A STATISTICAL ANALYSIS OF TRAFFIC FLOW CHARACTERISTICS OF MULTILANE HIGHWAYS IN BAGHDAD CITY

Part A: Traffic Elements Characteristics[1]

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ABSTRACT

Basic traffic elements (flow, speed, density) are used in many stages of transportation process. Flow-speed-density relationship is an important concept, which translates traffic stream characteristics into mathematical or statistical models. These models are widely used in transportation engineering. The main objective of this research is finding out the nature of the relationships between the basic traffic elements characteristics for multi-lane highways in Baghdad city.

Data has been collected throughout an extensive field survey on twenty selected sections in the study area. Photograph technique is used to determine the basic traffic elements. Statistical technique is applied to analyze the collected data in order to present the best models to describe flow- speed- density relationships. The results of this study indicate that the linear relationship between speed and density is signification with confidence level (99%). The nature of this relation is considered during the formulation of the other relation-ships between traffic elements.

KEYWORDS

Multilane highway, traffic flow, traffic speed, traffic density

INTRODUCTION

The effectiveness of a highway design is evaluated on a number of quantitative and qualitative elements. Such elements include the number of vehicles that can travel, the speeds at which they travel, the density of vehicles along the highway, the distance between vehicles, the freedom to maneuver among lanes, and so on. These traffic characteristics has been widely modeled using the statistical techniques, based on the assumption of an underlying stochastic nature of the traffic system[2,3].

Multilane highway is defined as uninterrupted flow facilities, it have no fixed elements, such as traffic signals, and no time limitation on the use of roadway space[4,5]. Multilane highways have four or six lanes, often with physical median.

Study Problem and Objective

Baghdad city, the capital of the republic of Iraq, has had a considerable leading position in the middle of Iraq. The city is a major activity center and focus of traffic generation. It is drawing significant quantities of traffic from wide spreads area, for many different purposes. In addition, the rapid growth in the level of car ownership of city population due to many reasons. Therefore, the city has many characteristics as a major trip generator activity.

Many successful and reliable relationships have been established in developed areas of the world. Applying these relations directly to Iraqi multilane highways give rise to unreliable results, as each country has its own special traffic characteristics .For these reasons, it was felt useful to present this work. The main objective of this study is to present, throughout extensive field and statistical analysis, the characteristics of the traffic elements of multilane highway in Baghdad city network. In addition, the study seeks to find the best statistical relationship between these characteristics.

Definition of Study Area

In Baghdad city, the multilane highways have an important and influential role for traffic operations, design and planning. There are several multilane highways in city network. The study area consist of 20 section selected from four multilane highways . These multilane classified as 6-lane and 4- lane highways, for each class of highways four sections are selected to collect traffic elements data. The selection of these sites are based on the following reasons:

1. The variation of traffic volume elements.
2. Availability of the best required conditions for study data collection and measuring.
3. The pavement surface condition is good.
4. Level, straight, mid-block location.
5. There was no shielding to reduce the number of variables that might affect accuracy of the field data collection .

The study area consists of the following multilane highways [see Figure (1)]:

1. Army Canal Multilane Highways

This highway starts from Al-Rashdeiah area, north of Baghdad, and ended at Al-Rastamyah in the south, throughout its length about (21.0) Km. The highways intersects with other multilane highways by six underpasses. This highway is classified as 6-lane highway, with eight on-ramps and seven off-ramps in the north direction, while there are eight on-ramps and eight off-ramps in the south direction.

2. AL-Taji Multilane Highways

This highway is a part of Baghdad-Mosul highway, this highway is about (20.0) km in length, extended from Al-Taji area and ended at Aden Square in the south direction. This highway intersects with other multilane highways by four underpasses, with only three on-ramps in north direction, two on-ramps and three off-ramps in south direction. The class of this highway changed from 4- lane highway to 6- lane highway, in the last (3.0) km of its length.

3. Al-Moheet Multilane Highways

This multilane is classified as 4-lane divided highway. For north direction, this highway extends from Al-Ayemma bridge to Salah Al-Deen Al-Ayobey Square. Through a (5.0) Km, of its length the highway intersect with other major streets by three major intersections.

4. Al-Kazaliaa Multilane Highways

This highway started from Al-Hamza Mosque to the Al-Kaffat Bridge in the south direction. This highway is classified as 6-lane divided highway, with median width of 15m. Throughout the total length of about (5.0) km of this highway there are many exclusive left turns but without any intersection.

Data Collection

The counting period, for collecting and measuring the required data should avoid special event conditions, such as holidays, exhibitions or fairs, unusual weather, or temporary street closures. Commonly the data was collected on weekday through the week (from Sunday to Wednesday), bad weather conditions have adverse effects on the roadway, and therefore, all measurements were carried out from March to June 2004.

Traffic elements include traffic volume, traffic speed, traffic density, which are collected and measured from the field work using photographic method. Photographic methods were the primarily tools used in the research work however, the interpretation of the photographs was a tedious task and transcription of the data as time consuming. Photographic methods were the most useful in studying the interrelationships of traffic elements .The photographic methods would be used from fixed elevated observation points at some locations in the study area to obtain travel time over some road segments and number of vehicles passing through the occupied segments .The height of the camera was limited to that permit for the identification of vehicles on successive photographs and as a result, the field view was covered by the camera included a relatively short section of highway .Observations were limited to day light hours with favorable atmospheric conditions .Data was collected during the peak and off peak hour period (for more details see Al- Ramahay [1]).

Sample Size

Sample size must depend upon the errors in the data collection. In this study, the following method was applied in order to estimate the sample size for the traffic elements [6, 7]:

$$N_{\min} = \left(\frac{SK}{E}\right)^2 \qquad \text{.. (1)}$$

Where:

N = minimum sample size. S = estimate sample standard deviation.

K= constant corresponding to the desired confidence level = 1.96 for 0.95 confidence level. E = permitted error = 2

DATA ANALYSIS

After collection of the field observation data , the collected data were combined and ranged together and feed to the computer programs in order to analyze these data .This programs were classified the field data collected and supplied data to provide values for the variables, like speed, density, flow. A statistical analysis techniques have been packaged attractively in the computer program routines to the point that little effort was required to meet the analysis needs. The Microsoft Statistica version (6.0) package was used in this study.

