ESTIMATION OF MISSING LEFT TURNING MOVEMENT FOR INTERSECTIONS TRAFFIC VOLUME COUNT

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ABSTRACT

Intersection traffic volume count must be in of the accurate data, because it is a crucial in the calibration and validation of traffic demand models. It is process in a continuous manner done by the analyst, planner or designer.

Many procedures were recently produced to estimate the intersection turning movement matrix. Sometimes, these procedures of traffic volume count may have unusual, unavailable or missing values especially for the left turn movement, which is more effective in capacity analysis.

Typical four mathematical and statistical methods of estimating the missing left turn movement volume were developed for about twenty signalized intersections. The most significant one is the typical curve estimation method. It is a power curve and in a simple formula compared with several other imputation techniques. This method can be superior to substitute the other methods in estimating the intersection traffic volume matrices.

KEYWORDS

Intersection Traffic Volume, Left Turn Movement, Missing Data.

INTRODUCTION

Accurate traffic volume information is important to many applications including intersection design and validation, etc. Yet, complete or even extensive coverage of a network to collect traffic count data is impractical due to the cost involved. Such efforts are often hampered by the lack of relevant detailed information that adequately explains variations in the traffic counts [1] . Many improvements have been made in the past few years in measuring approaches volume for intersections. These techniques are well known within both the transportation planning and traffic engineering communities [2],[3].

Although counting procedures provide a flexibility to schedule counts during specific periods, many studies would nevertheless experience at least some missed counts [4]. Missed counts should be re-scheduled in a systematic manner to avoid serious bias problem [5]. Additionally, traffic counts data coverage is often limited, especially for local roads or in large urban areas due to budgetary constraints. Typically, when count data are unavailable, unusual or unexpected, estimates are made based on comparisons to similar intersection volume [6]. Such comparisons may hold large errors and also may not be significant enough to be taken into consideration. However, it is

very difficult to accurately estimate individual turn movements for intersection volume [7].

Turning movement data are often required for the planning and design of highway intersections. Computerized traffic assignments rarely provide turning movement forecasts that can be directly used for these purposes, resulting in a need for significant refinement [8]. Often the system level forecasts do not provide any turning movement data. Therefore, procedures are presented enable analyst to develop these data from various sources and for various uses.

Because the needs for traffic count data will very markedly between the urbanized areas, a single model for missing traffic count cannot realistically be recommended. The following research suggested four traffic volume models, then carefully comparing between them to raise a recommendation for suggesting the missing left turn movement for intersection traffic count.

LITERATURE REVIEW

The research began with a review of published literature related to the intersection volume count and estimation of the approach movement distribution. This review summarized current knowledge on the volume count effects of a broad range of intersection features. Literature on estimating traffic counts is limited. Most of the relevant literature is on either estimating traffic volume for freeways or extrapolation of 24-hour traffic

count data to obtain AADT [4]. Other estimates the traffic intersection matrix from travel count [8].A common problem was the lack of data for some potentially important predictors, but attempt was abandoned due to unavailability of data.

Universal Traffic Data Format UTDF was developed by Traffic-ware in an effort to spur a standard format for traffic engineering variable [9]. UTDF enables data access through open-ended or nonproprietary software programs such as spreadsheets, text editors, or database programs. UTDF simply provides a means to electronically manipulate standard traffic data; in this case it is traffic volumes. For instance, the re-entering the turning movement volumes for an intersection many times, then moving onto the next intersection as in this case's study. The system spends more time in analyzing traffic conditions, testing alternatives, developing mitigation concepts rather than entering data or estimates the missing one [10] .

Based on the literature review, it is decided that the research should focus on quantifying in the effectiveness manner to estimate of left- and/or right-turn proposed missing volume through a well-designed before-after evaluation.

CHARACTERISTICS OF THE STUDY DATA

One of the most important parts of any warrants analysis is dealing with traffic volume representation. Data can be manually entered, but the most effect problem is the way to fit the data

directly to the analysis programs. Figure (1) illustrates traffic movements for typical intersection in the case study. All approaches movement volume was counted as header information with specific details to other analysis. In Figure (1), the header indicates to these turning movement counts, they are in vehicles per hour (vph) for 60 minute counts. Each possible turn movement (NBL, NBT, NBR, etc.) is identified as a cell of matrix (4x4). The main diagonal element deal with the U-turn movement, which is negligible or very small value, can be added to the left tune movement.

