

1-25-2021

## Speed / Flow Relationship on Some Important Urban Arterial Roads: Fayoum City as a Study Case.

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### Recommended Citation

El-Shourbagy, Mahmoud (2021) "Speed / Flow Relationship on Some Important Urban Arterial Roads: Fayoum City as a Study Case.," *Mansoura Engineering Journal*: Vol. 27 : Iss. 4 , Article 7.  
Available at: <https://doi.org/10.21608/bfemu.2021.143008>

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## SPEED / FLOW RELATIONSHIP ON SOME IMPORTANT URBAN ARTERIAL ROADS: FAYOUM CITY AS A STUDY CASE

استنباط العلاقة الرياضية بين حجم وسرعة المرور على بعض الوصلات للطرق الهامة بمدينة الفيوم

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خلاصة :

يهدف البحث إلى استنباط العلاقات الرياضية بين حجم وسرعة المرور على بعض الوصلات للطرق الهامة بمدينة الفيوم حيث اختير طريقتين للقياس وهما شارع أحمد شوقي وبطل السلام ، وقد استخدم في جمع البيانات طريقة العربة المتحركة لمدة حصر ١٢ ساعة بين الساعة ٨ صباحاً وحتى الساعة ٨ مساءً بعدد ٦ مرات في كل اتجاه لكل طريق ولكل ساعة حصر ؛ وقد تم تقدير التوزيع الاتجاهي للمرور للشوارع المختارة وكذلك تحديد ساعات الذروة المختلفة لها حيث أظهرت النتائج أن ساعة الذروة الصباحية لشارع أحمد شوقي تقع ما بين الساعة ٩ ص والساعة ١٠ ص بينما تقع ساعة الذروة المسائية بين الساعة ٣ م والساعة ٤ م لكل من اتجاهي الحركة وقد سجل أقصى حجم مروري في كلا الاتجاهين حجم قدره ٨٣٤١ عربة/ساعة.

كما أظهرت النتائج أيضاً أن ساعة الذروة الصباحية لشارع بطل السلام تقع ما بين الساعة ٩ ص والساعة ١٠ ص لكل من اتجاهي المرور بينما تقع ساعة الذروة المسائية بين الساعة ٢ م والساعة ٣ م بالنسبة للمرور المتجه إلى كلية الطب، وبين الساعة ٣ م والساعة ٤ م بالنسبة للمرور المتجه إلى شارع الشيخ حسن وقد سجل أقصى حجم مروري في كلا الاتجاهين حجم قدره ٧٩٢٧ عربة /ساعة.

كذلك أظهرت نتائج الإستقصاء أن أقصى سرعة مسير في كل من شارع أحمد شوقي وبطل السلام كانت على التوالي ٣٨ كم/ساعة ، ٤٤ كم/ساعة بينما كانت انسي سرعة ٢٩ كم/ساعة ، ٢٥,٧ كم/ساعة على التوالي ، وقد تم استنباط العلاقة الرياضية بين حجم وسرعة المرور لكل اتجاه عند الوصلات التي تم الحصر عليها ولتوضيح نتائج هذه العلاقة أن السرعة الارتباط المختلفة لكل علاقة رياضية باستخدام أسلوب البرمجة الخطية حيث أوضحت نتائج هذه العلاقة أن السرعة المرغوب فيها (المسموح بها) لكل من شارع أحمد شوقي وبطل السلام كانت على التوالي ٥٢ كم/ساعة ، ٥٥ كم/ساعة.

### Abstract

This paper was undertaken to investigate the relationships between speed and flow on urban arterial roads of Fayoum City. These roads serve some important areas in Fayoum City in Egypt. This research work was based on the traffic survey data collected for Batal El-Salam and Ahmad Shawki Streets through 12 hours using moving car method. The traffic survey was carried out between 8.00 a.m. and 8.00 p.m. for every direction. The survey results indicate that the morning peak hour for Ahmad Shawki Street lies between 9.00 a.m. to 10.00 a.m.; while the afternoon peak lies between 15.00 to 16.00. The maximum traffic volume for both directions in this street was 8341 vehicle/hr. Also the morning peak hour for Batal El-Salam street in both directions lies between 9.00 a.m. to 10.00 a.m. which gives maximum volume 7927 vehicle/hr.

In addition the maximum and minimum speeds of Ahmad Shawki Street were 38 km/hr. and 29 km/hr. respectively. While the maximum and minimum speeds of Batal El-Salam Street were

44 km/hr. and 25.7 km/hr. respectively. The collected data was analyzed by using the regression analysis.

### 1. Introduction

Traffic studies form a major part of the traffic engineer's work, as most control and design problems demand a detailed knowledge of the operating characteristics of the traffic concerned [1]. The speed / flow relationship is important to the traffic engineer and its results are used in traffic planning, design, economics and environmental studies.

In U.K., the speed / flow relations on recreational roads during summer 1973, are investigated. Observed speeds appeared to be more than 10% lower than speeds predicted for rural roads of comparable standard outside recreational roads [2].

Also, in U.K., the traffic speed / flow relationships in tunnel roads are studied. The traffic speeds and flows were observed at nine road tunnels at different times between October 1972 and August 1976 to obtain speed/flow relationship [3].

In addition, the speed/flow relationships on Cairo Urban Roads have been studied [4].

In U.K., the speed /flow relationships at approximately 100 sites throughout the Kingdom were investigated. The data was collected by using pneumatic tube [5] and the data were used to speed /flow analysis and various summary statistics were also derived.

In Egypt, the measurement of average running speed in suburban area of Cairo City and traffic flow characteristics have been studied [6].

The purpose of this research work is to study and obtain the speed /flow relations on some selected urban arterial roads in Fayoum City. The field survey was carried out through different hours of day during April 2001, and collected data was analyzed and fitted by regression analysis.

### 2. Calculations Background

Hourly volume, average journey time, and space mean speed under existing conditions are determined for every section by using the following formula [1,7].

$$V_n = \frac{60(M_s + O_n - P_n)}{T_n + T_s}$$

$$T_n^{\lambda} = T_n - \frac{60(O_n + P_n)}{V_n}$$

$$S_n = \frac{60d}{T_n^{\lambda}}$$

Where:

$V_n$  = Volume /hour, in one direction (for the other direction volume, subscripts are reversed),

$M_s$  = Opposite traffic count of vehicles met test car when the test car was traveling south,

$O_n$  = Number of vehicles overtaking the test car,

$P_n$  = Number of vehicles passed by the test car,

$T_n$  = Travel time when test car traveling the first direction, in minutes,

$T_s$  = Travel time when test car traveling the other direction, in minutes,

$T_n^{\lambda}$  = Average travel time of all traffic in the first direction,

$S_n$  = Space mean speed in the first direction, in Km/hour, and

$d$  = Length of test section in Km.

### 3. Data Collection Procedures

#### 3.1. General

Fayoum city is considered one of the most rapidly expanding cities in Egypt. Over the last 20 years its population has increased considerably to reach approximately 400000 capita as a reason of the migration of people from surrounding rural areas and high rate of birth. Educational, industrial, commercial, and new residential developments in the urban and suburban areas have led to acute traffic problem especially along the main corridors of the city. As result of continuing growth in vehicle ownership and lack of road spaces, many arterials of Fayoum road network started to suffer from various traffic problems. The most important corridors in Fayoum, Ahmed Shawki, City zoo, Batal El-Salam streets are shown in fig. (1).

The field survey was carried out by using moving car method during 12 hours between 8.00 a.m. till 8.00 p.m.

Two sections were taken into consideration as follows:

- i) *Ahmad Shawki*: This section is 1.0 km length, three lane per direction, and 3.75 m lane width. This section lies between the intersection of Ahmad Shawki with City Zoo Street and its intersection with Mohafza Villa Street.
- ii) *Batal El-Salam*: This section lies between El-Shiakh Hassen intersection and Faculty of Medicine intersection with the length of 1.6 Km, and has three lanes per direction, and 3.70 m lane width.

#### 3.2 Sample Size Requirements

The recommended number of test runs to obtain overall speed, travel time or traffic volume within certain limits of error and with 90% confidence level are given in reference [7]. At multi-lane uncongested road, five test runs are required to collect data with 90% confidence level. In this paper, the number of runs is taken as 6 runs for every hour period and for every direction of field survey locations. The excess test runs is used to increase the accuracy of data analysis.

#### 3.3 Traffic Survey Data

The data are recorded for each direction along the road section under survey and include the following items:

- Travel time obtained by a stopwatch.
- Opposing traffic, a manual count of the number of vehicles moving in the opposite direction that are met by the test car.
- Overtaking traffic, a count of vehicles, moving in the same direction, that overtake the test car.
- Passed traffic, a count of vehicles, moving in the same direction that are passed by the test car.

Data are shown in tables (1) and (3).

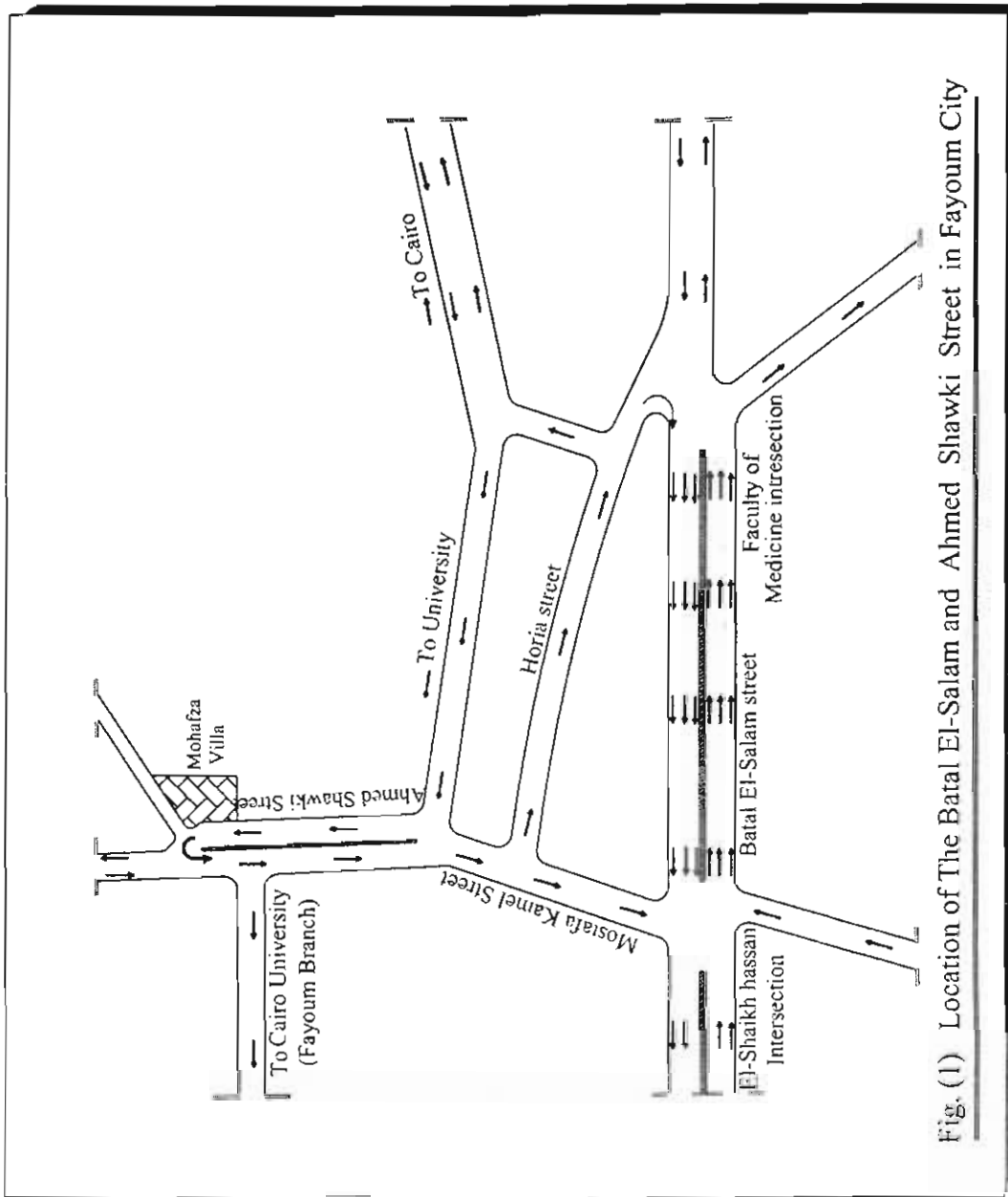


Fig. (1) Location of The Batal El-Salam and Ahmed Shawki Street in Fayoum City

#### 4. Analysis of speed/flow data and results:

##### 4.1. Ahmad Shawki Street

Table (1) shows the results of average values of data collection through different hours of the day for the vehicles using Ahmad Shawki Street. Also, the table shows the results of calculated hourly volume, average journey time, and space mean speed by applying the previous described formula.

Table (1) Results of average 6 runs for the test car in Ahmad Shawki Street

Hour of day	To Mohafza Villa						To City Zoo							
	$T_n$	$M_n$	$O_n$	$P_n$	$V_n$	$T_n \setminus S_n$	$T_n$	$M_n$	$O_n$	$P_n$	$V_n$	$T_n \setminus S_n$		
8-9	2.00	185	2.2	1.8	3006	1.92	31.7	1.70	142	2.1	1.1	2319	1.62	37
9-10	2.06	239	3.1	2.2	3599	1.97	30.4	1.95	181	2.8	1.9	2722	1.85	32.4
10-11	2.04	190	3.3	2.4	2767	1.92	31.3	2.10	163	3.1	1.6	2384	1.98	30
11-12	2.02	150	3.3	2.3	2341	1.87	32.1	1.85	149	3.2	1.3	2340	1.74	34.5
12-13	2.00	141	2.6	2.2	2192	1.87	32.1	1.87	138	2.9	1.2	2166	1.76	34.1
13-14	2.10	175	4.2	3.3	2574	1.92	31.2	2.00	161	4.1	2.2	2384	1.84	32.6
14-15	2.06	172	4.1	3.1	2465	1.88	31.9	2.15	169	3.8	2.1	2433	2.00	30
15-16	2.12	335	4.2	3.2	5027	2.03	29	1.89	220	3.9	2.4	3314	1.76	34.1
16-17	2.09	255	3.6	2.6	3623	1.99	30.2	2.15	194	3.3	2.0	2764	2.03	29.6
17-18	1.8	135	3.9	3.4	2085	1.59	38	1.88	169	3.2	1.9	2777	1.76	34.1
18-19	2.08	232	3.7	3.2	3436	1.96	30.6	1.98	207	3.7	1.8	3087	1.87	32.1
19-20	2.00	147	2.4	1.9	2305	1.89	31.7	1.84	134	2.1	1.2	2108	1.75	34.3

##### 4.1.1. Hourly Distribution of Traffic Volume

Fig (1) shows the hourly distribution of traffic volume for both directions in Ahmad Shawki Street through the hours of the day.

In this figure, the morning peak hour of the direction leading to City zoo lies between 9:00 to 10:00 a.m., while the afternoon peak lies between 15:00 to 16:00. In addition, the morning and afternoon peaks for the other direction lies between 9:00 to 10:00 a.m. and between 15:00 to 16:00, respectively. Also, the maximum traffic volume for both directions was 8341 vehicle/hr which occurs between 15:00 to 16:00.

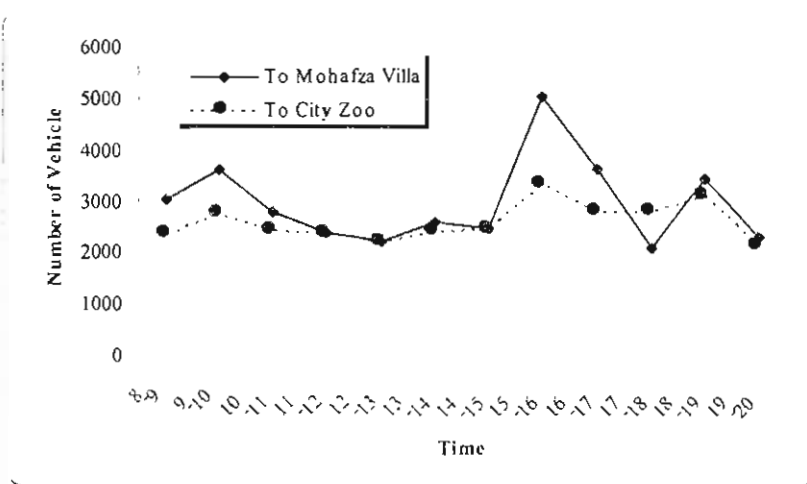


Fig. (1) hourly distribution of traffic volume Ahmad Shawki street



### 4.1.2 Hourly Distribution Of Space Mean Speed

Fig. (2) shows the hourly distribution of space mean speed through different hours of the day for every direction of the street.

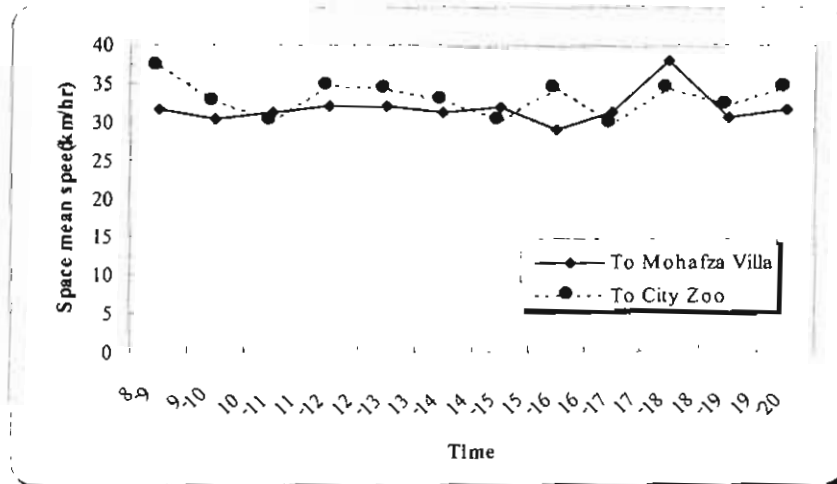


Fig. (2) Hourly distribution of space mean speed in Ahmad Shawki Street

In this figure, the average speed of the direction leading to Mohafza villa lies between 29 Km/hr as a minimum speed and 38 Km/hr as a maximum speed. The same values for the other direction was 29.6 Km/hr and 37 Km/hr respectively.

### 4.1.3. Directional Distribution Factor

Table (2) shows the directional distribution factor ( $F_D$ ) through the different hours of the day. It indicates that, the direction of vehicles leading to Mohafza villa represent the prevailing direction.

Table (2) Directional distribution factor ( $F_D$ )

Hours	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
To Mohafza Villa	57	57	54	50	51	52	51	60	57	43	53	52
To city Zoo	43	43	46	50	49	48	49	40	43	57	47	48

The table indicates the tendency of car drivers to use Mohafza villa direction with the highest traffic volume occurring during the period 15:00 to 16:00 .

### 4.1.4. Speed/Flow Relationship

The speed/flow relationship was estimated in both directions of Ahmad Shawki Street by using the regression analysis technique after excluding unreasonable data of speeds or volumes [8,9,10,11].

The results showed the following equation:

$$S = 52.359 e^{-0.00001V} \quad (R^2 = 0.42)$$

Where:

- S = Space mean speed (Km/hr.),
- V = Average traffic volume (veh./hr/direction), and
- R<sup>2</sup> = Correlation coefficient.

The above equation is valid for traffic volume less than or equal to road capacity (i.e. in this case 6400 veh/hr/direction).

For flows greater than capacity the relationship becomes unstable. In this equation, it may be noticed that the free flow speed is equal to desired speed. The desirable speed can be estimated as 52.4 Km/hr. at traffic volume equal to zero. Fig. (3) shows the theoretical and observed volume/speed relationship of Ahmad Shawki Street.

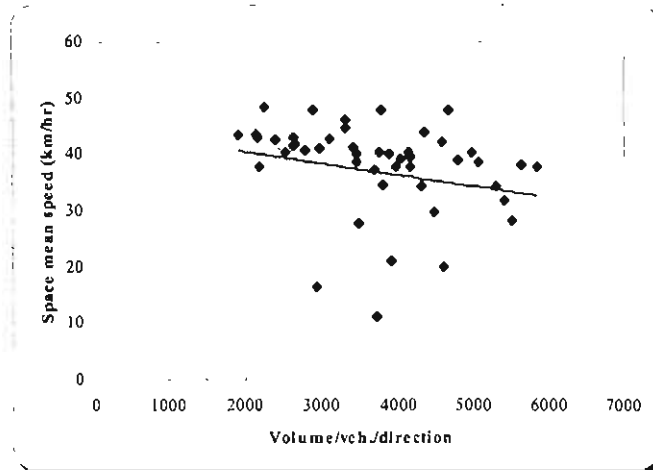


Fig. (3) Speed/Flow relationship for Ahmad Shawki Street

#### 4.2 Batal El-Salam Street

Table (3) shows the results of average values data collection through the different hours of the day for the vehicles using Batal El- Salam Street.

In this table, the hourly volume, average journey time, and space mean speed are calculated.

Table (3) Results of average 6 runs for the test car in Batal El- Salam street.

Hour of day	To Faculty of Medicine							To El-Shaikh Hassan						
	T <sub>n</sub>	M <sub>n</sub>	O <sub>n</sub>	P <sub>n</sub>	V <sub>n</sub>	T <sub>n</sub> \ S <sub>n</sub>	T <sub>n</sub>	M <sub>n</sub>	O <sub>n</sub>	P <sub>n</sub>	V <sub>n</sub>	T <sub>n</sub> \ S <sub>n</sub>	S <sub>n</sub>	
8-9	3.2	310	3.4	2.0	3114	3.09 \ 31.1	3.75	380	4.0	1.2	3146	3.74 \ 25.7		
9-10	2.60	405	3.8	2.4	4781	2.52 \ 38.1	2.5	320	2.5	1.6	3775	2.43 \ 39.5		
10-11	2.90	400	3.9	2.1	4229	2.81 \ 34.2	2.8	310	3.4	2.3	3275	2.69 \ 35.7		
11-12	2.75	395	3.3	2.2	4484	2.67 \ 35.9	3.2	267	3.1	2.2	2329	3.06 \ 31.4		
12-13	3.70	290	3.2	2.4	2529	3.56 \ 26.9	2.8	290	3.2	2.3	2909	2.68 \ 35.8		
13-14	3.0	320	3.6	2.1	3163	2.89 \ 33.2	2.9	285	2.8	2.0	2858	2.79 \ 34.4		
14-15	3.1	370	3.6	2.3	3713	3.0 \ 30.0	3.1	280	2.8	1.9	2763	2.99 \ 32.1		
15-16	3.55	420	4.2	2.3	3468	3.44 \ 27.9	2.55	300	2.9	1.8	3408	2.47 \ 38.8		
16-17	2.95	250	3.3	2.3	2531	2.82 \ 34	3.0	210	2.9	1.8	2128	2.86 \ 33.5		
17-18	2.45	170	2.9	1.8	2387	2.33 \ 41.2	2.30	155	2.8	1.8	1970	2.16 \ 44		
18-19	2.87	265	3.2	2.1	2918	2.76 \ 34.8	2.6	185	2.6	2.2	2033	2.45 \ 39.2		
19-20	3.12	275	3.0	1.9	2729	3.01 \ 31.9	2.95	230	2.90	2.1	2281	2.82 \ 34		

#### 4.2.1 Hourly Distribution Of Traffic Volume

Fig. (4) shows the hourly distribution of traffic volume for every direction of Batal El- Salam Street through the different hours of day. In this figure, the morning peak hour of the direction



leading to Faculty Of Medicine intersection lies between 9:00 to 10:00 a.m., while the afternoon peak lies between 14:00 to 15:00. For the other direction, the two peaks happen between 9:00 to 10:00 a.m, and 15:00 to 16:00 respectively. In addition the maximum volume for both directions of street was 7927 veh/hr. which happened between 9:00 to 10:00 a.m.

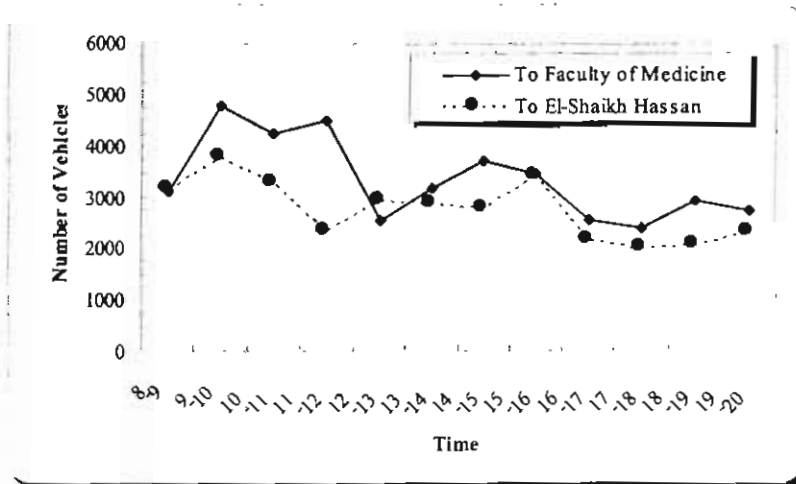


Fig.(4) Hourly distribution of traffic volume in Batal El-Salam street

#### 4.2.2 Hourly Distribution of Space Mean Speed

Fig. (5) shows the hourly distribution of space mean speed for every direction of street through different hours of the day. For the direction leading to Faculty Of Medicine, the maximum speed was 41.2 Km/hr. and minimum space mean speed was 26.9 Km/hr. For the other direction the values of speed are 44Km/hr. and 25.7 Km/hr. respectively.

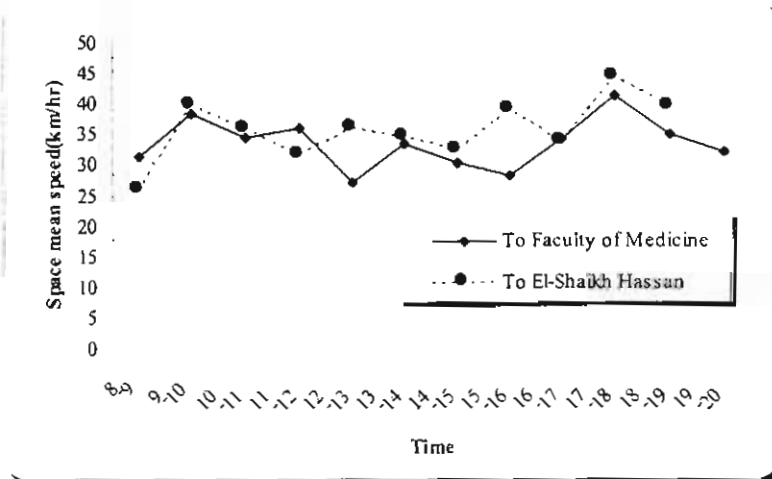


Fig. (5) Hourly distribution of Space mean speed in Batal El-Salam street

#### 4.2.3 Directional Distribution Factor

Table (4) shows the results of directional distribution factor ( $F_D$ ) for every direction of street through hours of the day. It indicates that, the direction of vehicles leading to Faculty Of Medicine represent the prevailing direction, while the other direction represents the prevailing direction rest of the day.

Table (4) Directional distribution factor ( $F_D$ )

Hours	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
To Medicine Faculty	50	56	56	66	47	53	57	50	54	55	59	54
To El-Sheikh Hassan	50	44	44	34	53	47	43	50	46	45	41	46

The table indicates the tendency of car drivers using Faculty Of Medicine direction with the highest occurring during the period 11:00 to 12:00 which the normal mid-day peak hour.

#### 4.2.4 Speed/Flow Relationship

The speed/flow relationship for the vehicles using Batal El-Salam Street was estimated in both direction by the use of regression analysis. The relationship between speed and flow was yielded to the following formula:

$$S = 85.1 e^{-0.00015 V} \quad (R^2 = 0.41)$$

Where :

S = Space mean speed (Km/hr)

V = Volume of traffic (vph/direction)

$R^2$  = Correlation coefficient.

This equation is valid for traffic volume less than or equal to street capacity. The flow free speed or the desire speed of Batal El- Salam Street is equal to 55 Km/hr. By comparing between the values of desire speed for both streets, the value of desire speed in Ahmad Shawki Street was smaller than in Batal El-Salam Street, due to the differences of land use for both streets. Also, the pedestrians crossing volume in Ahmad Shawki Street is bigger. Fig. (6) shows the volume/speed relationship of Batal El-Salam Street.

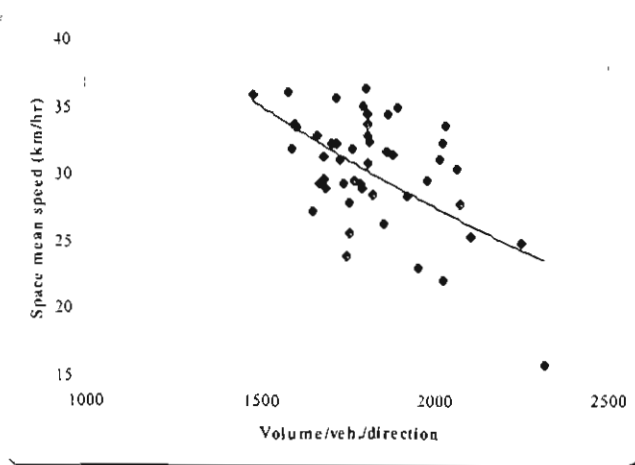


Fig. (6) Speed/Flow relationship for Batal El-Salam Street

## 5. Conclusions

This paper studied the speed/flow relationships of vehicles using some selected urban arterial roads in Fayoum City. The data was collected at two sections of Ahmad Shawki and Batal El-Salam streets through the different day hours by using moving observe car method.

The main results can be concluded as follows:

- 1- The maximum traffic volume of Ahmad Shawki Street in both directions was 8341 veh./hr. which happened between 3:00 to 4:00p.m. Also, the maximum traffic volume of Batal El-Salam in both directions was 7927 veh./hr.
- 2- Minimum speed of vehicles using Ahmad Shawki in the direction of vehicles leading to Mohafza villa was 29 Km/hr. and the maximum speed was 38 Km/hr. For the other direction the minimum and the maximum speeds were 29.6 Km/hr. and 37 Km/hr. respectively.
- 3- In Batal El-Salam Street the minimum and the maximum speeds for the vehicles using the direction leading to El-Shiag Hassen were 26.9 Km/hr. and 41.2 Km/hr. For the other direction the same values were 25.7 Km/hr. and 44 Km/hr. respectively.
- 4- The relationship between speed and flow in Batal El-Salam and Ahmad Shawki streets were yielded to exponential distribution.
- 5- The desire speed of Batal El-Salam street is 55 Km/hr. , while the desire speed of Ahmad Shawki Street is 52.4 Km/hr.

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