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Development of an Intersection
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James D. Brogan
Major professor

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DEVELOPMENT OF AN INTERSECTION TURNING MOVEMENT PREDICTIVE MODEL

By

Bruce L. Floyd

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ABSTRACT

DEVELOPMENT OF AN
INTERSECTION TURNING MOVEMENT
PREDICTIVE MODEL

By

Bruce L. Floyd

An intersection turning movement estimation technique is developed using multi-variate regression analysis. The intersection is modeled by developing regression equations for the turning movements using the machine-counted ingress-egress volumes as independent variables. A computer program written to develop and test the model using the necessary field collected data as input is described.

Using data collected from four intersections in Michigan, the regression theory is tested by developing actual intersection models. Analysis of these models shows the possibility of utilizing the regression technique as standard practice in turning movement estimation. The thesis concludes with an overall analysis of the theory and recommendations for future study.

ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude to the numerous individuals in the Traffic and Safety Division and Computer Services Division, Michigan Department of Transportation and the College of Engineering, Michigan State University, who have aided me in completing this thesis. I would especially like to thank Dr. James Brogan, my advisor, and the other members of my committee, Dr. William Taylor and Dr. Adrian Koert for their assistance.

The views, conclusions, and recommendations contained herein are the author's and not necessarily those of the Michigan Department of Transportation. The author is solely responsible for data and analysis accuracy.

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INTRODUCTION

Highway engineers and planners often have a need to know the directional flow of traffic within a highway intersection. An American Association of State Highways and Transportation Officials (AASHTO) publication, for example, states that "The pattern of traffic movements at the intersections and volume of traffic on each approach, including pedestrians, during one or more peak periods of the day are indicative of the type of traffic control devices necessary, the widths of pavements required, including auxiliary lanes, and, where applicable, the degree of channelization needed to expedite the movement of all traffic." (1, p. 675)*

One key to understanding an intersection's flow characteristics is a knowledge of the vehicular turning movements at the intersection. Turning movements are thus a main ingredient in almost every traffic intersection study. For example, the Federal Highway Administration's network simulation model, NETSIM, (4) requires that either turning movement counts or turning percentages be given. This data is entered in "NETSIM Card 7 - Link Turning Movements", a copy of which is shown in Figure 1.

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*Numbers refer to The List of References

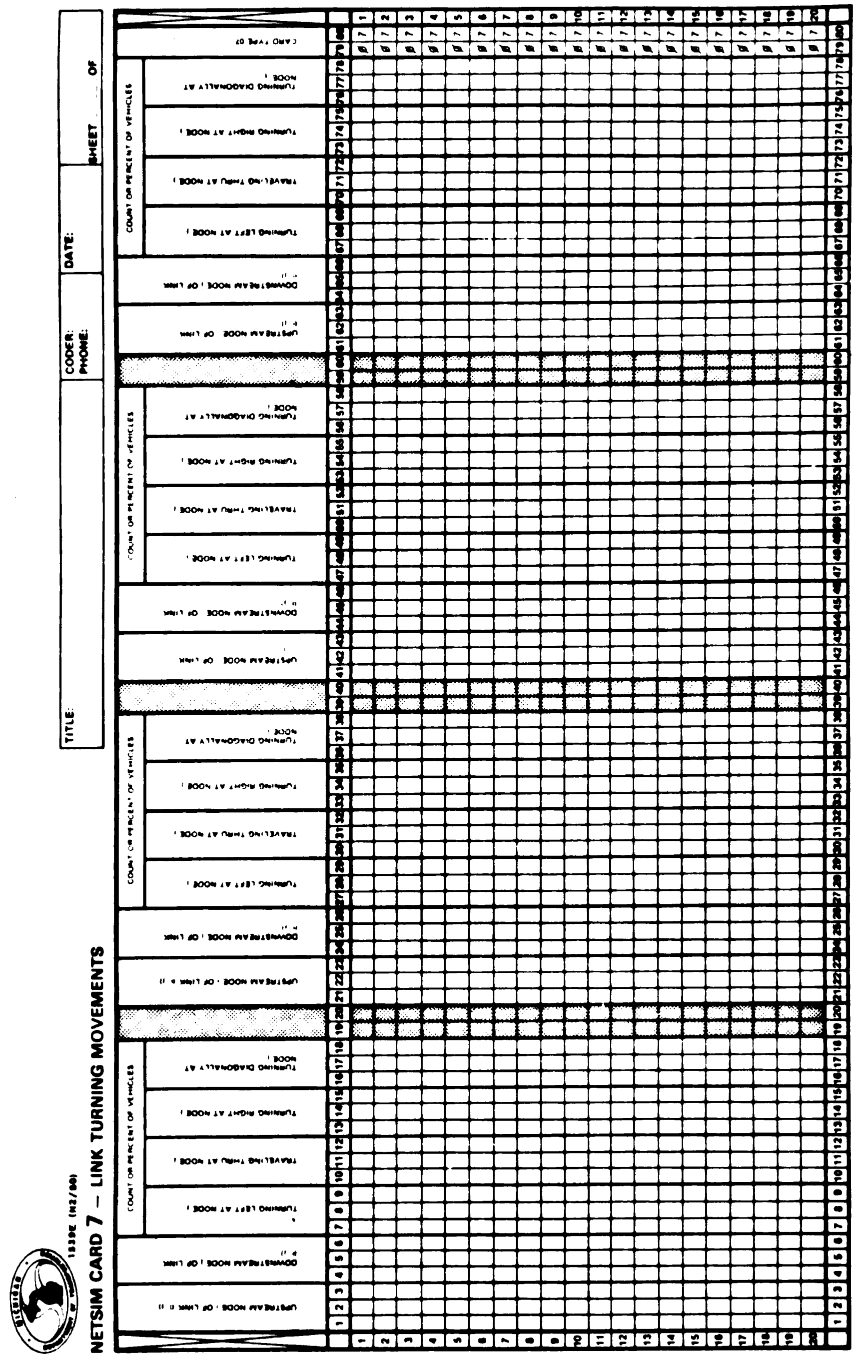
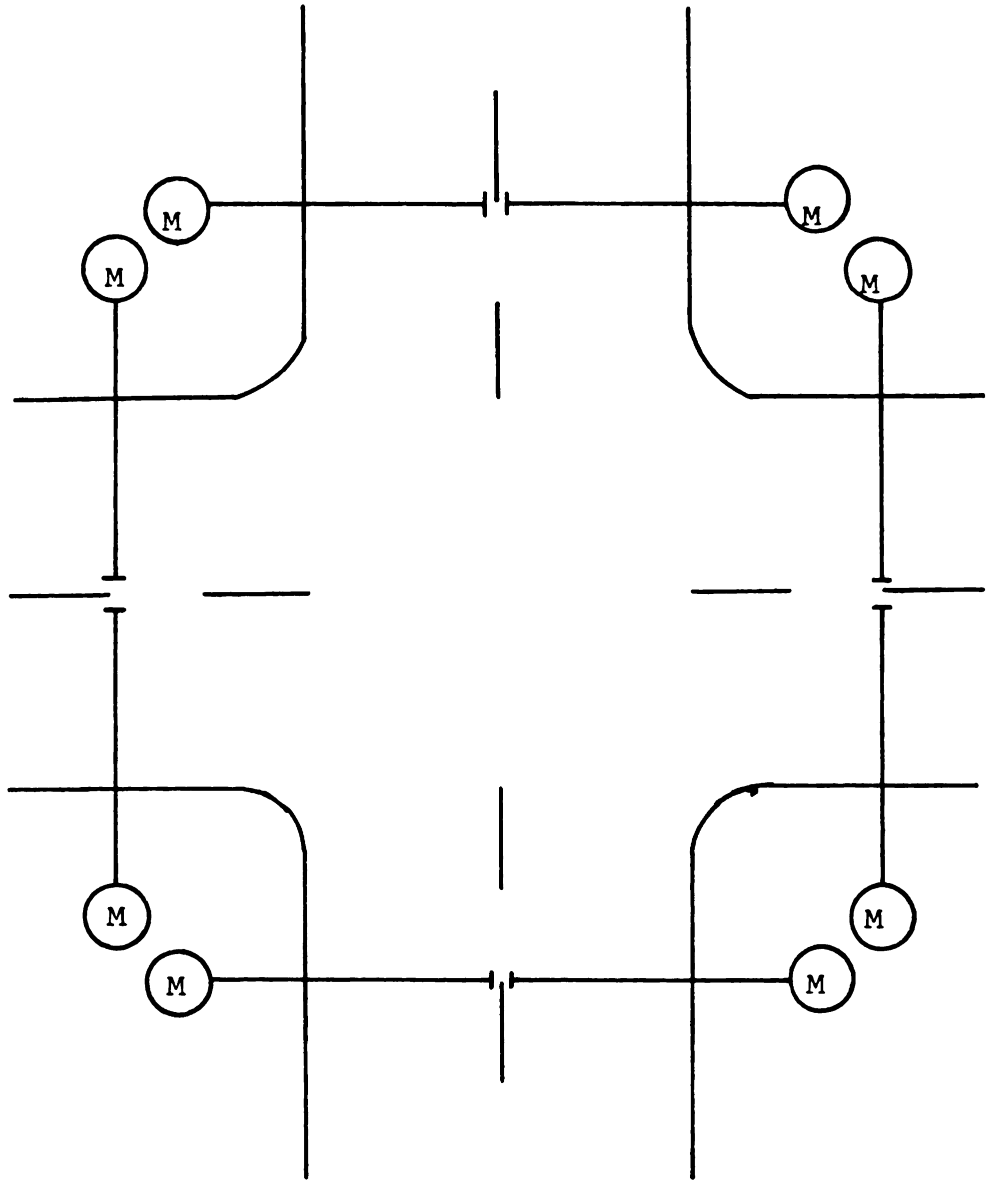


Figure 1

NETSIM - Turning Movement Input Form

The signal optimization program, TRANSYT, (9) also requires intersection turning movement data in order to estimate link flows. Highway capacity analysis, signalization studies, conflict analysis, accident analysis and signalization phasing studies all require turning movement knowledge at the intersection under study. Planners, as well as engineers, may use turning movement information in checking origin-destination studies and in network analysis. There is, therefore, a large demand for intersection turning movement information.