Regression Analysis

Regression analysis, simple regression or multiple regressions, is mathematical based procedure utilizing statistical measures to determine, and predict the effects of independent variables have on models. The process of estimation is often referred to as regression. In general the dependent variable or response Y may be related to K independent or variables .The regression model form is[8]:

$$Y=B_0+B_1X_1+B_2X_2+\dots\dots\dots+B_kX_k+E \qquad \dots\dots\dots\dots\dots\dots\dots (2)$$

It is called a multiple regression model with K regression variable. The parameters B_i (i=0, 1, k) are called the regression coefficients .The E is a random error term.

Calibration of the Models

The models of 4-lane and 6-lane multilane highways had been calibrated entirely on the same existing data can be used in developing these data. According to traffic analysis principles[11], random samples of 500 observations were selected in order to calibrate the models.

Models Validation

If the empirical model and theoretical framework upon which it is based are valid, then re-estimation of the model using a data set different from the original estimation data set can be used to produce coefficient of estimates that are statistically significant with respect to the original estimates. [9, 10]

The models were re-estimated using new data set consisting of about 750 observations that were selected randomly from different sections in the study area. Statistical test were done for this purpose by using chi-square method, which is based on the error between the observed and assumed sets of distribution.

Flow-Speed-Density Models

The best known early description of the relationships assumed to estimate traffic density, (k in veh/km), space mean speed (v_S in km/h) and flow (q in vph). In this study total section and total observation on 6-lane and 4-lane multilane highways were determined.

Using the data collected in the study area, the equation of [$q=v_S*k$] is tested by two methods. In the first method, the examination of the difference between the observed flow and the calculated flow (observed speed multiply by observed density) at the same time and location for 6-lane and 4-lane highways were done.

The second method was a measure of the discrepancy existing between observed and calculated frequencies of flow is supplied by the statistic chi-square. For 99% confidence level, the observed and calculated frequencies do not agree exactly. However, the results indicated method which was done by using multiple regression analysis with the general model [$q=v_S. k$]. The final results of this method are shown in Table (1).

Speed-Density Relationships

The most intuitive starting point for developing a consistent generalized traffic model is to focus on the relationship between speed (v_s) and density (k) [11]. Speed-density data was tested by statistic a program using regression analysis in order to construct the speed–density model for multilane highways. Speed have been chosen as a dependent variable while density as an independent variable.

The summary results after many runs of this program for linear and transformation of independent variable taken logarithm, inverse, quadratic and cubic equations which they are shown in Table (2) with Figure (2) for 6-lane highway and, Table (3), with Figure (3) for 4-lane highway.

According to the value of the coefficient of determination (R^2), and F- test (computed F). Tables (2) and (3) indicated that the best model described this relationship is a linear model. Where the selection of a linear relationship between speed and density refer to use the Greenshield model with the following advantage:

1. Easy to study and more flexible in applications.
2. Provides a basic insight into relationships among traffic flow, speed and density.
3. The value of free flow speed (v_f) is relative and reliable to actual field speed (where $v_f \neq \infty$).

The calibration for these models was done by using new data which was collected from the study area and the result gave the following equation:

For 6-lane highways:

$$v_s = 96.334 - 1.051\ k \qquad \text{.............................(3)}$$

Where:

Free flow speed (v_f) = 96.334 km/hr

Jam density (k_j) = 91.659 veh/km/ln

Critical speed (v_m) = 48.167 km/hr

Critical density (k_m) = 45.83 veh/km/ln ; and

Maximum flow (q_{max}) = 1958 veh/hr/ln

For 4-lane highways:

$$v_s = 92.25 - 0.951\ k \qquad \text{.................................. (4)}$$

Where:

Free flow speed (v_f) = 92.25 km/hr

Jam density (k_j) = 97.00 veh/km/ln

Critical speed (v_m) = 46.13 km/hr

Critical density (k_m) = 48.5 veh/km/ln ; and

Maximum flow (q_{max}) = 2045 veh/hr/ln

Figures (4) and (5) show calibrated speed-density model for 6-lane and 4-lane multilane respectively. It is obvious from these figures that the location of all observations in the stable flow side.

According to the data collection for each lane of the multilane highway the speed-density linear model was determined using regression analysis too, as shown in Table (4). Data were used to test the general linear calibrated model with statistic chi-square method. With significance levels of 1% and 5%, the tests indicate that the calibrated model can produce similarly accurate results regardless of the position lane.

Flow-Density Model

The calibrated linear speed density model, leading the study to propose a parabolic function as an approximation to the flow density relation. Flow density model was determined as follows:

$$q = v_f k - \frac{v_f}{k_j} k^2 \qquad \text{.................................. (5)}$$

For 6-lane multilane highway, the general flow-density model can be written as following and as shown in Figure (6):

$$q=85.448\,k-0.932\,k^2 \qquad \text{.......................................} (6)$$

For 4-lane multilane highway, the general flow-density model can be written as following and as shown in Figure (7):

$$q=84.316\,K-0.869\,k^2 \qquad \text{.......................................} (7)$$

Flow-Speed-Model

Returning to the general linear speed-density model a corresponding speed-flow model can be developed by rearranging this equation:

$$q=k_j v_s-\frac{k_j}{v_f}v_s^2 \qquad \text{.......................................} (8)$$

The parabolic function of equation (8) represents the general flow-speed model. With respect to the results of this study for 6-lane multilane highway, the general flow-speed model can be written as following and as shown in Figure (8):

$$q=81.30\,v_s-0.843\,v_s^2 \qquad \text{.......................................} (9$$

For 4-lane multilane highway, the general flow speed model can be written as following and as shown in Figure (9):

$$q=88.658\,v_s-0.961\,v_s^2 \qquad \text{.......................................} (1$$

Effect of Heavy Vehicles on Traffic Speed

The performance of a highway is affected by percentage of heavy vehicles using it.

Trucks are generally slower, and occupy more roadway space and consequently impose a greater traffic effect on the highway than passenger vehicles do. The overall effect on traffic operation of one truck is often equivalent to several passenger cars. The number of equivalent passenger cars depends on the gradient and the allowable passing sight distance .Thus, the larger the proportion of trucks in a traffic stream , the greater are the traffic volume and the highway capacity required[5,12].

