Evaluating Traffic Operation for Multilane Highway (Ramadi – Fallujah) Highway as Case Study

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Abstract

Multilane highways typically are located in suburban communities, leading into central cities, or along high-volume rural corridors connecting two cities or significant activities that generate a substantial number of daily trips. The objectives of the present study include the analysis, and evaluation the level of service (LOS) on section for multilane highway in Ramadi city. The LOS multilane highway is based on density, which is calculated by dividing per lane flow by speed. The required traffic and geometrical data has been collected through field surveys on the section for multilane highway. Traffic volume data were collected manually and classified by vehicles types during each 15 minute interval. Highway Capacity Software 2000 (HCS 2000) program is used for the requirements of traffic analysis process to determine the level of service. It has concluded that the level of service on selected section for east bound is (A), and for west bound is (B).

Key Words: Traffic operation, Level of service(LOS), Multilane highway.

تقييم الحركة المرورية لطريق متعدد الحارات، طريق الرمادي – الفلوجة كحالة دراسية

حامد أحمد عواد حميد أسود محمد

الخلاصة

الطرق العامة ذات الحارات المرورية المتعددة تكون موجودة في المجتمعات شبه الحضرية والتي تؤدي إلى مراكز المدن أو تكون على طول الممرات الريفية التي تربط بين مدينتين أو بين نشاطين مهمين والتي بالتالي تولد عدد كبير من الرحلات اليومية.

الهدف من الدراسة الحالية يتضمن تحليل وتقييم مستوى الخدمة لمقطع معين من الطريق متعدد الحارات المرورية في مدينة الرمادي. مستوى الخدمة للطريق متعدد الحارات المرورية يعتمد على الكثافة المرورية والتي عادة يتم حسابها بقسمة الحجم المروري على السرعة. المعلومات المطلوبة للحجوم المرورية والتخطيط الهندسي تم الحصول عليها من خلال المسح الميداني لمقطع من الطريق متعدد الحارات المرورية. لقد تم جمع معلومات الحجوم المرورية يدويا وثم تصنيفها حسب نوع المركبات خلال كل ١٥ دقيقة.لقد تم استخدام البرنامج الحاسوبي (HCS 2000) لتحليل العمليات المرورية المطلوبة وإيجاد مستوى الخدمة . لقد تم الاستنتاج بان مستوى الخدمة للاتجاه الشرقي هو (A) بينما كان هو (B) للاتجاه الغربي.

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1. Introduction

Increasing traffic flow has forced engineers to increase the number of lanes of highways in order to provide good maneuvering facilities to the users. A highway is a public road especially a major road connecting two or more destinations (Khistyand Lall, 2003). A highway with at least two lanes for the exclusive use of traffic in each direction, with no control or partial control of access, but that may have periodic interruption to flow at signalized intersections not closer than 3km is called multilane highway(Abdullah, 2005).Multilane highways exist in a number of setting, from typical suburban communities leading to central cities or along high-volume rural corridors that connect two cities or significant activities generating a substantial number of daily trips. Multilane highways range from the uninterrupted flow of freeways to the flow conditions on urban streets, which are frequently interrupted by signals. The capacity of a multilane highway is the maximum sustained hourly flow rate at which vehicles reasonably can be expected to traverse a uniform segment under prevailing roadway and traffic conditions (Al-Sughaiyer, 2005). They generally have posted speed limits of between 60 km/h and 90 km/h. They usually have for or six lanes, often with physical medians or two-way right turn lane (TWRTL), although they may also be undivided (Abdullah, 2005). The traffic volumes generally varies from 1500-40000 per day. It may also vary up to 100000 per day with grade separations and no cross-median access. Traffic signals at major intersections are possible for multilane highways, partial control access(Abdullah, 2005).

The main objectives of this study is to analyze level of service (LOS) which is very important issue for traffic engineer because it describes the traffic operational conditions within a traffic stream. Also we are going to study the characteristics and capacity for multilane highways. Free-flow speed (FFS) is a parameter that is being used extensively for capacity and level of service analysis of various types of highway facilities.

2. Methodology

The methodology described in this study is intended for analysis of uninterrupted-flow highway segments. Figure (1) shows the inputs and basic computational order for the method described in this study. The primary output is level of service.

3. Level of Service for Multilane Highway

Basically any two of the following three performance characteristics can describe the level of service for a multilane highway(Khistyand Lall, 2003, Abdullah, 2005).:

1-Volume to capacity ratio.

2-Speed, in terms of mean passenger cars speed, and,

3-Density, in terms of passenger cars per kilometre per lane.

Each of these measures indicates how well the highway accommodates traffic flow. As speed does not vary over a wide range of flow, it is not a good indicator of service quality. Density which is a measure of proximity of other vehicles in the traffic stream is directly perceived.

4. Procedures to Determine Level of Service

The prediction of level of service for multilane highway involves three steps:

1-determine of free-flow speed.

2-determine of flow rate.

3-determine of level of service.