At the present time, relatively simple procedures are used by transportation agencies in collecting intersection turning movement data. In most cases, a crew of one or more people is dispatched to the intersection and a pneumatic tube or some other type of mechanical counter is placed at each entrance and exit of the intersection. Figure 2 shows a typical configuration. The machines then count the ingress and egress traffic of the intersection, typically for a 48 hour period with tabulations every 15 minutes. There are thus four counts per hour. At some time during the two days, usually during the AM and PM traffic peaks, crews hand count the turning movements within the intersection using a tally sheet or hand-held counter. These turning movement counts, like the machine counts, are tabulated every fifteen minutes. (The period of tabulation may vary from study to study or from agency to agency, but fifteen minutes is relatively standard.)



Machine Counter with Pneumatic Tube = (M)——|

Figure 2

Typical Machine Counter Configuration

All of the data is tabulated in an intersection turning movement report. Figure 3 shows the graphic summary of one such report. This sheet gives the intersection description and location, the final counts of the total time studied, and when the counts were taken. Subsequent pages of the report give more specific information, such as the machine counts, 15 minute tabulations, any unusual incidents that occured during the study period, and so forth.

The method just outlined is labor intensive and thus costly. Since there are many users of intersection information, transportation agencies are hard pressed to keep up with the demand for information. If all requests are to be fulfilled within a reasonable time, a large labor force is required. If a large labor force cannot be hired because of budget limitations, a backlog of requests usually results.

Because of the long wait associated with obtaining intersection turning movement data, many users estimate this data or simply do without it. If a method can be developed by which intersection turning movement information can be estimated with sufficient accuracy three major benefits will result. First, more intersections can be studied at approximately the same cost of the present method. Thus, potential users who would like to have information, but do not request it because of the time delay or cost to their unit, will now be able to do so.

VEHICLE VOLUME COUNT

GRAPHIC SUMMARY SHEET

Study #203

1763 (7/78)

DATE 7-26-78 DAY Wednesday COUNTY Delta

TWP., VILLAGE OR CITY Escanaba WEATHER Clear

INTERSECTION OF US-2, US-41, M-35(Lincoln) @ 12th Ave.N.

TIME 7A TO 9A, 11A TO 1p, 2P TO 6P

8 Hr. Total

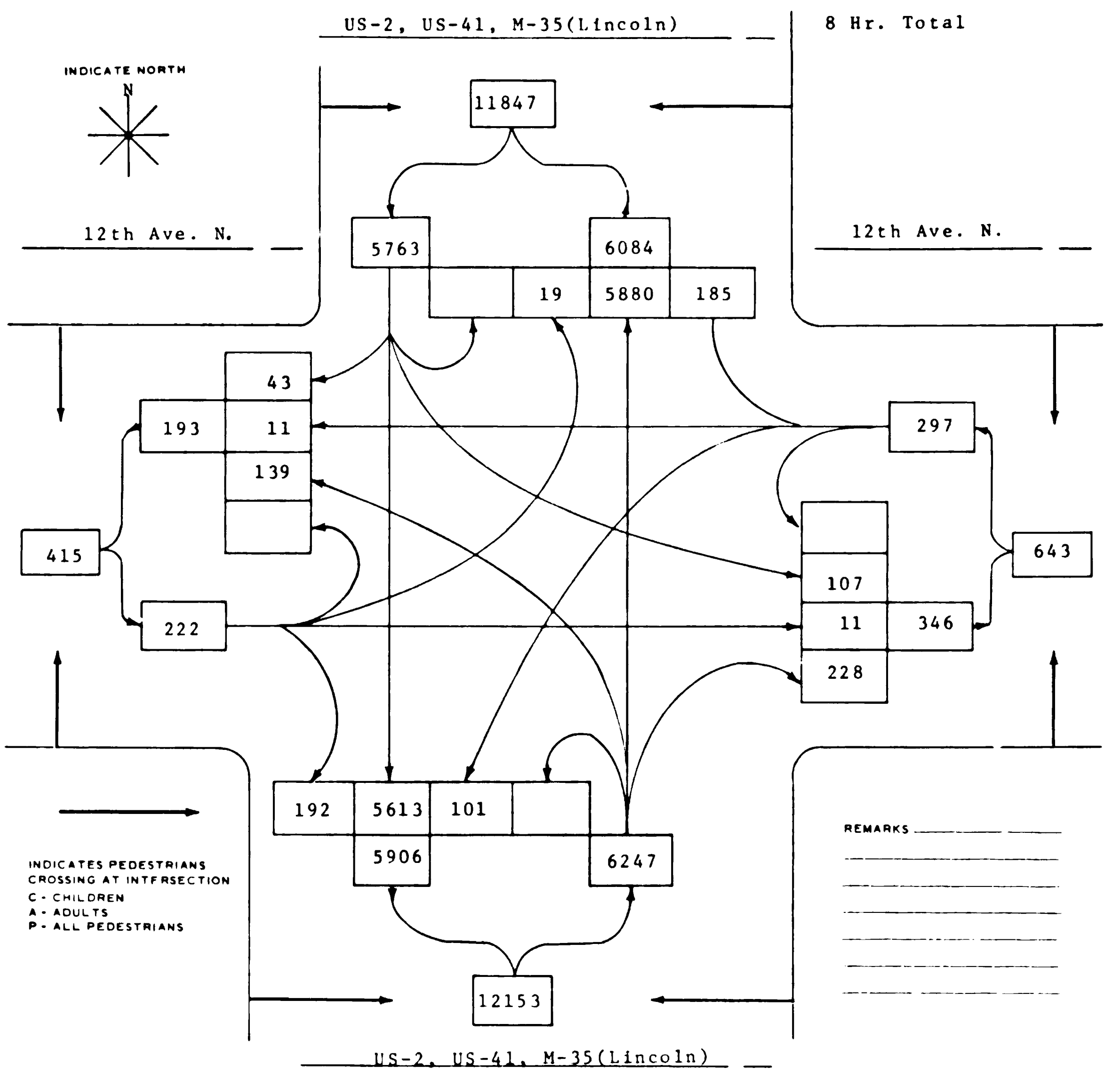


Figure 3

Typical Vehicle Count Summary Sheet

The time delay to users will be shortened because hand counts will be taken at only those intersections which require it. Second, the estimation should allow study of the intersection turning movements on a twenty-four hour basis. If a technique can be developed which does not require constant human attention, night-time operation studies, which are now generally cost prohibitive, can be made. Finally, if an estimation technique can be developed and applied to large volume intersections, little accuracy may be lost and the accident potential associated with hand-counting operations may be lessened.

Therefore, if a method can be developed by which an accurate estimation of turning movements can be made quickly from the machine counts, the need for information may be met and the aforementioned benefits realized. This thesis developed just such an estimation procedure. The estimation technique was based on statistical analysis and utilizes a large computer for rapid processing.

The procedure which the thesis developed is outlined in Figure 4, on page 16, which shows a typical four-legged intersection in which U-turns are not allowed. The notation used throughout the study is shown in Figure 4 and is as follows:

The numbers represent the major compass directions:

1 = North or Northeast,
2 = East or Southeast,
3 = South or Southwest,
4 = West or Northwest.

I = Ingress traffic, the total traffic entering the intersection from a particular direction (vehicles/time unit),

E = Egress traffic, the total traffic exiting the intersection to a particular direction (vehicles/time unit),

X_{IE} = The traffic entering from the I th direction and exiting to the E th direction (vehicles/time unit)

As can be seen, the values of the turning movements, (X_{IE}'s), are dependent on the values of the ingress and egress traffic (I's and E's). This research proposes that an estimation of any of the turning movements can be made from its relationship with the ingress and egress variables. A linear model was suggested as the first possible approach, with the dependent variables the individual turning movements and the independent variables the ingress and egress volumes. The following regression equation type was thus proposed:

$$X_{IE} = b_{0_{IE}} + b_{1_{IE}} (I_1) + b_{2_{IE}} (I_2) + b_{3_{IE}} (I_3) + b_{4_{IE}} (I_4) + b_{5_{IE}} (E_1) + b_{6_{IE}} (E_2) + b_{7_{IE}} (E_3) + b_{8_{IE}} (E_4) \quad \text{(Eq. 1-1)}$$

Where the b_{IE}'s are regression equation coefficients and the I_i's and E_j's are the ingress and egress volumes respectively. The basic objective of the thesis was to develop and test such a regression model using actual intersection data. The following procedure was used.

First, a literature search was made to determine the present theoretical "state-of-the-art" of intersection counting procedures. The present field operations for collecting intersection data have already been described. The literature review thus focuses on recent efforts relating to the estimation of turning movements from flow volumes.

Second, a theory of the intersection model development is presented. This chapter explains how the proposed intersection model(s) were developed and tested and what results were expected. Analysis of expected error is also discussed in this chapter.

Third, in order to test the regression model, actual intersection data was used from previous traffic studies conducted by the Michigan Department of Transportation. The descriptions of these locations is given in the chapter on case studies. Both four-legged and three-legged intersections were studied.

Finally, conclusions and recommendations are presented. This chapter discusses how well the model(s) worked, what degree of error was present, and where future study should be directed.

Chapter Two

LITERATURE REVIEW

A literature search produced little previous research on the subject of turning movement estimation from known ingress and egress movements. Most articles and publications reviewed assumed that turning movements at intersections were hand-counted. For example, according to the Institute of Transportation Engineer's "Transportation and Traffic Handbook": "Intersection counts are usually conducted manually. Low-volume intersections may be counted by one person, but heavier volumes are usually counted by a team of two or more observers." (2, p. 408).

Recent articles in "Traffic Engineering & Control", however, discuss turning movement estimation. After a brief explanation of terms, a review of these articles will follow.

In this thesis and in the recent articles, the following definitions and constraints (using the notation of Figure 4, page 16) apply:

1) The only intersections considered for study are those in which storage, the retention of vehicles within the intersection, is not allowed. Thus, the sum of the ingress counts equals the sum of the egress counts:

$$\sum_{i=1}^{4} Ii = \sum_{j=1}^{4} Ej \qquad \text{(Eq. 2-1)}$$

If this is not the case for any collected data, the source of error must be identified, and the data "corrected" to satisfy this constraint.

2) The only intersections considered for study are those in which U-turns are not allowed. Therefore, equation (2-2) holds.

$$X_{11} = X_{22} = X_{33} = X_{44} = 0 \qquad \text{(Eq. 2-2)}$$

3) A solution is a set of numeric values which are assigned by some method to the turning movement variables, X_{12}, X_{13}, X_{14}, and so forth.