For this study, the model utilizes a large sample size (20 intersections in the country) and has involved the investigation of up to three period a.m. peak, p.m. peak and off peak. These offer about (60 cases) for analysis data. The data was taken in a typical day for the year from 2000 to 2003. No matter if the data will not taken in the same day or if the rush hour is vary from intersection to another, because the pattern of missing values was random and was achieved by use of random numbers [8]. As well as, the analysis is not specifying a single condition of traffic forecasting models. The twenty intersections would selected to conform the analysis characteristics, which they have four legs (approaches) and have no specification about the turning movement. So these intersection where located in five cities. First, in Mosul city they are (Al-Suez, Al-Muthanna, Al-Senaa, Al-Maleia and Fourth Bridge) intersections. Second, in Kurkuk city they are (Al-

Shuhadaa and Al-Muntazah) intersections. In Tikrit city they are (Al-Tarbiea, Al-Tajneed, Al-Jamaa alkabeer and the Hospital) intersections. In Samarra city they are (Al-Malwiya, Bab Al-Kubla, Al-Katool , Asmaa school, Al-Malaab, Al-Atfaa and Al-Astashariya) intersections [11]. Finally, in Baghdad city (Al-Senak and 17th-July Bridge) intersections. The accuracy and completeness of the raw data are extremely important to the accuracy of the model results. Therefore, data were formatted and techniques used to aggregate data in about (240 observations) of any turn movement. Then, data were verified to the specification for the capacity and validation according to HCM2000 [12].

After that the results of the modified data are practice for the statistical descriptive with frequencies. One of the movements can be shown in Figure (2) for the left turn's movement. The histogram chart with normal distribution curve have central tendency to the mean value, which is about (159.379) with Std. Error of the mean is (7.222). The skewness value about the mean is (0.589). The distribution reveals that lack of data or data that gathered in different common period will affect the central tendency to some degree. It does serve as a warning against applications of the model outside the range of the original data.

The key to getting a good statistical estimate is to use a large sample size and reliable data. Compared with the previous

studies [7], there are two distinct features with the data gathered in the present study. First, the model may be developed in this study was based on a much larger sample size (more than 60 cases) [13] and more complete data sets. Generally speaking, a larger sample size (240 observations) would generate more reliable statistical results. Second, several methods are employed to generate the predicted values required for statistical analysis.

DEGREE OF UNCERTAINTY

The way initial correlation matrix that is computed from complete data to develop correlation equations is controversial. The use of incomplete data is considered a poor choice when data matrix has large number of missing data [10]. Other suggestion to impute missing values by their respective total means or an initial value compute correlation matrix from this completed data matrix, develop correlation equation, and then re-impute missing values using predicted scores [6].

Therefore, there is a numerous method for searching for optimal number of missing value. This is called the degree of uncertainty, which can be defined as acceptable quantity of missing information (E_s)[10] associated with the system:

$$E_s = k * log (n) ....(1)$$

Where ;- k ~ constant greater than zero ,

n ~ number of possible ways (state) that the system can exist in .

In physics E_s is called "entropy" and value of n is a logical as it includes all of the existing possibilities. For this case study at a four–leg junction there are twelve movements (excluding U-Turns), the average value of (k) where obtained from the all cases is equal to (3.316). Thus the maximum number of missing information in the matrix of $(4x^4)$ equal to (3.316 log (12) = 3.579), which can be rounded to (4).

The idea is supported by the results of a simulation study in which estimates of correlation matrix produced by complete records were found inferior to the ones produced by other methods. This will happen when data matrix had more than four missing variables [7]. Therefore it is decided to choose the left turn movement only in the volume matrix to be the missing value in each approaches of the intersection. This selection is depended to the idea that this movement has large effect to intersection capacity with less volume, compare with through movement, which rather has greatest volume.

METHODS OF ESTIMATION

Using predicted scores as estimates of missing values is one of the most frequently used techniques [13]. Four prediction methods are chosen to estimate the missing left turn volume for the intersection. They include typical curve estimation, statistical estimation, two-way interpolation and directional flow methods. By assuming that specific elements of the data matrix are

missing, prediction can be made by this method then comparison between the exact and predicted value will distinguish the best method to estimate the missing value. Although, the quality of predicted method for estimates of missing values depends on the correlation of predictors in the regression techniques and their significant with the criterion variable.

The method was first proposed based on the assumption that the values are missing at location of the left turn movement $(T_{12}, T_{23}, T_{34}, T_{41})$ as shown in Figure (1).These movements denote the missingness indicator element with the same dimensions of data matrix. Each element have initial value of zero, then iteration will modify new value till satisfy the condition of that method with degree of confidence is equal to 0.05.

After reviewing the characteristics of the data four kinds of predictors (independent variables) are included to estimate left turn volume. These methods are described below in more detail.

(a) Typical Curve Estimation Method

The method is based on a statistical model, the complexity of which is adapted to the amount of data available. The typical curve method estimates the left turn's movement volume for count observations where counts are available for only a limited data of the base year[14]. The procedure has two-step process. First, the statistical correlation to find best equation representation, which are adjusted to capacity as described above. Second, is the estimating the left turn movement

depending on the intersection volume characteristics.

Predicted scores become good estimates of missing values when correlation among variables is high. Theoretically, an increase in the number of predictors used improves the quality of the predicted score and makes it a better estimate of missing value. Use of too many predictors, however, over fits the regression equation causing it to produce poor estimate [13]. So in this method, the curve estimation of miscellaneous regression models has been trailed. By employing stepwise selection technique, a variety variables and variables transform are developed and tested with the same degree of detail. While most are statistically significant, few add enough explanatory power to be practical and useful. The three most important variables are the row sum, column sum and the total sum of intersection volume.