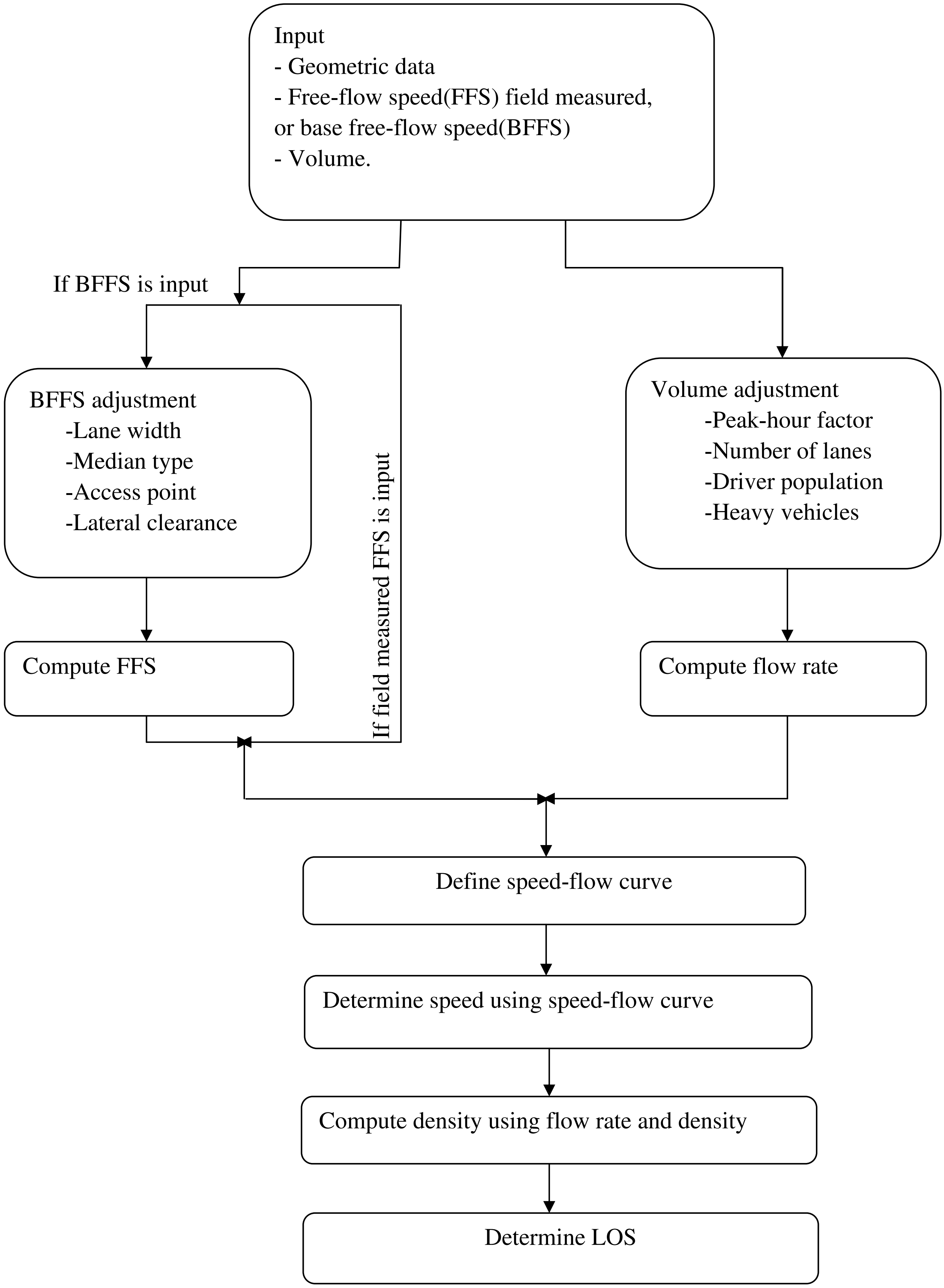

Figure1.Multilane highway methodology

4.1. Determination of Free-Flow Speed

Free-flow speed is the theoretical speed of traffic density approaches zero. It is the speed at which drivers fell comfortable traveling under physical, environmental, and traffic conditions existing on an uncongested section of multilane highway(Abdullah, 2005).Free-flow speed is measured using the mean speed of passenger cars operating in low to moderate flow condition (up to 1400 pc/h/ln). Mean speed is virtually constant across this range of flow rates(Highway Capacity Manual 2000). If the speed study must be conducted at a flow rate of more than 1400 pc/h/ln, the free-flow speed can be found by using the model speed-flow curves assuming that data on traffic volumes are recorded at the same time (Highway Capacity Manual 2000).

The maximum sustained hourly flow rate, which forms the basis for defining capacity, is considered a function of density and therefore speeds. Because free-flow speed is a direct input to the density computation, adjustments for geometric factors are applied to free-flow speed. Several traffic control, physical, and traffic conditions affect the free-flow speed along a given highway. If speed enforcement is common, it can be anticipated that traffic operation will often be affected. Under those circumstances, the user may make local measurements to calibrate the relationship between the 85th-percentile speed and the free-flow speed. Design speed and posted speed limits may also impact free-flow speed. Level of service criteria for multilane highways are defined in terms of density. These LOS boundaries are represented in Figure (2) by slope lines, each corresponding to a constant value of density. Complete LOS criteria are given in Table (1). For average free-flow speed 70,80,90,and 100 km/h, the Table gives the average travel speed, the maximum service flow (MSF) rate for each level of service. Under base conditions, the speeds, v/c ratios, and tabulated MSF are expected to exist in traffic streams operating at the densities defined for each level of service.