4) A solution is defined as feasible if the values of X's are non-negative and meet the following constraints:

$$I_1 = X_{12} + X_{13} + X_{14} \qquad \text{(Eq. 2-3)}$$
$$I_2 = X_{21} + X_{23} + X_{24} \qquad \text{(Eq. 2-4)}$$
$$I_3 = X_{31} + X_{32} + X_{34} \qquad \text{(Eq. 2-5)}$$
$$I_4 = X_{41} + X_{42} + X_{43} \qquad \text{(Eq. 2-6)}$$
$$E_1 = X_{21} + X_{31} + X_{41} \qquad \text{(Eq. 2-7)}$$
$$E_2 = X_{12} + X_{32} + X_{42} \qquad \text{(Eq. 2-8)}$$
$$E_3 = X_{13} + X_{23} + X_{43} \qquad \text{(Eq. 2-7)}$$
$$E_4 = X_{14} + X_{24} + X_{34} \qquad \text{(Eq. 2-8)}$$
$$I_1 + I_2 + I_3 + I_4 = E_1 + E_2 + E_3 + E_4 \qquad \text{(Eq. 2-9)}$$

5) A symmetrical intersection flow is defined as one in which the ingress volume of any direction equals the egress volume to the same direction. Thus, $I_1 = E_1$, $I_2 = E_2$, $I_3 = E_3$, and $I_4 = E_4$.

6) A symmetrical intersection turning flow is defined as one in which $X_{ij} = X_{ji}$ for all i's and j's. Thus, $X_{12} = X_{21}$, $X_{13} = X_{31}$, and so forth.

The particular problem, as will be discussed in detail in Chapter 3, to which other recent research and this thesis address themselves is that when only ingress and egress volumes (link flows) are known, there is no unique feasible solution. There is, instead, a finite set of feasible solutions. The goal of finding a technique to determine the most appropriate feasible solution is common to the other recent studies and this thesis.

Martyn Jeffreys and Michael Norman, British transportation consultants, have shown that using linear programming and matrix algebra, the finite set of solutions can be defined. (7) They also contend that as an intersection reaches saturation flow, the intersection flow matrix approaches symmetry. Given symmetrical flow, they develop techniques for finding a unique solution.

M.L. Marshall, a British planner in Dorset County, has shown that it is not necessary to count all turning movement flows, (X_{IE}'s), in order to determine a unique solution. (8) He also explains that if probabilities are assigned to the correct number of turning movements, an estimated solution can be reached without any observers. These probabilities are to be assigned assuming an "a priori" knowledge of the intersection's behavior.

Ali Mekky, a lecturer at Alfateh University in Tripoli, has developed an iterative technique for updating an intersection flow matrix from a base year knowledge. (10) This technique involves using a Lagrangian equation which minimizes the distance between the base year turning movement matrix and the unknown turning movement matrix. The equation is solved iteratively using either the Furness method or the biproportionate method. H. VanZuylen has developed a similar technique using "a priori" probabilities of turning. (13) Again a Lagrangian equation is solved using an iterative process.

Finally, Norman, Hoffmann, and Harding describe three techniques that can be used to determine a unique feasible solution. (14) These techniques are non-iterative and are based on using "a priori" knowledge to change a non-constrained flow matrix to a constrained flow matrix. These techniques are compared to an iterative technique, the Entropy-Maximization solution.

Although the goal of both previous research and this thesis is the same, the scope is quite different in nature. Whereas previous studies were attempting to solve the turning movement estimation problem primarily in order to update flow networks to be used in transportation planning, in this thesis the estimation technique was developed to fulfill a traffic operations need for turning movement information, such as for the NETSIM and TRANSYT computer programs mentioned earlier. Therefore, this thesis developed a technique that is much more specific in nature than previous research and therefore leads to several differences in the direction of future studies.

Since most of the authors of previous studies are planners, their research reflects transportation planning needs. They are searching primarily for a reliable but inexpensive procedure to update traffic network flows so that they can be used for planning purposes. This goal has led them to develop iteration techniques similar to the "gravity" model to determine a solution. The time base is generally one year. Errors due to counting or to minor changes in traffic operations are not studied since they are assumed not to be significant.

The research in this thesis, because its scope is directed towards intersection operation, differs from previous research in the following ways:

1) Tabulations were taken at shorter intervals, in order to describe variations in intersection behavior more accurately.

2) Because of the shorter tabulation period, machine count error and operations error must be described and compensated for.

3) The intersection model should be able to detect changes in intersection flow using only machine counts.

4) Collection of several tabulations will provide a data base for a linear regression technique, rather than using an iterative technique such as the gravity model which uses one set of data.

5) Last, and most important, the linear regression technique should become a basis for developing "standard" estimation models. Data from intersections never before studied would be input into these models and the "best fitting" turning movement estimations used.

In the next chapter, the theory of the linear regression technique is fully described with a sample problem. References to previous research will be made where appropriate.

Chapter Three

BASIC THEORY OF THE MODEL

In this chapter the basic theory of building a linear regression model of intersection flow is discussed. First, the basic problem of turning movement estimation is analytically stated. Second, the problem of counting error is discussed and treated. Third, a step-by-step explanation of the model building technique is given for a four-legged intersection. Then, the theory of a third-legged intersection as a special case is presented. Finally, test data is used to build an actual intersection turning movement model.

PROBLEM STATEMENT

The basic notation and assumptions presented in the first two chapters are the basis for the problem statement. The notation shown in Figure 4 is used. The basic intersection equations, as given in Chapter Two are:

$$I_1 = X_{12} + X_{13} + X_{14} \qquad \text{(Eq. 3-1)}$$
$$I_2 = X_{21} + X_{23} + X_{24} \qquad \text{(Eq. 3-2)}$$
$$I_3 = X_{31} + X_{32} + X_{34} \qquad \text{(Eq. 3-3)}$$
$$I_4 = X_{41} + X_{42} + X_{43} \qquad \text{(Eq. 3-4)}$$
$$E_1 = X_{21} + X_{31} + X_{41} \qquad \text{(Eq. 3-5)}$$
$$E_2 = X_{12} + X_{32} + X_{42} \qquad \text{(Eq. 3-6)}$$
$$E_3 = X_{13} + X_{23} + X_{43} \qquad \text{(Eq. 3-7)}$$
$$E_4 = X_{14} + X_{24} + X_{34} \qquad \text{(Eq. 3-8)}$$
$$I_1 + I_2 + I_3 + I_4 = E_1 + E_2 + E_3 + E_4 \qquad \text{(Eq. 3-9)}$$

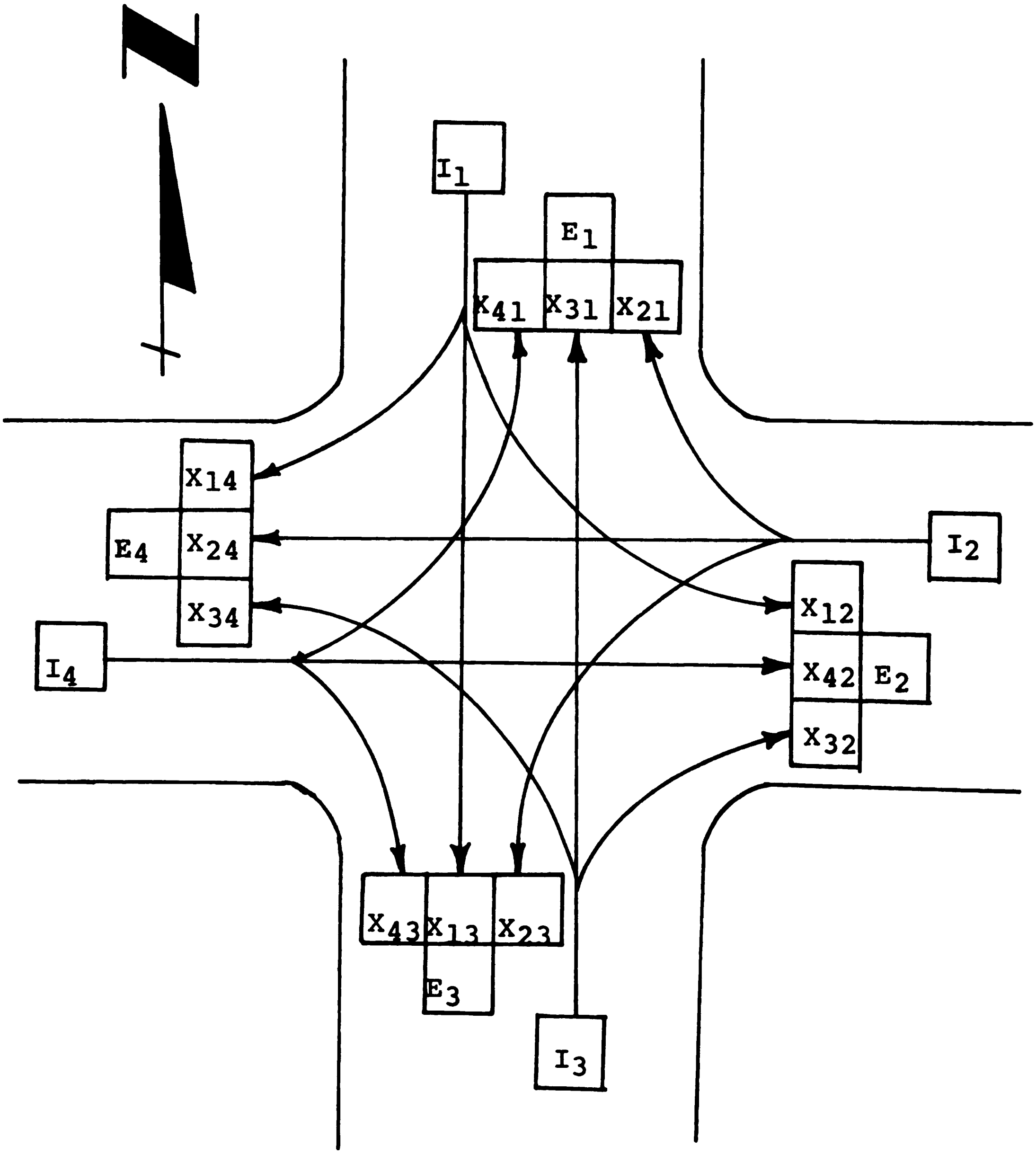


Figure 4

Intersection Flow Notation

The degrees of freedom equals the number of unknowns, (Xij, the turning movements), minus the number of independent equations, (Equations 3-1 through 3-8), plus the number of redundancies, (Equation 3-9). For the four-legged intersection, there are 12 unknowns, 8 independent equations and 1 redundancy. Therefore, there are 5 degrees of freedom for the model's system equations; that is, the system is indeterminate by five unknown variables.