In a level terrain, heavy vehicles are often traveling more slowly than passenger car traffic, and its bulk may restrict sight distance.

Using statistica program the study tested the effect of the heavy vehicles as percentage (independent variables) on the space mean speed, v_s (dependent variables). Tables (5), and (6) show the correlation between these two variables for 6-lane and 4-lane highway respectively. From these tables, the linear model give the best correlation between these variables and maximum adjusted R^2 with minimum standard error (S.E) and F test (computed F-value). Figures (10) and (11) show best space mean speed-percentage of heavy vehicle models.

CONCLUSIONS

Flow-speed-density relationships are important concepts which provide key input to the general transportation planning process. They are used in describing the performances of highways to enable the planner to arrive at decision as to which type of highways needs to be built or improved to satisfy demand.

Based on field survey data and statistical analysis techniques used to derive the flow-speed-density models along two types of multilane highways in Baghdad city, the following conclusions can be drawn out:

1. The photographic techniques represent an appropriate interesting methods that have been used to study stream flow characteristics.
2. The best fitting and the most significant model that explain the speed-density relationships for multilane highways is the linear model like Greenshield's model . This model represents the appropriate and flexible application model which is significant for 1% confidence level. While other traffic elements relationships models are developed according to this linear function.
3. The linear form shows the better correlation between the speed and the percentage of heavy vehicles which produce a decrease in speed.
4. The most observed of traffic flow data that collected in the study area are below the maximum flow, with speed equal or less than critical speed. That refers to the stable flow state of these data. Therefore, the characteristics of traffic flow for unstable state dose not exist and discussed in details.
5. Additional work is still required to overcome all the limitation and problems of this study. The research work should be encouraged to deal with many issues in this field.

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Table (1). Multiple regression analysis for flow- speed-density model in the study area (Baghdad 2004).

Multilane Highways Class	Model	Adjusted R^2	Standard Error	Computed F – value
6-lane	$q = v_s . k$	0.705	1.833	1799.654 †
4-lane	$q = v_s . k$	0.870	3.063	161.458 †

† Significant for 1% confidence level .

Table (2). Speed-density relationship model for 6-lane multilane highways (Baghdad 2004).

Predication Model	Type	Adjusted R^2	Standard Error S.E.	Computed F – value
$v_s=95.875 - 0.988*k$	Linear	0.897	1.212	394.101 †
$v_s=174.950 - 31.200*\log(k)$	Log	0.800	3.911	111.001 †
$v_s=31.669 +1083.616*(1/k)$	Inverse	0.801	4.651	212.612 †
$v_s=112.357 - 1.789*k + 0.011*k^2$	Quadratic	0.823	3.881	282.431 †
$v_s=128.548 - 3.4054*k + 0.042k^2 - 0.00002*k^3$	Cubic	0.770	6.909	81.281 †

† Significant of 1% confidence level .

Table (3). Speed-density relationship model for 4-lane multilane highways (Baghdad2004).

Predication Model	Relation Type	Adjusted R^2	Standard Error S.E.	Computed F – value
$v_s=93.605-1.058*k$	Linear	0.956	2.017	196.458 †
$v_s=180.842-4.403*\log(k)$	Log	0.948	2.911	99.331 †
$v_s=30.521+971.385*(1/k)$	Inverse	0.931	3.041	86.613 †
$v_s=115.357-1.078*k +0.011*k^2$	Quadratic	0.943	2.505	101.322 †
$v_s=124.196-5.036*k +0.111k^2-0.001*k^3$	Cubic	0.899	6.313	75.571 †

† Significant of 1% confidence level .

Table (4). Speed-density model according to the lane position of multilane highways (Baghdad 2004).

Multilane Class	Lane position	Predication Model	Adjusted R^2	Significance Levels%
6-lane	Shoulder	v_s=93.527-0.983*k	0.854	5
	Center	v_s=97.217-1.082*k	0.879	1
	Median	v_s=103.055-1.179*k	0.834	5
4-lane	Shoulder	v_s=88.504-0.957*k	0.796	5
	Median	v_s=96.613-1.104*k	0.791	5

Table(5).Correlation between space mean speed (v_s) and Percentage of heavy vehicles (HV%) on 6-lane highways (Baghdad 2004)

Production model	Relation Type	Adjusted R^2	Standard Error S.E.	Computed F- value
v_s=84.051+(-1.861)*HV%	Linear	0.797	4.192	111.738†
v_s=107.403-18.975*log(HV%)	Log	0.713	6.011	91.111 †
v_s=49.703+117.597*(1/HV%)	Inverse	0.552	9.331	3.703
v_s=90.437-7.015*HV%+0.046 *$(HV\%)^2$	Quadratic	0.710	8.881	61.019 †
v_s=96.526-4.922*HV%+0.216 *$(HV\%)^2$-0.004*$(HV\%)^2$	Cubic	0.711	5.414	26.216 †