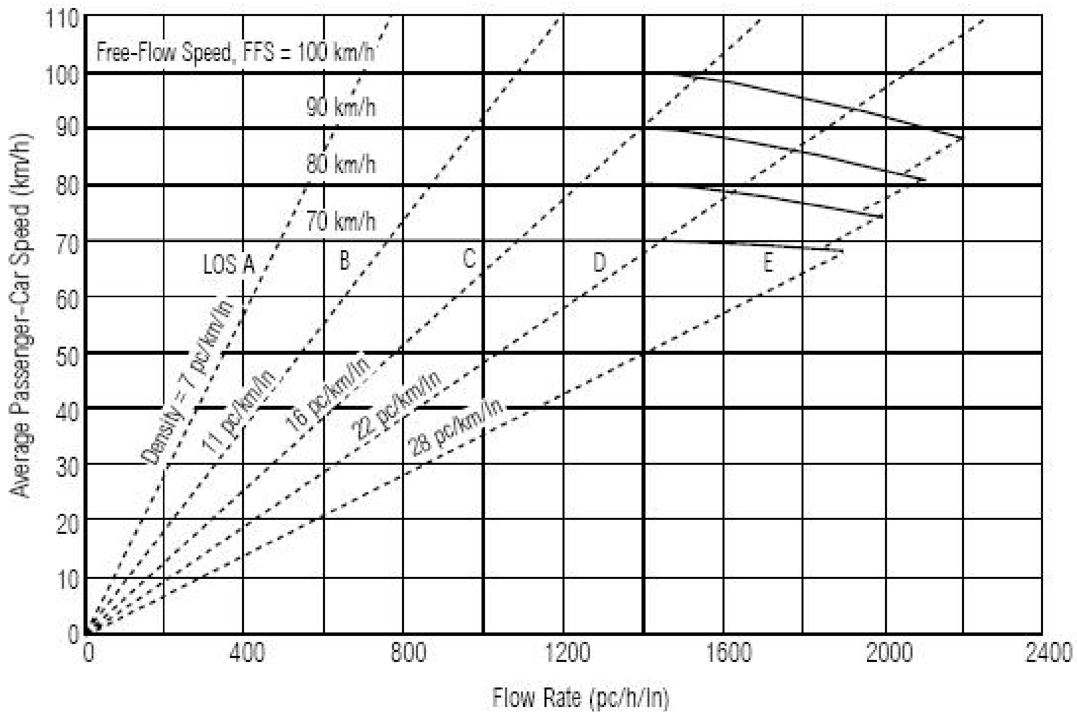

Figure 2.Speed-flow curves with los criteria for multilane highway.

The average passenger car speed under low-volume conditions can be used directly as the free-flow speed if the field measurements were made at flow rates at or below 1400 pc/h/ln. If field-measured data are used, no adjustments need to be made to free-flow speed. Thisfree flow speed reflects the net effects of all conditions at the site that influence speed, including those identified in this procedures (lane width, lateral clearance, type of median and access points), as well as others, such as speed limit and vertical and horizontal alignment (Highway Capacity Manual 2000). Recent research suggests that free-flow speed on multilane highways under base conditions is approximately 11 km/h higher than the speed limit for 65 km/h to 70 km/h speed limits, and it is 8 km/h higher for 80 km/h to 90 km/h speed limits (Highway Capacity Manual, 2000).

Table 1.LOS criteria for multilane highway

Free Flow Speed	Criteria	LOS				
		A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100	100	98.4	91.5	88
	Maximum volume to capacity ratio (v/c)	0.32	0.50	0.72	0.92	1.0
	Maximum service flow rate (pc/h/ln)	700	1100	1575	2015	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum volume to capacity ratio (v/c)	0.30	0.47	0.64	0.89	1.0
	Maximum service flow rate (pc/h/ln)	630	990	1435	1860	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum volume to capacity ratio (v/c)	0.28	0.44	0.64	0.85	1.0
	Maximum service flow rate (pc/h/ln)	560	880	1280	1705	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.5	67.9
	Maximum volume to capacity ratio (v/c)	0.26	0.41	0.59	0.81	1.0
	Maximum service flow rate (pc/h/ln)	490	770	1120	1530	1900

4.2. Determination of Flow Rate

Two adjustments must be made to hourly volume counts or estimates to arrive at the equivalent passenger-car flow rate used in LOS analyses. These adjustments are the PHF and the heavy-vehicle adjustment factor. The number of lanes also is used so that the flow rate can be expressed on a per-lane basis. These adjustments are applied as follows(Highway Capacity Manual 2000):

$$V_P = V \Big/ \left(PHF * N * f_{HV} * f_p\right). \quad (1)$$

Where:

V_p= 15-min passenger-car equivalent flow rate (pc/h/ln),

V= hourly volume (veh./h),

PHF= peak-hour factor,

N= number of lanes,

f_{HV} = heavy-vehicle adjustment factor, and

f_p = driver population factor.

PHF represents the variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15-min period within an hour are not sustained throughout the entire hour. The PHFs for multilane highways have been observed to range from 0.75 to 0.95. Lower values are typical of rural or off-peak conditions, whereas higher factors are typical of urban and suburban peak-hour conditions.