The matrix form of the independent equations is:

$$\begin{bmatrix} X_{12} & X_{13} & X_{14} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & X_{21} & X_{23} & X_{24} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & X_{31} & X_{32} & X_{34} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & X_{41} & X_{42} & X_{43} \\ 0 & 0 & 0 & X_{21} & 0 & 0 & X_{31} & 0 & 0 & X_{41} & 0 & 0 \\ X_{12} & 0 & 0 & 0 & 0 & 0 & 0 & X_{32} & 0 & 0 & X_{42} & 0 \\ 0 & X_{13} & 0 & 0 & X_{23} & 0 & 0 & 0 & 0 & 0 & 0 & X_{43} \\ 0 & 0 & X_{14} & 0 & 0 & X_{24} & 0 & 0 & X_{34} & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ E_1 \\ E_2 \\ E_3 \\ E_4 \end{bmatrix}$$

(Eq. 3-10)

As shown, even if the ingress and egress volumes are known, it is impossible to obtain a unique solution. However, if five non-redundant turning movements are known, the equation has a unique solution. This was alluded to by Marshall. (8) Labor can thus be reduced if only the necessary number of movements are hand-counted.

The number of possible solutions to the matrix equation is finite, since Xij can vary only between 0 and Ii or Ej, whichever is less. Thus, using knowledge of the previous performance of the intersection, or of a similar type intersection, it should be possible to estimate the most probable solution to the turning movement matrix. As was stated in Chapter 1, this thesis suggests that a linear regression approach for estimating turning movements is an appropriate one. The proposed linear regression equation is:

$$Xij = b_0 + b_1\ (I_1) + b_2\ (I_2) + b_3\ (I_3) + b_4\ (I_4) + b_5\ (E_1) + b_6\ (E_2) + b_7\ (E_3) + b_8\ (E_4) \qquad \text{(Eq. 3-11)}$$

Where: $b_0, b_1, b_2, \ldots, b_8$ are the regression coefficients developed by a step-wise linear regression subroutine, Xij is the unknown turning movement count from direction i to direction j, Ii is the ingress count from direction i, and Ej is the egress count to direction j during time T.

Turning movement estimation will be made for the individual fifteen minute time periods and for the overall time period studied. These estimations have two distinct purposes. The estimation of the individual time periods will reflect the degree of variance or non-linearity in the model. The overall estimation, however, can be useful, even if the linear regression equations do not accurately estimate the individual time period turning movements. Therefore, there are two types of model verification tests. First, there are chi-square tests which test the goodness-of-fit of the model. Then, there are tests of the performance of the model in estimating the overall turning movements. The estimation of the overall turning movement percentages is the most important output of the model since the NETSIM and TRANSYT computer programs do not allow variance in the turning movement percentage input. In other words, a single value for each turning movement is required for these programs. If the intersection operates differently during other time periods, more NETSIM or TRANSYT computer runs have to be made.

COUNTING ERROR

Errors in machine counts from which ingress and egress volumes are obtained may result from several causes:

1) Improper placement of the tube on the pavement,

2) Inherent machine error,

3) Multiaxle vehicles, since machine counts assume 2 axles per vehicle, and

4) Driver behavior, such as deliberate attempts to avoid the counter.

A thorough investigation of machine count error would be a time-consuming study in itself. Therefore, the following assumptions are made in this study:

1) Errors due to improper placement are so large that they are easily detected,

2) Inherent machine error is negligible,

3) The majority of machine error is due to multiaxle vehicles and driver behavior, and

4) Machine count error within an intersection does not change significantly over time.

The major constraint on the model is thus the assumption that the machine count error does not significantly change over time. If this is not true, the model may not be able to detect the change and therefore will give results with large unknown errors. This hypothesis will be tested in the thesis.

DATA COLLECTION PROCEDURES

First, base data is collected at a subject intersection. This data includes manual counts of the turning movements and of the ingress-egress movements for "n" time periods of 15 minutes. The data also includes machine counts of the ingress-egress movements for the same studied time periods. The hand counts, which are assumed in this study to be error-free, were inserted in Matrix (A) shown in Figure 5. In this figure, the rows are time periods for which the counts are tabulated and the columns are the specific ingress-egress volumes, using the notation of Figure 4. The machine counts are inserted into another matrix, Matrix (B) with the same format.

To construct a turning movement model, the turning movements must be hand-counted. The counts are tabulated in Matrix (T) as shown in Figure 6. The rows, again, are the time periods and the columns are the individual counts.

Time	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
5	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
n	a_{n1}	a_{n2}	a_{n3}	a_{n4}	a_{n5}	a_{n6}	a_{n7}	a_{n8}

Figure 5

INGRESS-EGRESS COUNTS - MATRIX FORMAT

Time	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
1	$T_{1,1}$	$T_{1,2}$	$T_{1,3}$	$T_{1,4}$	$T_{1,5}$	$T_{1,6}$	$T_{1,7}$	$T_{1,8}$	$T_{1,9}$	$T_{1,10}$	$T_{1,11}$	$T_{1,12}$
2	$T_{2,1}$	$T_{2,2}$	$T_{2,3}$	$T_{2,4}$	$T_{2,5}$	$T_{2,6}$	$T_{2,7}$	$T_{2,8}$	$T_{2,9}$	$T_{2,10}$	$T_{2,11}$	$T_{2,12}$
3	$T_{3,1}$	$T_{3,2}$	$T_{3,3}$	$T_{3,4}$	$T_{3,5}$	$T_{3,6}$	$T_{3,7}$	$T_{3,8}$	$T_{3,9}$	$T_{3,10}$	$T_{3,11}$	$T_{3,12}$
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
n	$T_{n,1}$	$T_{n,2}$	$T_{n,3}$	$T_{n,4}$	$T_{n,5}$	$T_{n,6}$	$T_{n,7}$	$T_{n,8}$	$T_{n,9}$	$T_{n,10}$	$T_{n,11}$	$T_{n,12}$

Figure 6

TURNING MOVEMENT COUNTS - MATRIX FORMAT

MODEL BUILDING THEORY AND APPLICATION

To develop the linear regression model, this thesis will use the theory outlined in Figure 7. There are basically five main blocks: data collection, error measurement and adjustment, regression analysis, model verification, and model acceptance. Data collection has already been explained in Chapter 1 and in this chapter. The data tabulations, Matrices (A), (B), and (T) are the basis for building an intersection turning movement model.

Comparing the hand-counted ingress-egress volumes, Matrix (A), to the machine counts in Matrix (B), the mean percentage error and standard deviation for each movement is calculated as follows:

$$\overline{\%e_{I_i}} = \frac{\sum_{t=1}^{n} \frac{I_i(t)_m - I_i(t)}{I_i(t)} \times 100}{n}$$

(Eq. 3-12)

$$S_{\overline{\%e_{I_i}}} = \sqrt{\frac{\sum_{t=1}^{n} \frac{I_i(t)_m - I_i(t)}{I_i(t)} \times 100 - n\left(\overline{\%e_{I_i}}\right)^{2}}{n-1}}$$

(Eq. 3-13)