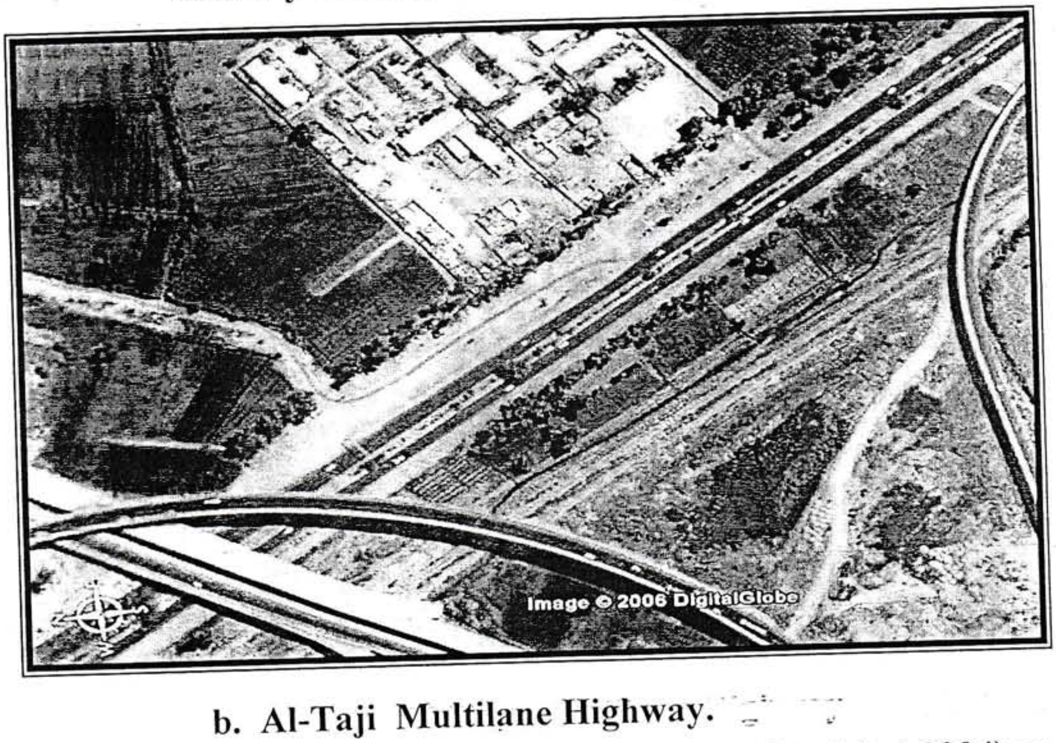
† Significant of 1% confidence level .

Table (6). Correlation between space mean speed (v_s) and Percentage of heavy vehicles (HV%) on 4-lane highways (Baghdad 2004).

Production model	Relation Type	Adjusted R^2	Standard Error S.E.	Computed F value
v_s=81.432-1.181*HV%	Linear	0.597	5.618	15.249 †
v_s=95.823-12.041*log (HV%)	Log	0.540	7.001	10.114 †
v_s=57.886+90.284*(1/HV%)	Inverse	0.458	5.617	9.331
v_s=81.917-1.278*HV%+0.003 *$(HV\%)^2$	Quadratic	0.560	9.313	12.332 †
v_s=90.305-3.324*HV%+0.259 *$(HV\%)^2$-0.006*$(HV\%)^2$	Cubic	0.562	9.332	11.442 †

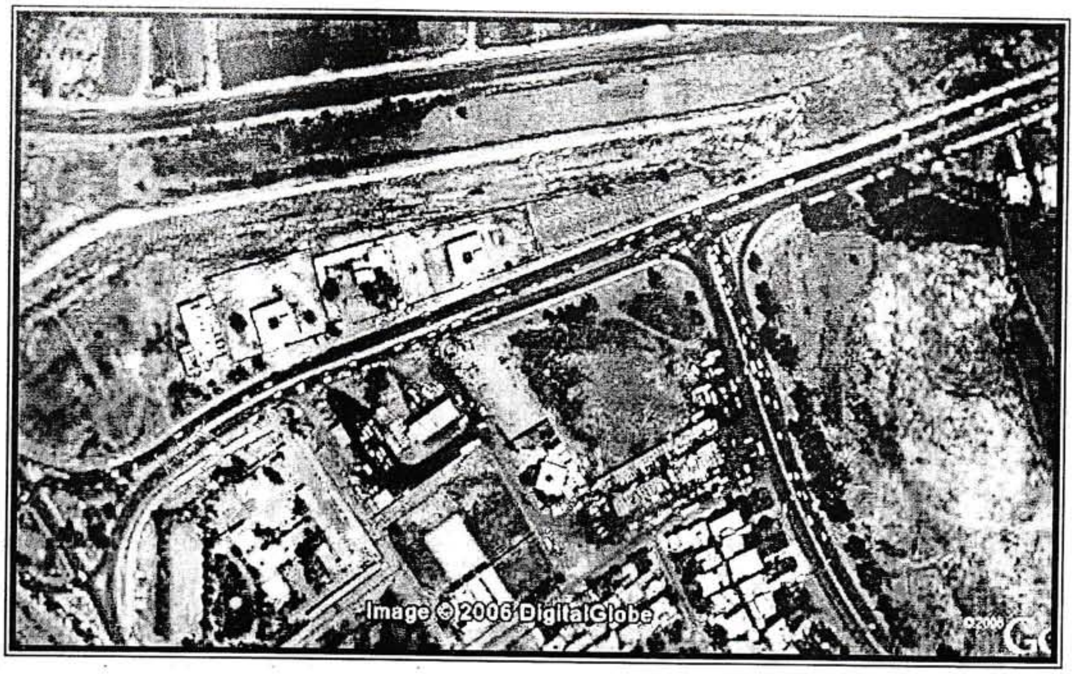
† Significant of 1% confidence level .

a. Army Channel Multilane Highway.