Besides that, the presence of heavy vehicles in the traffic stream decrease the free-flow speed because base conditions allow a traffic stream of passenger cars only. Therefore, traffic volumes must be adjusted to reflect an equivalent flow rate expressed in passenger cars per hour per lane (pc/h/ln). This is accomplished by applying the heavy-vehicle factor (f_{HV}). Once values for ET and ER have been determined, the adjustment factor for heavy vehicles may be computed as shown in Equation (2).

$$f_{HV} = {}^{1}/[1 + PT(ET - 1) + PR(ER - 1)]. \quad (2)$$

where:

ET,ER= passenger-car equivalents for trucks and buses and for recreational vehicles (RVs), respectively,

PT,PR= proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction), and

f_{HV} = adjustment factor for heavy vehicles.

Adjustment for heavy vehicles in the traffic stream applies to three types of vehicles : trucks, RVs, and buses. No evidence indicates any distinct difference in the performance characteristics of trucks, and buses on multilane highways; therefore, buses are considered trucks in this method. Finding the heavy-vehicles adjustment factor requires two steps. First, find an equivalent truck factor (ET) and RV factor (ER) for prevailing operating conditions. Second, using ET and ER, compute an adjustment factor for all heavy vehicles in traffic stream. Table (2) is used to select passenger-car equivalents for trucks and buses (ET) and for RVs (ER).

Table 2.Passenger-car equivalents on extended general highway segment[3]

Factor	Type of Terrain		
	Level	Rolling	Mountainous
ET (trucks and buses)	1.5	2.5	4.5
ER (RVs)	1.2	2.0	4.0

The adjustment factor fp reflects the effect weekend recreational and perhaps even midday drivers have on the facility. The values of fp range from 0.85 to 1.00. Typically, a value of 1.00 can be selected unless there is sufficient evidence to apply a lesser value to reflect recreational traffic characteristics[3].

4.3. Determination Level of Service (LOS)

The LOS on a multilane highway can be determined directly from Figure (2) on the basis of the FFS and the service flow rate (vp) in pc/h/ln. The procedure is as follows:

• Step 1. Define and segment the highway as appropriate.

• Step 2. On the basis of the measured or estimated FFS, construct an appropriatespeed-flow curve of the same shape as the typical curves shown in Figure (2). Thecurve should intercept the y-axis at the FFS.

• Step 3. Based on the flow rate vp, read up to the FFS curve identified in Step 2and determine the average passenger-car speed and LOS corresponding to that point.

• Step 4. Determine the density of flow according to Equation (3).

$$D = {}^{V_P}/_{S} \quad (3)$$

Where:
D= density (pc/km/ln),
V_P = flow rate (pc/hr/ln), and
S= average passenger-car travel speed (km/hr).
The LOS also can be determined by comparing the computed density with thedensity ranges provided in Table (1).

5. Case Study

5.1. Road Section Condition

The road section is about 4km, located in Ramadi city. The road is respected a multilane where it has two lanes in each direction. The road width is 7 m in each direction, flexible pavement, and divided by median. There are many of houses, schools, and service facilities along both the side of road section and many access branches. The terrain of road section is level. Figure (3) shows a satellite image for multilane highway in Ramadi city.

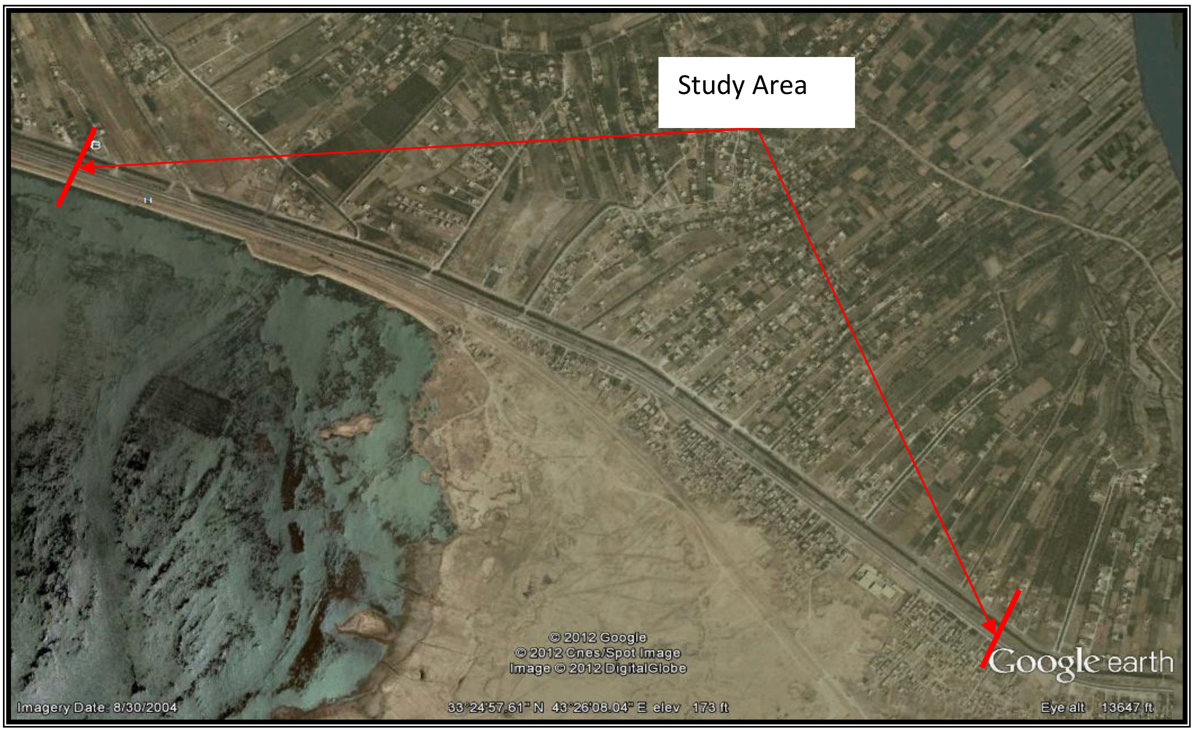

Figure 3.Satellite Image for Multilane Highway in Ramadi City

5.2. HCS Multilane Highways

Highway Capacity Software (HCS 2000) is a program based on the Highway Capacity Manual. It is primary function is to analyze capacity and provide level of service on multilane highway. HCS requires the following traffic inputs: number of lanes, lane width, lateral clearance, median (yes/no), access-point density, specific grade or general terrain, free-flow speed, traffic volume, length of analysis period, peak-hour factor, percentage of heavy vehicles, and driver population factor. HCS output is the level of service on multilane highway (Highway Design Manual, 1994).

5.3. Traffic Volume

The traffic account is carry out at multilane highway (Ramadi-Baghdad highway) for two directions from 7:00 am to 5:00 pm during the work day of the week on January month in 2012 and the highest recording traffic volume in each direction is recorded to be used in the analysis of the present study. The vehicles are classified into two types:

1-Small vehicles: any vehicles move on four wheels includes the passenger cars.

2-Large vehicles: any vehicles move on more than four wheels includes buses and trucks (heavy vehicles). This type of vehicle is converted to passenger car by using passenger car unit (PCU) factor equal to 1.5 according to Table (2).Tables (3 and 4) appear the highest account traffic volume in each direction for every 15 min. and Table (5) shows the traffic volume for every one hour from 7:00 am to 5:00 pm.

5.4. Geometric Data

Table (6) clear existing geometric design, number of lanes, lane width, and, shoulder width are represented significant international factors for the preparation of multilane highway traffic in study area.

5.5. Analysis and Results

Highway Capacity Software (HCS) program was applied in this study for requirements of evaluating and analyzing the multilane highway, the following parameters were calculated:

1-Traffic volume adjustment.

2-Free flow speed (FFS).

3-Level of service (LOS).

5.5.1 Determine Peak Hour Volume (PHV)

The traffic volume account every 15 min. is carried out from 7:00 am to 5:00 pm. The peak hour volume for Westbound direction on multilane highway is found between 8:00 am to 9:00 am and for Eastbound direction is found between 2:00 pm to 3:00 pm that is represented in Figures (4 and 5). The percentage of heavy vehicles for two directions is as shown in Table (7).

Table 3.Traffic volume of westbound direction for multilane highway from7:00 am to 5:00pm

Time (15 min)	Passenger cars (V/15 min)	Heavy vehicles		Total (V/15 min)
		Buses (V/15	Trucks (V/15	
7:00-7:15	59	0	34	93
7:15-7:30	76	0	30	106
7:30-7:45	138	0	31	169
7:45-8:00	258	0	18	276
8:00-8:15	323	1	24	348
8:15-8:30	296	0	25	321
8:30-8:45	260	1	36	297
8:45-9:00	206	0	34	240
9:00-9:15	192	1	29	222
9:15-9:30	231	2	33	266
9:30-9:45	176	0	28	204
9:45-10:00	165	0	30	195
10:00-10:15	192	0	42	234
10:15-10:30	125	0	16	141
10:30-10:45	142	0	24	166
10:45-11:00	135	0	21	156
11:00-11:15	122	1	19	142
11:15-11:30	85	0	32	117
11:30-11:45	86	0	17	103
11:45-12:00	115	0	10	125
12:00-12:15	94	1	25	120
12:15-12:30	87	0	20	107
12:30-12:45	74	0	18	92
12:45-1:00	91	0	10	101
1:00-1:15	72	0	10	82
1:15-1:30	84	0	29	113
1:30-1:45	86	0	21	107
1:45-2:00	116	0	12	128
2:00-215	140	0	25	165
2:15-2:30	114	0	26	140
2:30-2:45	127	0	28	155
2:45-3:00	102	0	20	122
3:00-3:15	134	0	21	155
3:15-3:30	75	0	27	102
3:30-3:45	108	0	12	120
3:45-4:00	110	0	22	132
4:00-4:15	113	1	17	131
4:15-4:30	129	0	31	160
4:30-4:45	114	0	18	132
4:45-5:00	125	0	21	146

Table 4.Traffic volume of eastbound direction for multilane highway from7:00 am to 5:00 pm