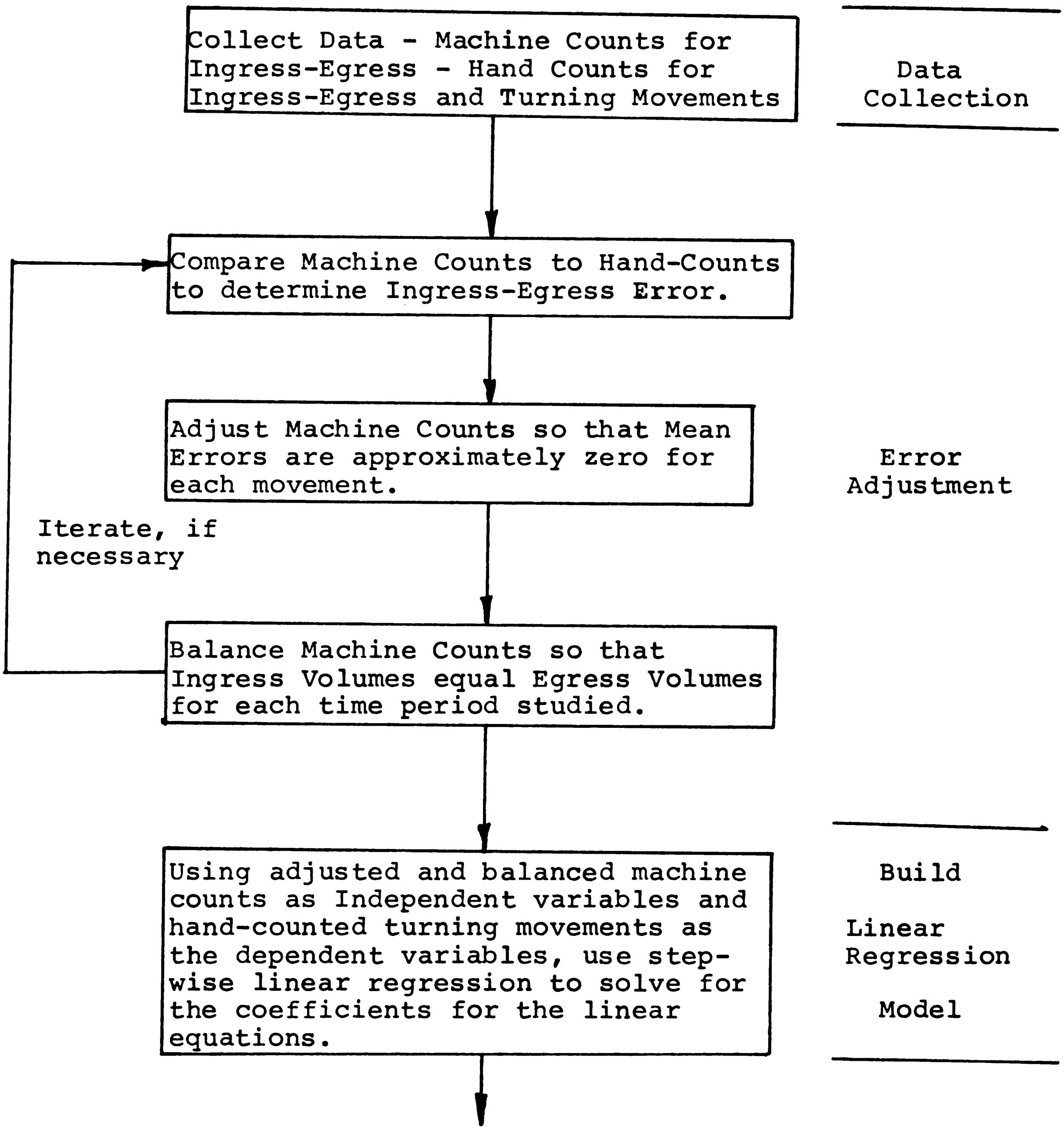


Figure 7

Linear Regression Model Theory

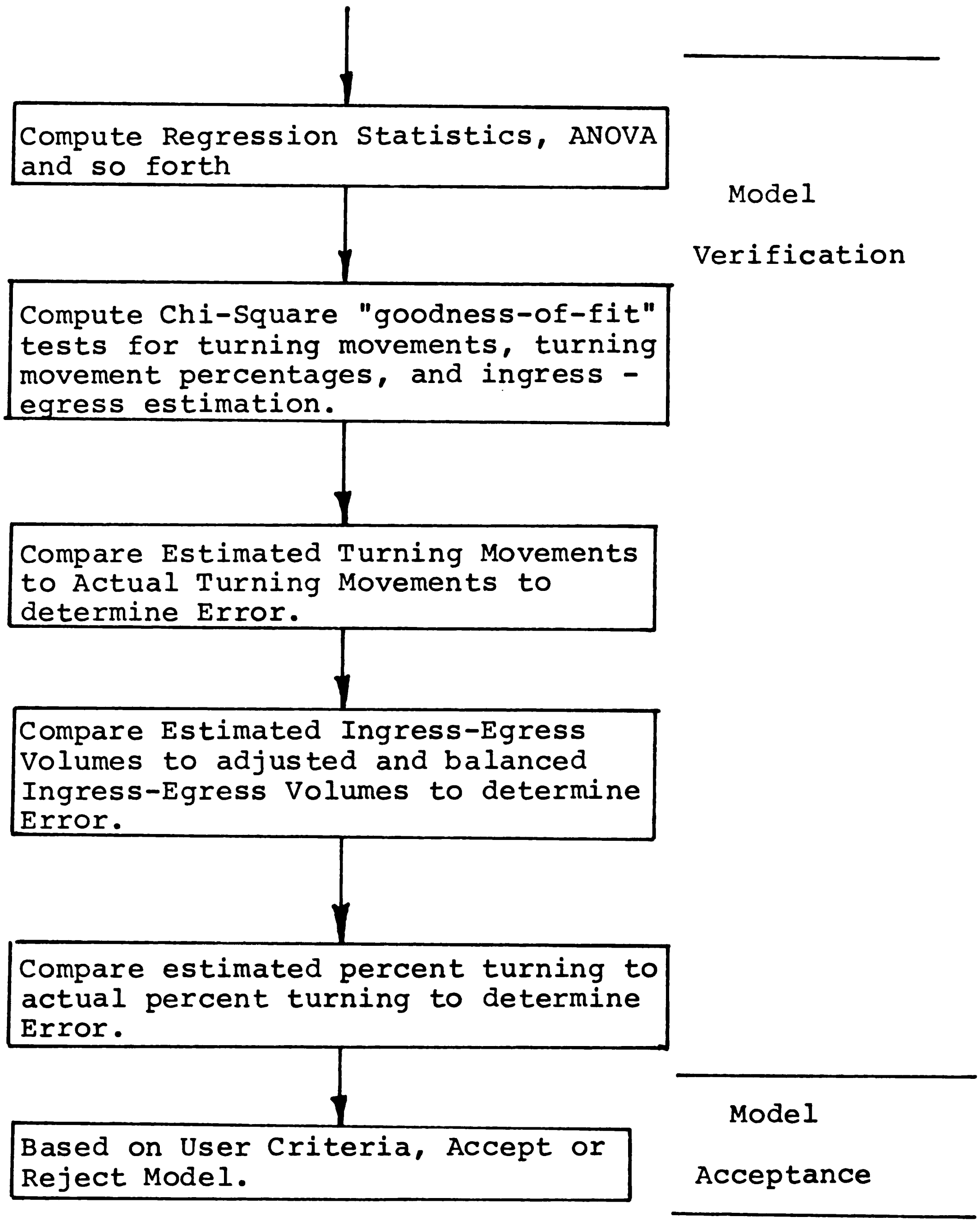


Figure 7

(cont'd.)

(Eq. 3-14)

$$\overline{\%\, e_{Ej}} = \frac{\sum_{t=1}^{n} \frac{Ej\,(t)m - Ej(t)}{Ej\,(t)} \times 100}{n}$$

(Eq. 3-15)

$$S_{\overline{\%e_{Ej}}} = \sqrt{\frac{\sum_{t=1}^{n} \left(\frac{Ej(t)m - Ej(t)}{Ej(t)} \times 100\right)^{2} - n(\overline{\%e_{Ej}})^{2}}{n-1}}$$

where:

$Ii(t)$ = the number of hand-counted vehicles that ingress from direction i during time period t,

$Ii(t)_m$ = the number of machine-counted vehicles that ingress from direction i during time period t,

$Ej(t)$ = the number of hand-counted vehicles that egress to direction j during time period t,

$Ej(t)_m$ = the number of machine-counted vehicles that egress to direction j during time period t,

$\overline{\%e_{I_i}}$ = the mean percentage error for ingress from direction i,

$S_{\overline{\%e_{I_i}}}$ = the standard deviation for the mean percentage error for ingress from direction i,

$\overline{\%e_{Ej}}$ = the mean percentage error for egress to direction j,

$S_{\overline{\%e_{Ej}}}$ = the standard deviation for the mean percentage error for egress to direction j,

n = the number of time periods studied.

The assumption is made that the errors are non-time dependent and normally distributed about a mean value. Based on this assumption, the machine counts are increased or decreased by the mean percentage error so that the mean percentage error is approximately zero for all movements, the adjusted counts form a new matrix, Marrix (C), using the following equations: (Eq. 3-16)

$$c_{tl} = b_{tl} - b_{tl} \times \frac{\%e_{Il}}{100} \quad \text{for } 1 \leq \ell \leq 4$$

(Eq. 3-17)

$$c_{tl} = b_{tI} \quad b_{tl} \times \frac{\%e_I\ (1-4)}{100} \quad \text{for } 5 \leq \ell \leq 8$$

where: c_{tl} = the numerical entry in the t th row and l th column of Matrix (C), and

b_{tl} = the numerical entry in the t th row and l th column of Matrix (E).

Even though the mean percentage machine error is now distributed about zero, there is still another constraint which must be met. Since this mdoel assumes that the time period for tabulated counts is 15 minutes, it also assumes that this period is long enough so that there is negligible storage within the intersection. Therefore, the model must meet the following constraint:

(Eq. 3-18)

$$\sum_{i=1}^{4} I_{t_i} = \sum_{j=1}^{4} E_{tj} \quad \text{for each } t=1,2,3,\ldots n$$

Each row in Matrix (C) is thus balanced to meet this constraint. This balancing forms Matrix (D). The balancing technique assumes that the error is distributed proportionally among the counts during the particular time period under consideration. The following formulas are used:

(Eq. 3-19)

$$R_t = \sum_{i=1}^{4} I_{t_i} - \sum_{j=1}^{4} E_{tj}$$

(Eq. 3-20)

$$d_{tl} = c_{tl} - \frac{Rt}{2} \; \frac{c_{tl}}{4} \quad \text{for } 1 \leq \ell \leq 4$$

t=1 ti

(Eq. 3-21)

$$d_{tl} = c_{tl} + \frac{Rt}{2} \; \frac{c_{tl}}{4} \quad \text{for } 5 \leq \ell \leq 8$$

where: R_t = balance error for the t th row,

d_{tl} = the numerical entry in the t th row and l th column of Matrix (D), and

c_{tl} = the numerical entry in the t th row and l th column of Matrix (C).

The adjusted and balanced machine counts of Matrix (D) are compared to the hand-counted ingress-egress volumes of Matrix (A) using Equations 3-12 through 3-15. The mean percentage error should be zero for all ingress and egress volumes. The more the mean percentage errors deviate from zero, the less successful the error adjustment. If the deviations from zero are unacceptable to the model builder, the error-adjustment process can be iterated until acceptable deviations are obtained. The intersection data can also be studied for time-varying dependence or for any violations of the machine count assumptions stated in this chapter. The level of tolerable deviation from zero mean percentage error is dependent upon the users' needs. In this study, the error process is iterated if the absolute value of any of the mean percentage errors is greater than five percent. The iterative process is cut off when the acceptable tolerance is reached or after five unsuccessful iterations. If the adjustment process is unsuccessful, the data should be reexamined.

Assuming that the error adjustment has been successful, the hand-counted turning movements, Matrix (T), and the balanced and adjusted machine counts, Matrix (D), are used in regression analysis. The regression equation for each of the 12 dependent variables (the turning movements) is of the form:

(Eq. 3-22)

$$X_{IE} = b_0 + b_{1_{IE}} I_1 + b_{2_{IE}} I_2 + b_{3_{IE}} I_3 + b_{4_{IE}} I_4 + b_{5_{IE}} E_1 + b_{6_{IE}} E_2 + b_{7_{IE}} E_3 + b_{8_{IE}} E_4$$

The coefficients are calculated using a step-wise linear regression computer program (11), and are placed into a 9 x 12 matrix, Matrix (E), as shown in Figure 8.

The model is tested by multiplying Matrix (E) and Matrix (D*) as shown in Equations 3-23 and 3-24, (Figure 9). Matrix (D*) is Matrix (D) with a column of dummy 1's added. The dummy 1's are the coefficients of the intercepts. Matrix (F), the estimated turning movement counts, is the result.