More details about the typical curve method can be found in Table (1) , which show the most correlated variables with various criteria. To developed of the typical curve method Figure (3) show that power relation is better representation by curve estimation equation as follows: -

Left Turn Movement Volume = (Total Intersection Volume) $^{0.643}$ . ...(2)

The application have iteration properties, so the trial will repeated to reach the steady state, as shown in Figure (4) for

typical observation. The motivation of developing statistical model lies in needs for simple statistical based methods thus could be applied to different case estimation. The high correlation between Left turn and total volume may be expected. The more collinear can be shown in Figure (5).

(b) Statistical Method

Statistical estimation of missing observation has been developed for estimating left turn for the intersection volume matrix. The use of an iterative technique is to estimate the missing data when the observation is arranged in orthogonal raw and column. The algorithm is a way to reduce the error to minimum value, when the summation of the cell dependent of the cell itself.

This can be expressed in the following equation [13]: -

$$SS_e = SS_t - SS_T - SS_b ... \qquad \text{..(3)}$$

Where: - SS_e ~ Sum of squares of error,

SS_t ~ Sum of squares between the treatments (observation) ,

SS_T ~ Sum of squares of total $= \sum(Yi - \overline{Y})^2$

SS_b ~ Sum of squares between the sectors (β).

By derive this equation in general formula with respect to the missing value, then equalize with zero to get the missing value equation as follows [13]:-

$$yij = \frac{nTi. + rT.j - T..}{(n-1)(r-1)} .. \qquad \text{.......................................(4)}$$

Where: -

yij ~ is the missing observation value,

Ti.~ Sum of raw where the missing observation lay,

T.j~ Sum of column where the missing observation lay,

T..~ Total sum of the matrix,

n ~ number of raw (*n = 4*),

r ~ number of column (*r = 4*).

This is used to fill in a missing datum. The value of a datum that is present will not be exactly equal to this theoretical expected value. In fact, the errors are the differences between them. The sum of squares of these errors plays an essential role in this estimation, but going into that in detail is not the case now. Therefore, repetition of the estimation equation till the difference between the new and old value will be in the degree of confidence 0.05. This can be shown in Figure (4) for typical observation.

The sign of the missing left turn volume is as expected positive. The negative sign does not have any significant physical meaning. So, after iteration the absolute value will be taken. The relative estimation value with the exact one were plotted against the exact one and is given in Figure (6)

(c) Two Way Interpolation Method

Mathematical interpolation has many problems related to the restriction of data range [7]. The prediction at the end points cannot be as accurate as that in the middle of the matrix. The focus is on the variation of three cell means and the extent to which it can be associated with the number of row and column.

The within-cell variances are supposed to be constant across cells. However, the response variable (approach volume) has a restricted range; this will not be true in traffic analysis [10]. The variance of the rest three-point coded as 1, 2, 3, is reasonably modeled as being related to the mean, according to second degree of difference only. This will be done in two ways (vertical and horizontal). It may be a good idea to use the row and column transformation. A relevant transformation for the case of end cell can avoid such a problem. Therefore ideal case can be deriving as shown in equation (5) and application to all missing value was applied on it after made this transformation.

Left Turn Movement Volume=3/8(Through volume in Raw+Through volume in

column) -3/16 (Right turn volume in Raw+Right turn volume in

column).   ....(5)

In this method the dependent variable (left turn movement volume) have not internally in the dependent variables . So that no iteration made for this method, the output will be a specific result as shown in Figure (4). The relative correlation between predicted and exact value for this method was plotted and is given in Figure (7).

(d) Directional Flow Method

The idea of this method came from obtains of intersection movement distribution from the origin - destination count. Each approach is considered an origin. Each departure leg is a destination as shown in Figure (1). The problem then becomes

one of estimating the distribution table given the movements on each approach [12].

The iterative procedures are different, because this method depending on the directional flow not on the non-directional one as the HCM2000 does [12]. The non-directional volume method requires considerably more judgment on the part of the analysis. While, the directional method matches as closely as possible a pre-determined estimate of turning movement value [8]. It can be applied whether or not base year turning movements are known. The method can apply a significant number of iteration until the predicted values converge.

The estimation can be made by analyzing the total input volume in the missing cell approach by the sum of the outlet volume in the same approach divided by the total intersection volume as in the following equation [12]:-

$$Tij = \frac{Ti \times Tj}{\sum T} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(6)$$

Where: -

Tij ~ is the missing observation value (Left turn volume), Ti~ Summation of input volume where the missing observation lay,

Tj ~ Summation of outlet volume where missing observation lay,

$\sum T$ ~Total summation of the matrix volume,

After prediction the missing value, new sum of row and column as well as the total sum is calculated to reenter

equation(6). Thus calculation a new value of left turn movement volume is required to balance the volume to traffic entering and leaving the intersection as shown in Figure (4). The readability of the result can exemplify by the straight line function as shown in Figure (8)

METHODS DISCUSSION AND CONCLUSIONS

The present study investigated four variations of prediction methods of estimation the missing left turn movement volume in intersection count. This is done for single predictor, two predictors, and all available left turn predictors.

There is a systematic trend establishing superiority of one method over the other across the sample data. Variations of tendency of the simple linear regression without constant (intercept) can be shown through Figure (5) to Figure (8). They are illustrating the better representation of the exact data for the prediction methods. The analysis revealed that all imputation methods studied altered the covariance structure of the original sample when missing values were imputed by their respective estimates. This correlation can be shown extremely in Table (2).

Several statistical criteria of these methods can be shown in Table (2) for estimating regression coefficients from data having missing values. The method that had the highest correlation with the variable and coefficient near to the unit value (1) would be the better method of estimation. The Typical Curve Estimation Method, whose value was to be imputed, was the first

selected as predictor. The second can be either the Statistical or Directional Flow methods. The used two best predictors in these methods depend on the sample data. The prediction method whose coefficient is found approaches to unity means that more representation of the exact value. However, large value is recommended for the safe side of analysis.

The procedure adopted here considers all reasonable regression models and compares them on the basis of several criteria. One criterion is R^2, the multiple coefficient of determination. R^2 is defined as the proportion of explained variation among the total variation in the model. However, a balance should be made between the magnitude of R^2 against the difficulty and expense of using the regression model. Another statistical test is the confidence degree between the predictors and exact value as shown in Table (3). The overall F-test is very significant, while some of t- statistic for individual variables are insignificant ($|t| > 1.96$). The significance of F test indicates that the model does have significant overall utility. At the same time, these values related to some individual t statistics are large, indicating that some of the individual independent variables in the model are not as important as others.

Because a large number of sample sizes are included, the high correlation may exist among methods. A matrix of correlation of all variables including the dependent variable is constructed. So the use of any method can be replace to another

but in vary degree of significant due to the state of the case uses. In addition, the typical curve method supplies the precision of the traffic volume estimates as a function of the sampling design, i.e. when and how long the traffic is counted. In general the uncertainty will decrease when the counting period becomes longer. Based on hourly traffic counts, the typical curve method may be used to calculate available count data. It is more precise than the traditional methods of estimate. It needs less data than the other methods to achieve the same precision.

This approach allows the analyst to estimate the missing data to achieve a specified level of precision, or conversely, to determine the level of precision associated with an established traffics count. After reviewing the characteristics of the data and variety of traffic forecasting models, the equation (2) may be chosen for estimation of missing left turn movement's volume from total intersection volume.

RECOMMENDATIONS

◅ Before using the model to estimate left turn movement volume of other intersections, the model needs to be validated by other cases to make sure that it is capable of estimating reasonably well.

◅ An auxiliary variable must be added into the design of the study when a certain variable is expected to have missing values. Failure to do so causes a bias in the standard error of estimate.

✦   Other factors that affect the quality of estimates include pattern of missing values, sample size, number of missing values in a single record, and the purpose of estimation.

✦   Various methods including geographic information systems (GIS) have been explored to convert the current digital data.

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Table (1) Various Correlation's without Constant between the Dependent Variables Exact left Turn Movement Volume and Independent Variables Intersection Movements Volume Summation of the Study Cases.

Independent Variable	Relation Type	(Adj. R^2)	F-Test	Estimated Coefficients
Total Intersection Volume	Linear	0.830	1170	0.07
Total Intersection Volume	Power	0.987	18131	0.643
Row+ Column Volume Sum	Linear	0.786	877	0.1708
Row+ Column Volume Sum	Power	0.986	17604	0.7375
Sum of Total+ Row + Column Vol.	Linear	0.822	1100	0.0499
Sum of Total +Row+ Column Vol.	Power	0.986	17342	0.6161

Table (2) Model of Simple Regression Analysis without Constant for the Independent Variable Exact Observation Left Turn Movement Volume and Dependent Variables (Methods of Estimation) of the Study Cases.

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**Table (3) Statistical Criteria for the Prediction Methods Against the
Exact Observation Value of the Study Cases.**

Predicted Method of Estimation	(Adj. R^2)	Standard Error	F-Test	Estimated Coefficients
1-Typical Curve Method	0.838	58.35	1244	0.6828
2-Statistical Method	0.647	1185.66	442	1.2956
3-Two Way Interpolation Method	0.564	164.31	312	0.9632
4-Directional Flow Method	0.654	100.12	455	0.7086

Predicted Method of Estimation	Average value	Average Deviation	Standard Error of Estimate	t -value Calculate	Adj. R^2
Observations	159.379	93.88	104.06	---	1.000
1-Typical Curve Method	132.612	48.19	20.95	3.90**	0.838
2-Statistical Method	238.770	156.85	119.44	-7.76**	0.647
3-Two Way Interpolation Method	178.866	127.05	109.64	-1.99**	0.564
4-Directional Flow Method	131.145	82.39	62.50	3.60**	0.654

** mean significance
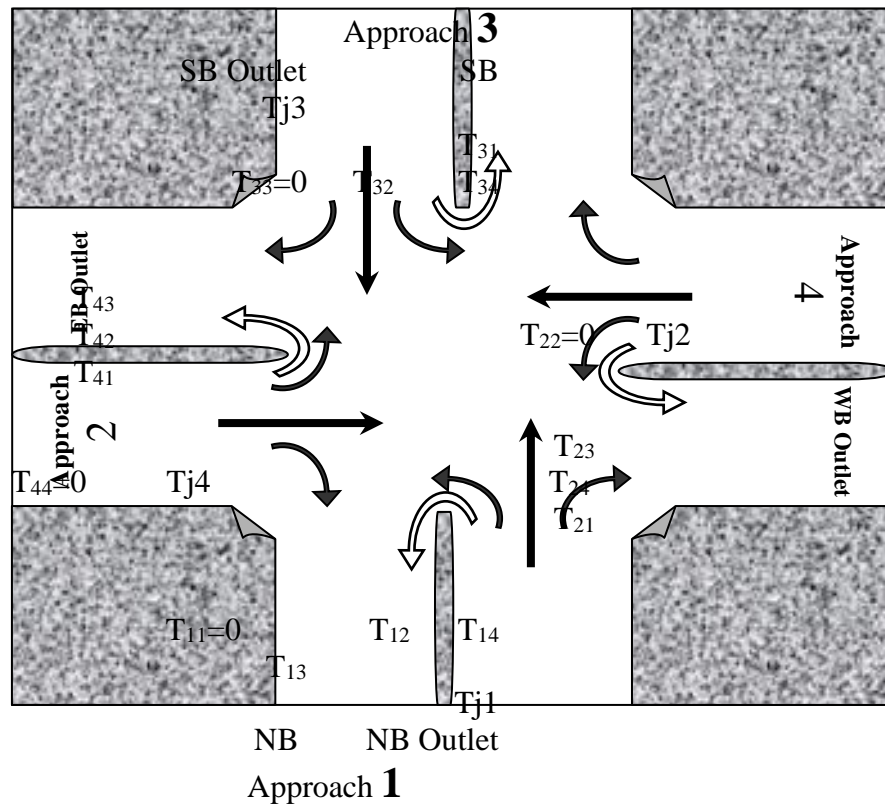
	NB Outlet	EB Outlet	SB Outlet	WB Outlet	Sum of
NB Approach 1	T_{11}	T_{12}	T_{13}	T_{14}	$T_{\cdot i=1}$
EB Approach 2	T_{21}	T_{22}	T_{23}	T_{24}	$T_{\cdot i=2}$
SB Approach 3	T_{31}	T_{32}	T_{33}	T_{34}	$T_{\cdot i=3}$
WB Approach 4	T_{41}	T_{42}	T_{43}	T_{44}	$T_{\cdot i=4}$
Sum of Column	$T_{\cdot j=1}$	$T_{\cdot j=2}$	$T_{\cdot j=3}$	$T_{\cdot j=4}$	$T_{\cdot\cdot total}$

Figure (1) Traffic Movement Matrix for Typical Intersection in the Study.
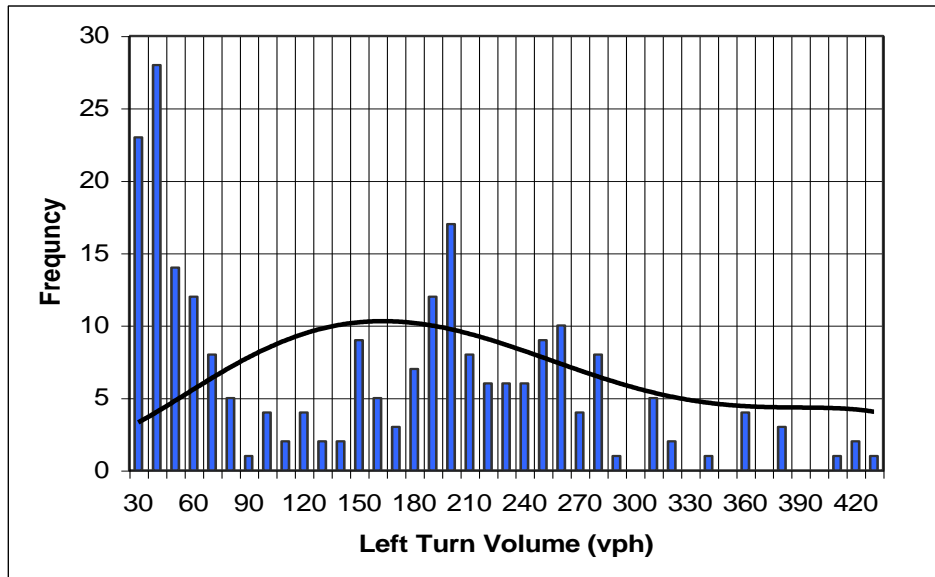
**Figure (2) Left Turn Movement Histogram With Normal
Distribution Curve**
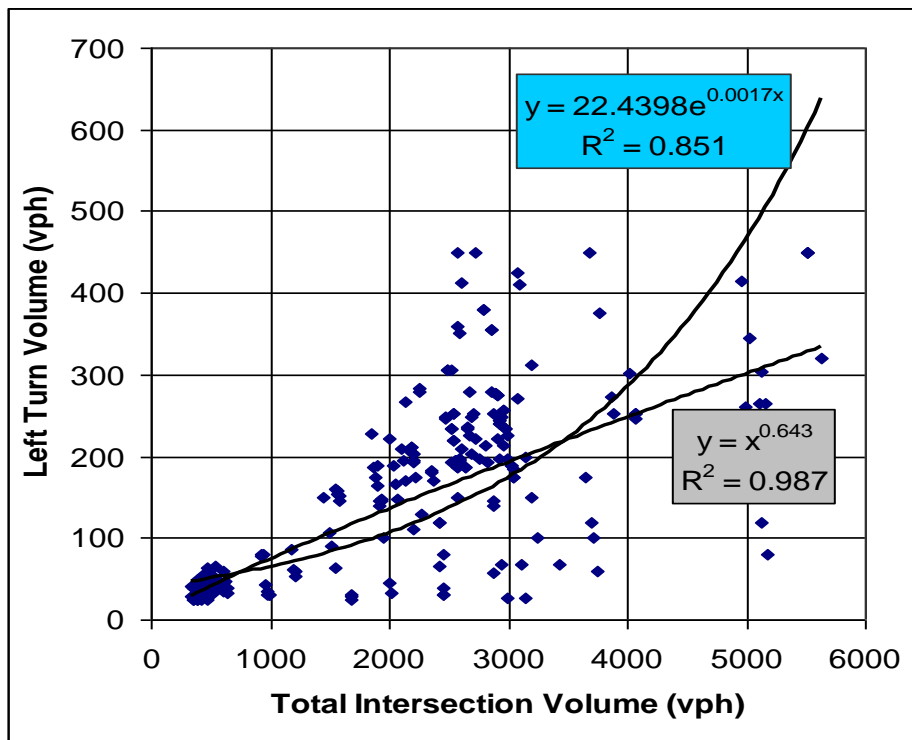
**Figure (3) Correlations between Left Turning Movement and Total
Volume for Study Data.**
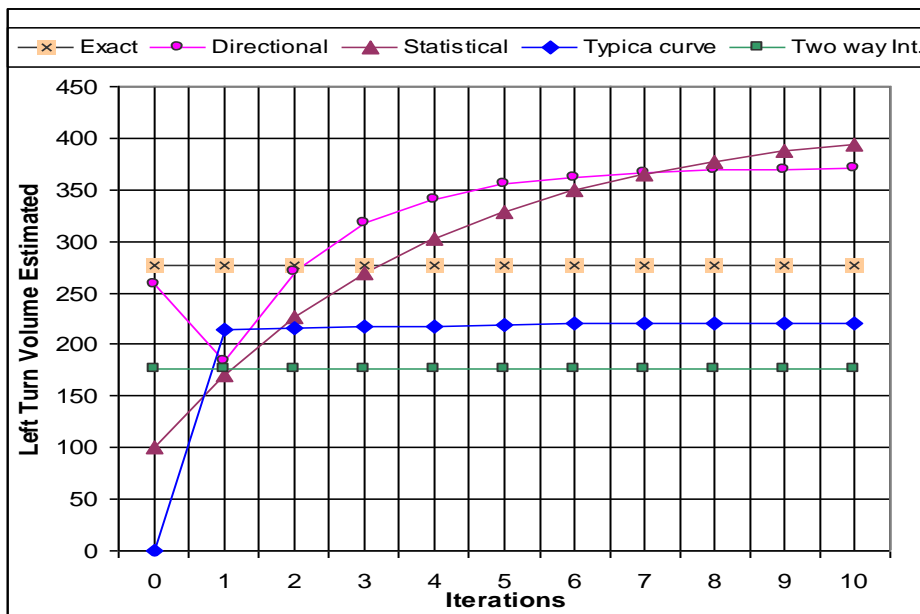
Figure (4) Estimation of Left Turning Movement Iteration for All Methods with Exact Value for One Observation.
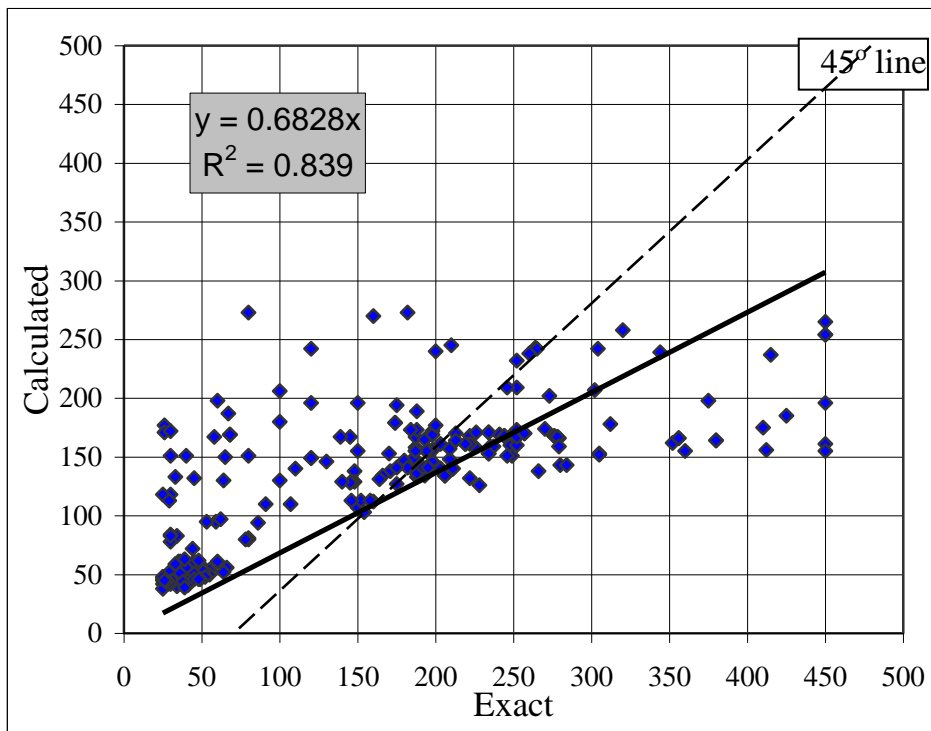

Figure (5) Typical Curve Estimation of Left Turning Movement Against Exact Value for Selected Approaches.
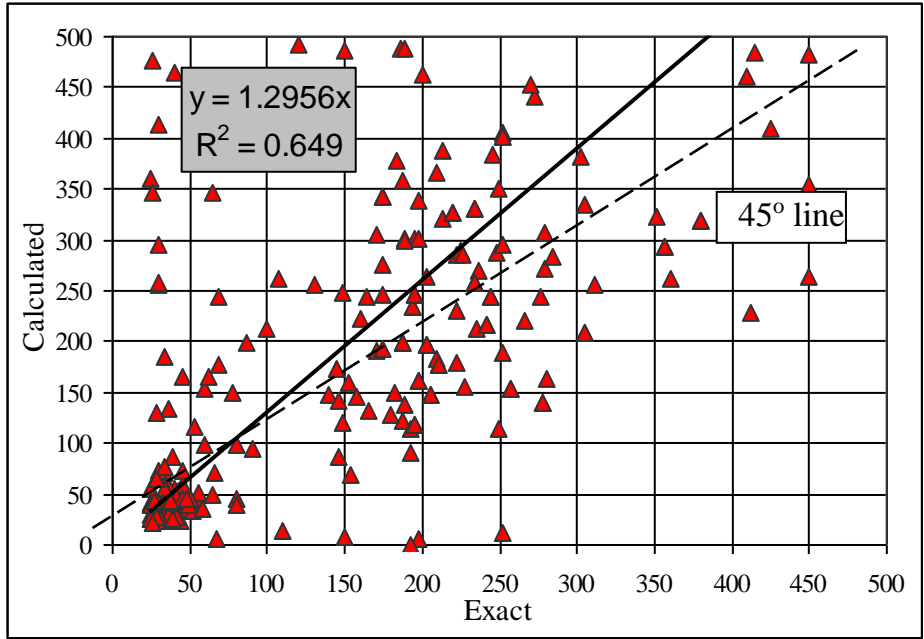
Figure (6) Statistical Estimation of Left Turning Movement Against Exact Value for Selected Approaches.
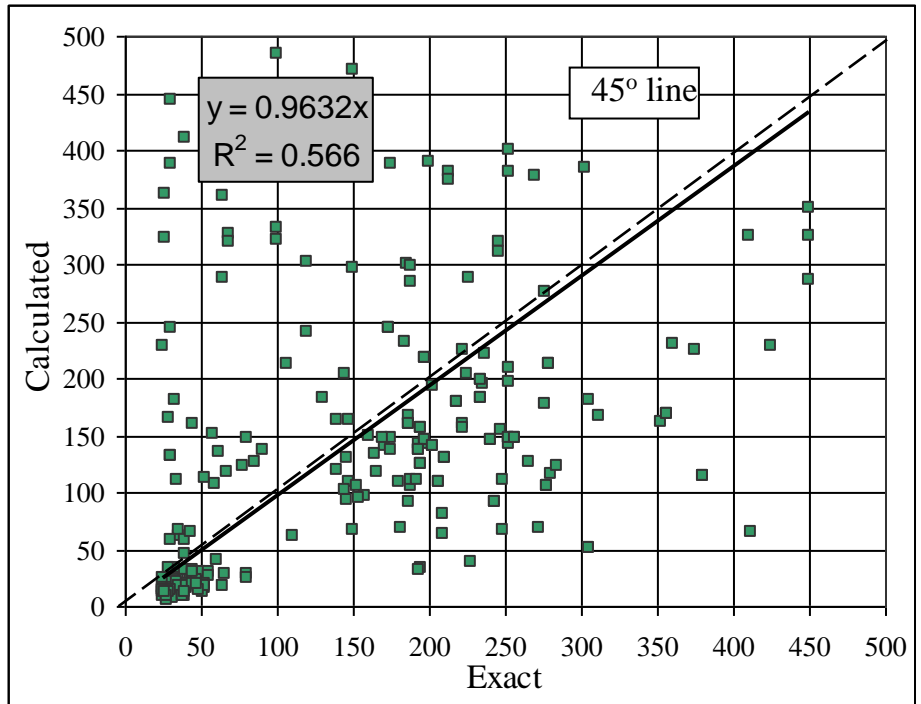

Figure (7) Two Way Interpolation of Left Turning Movement Against Exact Value For Selected Approaches.
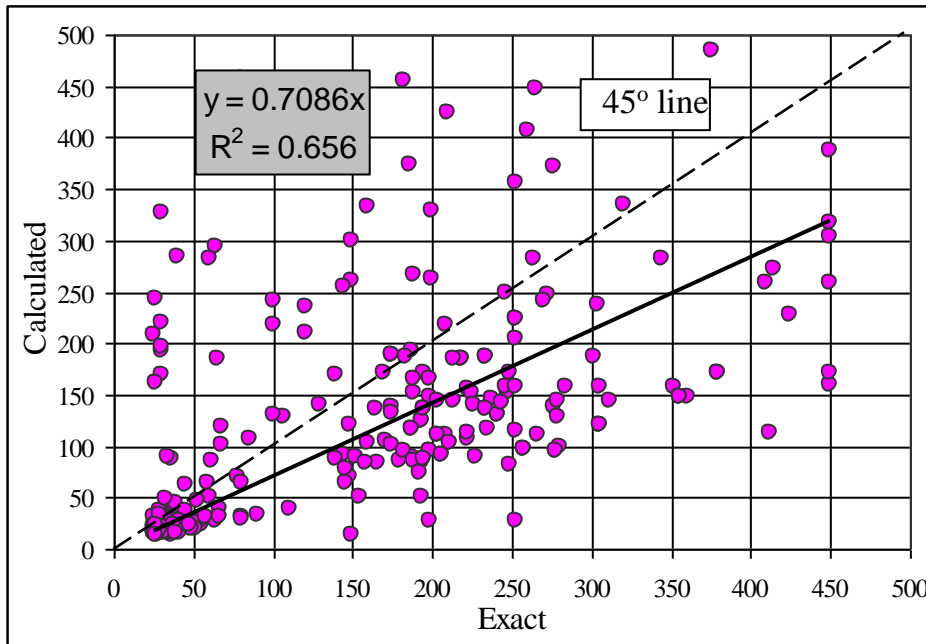
**Figure (8) Directional Flow Estimation of Left Turning Movement
Against Exact Value For Selected Approaches.**

تقدير القيمة المفقودة للحركة المنعطفة يسارا"
في حساب الحجم المروري للتقاطعات

محمد أحمد حمودي

قسم الهندسة المدنية – جامعة تكريت

الخلاصة

تعتبر عملية حساب الحجم المروري في التقاطعات من العمليات المستمرة والتي يجب أن تكون دقيقة بغية تقييم الوضع الحالي أو للتنبؤ المستقبلي أو أحيانا" لغرض أجراء التصاميم أو أجراء التحويرات. تتم العملية بعدة طرق ولكن يحدث أحيانا" أن تفقد قيمة الحجم المروري لحركة ما في أي مقترب من التقاطع، فمثلا" عدم استطاعة متابعة حساب الحجم المروري المتجه يسارا" ، أو قد يتم أحيانا" الحصول على قيم غير منطقية (شاذة). لذا تم تطبيق ومقارنة أربع طرق رياضية وإحصائية لإيجاد هذه القيمة المفقودة على حوالي عشرين نموذج من التقاطعات المسيطر عليها بالإشارات الضوئية. وجد أن أفضل طريقة لإيجاد القيم المفقودة للحجم المروري للتقاطعات هي طريقة استخدام منحني أسي مبسط, ويمكن اعتبارها من أهم الطرق المستخدمة في أيجاد مصفوفة الحجم المروري.

الكلمات الدالة

الحجم المروري للتقاطعات , المرور المتجه الى اليسار, القيم المفقودة.