Time (15 min)	Passenger cars (V/15 min)	Heavy vehicles		Total (V/15 min)
		Buses (V/15	Trucks (V/15	
7:00-7:15	22	0	2	24
7:15-7:30	24	0	8	32
7:30-7:45	42	0	11	53
7:45-8:00	23	0	4	27
8:00-8:15	49	0	12	61
8:15-8:30	71	0	13	84
8:30-8:45	75	0	13	88
8:45-9:00	90	0	11	101
9:00-9:15	74	0	13	87
9:15-9:30	81	0	17	98
9:30-9:45	98	0	29	127
9:45-10:00	112	0	25	137
10:00-10:15	134	0	25	159
10:15-10:30	107	0	21	128
10:30-10:45	133	0	25	158
10:45-11:00	134	1	22	157
11:00-11:15	147	0	24	171
11:15-11:30	173	0	17	190
11:30-11:45	154	0	25	179
11:45-12:00	163	0	29	192
12:00-12:15	157	1	33	191
12:15-12:30	192	0	37	229
12:30-12:45	162	1	31	194
12:45-1:00	194	1	23	218
1:00-1:15	220	0	18	238
1:15-1:30	181	0	16	197
1:30-1:45	173	0	28	201
1:45-2:00	178	0	22	200
2:00-215	202	0	31	233
2:15-2:30	180	1	24	205
2:30-2:45	227	3	23	253
2:45-3:00	177	2	20	199
3:00-3:15	150	2	21	173
3:15-3:30	148	2	24	174
3:30-3:45	156	0	18	174
3:45-4:00	126	0	27	153
4:00-4:15	111	0	28	139
4:15-4:30	133	0	34	167
4:30-4:45	136	0	26	162
4:45-5:00	114	0	37	151

Table 5.Total Traffic Volume for Both Directions on Multilane Highway from 7:00 am to 5:00pm

Time (hr)	Traffic Volumes (WB) (V/hr)	Time (hr)	Traffic Volumes (EB) (V/hr)
7:00-8:00	644	7:00-8:00	136
8:00-9:00	1206	8:00-9:00	334
9:00-10:00	887	9:00-10:00	449
10:00-11:00	697	10:00-11:00	602
11:00-12:00	487	11:00-12:00	732
12:00-1:00	420	12:00-1:00	832
1:00-2:00	430	1:00-2:00	836
2:00-3:00	582	2:00-3:00	890
3:00-4:00	509	3:00-4:00	674
4:00-5:00	569	4:00-5:00	619

Table 6.Geometric characteristics for multilane highway

Road Direction	Number of Lanes	Lane Width (m)	Shoulder Width(m)
Westbound	2	3.5	2.25
Eastbound	2	3.5	2.25

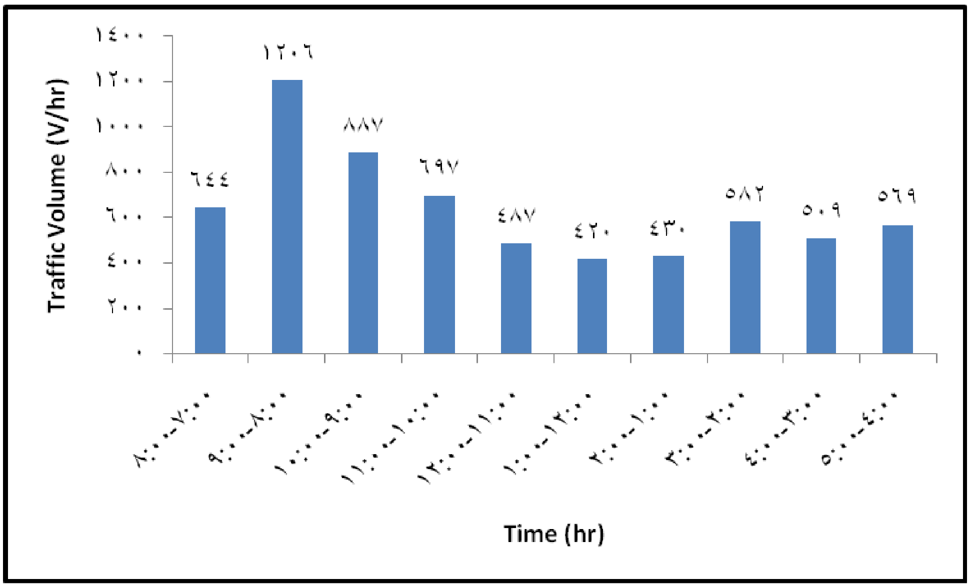

Figure 4. Distribution of traffic volume during phv in westbound direction for multilane highway

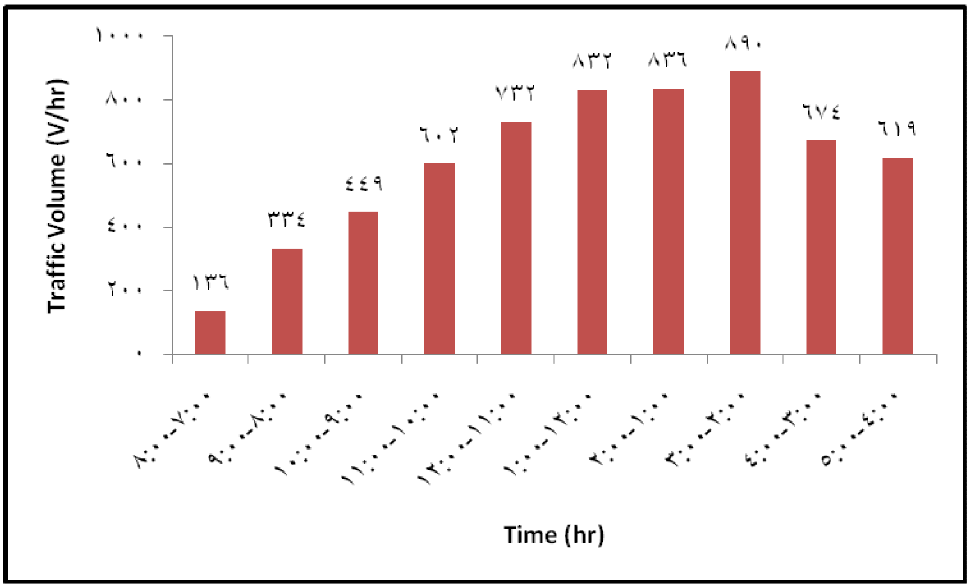

Figure 5.Distribution of traffic volume during phv in eastbound direction for multilane highway

Table 7.Percentage of heavy vehicles for multilane highway

Road Direction	% of Heavy Vehicles
Westbound	15
Eastbound	15

5.5.2. Calculating of Peak Hour Factor (PHF)

The peak hour factor is defined as the ratio of total hourly volume to the maximum 15min. rate of flow within the hour as following Equation:

$$\mathbf{PHF} = \left(\mathbf{HourlyVolume} \big/ \mathbf{Peakrateofflow\ (withinhour)} \right)$$
$$\mathbf{PHF} = \left(\mathbf{HourlyVolume} \big/ \mathbf{4 * V_{15\ min.}} \right) \quad (4)$$

Where:

PHF= Peak-hour factor

$V_{15min.}$= Volume during the peak 15 min of the peak hour, on veh/15min

The peak hour factor is calculated for each direction of multilane highway by using the data mentioned in Tables (3 and 4). Results of PHF is shown in Table (8).

Table 8.PHF values for multilane highway

Road Direction	PHF
Westbound	0.87
Eastbound	0.88

5.5.3. Field Measured of Free Flow Speed

Free flow speed is measured for both direction depending on spot speed studies, where the free flow speed is the average speed as shown in Table (9) and figures (6 and 7).

Table 9.Speed Class for Both Directions

Class Width (Km/hr)	Frequency(Westbound)	Frequency(Eastbound)
50-55	2	8
55-60	5	7
60-65	7	8
65-70	13	11
70-75	16	9
75-80	11	16
80-85	14	14
85-90	18	22
90-95	25	12
95-100	26	20
100-105	15	18
105-110	13	15
110-115	12	20
115-120	13	13
125-130	10	7

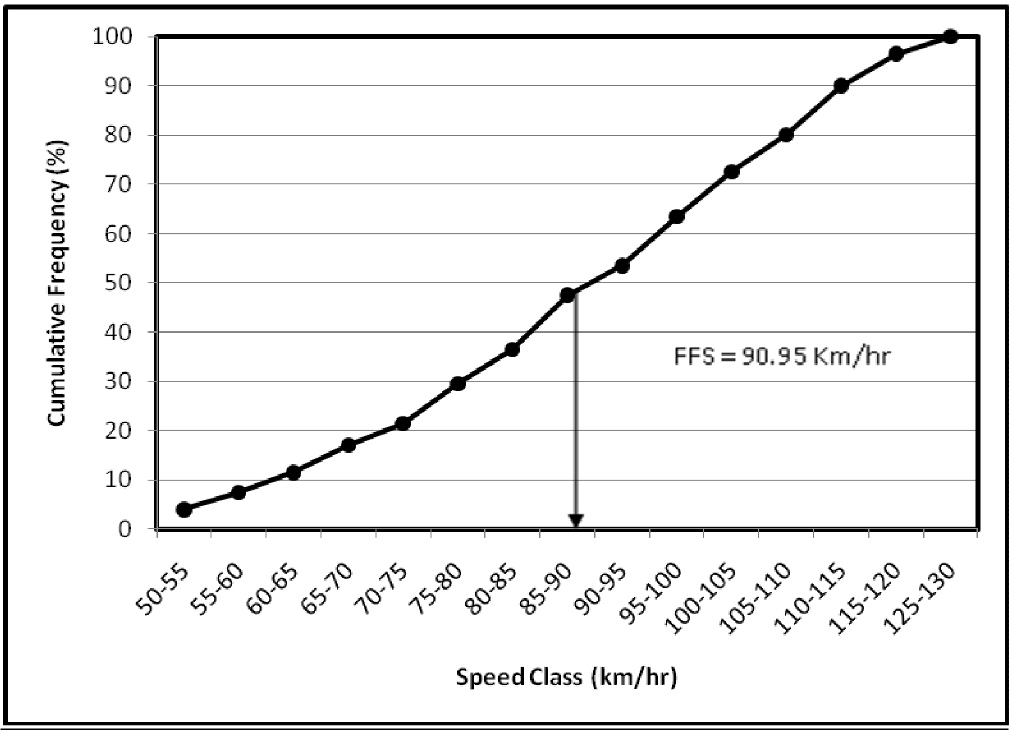

Figure 6.Free flow speed measurement in westbound direction for multilane highway

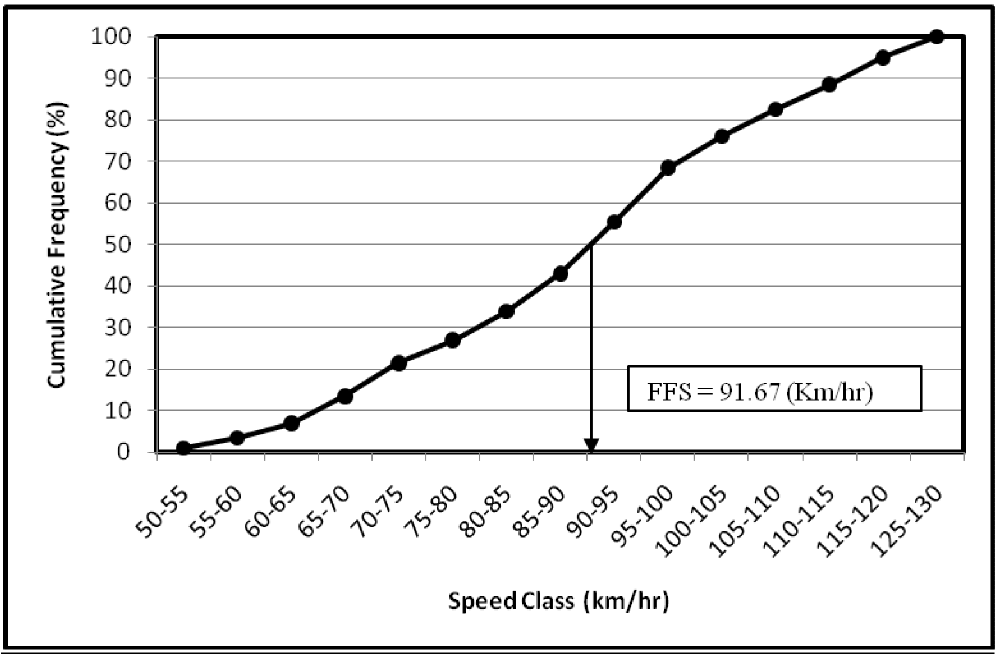

Figure 7.Free flow speed measurement in eastbound direction for multilane highway

5.5.4. Compute Level of Service for Two Directions

(HCS 2000) computer software used to compute the level of service for two directions in Ramadi – Fallujah Highway, where the results of analysis is shown below.

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___________________________OPERATIONAL ANALYSIS____________________________

Analyst:         HAMID & HAMEED
Agency/Co:       Engineering College
Date:            20/1/2012
Analsis Period: one hour
Highway:         Ramadi - Fallujah Highway
From/To:         Sjarea - Heseba
Jurisdiction:
Analysis Year:   2012
Project ID:      Evaluation Of Level of Service of Ramadi - Fallujah Highway

_______________________________FREE-FLOW SPEED_____________________________

                   Direction            1                  2
Lane width                             3.6       m        3.6       m
Lateral clearance:
     Right edge                        1.8       m        1.8       m
     Lem  edge                         1.8       m        1.8       m
     Total lateral clearance           3.6       m        3.6       m
Access points per mile                 0                  0
Median type
Free-flow speed:                       Measured           Measured
     FFS or BFFS                       91.6      km/h     90.9      km/h
Lane width adjustment, FLW             0.0       km/h     0.0       km/h
Lateral clearance adjustment, FLC      0.0       km/h     0.0       km/h
Median type adjustment, FM             0.0       km/h     0.0       km/h
Access points adjustment, FA           0.0       km/h     0.0       km/h
Free-flow speed                        91.6      km/h     90.9      km/h
```

VOLUME

Direction	1		2	
Volume, V	890	vph	1206	vph
Peak-hour factor, PHF	0.88		0.87	
Peak 15-minute volume, v15	253		348	
Trucks and buses	15	%	15	%
Recreational vehicles	0	%	0	%
Terrain type	Level		Level	
Grade	0.00	%	0.00	%
Segment length	0.00	km	0.00	km
Number of lanes	2		2	
Driver population adjustment, fP	1.00		1.00	
Trucks and buses PCE, ET	1.5		1.5	
Recreational vehicles PCE, ER	1.2		1.2	
Heavy vehicle adjustment, fHV	0.930		0.930	
Flow rate, vp	543	pcphpl	748	pcphpl

RESULTS

Direction	1		2	
Flow rate, vp	543	pcphpl	748	pcphpl
Free-flow speed, FFS	91.6	km/h	90.9	km/h
Avg. passenger-car travel speed, S	91.6	km/h	90.9	km/h
Level of service, LOS	A		B	
Density, D	5.9	pc/km/ln	8.2	pc/km/ln

6. Conclusions

It concluded that the selected section (Sejarea – Hesaba) in Ramadi – Fallujah highway for both directions work under high level of service, where the level of service for east direction (from Ramadi to Fallujah) is (A) And for west direction (from Fallujah to Ramadi) is (B).

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