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
Int.	$b_{0(12)}$	$b_{0(13)}$	$b_{0(14)}$	$b_{0(21)}$	$b_{0(23)}$	$b_{0(24)}$	$b_{0(31)}$	$b_{0(32)}$	$b_{0(34)}$	$b_{0(41)}$	$b_{0(42)}$	$b_{0(43)}$
I_1	$b_{1(12)}$	.	.	.	.	.	.	.	.	.	.	.
I_2	$b_{2(12)}$	.	.	.	.	.	.	.	.	.	.	.
I_3	$b_{3(12)}$	.	.	.	.	.	.	.	.	.	.	.
I_4	$b_{4(12)}$	.	.	.	.	.	.	.	.	.	.	.
E_1	$b_{5(12)}$	.	.	.	.	.	.	.	.	.	.	.
E_2	$b_{6(12)}$	.	.	.	.	.	.	.	.	.	.	.
E_3	$b_{7(12)}$	.	.	.	.	.	.	.	.	.	.	.
E_4	$b_{8(12)}$	$b_{8(13)}$	$b_{8(14)}$	$b_{8(21)}$	$b_{8(23)}$	$b_{8(24)}$	$b_{8(31)}$	$b_{8(32)}$	$b_{8(34)}$	$b_{8(41)}$	$b_{8(42)}$	$b_{8(43)}$

Figure 8

Regression Coefficients - Matrix Format

$$
\begin{bmatrix}
1 & d_{11} & d_{12} & d_{13} & d_{14} & d_{15} & d_{16} & d_{17} & d_{18} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
1 & d_{n_1} & d_{n_2} & d_{n_3} & d_{n_4} & d_{n_5} & d_{n_6} & d_{n_7} & d_{n_8}
\end{bmatrix}
\times
\begin{bmatrix}
b_{o_{12}} & b_{o_{13}} & b_{o_{14}} & b_{o_{23}} & \cdot & \cdot & \cdot & b_{o_{43}} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b_{8_{12}} & b_{8_{13}} & b_{8_{14}} & b_{8_{23}} & \cdot & \cdot & \cdot & b_{8_{43}}
\end{bmatrix}
=
\begin{bmatrix}
f_{1(12)} & f_{1(13)} & f_{1(14)} & f_{1(21)} & f_{1(23)} & f_{1(24)} & f_{1(31)} & f_{1(32)} & f_{1(34)} & f_{1(41)} & f_{1(42)} & f_{1(43)} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
f_{n(12)} & f_{n(13)} & f_{n(14)} & f_{n(21)} & f_{n(23)} & f_{n(24)} & f_{n(31)} & f_{n(32)} & f_{n(34)} & f_{n(41)} & f_{n(42)} & f_{n(43)}
\end{bmatrix}
$$

Figure 9

Linear Regression Matrix Equation

(Equation 3-24)

$$(D^*) \times (E) = (F) \qquad \text{(Eq. 3-23)}$$
$$n \times 9 \quad 9 \times 12 \quad n \times 12$$

Comparing the actual turning movement matrix, Matrix (T) and the estimated turning movement matrix, Matrix (F) creates the turning movement percentage error matrix, Matrix (TE). The following formula is used:

(Eq. 3-25)

$$TE_{tl} = (F_{tl} - T_{tl})/T_{tl} \times 100$$

where: TE_{tl} = the turning movement percentage error in the t th row and the l th column of Matrix (TE),

F_{tl} = the estimated turning movement in the t th row and the l th column of Matrix (F), and

T_{tl} = the actual turning movement in the t th row and l th column of Matrix (T).

The mean and standard deviation of the turning movement percentage error is computed for each Xij. These are measures of how well the model is calibrated. The means and standard deviations would equal zero if the model were perfect. The further from zero means are, the more imperfect the model.

Applying the intersection equations, Equations 3-1 through 3-9, estimated ingress-egress volumes can be computed from the estimated turning movements contained in Matrix (F). The results are placed in Matrix (G).

Comparing Matrix (D), the adjusted and balanced machine counts, with Matrix (G), the estimated ingress-egress counts, an error matrix, Matrix (H), is computed using the following equation:

(Eq. 3-26)

$$H_{tl} = (G_{tl} - D_{tl})/D_{tl} \quad x\ 100$$

where: H_{tl} = the percentage error in the t th row and l th column in Matrix (H).

G_{tl} = the estimated ingress or egress movement in the t th row and l th column in Matrix (G), and

D_{tl} = the adjusted and balanced machine count in the t th row and l th column in Matrix (D).

The mean error and standard deviation are also computed and are shown in the last two rows of Matrix (H). The mean values of Matrix (H) provide another verification check of the model. The closer to zero the means and standard deviations of error matrix, the better fitting is the model. The estimated turning movements matrix, Matrix (F), can be adjusted to reduce the mean errors of Matrix (H).

For each value X_{IE} of Matrix (F), there is an error from the I component and an error from the E component. The values of the (F) Matrix are adjusted to give a new (F) Matrix by the following equation:

$$F_{tl} \text{ new} = F_{tl} \text{ old} + (I_i GDE/3) + (E_j GDE/3)$$

(Eq. 3-27)

where: F_{tl} new = the new value for the t th row and l th column of the new Matrix (F),

F_{tl} old = the old value for the t th row and l th column of the new Matrix (F),

I_iGDE = the error in Ii between the (D) and (G) matrices = Ii (D) - Ii(G),

i = 1 when l = 1,2,3

i = 2 when l = 4,5,6

i = 3 when l = 7,8,9

i = 4 when l = 10,11,12, and

E_jGD = the error in Ej between the (D) and (G) matrices = Ej (D) - Ej (G),

j = 1 when l = 4,7,10

j = 2 when l = 1,8,11

j = 3 when l = 2,5,12

j = 4 when l = 3,6,9.

From the new (Fl) matrix, new (Gl) and Hl) matrices are computed. For this study the process is repeated until all mean values of (H(n)) are less than 5.00% in absolute value or a maximum of five iterations is reached.

The next validation test of the model calibration is the comparison of the actual and estimated percent turning matrices. The percent turning of the hand-counted data is placed in Matrix (P) and is calculated as follows:

(Eq. 3-28)

$$P_{tl} = (T_{tl} / \sum_{l=k}^{kk} T_{tl}) \times 100$$

where: P_{tl} = the percent turning in the t th row and l th column of Matrix (P), and

T_{tl} = the number of turning in the t th row and l th column of Matrix (T),

if l = 1,2,3 k = 1, kk = 3

if l = 4,5,6 k = 4, kk = 6

if l = 7,8,9 k = 7, kk = 9

if l = 10,11,12 k =10, kk =12.

The mean percentage turning and the standard deviation are computed and placed in the last rows of Matrix (P). Matrix (PP) is the estimated turning percent matrix and is computed in the same manner as Matrix (P) except using Matrix (F) instead of Matrix (T).

The closer the estimated percentages are to the actual percentages, the better the model is. The maximum allowable magnitude of error is a choice of the model builder. However, since these values are a primary output of the model, as described in Chapter 1 (for the NETSIM computer program), careful consideration should be given to their acceptance. For this study, the model is considered acceptable if the estimated error percentages are not more than 2%.

The final validation tests are chi-square tests for the goodness-of-fit of the turning movement estimation, the percent turning movement estimation and the ingress-egress estimation. (3)

The general form of the chi-square test is:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \qquad \text{(Eq. 3-29)}$$

where:

χ^2 = the total chi-square value,

O_i = the observed or estimated value for cell i, and

E_i = the expected or actual value for cell i.

This test measures how well the model's output fits the actual intersection performance and is, therefore, an important test of linear fit for an intersection. Since the cells are the time periods and are considered independent, the degrees of freedom for the test equals the time period sample size. The autocorrelation coefficients and the residuals can be checked to determine the degree of time dependence.

The chi-square value for ingress-egress estimation is computed from Matrices (D) and (G) for each movement for each time period and placed in Matrix (GGG) using the following equation:

(Eq. 3-30)

$$GGG_{tl} = \frac{(G_{tl} - D_{tl})^2}{D_{tl}}$$

where:

GGG_{tl} = the chi square value for the t th row and the l th column of Matrix (GGG),

G_{tl} = the estimated ingress or egress volume for the t th row and the l th column of Matrix (G), and

D_{tl} = the adjusted and balanced ingress or egress volume for the t th row and l th column of Matrix (D).

The total chi-square values are computed using the following formulas:

(Eq. 3-31)

$$\chi^2_{I_l} = \sum_{t=1}^{n} GGG_{tl} \quad \text{for } 1 \leqq l \leqq 4$$

where:

$\chi^2_{I_l}$ = the total chi-square value for the ingress from direction l.

(Eq. 3-32)

$$\chi^2_{E_{(l-4)}} = \sum_{t=1}^{n} GGG_{tl} \quad \text{for } 5 \leqq l \leqq 8$$

where:

$\chi^2_{E_{(l-4)}}$ = the total chi-square value for the egress to direction (l-4).

The level of confidence at which the estimation is accepted is obtained from a chi-square distribution table, (3, pages 600-601) using n, the number of time periods as the degrees of freedom. Note that the balanced and adjusted counts are used in this test in order to measure the error introduced by the linear regression model. If the model is perfect, the chi-square value for each movement will equal zero.

The chi-square values for the turning movements are computed in same manner using Matrices (F) and (T) as follows:

(Eq. 3-33)

$$TTT_{tl} = \frac{(F_{tl} - T_{tl})^2}{T_{tl}}$$

where:

TTT_{tl} = the chi-square value for the t th row and the l th column of Matrix (TTT),

F_{tl} = the estimated turning movement for the t th row and the l th column of Matrix (F), and

T_{tl} = the actual turning movement for the t th row and the l th column of Matrix (T).

The total chi-square values are computed using the following formula:

(Eq. 3-34)

$$\chi^2_{x_{ij}} = \sum_{t=1}^{n} TTT_{tl}$$

where:

$\chi^2_{x_{ij}}$ = the total chi-square value for turning movement from the ith direction to the j th direction.

If the model would estimate each turning movement for each time period perfectly, the chi-square value would equal zero in all cases. In a similar fashion, the chi-square values for the turning movement percentages are calculated using Matrices (P) and (PP) as follows:

$$PPP_{tl} = \frac{(PP_{tl} - P_{tl})^2}{P_{tl}} \quad \text{(Eq. 3-35)}$$

where:

PPP_{tl} = the chi-square value for the t th row and the l th column of Matrix (PPP),

PP_{tl} = the estimated turning movement percentage for the t th row and l th column of Matrix (PP), and

P_{tl} = the actual turning movement percentage for the t th row and l th column of Matrix (P).

The total chi-square values are computed using the following formula:

$$\chi^2_{x\%_{ij}} = \sum_{t=1}^{n} PPP_{tl} \quad \text{(Eq. 3-36)}$$

where:

$\chi^2_{x\%_{ij}}$ = the total chi-square value for the turning movement percentage from the i th direction to the j th direction.

If the model's estimated turning movement percentages are exact, the chi-square values are zero. The level of confidence of acceptance is determined by the chi-square distribution table using the number of time periods as the degrees of freedom.

If the model is validated by all the tests, the error matrix(ices), Matrix (M), and the regression coefficients matrix, Matrix (E), are stored for future use. Any new machine count data is placed in a new Matrix (B). The model's error matrix(ices), Matrix (M), is (are) applied, giving an adjusted machine count matrix, Matrix (C). Matrix (C) is balanced giving an adjusted and balanced matrix, Matrix (D). The new Matrix (D) is multiplied by the model's regression coefficients matrix, Matrix (E), which produces the estimated turning movement matrix, Matrix (F). An estimated ingress-egress matrix, Matrix (G), is computed from Matrix (F). Matrix (D), the balanced and adjusted machine counts, and Matrix (G), the estimated ingress-egress counts, are compared, giving an error matrix, Matrix (H). A chi-square test is also performed using Matrices (D)and (F), producing Matrix (GGG). From these two matrices, the user can determine if the intersection has changed significantly since the model was developed. The larger the mean percentage errors in Matrix (H) or the chi-square values are, the more variance has developed that is not explained by the model. Matrix (F) can be adjusted, as was discussed previously in order to attempt to reduce the Matrix (H) error.

If the model is validated only by the overall performance tests, but not by the chi-square tests, the user may still be able to retain and use the model. However, the model cannot be relied upon to give an actual estimation for any particular time period, but may be suitable for an estimation of overall performance for several time periods.

A FORTRAN computer program was written which builds and stores an intersection turning movement model and can apply it to new data. A flow diagram and listing can be found in Appendix A. The model building computer program has a statistical output option for the evaluation of the step-wise linear regression. This output includes the covariance matrix, the correlation matrix, total sum of squares, the improvement of unexplained variance for each step, analysis of variance, and a t-test value. The user can trigger this option and analyze any of the turning movement regression equations.

THREE-LEGGED INTERSECTION MODEL THEORY

The basic theory of the three-legged intersection is similar to that of the four-legged intersection. In fact, a three-legged intersection is simply a special case of a four-legged intersection. Figure 10 shows a normal three-legged intersection where there is no southern leg. The direction of the missing leg is arbitrary, but for this discussion the intersection of

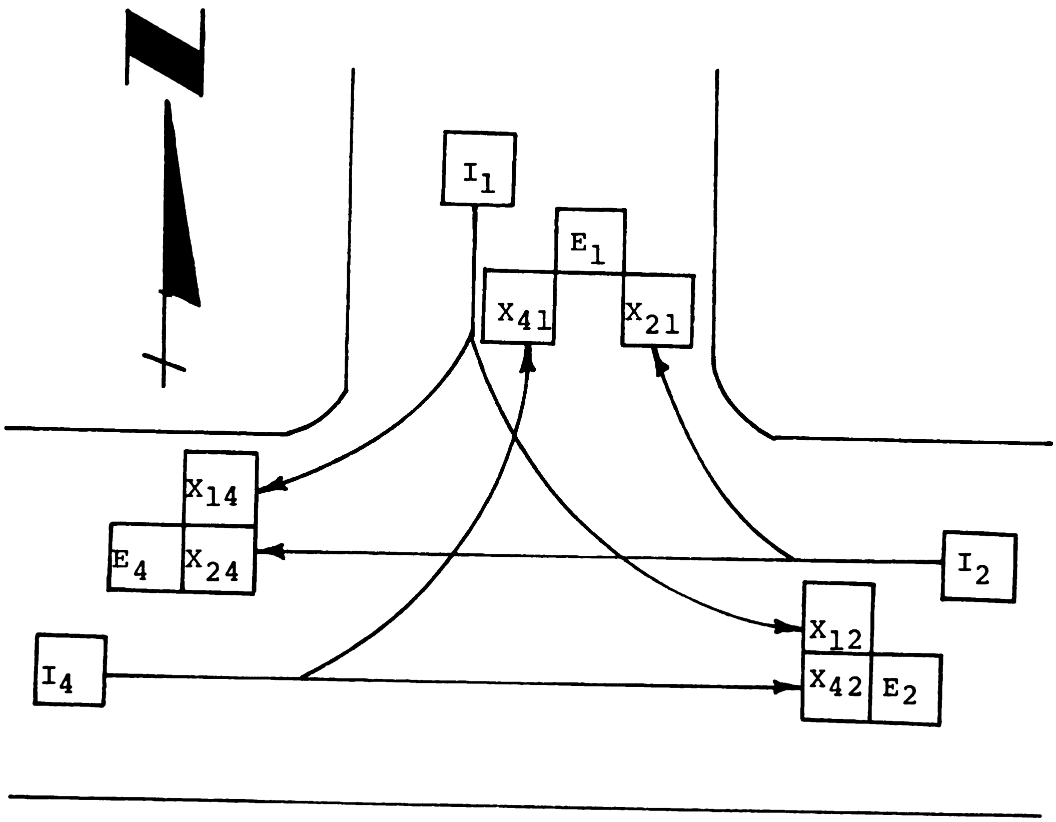


Figure 10

Typical Three-legged Intersection

Figure 10 will be used. The same theory applies regardless of which leg is missing. All previous assumptions and constraints on the four-legged intersection also hold for the three-legged case.

Since the southern leg is missing, the following equation holds: (Eq. 3-37)

$$I_3 = E_3 = X_{13} = X_{23} = X_{43} = X_{31} = X_{32} = X_{34} = 0$$

The following intersection equations also now hold:

$$I_1 + I_2 + I_4 = E_1 + E_2 + E_4, \quad \text{(Eq. 3-38)}$$

$$I_1 = X_{12} + X_{14} \quad \text{(Eq. 3-39)}$$

$$I_2 = X_{21} + X_{24} \quad \text{(Eq. 3-40)}$$

$$I_4 = X_{41} + X_{42} \quad \text{(Eq. 3-41)}$$

$$E_1 = X_{21} + X_{41} \quad \text{(Eq. 3-42)}$$

$$E_2 = X_{12} + X_{41} \quad \text{(Eq. 3-43)}$$

$$E_4 = X_{14} + X_{24} \quad \text{(Eq. 3-44)}$$

There are 6 unknowns, 6 independent equations and 1 redundancy. Therefore, there is 1 degree of freedom. Thus, if one turning movement count is known and the ingress-egress volumes are known, the intersection is determinate. The matrix form of the independent equation is:

(Eq. 3-45)

$$\begin{bmatrix} X_{12} & X_{14} & 0 & 0 & 0 & 0 \\ 0 & 0 & X_{21} & X_{24} & 0 & 0 \\ 0 & 0 & 0 & 0 & X_{41} & X_{42} \\ 0 & 0 & X_{21} & 0 & X_{41} & 0 \\ X_{12} & 0 & 0 & 0 & 0 & X_{42} \\ 0 & X_{14} & 0 & X_{24} & 0 & 0 \end{bmatrix} x \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_4 \\ E_1 \\ E_2 \\ E_4 \end{bmatrix}$$

A linear regression approach, using knowledge of previous performance, was used exactly like the four-legged intersection. Therefore, the equations, which are simply the special case of the four-legged theory just discussed, are not presented here. To build the model, hand-counted intersection data and machine-counted intersection data were used. The ingress-egress machine counts were adjusted and balanced. The regression equations were developed and turning movements are estimated. The model was checked and accepted or rejected. If accepted, the model was stored for future use.

INTERSECTION TEST PROBLEM

To better illustrate the linear regression model building process, intersection test data was used to build an example model. The input and output data are found in Tables B-1 through B-24 in Appendix B, and will be referred to in the following step-by-step explanation.

As in the case studies of the next chapter, only a summary table will be presented in the text. The summary table for the test problem is presented in Table 1 on the next two pages.

First, the intersection field data was collected. The hand-counted ingress-egress counts are placed in Matrix (A) as shown in Table B-1. The machine counts of the ingress-egress movements were placed in Matrix (B) as shown in Table B-2. The hand-counted turning movements were placed in Matrix (T) as shown in Table B-7. The headings show the movements using the notation of Figure 4, with the time periods numbered in the left column. These three matrices are the necessary input data for the computer program.

Using Equations 3-12 through 3-15, the error matrix, Matrix (M), is computed. To illustrate the calculation of the mean percent error matrix, the error for I_1 during the first time period, (t=1), is as follows:

$$\%e_{I_{1_1}} = \frac{132 - 125}{125} \times 100 = 5.60\%$$

where: 132 is the entry of the first column and first row of Matrix (B). It is the machine count for I_1 for time period 1, and

125 is the entry of the first column and first row of Matrix (A). It is the actual count for I_1 for time period 1.

TABLE 1

RESULTS OF TEST MODEL

(M) % Error

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	2.09	3.62	7.92	2.34	6.81	1.63	4.86	1.46
STAN:	15.28	15.73	10.45	8.19	13.36	10.26	12.90	9.44

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	0.39	0.98	0.03	-0.69	0.46	1.35	-0.21	-1.44
STAN:	12.11	9.81	5.01	4.75	7.09	7.72	10.41	3.75

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	34.2	14.0	4.6	4.2	10.8	14.1	22.8	3.0

TABLE 1

(CONT'D)

(TE) TURNING MOVEMENT ESTIMATION ERROR

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	0.7	-0.2	1.5	-0.7	2.6	1.8	0.4	1.6	3.5	9.5	0.6	-2.7
STAN:	16.3	11.7	22.4	15.3	29.0	18.0	11.1	28.9	24.4	70.7	20.0	17.0

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	25.7	57.4	16.9	30.7	13.4	55.8	66.2	19.2	14.6	25.2	62.7	12.1
STAN:	5.2	7.2	5.6	21.7	2.9	22.3	13.4	8.7	7.6	20.0	19.9	2.9

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	25.7	57.5	16.8	30.6	13.1	56.2	66.7	18.8	14.6	25.4	63.0	11.6
STAN:	4.0	6.3	4.9	21.8	1.5	22.3	12.9	8.1	6.9	20.7	20.7	2.4

(TTT) CHI-SQUARE TEST TURNING MOVEMENT ESTIMATION

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	14.1	19.0	13.4	10.7	19.0	22.9	14.7	20.4	19.5	25.2	22.8	6.8

(PPP) CHI-SQUARE TEST TURNING MOVEMENT PERCENTAGE ESTIMATION

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	5.6	3.2	8.7	4.8	14.9	4.6	4.2	21.1	9.0	19.8	10.7	8.1

If this calculation is made for all 20 time periods, then summed and divided by 20, as per Equation 3-12, the result is $\overline{\%e_{I_1}}$, which is 2.09%, as entered in Matrix (M), found in Table B-3, first column and first row. The standard deviation for the percent error in I_1, as calculated with Equation 3-13 is 15.28%. To summarize, from Matrix (M), we know that for the ingress movement from the North, I_1, the machine count is on the average 2.09% high with a standard deviation of 15.25%; for the egress movement to the North, E_1, the machine count is, on the average, 3.62% high with a standard deviation of 15.73%, and so forth. Matrix (M) is an important model matrix and is also found in the summary, Table 1.

To adjust the machine count error so that the mean percent error is approximately zero, Equations 3-16 and 3-17 are used. This produces Matrix (C), the adjusted counts matrix, as shown in Table B-4. To illustrate the calculation of Matrix (C), the adjustment calculation for I1 for the first time period is as follows:

$$C_{11} = 132 - 132 \times \frac{-2.09}{100} = 129.34$$

(rounded to 129)

where: 132 is the machine count for I_1 for the first time period, column 1 and row 1 in Matrix (B), and

> -2.09 is the mean percent error for I_1, as is shown in column 1 and row 1 of Matrix (M). The negative error means that the movement was undercounted due to machine insensitivity or vehicles missing the tube.

The adjustment is made on all the machine counts, making the mean percent error approximately zero for all ingress-egress variables.

Next, the counts are balanced for each time period, using Equations 3-19, 3-20, and 3-21. This satisfies the constraint that there is no storage in the intersection, that is, that the sum of the ingress volumes equals the sum of egress volumes for each time period. The adjustment for I_1 for the first time period is as follows: First, the constraint error is calculated:

$$\sum_{i=1}^{4} I_i = 129 + 58 + 100 + 80 = 367,$$

$$\sum_{j=1}^{4} E_j = 157 + 74 + 68 + 65 = 364,$$

$$R_1 = \sum_{j=1}^{4} E_j - \sum_{i=1}^{4} I_i = 367 - 364 = 3,$$

where: $\sum_{i=1}^{4} I_i$ is the sum of the ingress counts for time period 1 in Matrix (C), and

$\sum_{j=1}^{4} E_j$ is the sum of the egress counts for time period 1 in Matrix (C).

The adjustment for I_1 (t=1) for Matrix (D) is calculated next:

$$I_1 \ (t=1) = 129 - 3/2 \ (129/367) = 128.47$$
(rounded to 128),

where: 129 is the adjusted count for I_1 for time period 1 in Matrix (C),

367 is the sum of the ingress counts for time period 1 in Matrix (C), and

3/2 is R /2; since one half of the error is adjusted with the ingress and one half with the egress.

The completed Matrix (D) is shown in Table B-5. From Matrix (A) and Matrix (D) a new error matrix, Matrix (M1), is calculated and shown in Table B-6. Matrix (M1) shows that the mean percent errors of Matrix (D) are not greater than 5.00%. Therefore, the adjustment procedure has been successful.

To illustrate the statistical output that is available from the computer program, only the linear regression equation using X_{12} is used, since the output is quite lengthy. The output for the other eleven equations have the same format. This output is optional for the user and can be used to analyze and validate the linear regression equations. Tables B-8 through B-13 contain the data from the X_{12} equation.

Table B-8 gives the means, the standard deviations, the covariance matrix, and the correlation matrix of the dependent variable X_{12} and the eight independent variables. The total sum of squares error is also shown.

Tables B-9 through B-13 show the step-by-step analysis of variance for the regression analysis. The stepwise linear regression computer program is very similar to the one described by Neter and Wassermann (11, pages 382-386). The procedure used in this study's program is a forward selection one, since once an independent variable has entered the equation, it cannot be removed. For a variable to be allowed into the equation it must explain at least 0.1% of the remaining sum of squares error.

Each step of the regression can be studied to see if the parameters need to be changed. The procedures for analyzing linear regression are explained in detail by Neter and Wassermann (11). Intense statistical analysis of the linear regression equations is not done in this study, since the main objective was to demonstrate the feasibility of such a model. However, any statistical value which indicates the lack of fit for the model, or is abnormal in any way, is presented and discussed.

The final regression equation for turning movement X_{12}, as shown in Table B-14, is:

$$X_{12} = 7.84385 + 0.13931\, I_1 + 0.11028\, I_4 + 0.12895\, E_1 - 0.05258\, E_3 - 0.14424\, E_4 \quad \text{(Eq. 3-46)}$$

After all the dependent variables have undergone the regression procedure, there are twelve regression equations with twelve sets of coefficients. These coefficients are shown in Matrix (E) in Table B-14. Table B-15 contains the estimated values for X_{12} using the regression equation and the data of Matrix (D). The residuals, the standard model error, and the r value are also given. The residuals can expose any time-varying dependency or any lack of normalcy error, as described by Bhattacharyya and Johnson. (3)

Multiplying Matrix (D) and Matrix (E) with Equation 3-24 gives the estimated turning movements matrix, Matrix (F), shown in Table B-16. Comparing the estimated turning movements with the hand-counted turning movements by using Equation 3-24 gives the turning movement error matrix, Matrix (TE), shown in Table 1 and in Table B-17. From Matrix (TE), the first validation check can be made. The only mean error greater than 4% is from X_{41}.

Most of its error comes from a 300% error in time period 15. If the turning volumes are low, the percent error can be very large. For example, for X_{41}, time period 15, the estimated count from Matrix (F) is 8. The actual count from Matrix (T) is 2, thus giving a 300% overcount. Therefore, with this high error explained, we can accept the validation check.

Using the basic intersection equations, Equations 3-1 through 3-9, Matrix (G), the estimated ingress-egress volumes, are calculated using Matrix (F). Matrix (G) is shown in Table B-18. Using Equation 3-26, Matrix (G) is compared to the adjusted and balanced ingress-egress counts that entered the regression subroutine. The percent error calculation is similar to the other error calculation. For example, the count in Matrix (D) for I_1 (t=1) is 128; in Matrix (F) it is 130. Therefore, the percent error in this movement for this time period is:

$$\frac{130 - 128}{130} \times 100 = 1.22\%$$

The percent error is calculated for all movements and forms Matrix (H) shown in Table B-19.

The second validation check is to look at the mean % errors of Matrix (H), as shown in Table 1. These mean errors are all less than 5.00%. In fact, they are all less than 2.00%. Therefore, the second validation check is acceptable.

The third validation check is the comparison of the estimated percent turning with the hand-counted percent turning. Matrix (P), shown in Table 1 and in Table B-20, shows the hand-counted percent turning as calculated by Equation 3-28, using Matrix (T). Matrix (PP), as shown in Table 1 and Table B-21, gives the estimated percent turning as calculated by Equation 3-28 using Matrix (F) instead of Matrix (T).

As an example of the calculation of the percent turning matrices, X_{12} of for the first time period for Matrix (P) will be used. Looking at Matrix (T), X_{12} is 40 for the first time period. The sum of the turning movements from the North is $X_{12} + X_{13} + X_{14} = 40 + 55 + 30 = 125$. Therefore, the percent turning for X_{12} for time period 1 in Matrix (P) is:

$$\%P_{X_{12}} = 40/125 \times 100 = 32.00\%$$

as is shown in Matrix (P). Matrix (PP) is calculated in the same way, using Matrix (F).

Comparing the mean values of Matrix (P) with those of Matrix (PP), we can see that there is less than 1.00% difference. Therefore, this validation is acceptable. The model can be accepted for overall performance. Next, the chi-square tests for goodness-of-fit are made.

The chi-square test for the ingress-egress estimation is calculated using Equation 3-30. The chi-square value for time period 1 for I is calculated as follows:

$$GGG_{11} = \frac{(130 - 128)^2}{128} = 0.02$$

where:

GGG_{11} = is the value of the chi-square test for the first row and first column of Matrix (GGG), Table B-22,

130 = the value of the first row and first column of Matrix (G), Table B-18. It is the estimated ingress volume from the north for the first time period,

128 = the value of the first row and first column of Matrix (D), Table B-5. It is the adjusted and balanced machine count of the ingress volume from the north for the first time period.

The chi-square values for the other time periods and other movements are calculated in the same manner and placed in Matrix (GGG) shown in Table B-22. The total chi-square value is calculated for each movement, using Equations 3-31 and 3-32, and is shown in Table 1 as well as Table B-22.

The chi-square test for the turning movement estimation is calculated using Equation 3-33. The chi-square value for time period 1 for X_{12} is calculated as follows:

$$TTT_{11} = \frac{(41 - 40)^2}{40} = 0.03$$

where:

TTT_{11} = is the value of the chi-square test for the first row and first column of Matrix (TTT), Table B-23,

40 = the value of the first row and first column of Matrix (F), Table B-16. It is the estimated turning volume for X_{12} for the first time period,

41 = the value of the first row and first column of Matrix (T), Table B-7. It is the actual turning volume for X_{12} for the first time period.

The chi-square values for the other time periods and other movements are calculated in the same manner and placed in Matrix (TTT) shown in Table B-23. The total chi-square value is calculated for each movement using Equation 3-34 and is shown in Table 1 as well as Table B-23.

The chi-square test for the turning movement percentage estimation is calculated using Equation 3-35. The chi-square value for time period 1 for X_{12} is calculated as follows:

$$PPP_{11} = \frac{(31.5 - 32.00)^2}{32.0} = 0.01$$

where: PPP_{11} = is the value of the chi-square test for the first row and first column of Matrix (PPP), Table B-24,

31.5 = the value of the first row and first column of Matrix (PP), Table B-21. It is the estimated turning volume percentage for X_{12} for the first time period,

32.0 = the value of the first row and first column of Matrix (P), Table B-20. It is the actual turning volume percentage for X_{12} for the first time period.

The chi-square values for the other time periods and other movements are calculated in the same manner and placed in Matrix (PPP) shown in Table B-24. The total chi-square value is calculated for each movement using Equation 3-36 and is shown in Table 1 as well as Table B-24.

The summary table, