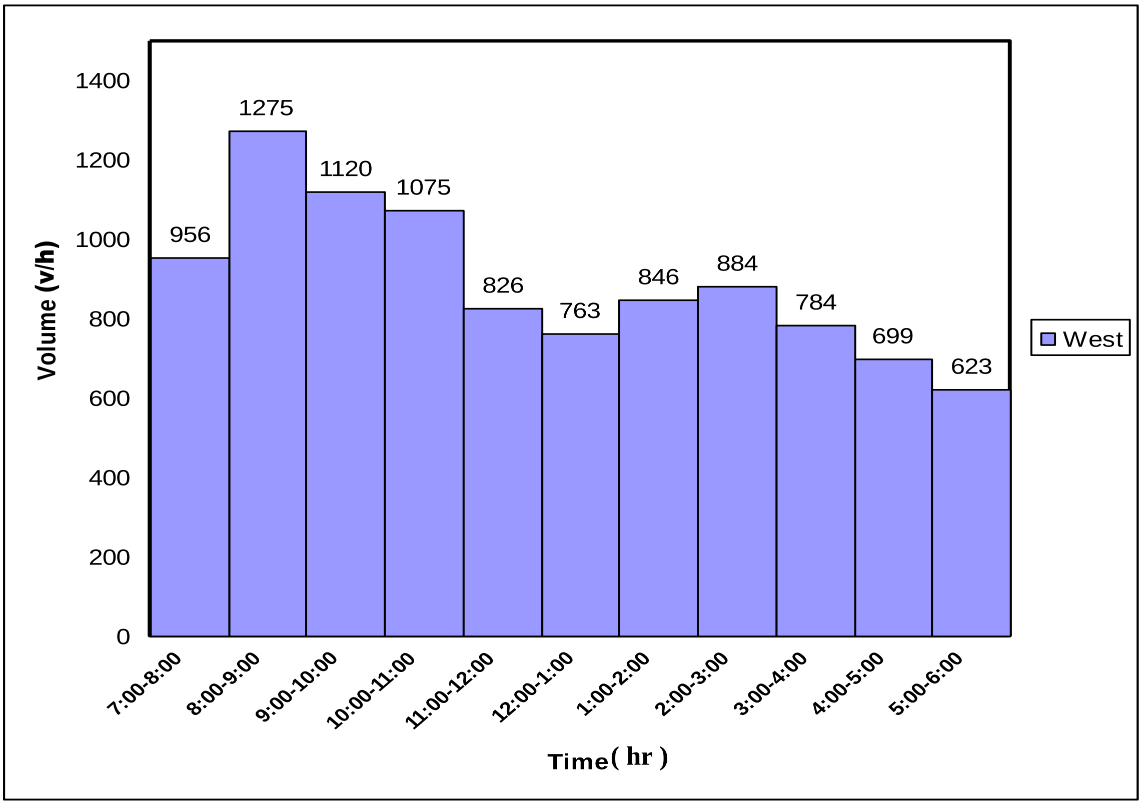



Figure ( 5 ):Distribution of Traffic Flow at 17th July Arterial ( WB ) from 7:00 A.m to 6:00 P.M

## Arterial Classification & Free Flow Speed

The first step in the analysis is to determine the arterial class, the arterial should be classified first by functional category and then by design category. The functional category is either principal or minor arterial [3].

A principal arterial serves major through movements between important centers of activity in a metropolitan area and a substantial portion of trips entering and leaving the area. A minor arterial is a facility that connects and augments the principal arterial system. Although its main function is still traffic mobility, it performs this function at a lower level and places. The arterial is classified by its design category into typical suburban design, typical intermediate design, and typical urban design [4].

Functionally, the 17$^{th}$ July arterial can be classified as principal street because it carries the highest traffic volumes for travel between major points in Ramadi city and serve the longer internal and external trips. While, according to its design category, it can be classified as a typical urban by design category because typical urban design represents an arterial with a high driveway access-point density, Parking is usually permitted, there are a few separate left-turn lanes, roadside development is dense with commercial uses, and speed limits range from 48 to 56 kph [4].

Free flow speed (FFS) is the average speed of vehicles over portions of arterial segments that are not close to signalized intersection, as observed during very low traffic volume conditions while drivers are not constrained by other vehicles or by traffic signals. There is a range of free flow speed within each arterial classification. Free-flow speeds may be measured by test cars or by spot speed observations away from the intersections [4].

In this study, free flow speed of arterial street was obtained directly by field measurement. This was determined by making runs with test car equipped with a calibrated speedometer during periods of low volume. The observer should read the speedometer at mid-block locations when the vehicle is not impeded by other vehicles and record speed readings for each section. Due to similarity in the traffic flow conditions and topographic for all arterial sections, four free flow speed samples were collected for one section of all arterial street.

The average free flow speed is determined as follows :

$$S = \frac{1}{n} \sum_{i=1}^{n} si$$

Where :

S = the average free flow speed (kph).

n = total number of samples.

si = the measure free flow speed of vehicle i (kph ).

## Arterial Delay

In order to compute the arterial or section speed, the individual intersection delays are needed. Because the arterial function is to serve through traffic, the lane group in which the through traffic is include is used to characterize the arterial [4]. The control delay for the through movement is the suitable delay to use in arterial evaluation because average travel time is influenced by both stopped delay and delay due to decelerating and accelerating [3].

Equation (1) below is used to compute the control delay and equations (2) and (3) are used to compute uniform delay and incremental delay, respectively.

$$d = d1\ PF + d2 + d3 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where :

d = control delay per vehicle, sec./ veh.
d1 = uniform delay assuming uniform arrivals, sec. / veh.
PF = progression adjustment factor for either quality of progression or type of control.
d2 = incremental delay to account for random arrivals and oversaturated queues.
d3 = initial queue delay to account for delay due to any initial queue at the beginning of the analysis period.
uniform delay is given by :

$$d1= \frac{0.5\,C\,(1-g/c)^2}{1-\{\min(1,x)\,g/c\}} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where :
C = cycle length (sec.).
g = effective green time for lane group (sec.).
x = volume to capacity (v/c) ratio for the lane group
(also termed degree of saturation).
Incremental delay is given by :

$$d2 = 900\,T\,\left[ (x-1) + \left[ (x-1)^2 + \frac{8KIX}{cT} \right]^{1/2} \right] \ldots\ldots\ldots (3)$$

Where :
T = duration of analysis period (h).
K = incremental delay adjustment for actuated control.
I = incremental delay adjustment for filtering or metering by upstream signals.
c = capacity of lane group (veh./h).

In this study, the signal is isolated intersection ( that is, it is not part of a signal progression ) the control type is pre-timed, there is no initial queue, and the type of arrival is random therefore, the values of PF,K and I are PF= 1, K = 0.5 , and I = 1. The value of initial queue delay ( d3 ) equal to zero.

## Arterial level of service

Arterial level of service is based on average through vehicle travel speed for the segment, section or entire arterial under consideration. Travel speed is the basic service measure for arterial streets. The average travel speed is computed from the running time on the arterial segment or segments and the intersection total delay for through movements at all intersections [4].

The control delay is the portion of the total delay for a vehicle approaching and entering a signalized intersection that is attributable to traffic signal operation. Control delay includes the delays of initial deceleration, move-up time in the queue, stops and reacceleration [3].

The level of service (LOS) for arterial streets is strongly influenced by the number of signals per mile and the average intersection delay. Inappropriate signal timing, poor progression, and increasing traffic flow can degrade the LOS substantially [4].

Table (2) lists arterial street LOS criteria based on average travel speed and arterial street class [3].

Table (2) : Arterial Street LOS By Class [3].

| Arterial Street Class | I | II | III | IV |
|---|---|---|---|---|
| Rang of free-flow speeds (FFS) | 55 to 45 mi/ h | 45 to 35 mi./ h | 35 to 30 mi./ h | 35 to 25 mi./ h |
| Typical FFS | 50 mi. / h | 40 mi. / h | 35 mi. / h | 30 mi./ h |
| LOS | Average Travel Speed (mi. / h ) | | | |
| A | > 42 | > 35 | >30 | > 25 |
| B | > 34 – 42 | >28 - 35 | > 24- 30 | > 19 – 25 |
| C | > 27 – 34 | > 22 – 28 | > 18 – 24 | > 13 – 19 |
| D | > 21 – 27 | > 17 – 22 | > 14 – 18 | > 9 – 13 |
| E | > 16 – 21 | > 13 – 17 | > 10 – 14 | > 7 – 9 |
| F | ≤ 16 | ≤ 13 | ≤ 10 | ≤7 |

## Analysis

The objective of operational analysis is generally the determination of the level of service for an existing or projected facility operating under existing or projected traffic demand. Evaluation of the 17$^{th}$ July arterial was achieved with two cases to predict the level of service, in the first case the street is considered as unsignalized intersection (existing condition) therefore, the travel time and travel speed data are computed by using license plate method. While in the second case the street is evaluated as signalized intersection therefore, for this case HCS 2000 program is used to evaluate and improve the level of service for the 17$^{th}$ July arterial.

## Result

The present study is based on the analysis and comparison of average travel speed over the 17$^{th}$ July arterial which is generated from the evaluation of existing traffic arterial conditions (unsignalized intersections ) and the signalized isolated intersections operation with its improvement strategies.

## Evaluation of the Arterial as Street with Unsignalized Intersections

The existing situation to control the traffic movements at 17$^{th}$ July arterial is carry out through the control of police men, where there is not less than three to four police men to arrange the traffic movements. The evaluation of unsignalized intersection can not be achieved by Highway Capacity Software (HCS) 2000 program because of its limitations, which was designed to evaluate the signalized intersection therefore, the 17$^{th}$ July arterial in normal conditions was evaluated by using license plate method to measure the travel time and travel speed for the street. Table (3) shows the evaluation of the level of service with unsignalized intersections along the 17$^{th}$ July arterial during the peak period for both Westbound and Eastbound directions while the present result appears that the street is operated at level of service (E) in both directions.

Table (3) : Arterial level of service with unsignalized intersections (existing conditions ).

| Section | Length ( m. ) | Travel Time (sec.) | Travel Speed (kph) | Arterial LOS | Direction | Art. class |
|---|---|---|---|---|---|---|
| 1 | 250<br>210 | 67<br>35 | 13.43<br>21.60 | F<br>E | WB<br>EB | 3<br>2 |
| 2 | 1263<br>682 | 205<br>91 | 22.18<br>26.98 | E<br>E | WB<br>EB | 3<br>2 |
| 3 | 682<br>1263 | 112<br>169 | 21.92<br>26.90 | E<br>E | WB<br>EB | 3<br>2 |
| 4 | 210<br>250 | 45<br>39 | 16.80<br>23.07 | E<br>E | WB<br>EB | 3<br>2 |
| Entire Arterial | 2405<br>2405 | 393<br>342 | 22.03<br>25.32 | E<br>E | WB<br>EB | 3<br>2 |

## Evaluation of the Arterial street with signalized intersections

Capacity, delay and level of service are major parameters for evaluating arterial street operations, by using the signalized intersections of the 17$^{th}$ July arterial instead of unsignalized intersections are represented the first stage to improve the performance of the arterial street therefore, the evaluation of the street is based on the consideration of the operation of traffic flow along the 17$^{th}$ July arterial with isolated signalized intersections. Table (4) shows the level of service evaluation along the arterial street for both directions (WB &EB ). There are three strategies improvement were designed to improve the efficiency of traffic flow operations along the arterial street :

* **First improvement strategy** : Eliminating on-street parking.

Parking bays are provided alongside the curb on both sides of the arterial street, these bays can be unrestricted parking facilities if the duration of parking is unlimited ,and parking is free, or they can be restricted parking facilities if parking is limited to specific times of the day for a maximum duration. The eliminating on-street parking along the 17$^{th}$ July arterial would be increased the lane group capacity therefore, the value of the traffic volume to the capacity (v/c) would be became low and the result would be improved in the level of service for the arterial street.

Table (4) : Arterial level of service with signalized isolated intersections.

| Section | Length (m.) | Art. class | Free flow speed (kph) | Run. time (sec.) | Inter. total delay (sec.) | Sum of time (sec.) | Art. Speed (kph) | Art. LOS | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 268<br>674 | 3<br>2 | 50<br>60 | 22.6<br>42.3 | 31.2<br>31.2 | 53.8<br>73.5 | 17.93<br>33.01 | E<br>D | WB<br>EB |
| 2 | 1283<br>1294 | 3<br>2 | 55<br>56 | 83.8<br>82.9 | 39.1<br>37.2 | 122.9<br>120.1 | 37.58<br>38.78 | C<br>C | WB<br>EB |
| 3 | 682<br>265 | 3<br>2 | 55<br>56 | 44.5<br>19.3 | 36.6<br>25.1 | 81.1<br>44.4 | 30.27<br>21.48 | C<br>E | WB<br>EB |
| Entire Arterial | 2233<br>2233 | 3<br>2 | 53<br>57 | 151.6<br>144.5 | 106.9<br>93.5 | 257.8<br>238 | 31.18<br>33.77 | C<br>C | WB<br>EB |

* **Second improvement strategy** : Exclusive left-turn lane (left- tern bay)
The provision of exclusive left-turn lane provides storage area of signalized intersection to accommodate left-turn movement such that through movement is not impeded and allows for the use of protected left-turn phasing.

* **Third improvement strategy :** Maintenance and repair the distresses in arterial street.

The arterial street is liable to more defects happening during the repeated traffic loads on the street while some of sections are contained clearly distresses specially, in section ( 1263 m. Westbound & 1294 m. Eastbound ) and the result would be more delay along these sections.

These parts of the arterial street must be maintained and repaired at a level that permit vehicles to travel safety and at speeds required to provide a profitable and competitive service. Table (5), (6) and (7) summarize the evaluation of the level of service (LOS) along the arterial after application the strategies improvement mentioned above for both directions (WB & EB).

Table (5) : Arterial level of service with signalized isolated intersections (1st improvement) ( Eliminating on-street parking ).

| Section | Length (m.) | Art. class | Free flow speed (kph) | Run. Time (sec.) | Inter. total delay (sec.) | Sum of time (sec.) | Art. Speed (kph) | Art. LOS | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 268<br>674 | 3<br>2 | 50<br>60 | 22.6<br>42.3 | 26.5<br>23.6 | 49.1<br>65.9 | 19.65<br>36.82 | E<br>C | WB<br>EB |
| 2 | 1283<br>1294 | 3<br>2 | 55<br>56 | 83.8<br>82.9 | 35.5<br>24.5 | 119.3<br>107.4 | 38.71<br>43.37 | C<br>C | WB<br>ES |
| 3 | 682<br>265 | 3<br>2 | 55<br>56 | 44.5<br>19.3 | 33.1<br>23 | 77.6<br>42.3 | 31.64<br>22.55 | C<br>E | WB<br>ES |
| Entire Arterial | 2233<br>2233 | 3<br>2 | 53<br>57 | 151.6<br>144.5 | 95.1<br>71.1 | 246.0<br>215.6 | 32.67<br>37.28 | C<br>C | WB<br>ES |

Table (6) : Arterial level of service with signalized isolated intersections (2nd improvement ) (left-turn bay).

| Section | Length (m.) | Art. class | Free flow speed (kph) | Run. Time (sec.) | Inter. total delay (sec.) | Sum of time (sec.) | Art. Speed (kph) | Art. LOS | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 268<br>674 | 3<br>2 | 50<br>60 | 22.6<br>42.3 | 24.1<br>22.4 | 46.7<br>64.7 | 20.66<br>37.50 | E<br>C | WB<br>EB |
| 2 | 1283<br>1294 | 3<br>2 | 55<br>56 | 83.8<br>82.9 | 34<br>23.3 | 117.8<br>106.2 | 39.21<br>43.86 | B<br>C | WB<br>ES |
| 3 | 682<br>265 | 3<br>2 | 55<br>56 | 44.5<br>19.3 | 31.5<br>21.6 | 76<br>40.9 | 32.30<br>23.32 | C<br>E | WB<br>ES |
| Entire Arterial | 2233<br>2233 | 3<br>2 | 53<br>57 | 151.6<br>144.5 | 89.6<br>67.3 | 240.2<br>211.8 | 33.42<br>37.95 | C<br>C | WB<br>ES |

Table (7) : Arterial level of service with signalized isolated intersections (3rd improvement ) (maintenance and repair the distresses).

| Section | Length (m.) | Art. class | Free flow speed (kph) | Run. Time (sec.) | Inter total delay (sec.) | Sum of time (sec.) | Art. Speed (kph) | Art. LOS | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 268<br>674 | 3<br>2 | 50<br>60 | 22.6<br>42.3 | 19.1<br>19.4 | 41.7<br>61.7 | 22.4<br>39.1 | D<br>C | WB<br>EB |
| 2 | 1283<br>1294 | 3<br>2 | 55<br>56 | 83.8<br>82.9 | 21<br>20.3 | 104.8<br>103.2 | 44<br>45 | B<br>C | WB<br>ES |
| 3 | 682<br>265 | 3<br>2 | 55<br>56 | 44.5<br>19.3 | 25.5<br>16 | 70<br>35.3 | 34.9<br>26.1 | C<br>D | WB<br>ES |
| Entire Arterial | 2233<br>2233 | 3<br>2 | 53<br>57 | 151.6<br>144.5 | 65.6<br>55.7 | 216.5<br>200.2 | 37.13<br>40.15 | C<br>C | WB<br>ES |

## Comparison analysis between unsignalized and signalized arterial intersections with its improvements

The evaluation of unsignalized arterial intersections which is based on the average travel speed and level of service as shown in table (3) is compared with evaluation of signalized arterial intersections which is also based on the average travel speed and level of service.

The effective of the arterial with signalized isolated intersections (before and after application of improvement strategies ) on the average travel speed and level of service is summarized in table (8) for both directions (WB & EB ). The table shows that, there is the importance increasing in average travel speed along the 17th July arterial for two directions. For the westbound, the average travel speed was increased by 41% for the arterial with signalized isolated intersections (without improvement), 48% for the arterial with signalized isolated intersections (1st improvement : prevention on-street parking ), 52% for the arterial with signalized isolated intersections (2nd improvement : left-turn bay ), and 69% for the arterial with signalized isolated intersections (3rd improvement : maintenance and repair the distresses ).

For the eastbound, the average travel speed was increased by 33% for the arterial with signalized isolated intersections (without improvement), 47% for the arterial with signalized isolated intersections (1st improvement : prevention on-street parking), 50% for the arterial with signalized isolated intersections (2nd improvement : left-turn bay), and 59% for the arterial with signalized isolated intersections (3rd improvement : maintenance and repair the distresses). As result, the level of service for the 17th July arterial was upgraded from level of service (E) to level of service (C) for both directions (WB & EB).

## Comparison analysis between the arterial with signalized isolated intersections and the improvement strategies

A comparison analysis was achieved between the arterial with signalized isolated intersections and the improvement strategies based on the arterial average travel speed and level of service, which is summarized in table (4), also in tables (5,6 and 7). The percent of increasing in the arterial average travel speed related to the improvement strategies was provided in table (9). The table shows that the arterial average travel speed for the westbound was increased by 5% for the 1st improvement (prevention on-street parking) 7% for 2nd improvement (left-turn bay) and 19% for 3rd improvement ( maintenance and repair the distresses ).

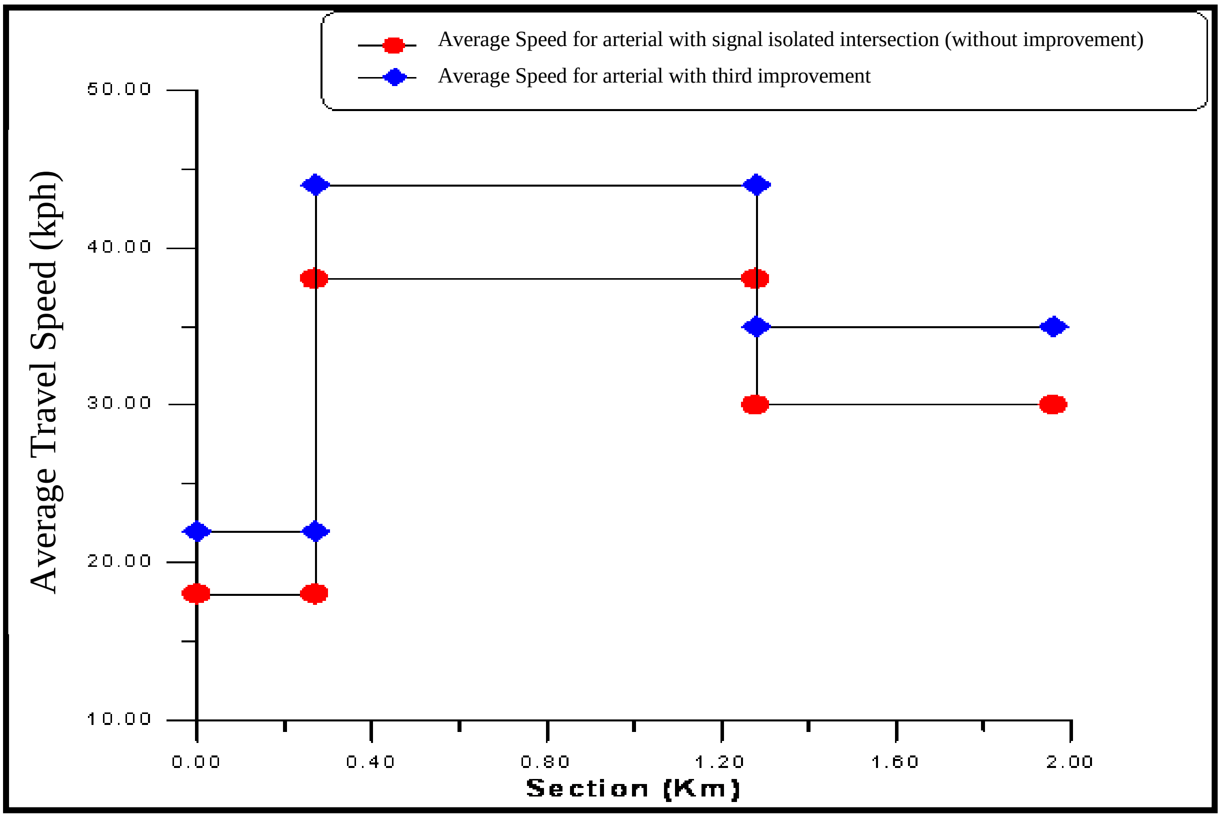
Also, the table shows that the arterial average travel speed for eastbound was increased by 10% for 1st improvement (prevention on-street parking), 12% for 2nd improvement (left-turn bay) and 19% for 3rd improvement (maintenance and repair the distresses). while the arterial level of service was unchanged (LOS C) Figures (4) & (5) illustrate the speed profile for the arterial for the improvement strategies (WB & EB ) which is considered as a valuable depiction of the operation along the arterial street.

Table (8) : Comparison analysis between arterial with unsignalized intersections (existing condition) and signalized isolated arterial intersections.

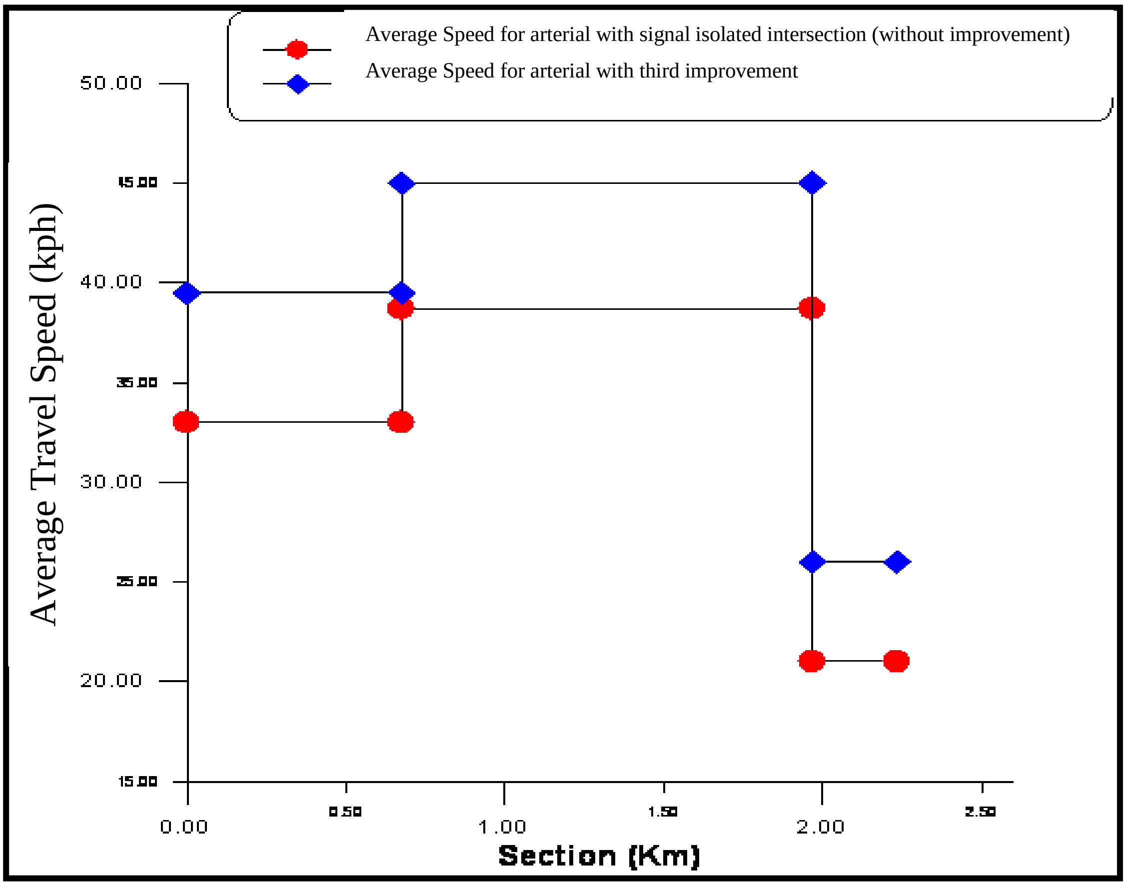
| Unsignalized intersection (existing condition) | | Signalized isolated intersection | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Without impro. | % increasing | 1st impro. | % increasing | 2nd impro. | % increasing | 3rd impro. | % increasing |
| **Av. speed over arterial (kph) (WB)** | **22.03** | **31.18** | **41** | **32.67** | **48** | **33.42** | **52** | **37.13** | **69** |
| **Av. speed over arterial (kph) (EB)** | **25.32** | **33.77** | **33** | **37.28** | **47** | **37.95** | **50** | **40.15** | **59** |
| **Art. LOS (WB)** | **E** | **C** | | **C** | | **C** | | **C** | |
| **Art. LOS (EB)** | **E** | **C** | | **C** | | **C** | | **C** | |

Table (9) : Comparison analysis between arterial with signalized isolated intersections and the improvement strategies.

| signalized isolated intersection without improvement. | | Signalized isolated intersection | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1st impro. | % increasing | 2nd impro. | % increasing | 3rd impro. | % increasing |
| **Av. speed over arterial (kph) (WB)** | 31.18 | 32.67 | 5 | 33.42 | 7 | 37.13 | 19 |
| **Av. speed over arterial (kph) (EB)** | 33.77 | 37.28 | 10 | 37.95 | 12 | 40.15 | 19 |
| **Art. LOS (WB)** | C | C | | C | | C | |
| **Art. LOS (EB)** | C | C | | C | | C | |




Figure( 6): Speed Profile for Arterial St.and Third Improvement (WB)




Figure(7): Speed Profile for Arterial St. and Third Improvement (EB)

## Conclusion

It is concluded that if the improvement scenarios is implemented, the level of service of the 17th July arterial may be upgraded from level of service (E) to level of service (C).

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