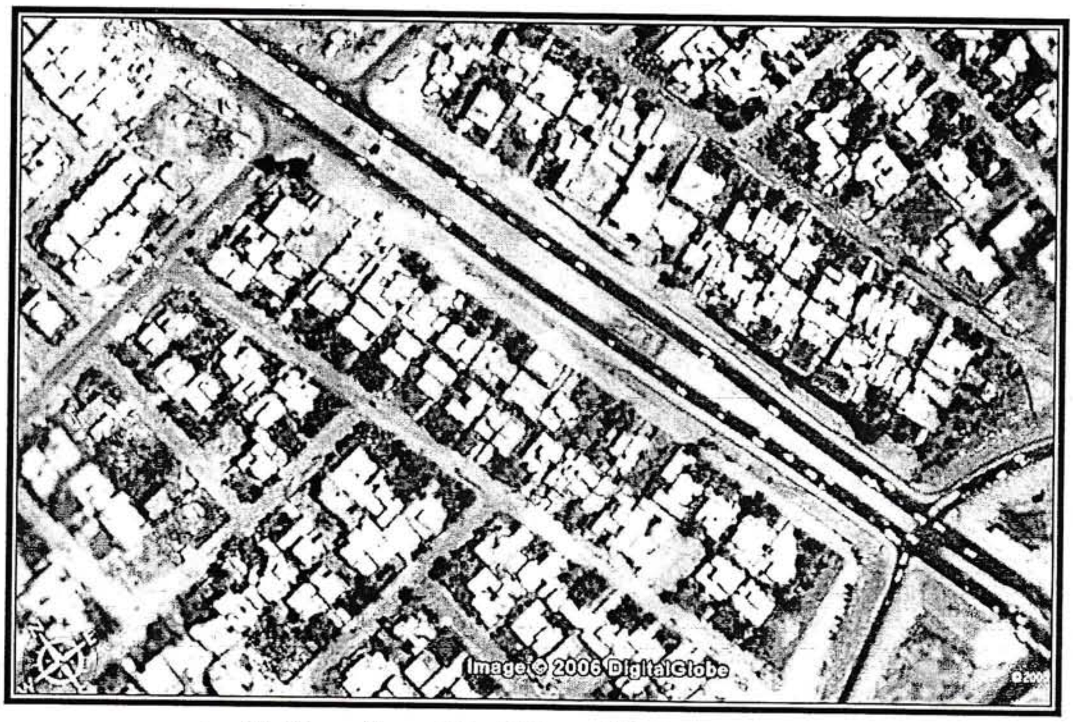


b. Al-Taji Multilane Highway.

Figure (1). Typical sections on study area (Baghdad 2004).

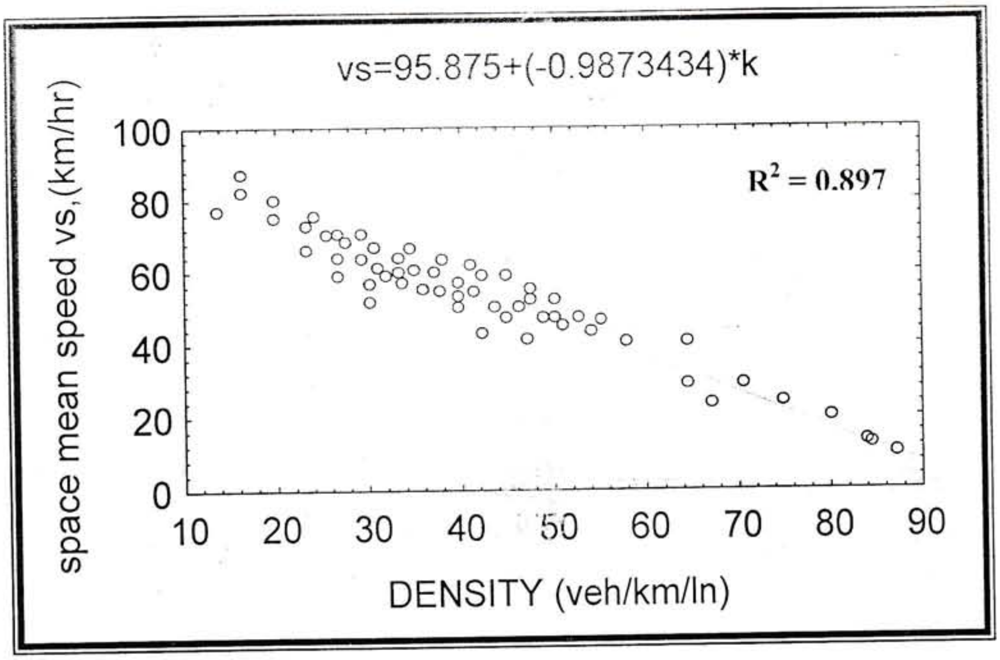


c. Al-Moheet Multilane Highway.

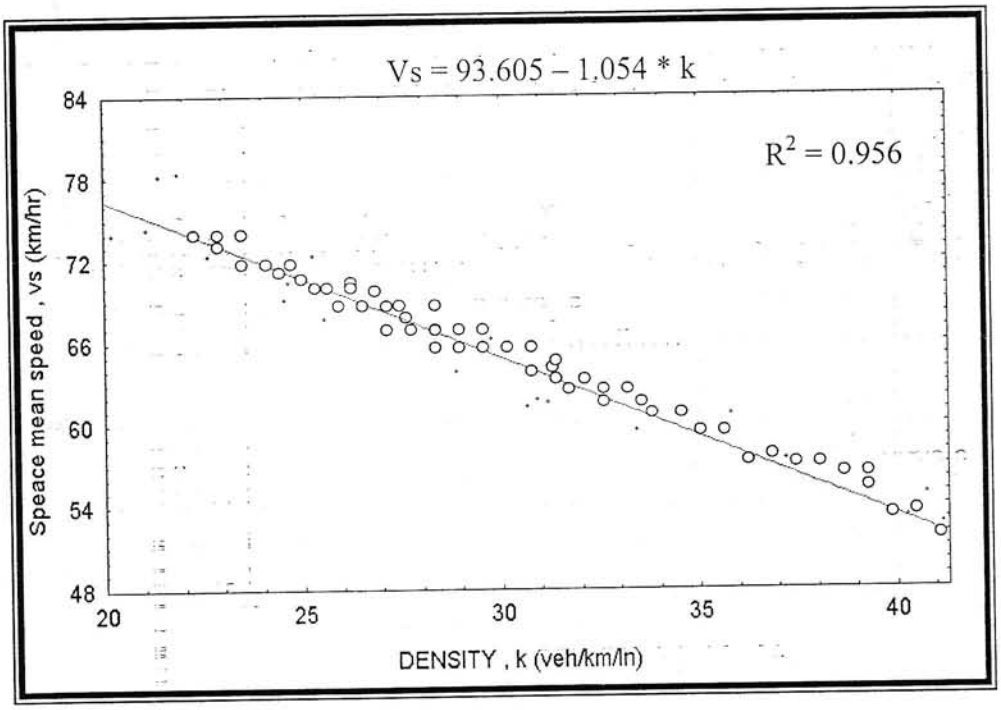


d. Al-Kazaliaa MultilaneHighway.

Figure (1). Continued.



Figure(2).Speed-density model for 6-lane multilane highways (Baghdad 2004).



Figure(3).Speed-density model for 4-lane multilane highways (Baghdad 2004).

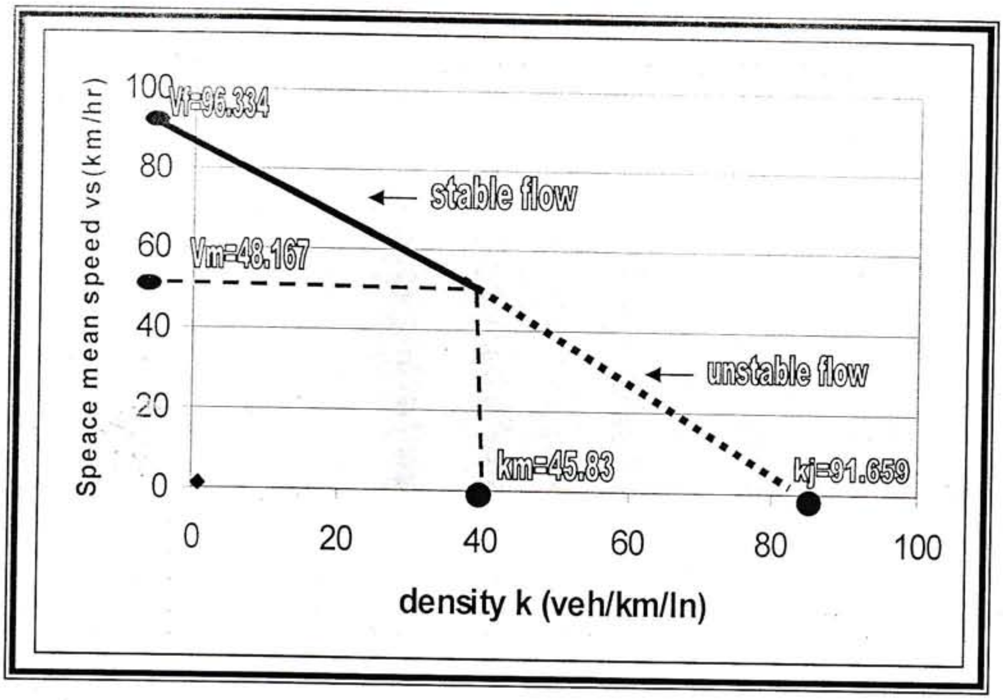


Figure (4). Calibrated speed-density models for 6-lane multilane highways (Baghdad 2004).

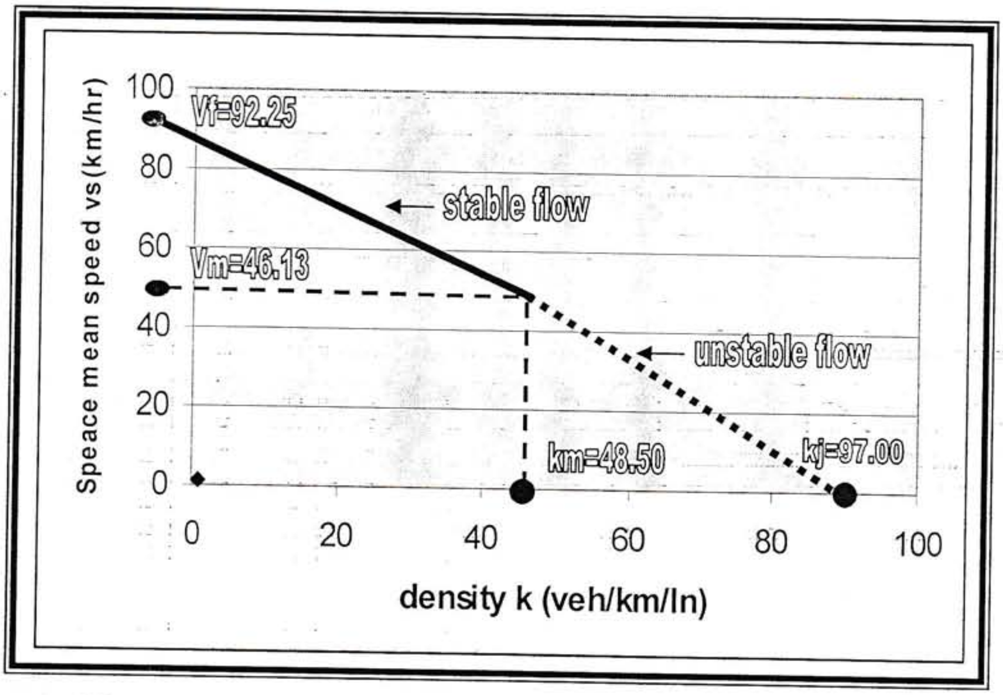


Figure (5). Calibrated speed-density models for 4-lane multilane highways (Baghdad 2004).

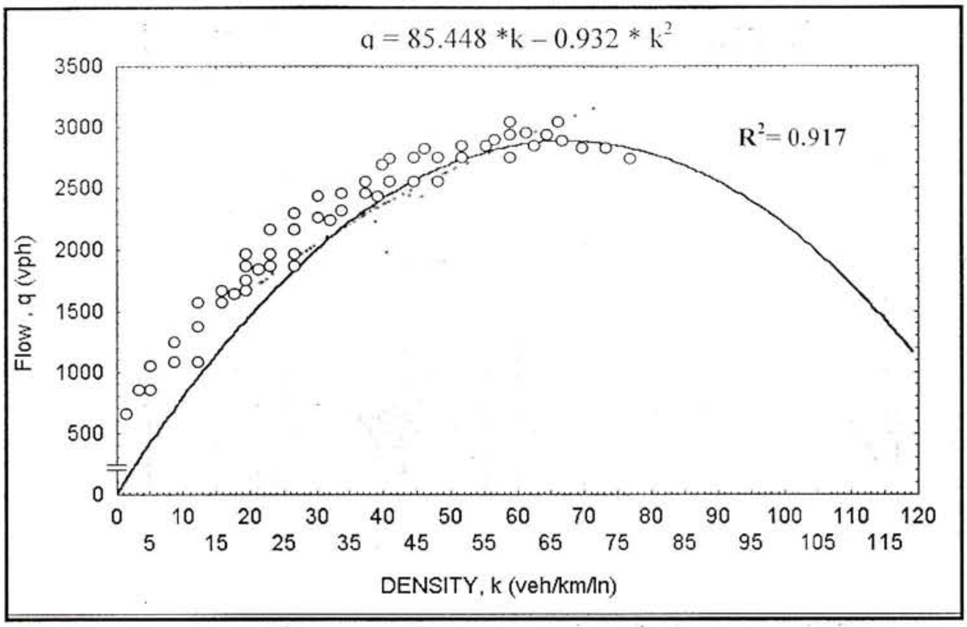


Figure (6). Flow-density model for 6-lane multilane highways (Baghdad 2004).

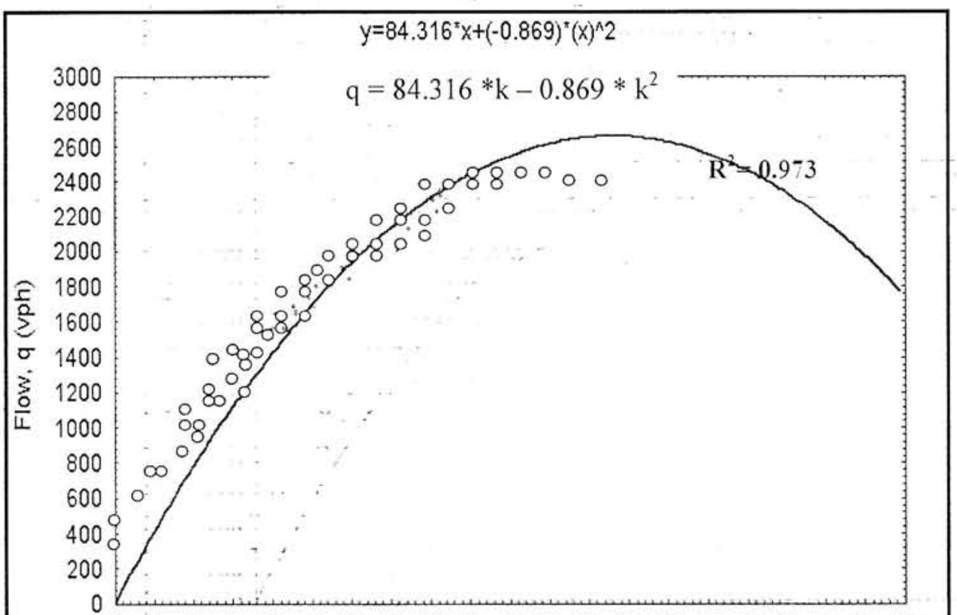


Figure (7). Flow-density model for 4-lane multilane highways (Baghdad 2004).

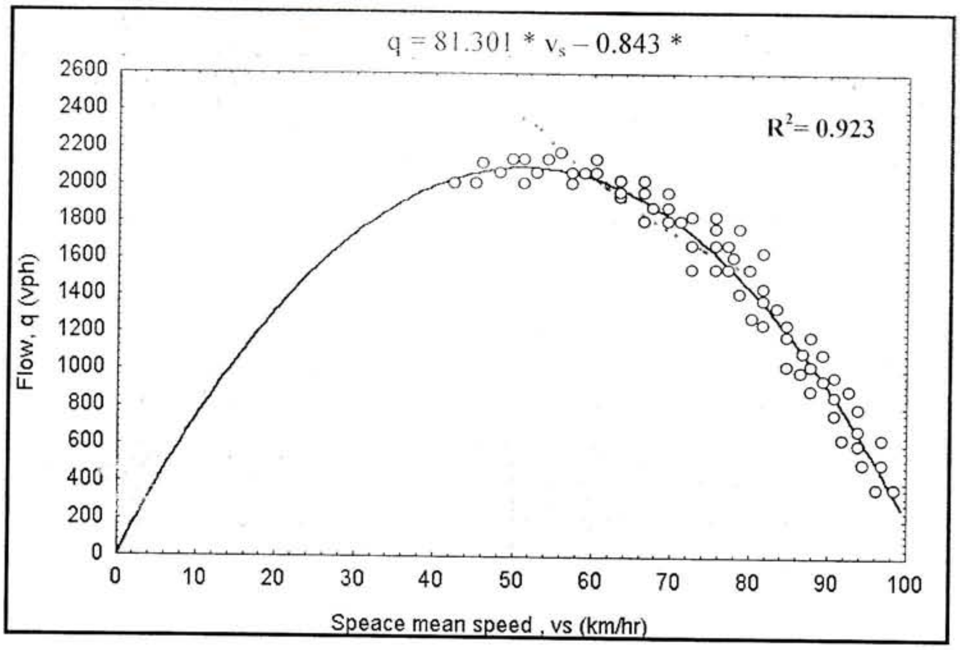


Figure (8). Flow-speed model for 6-lane multilane highways (Baghdad 2004)

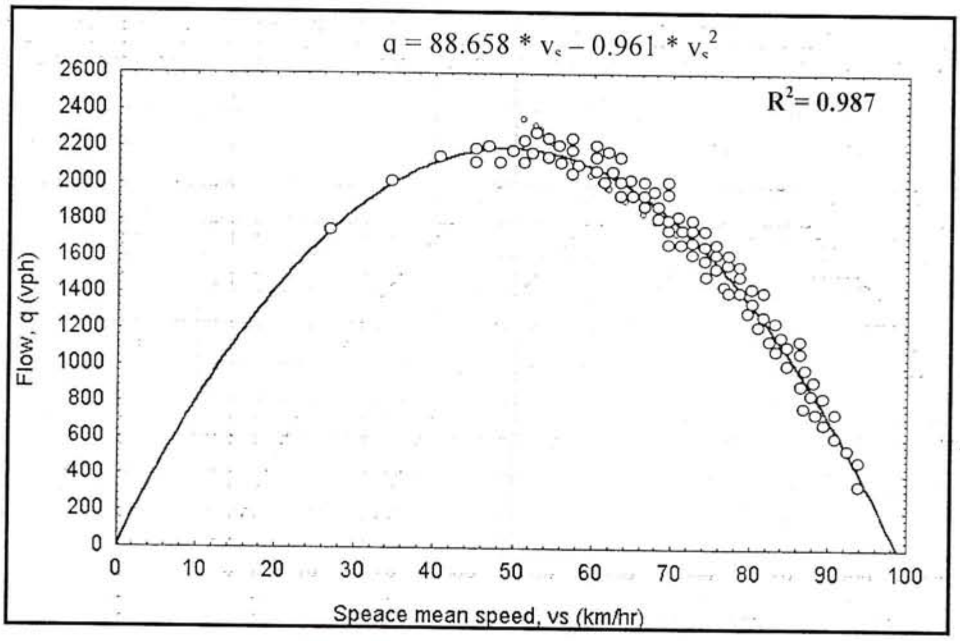
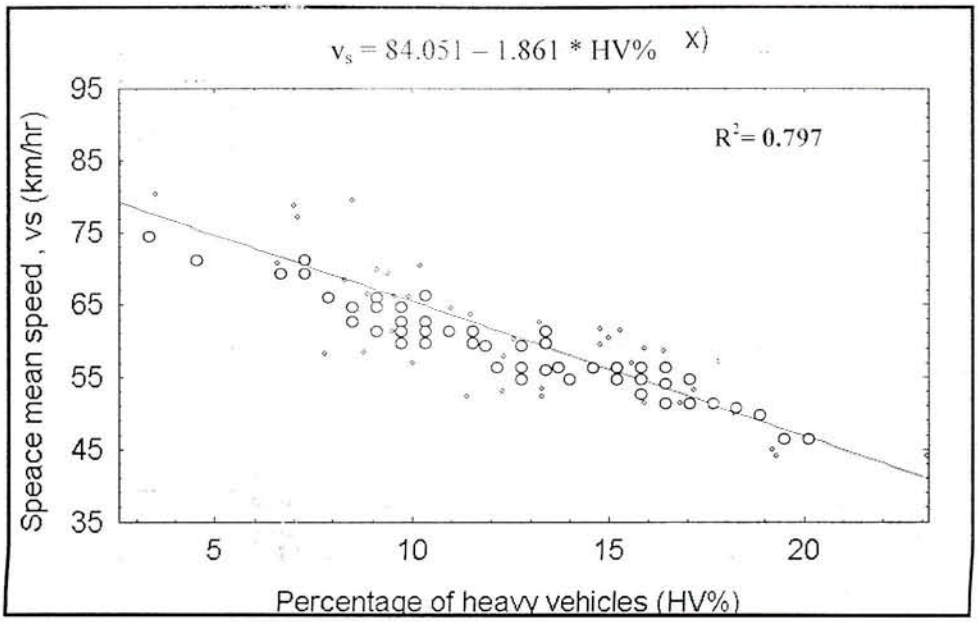


Figure (9). Flow-speed model for 4-lane multilane highways (Baghdad 2004)



Figure(10).Percentage of heavy vehicles (HV%) effect on space mean speed (vs) for 6-lane multilane highways (Baghdad 2004).

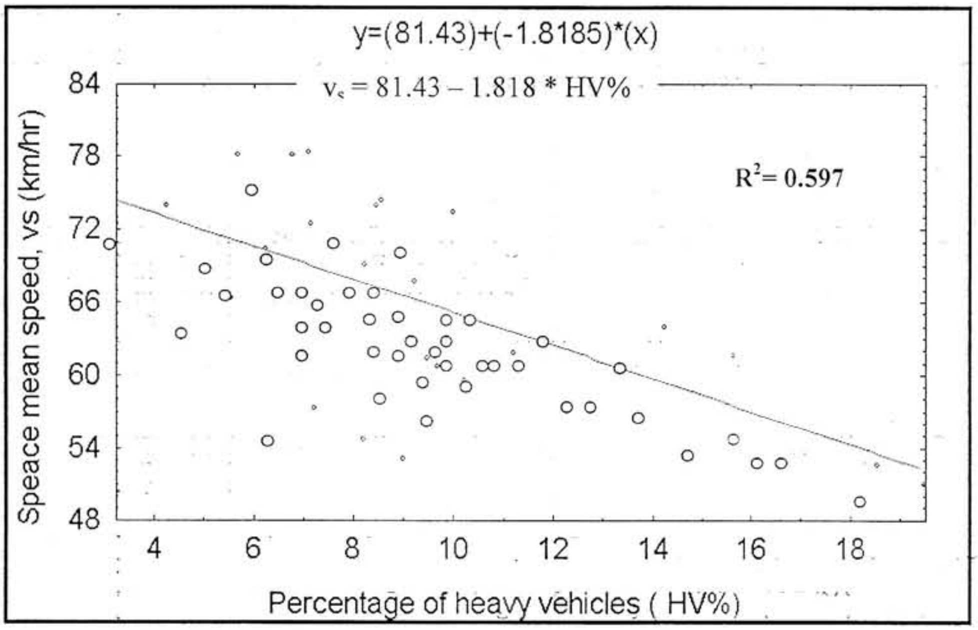


Figure (11). Percentage of heavy vehicles (HV%) effect on space mean speed (vs) for 4-lane multilane highways (Baghdad 2004)

التحليل الإحصائي لخصائص حركة المرور على الطرق متعددة الممرات في مدينة بغداد

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الخلاصة

العناصر الأساسية لحركة المرور (الحجم المروري والسرعة والكثافة المرورية) تستخدم في عدة مراحل من عمليات النقل. إن علاقة الحجم المروري والسرعة والكثافة المرورية ذات أهمية كبيرة، حيث إنها تترجم حركة المرور إلى موديلات رياضية و إحصائية والتي تستخدم بصورة واسعة في تقد يم الحلول الهندسية لمشاكل النقل.

الهدف الرئيسي من هذه الدراسة هو إيجاد العلاقة بين عناصر حركة المرور الأساسية للطرق المتعددة الممرات في مدينة بغداد.

تم جمع البيانات من خلال المسوحات الحقلية وذلك باختيار عشرون مقطع في منطقة الدراسة، حيث استخدمت طريقة التصوير في جمع البيانات المتعلقة بعناصر المرور الأساسية. تم استخدام التحليل الإحصائي للبيانات الحقلية وذلك لإيجاد أفضل علاقة تصف علاقات وتأثيرات عناصر المرور الأساسية بعضها على البعض الأخر.

من نتائج هذه الدراسة إن المعادلة الخطية هي أفضل ما تمثل علاقة السرعة والكثافة المرورية ولمستوى معنوي (99%) ،حيث اعتمدت هذه العلاقة كأساس في استنتاج علاقات عناصر المرور الأساسية الأخرى .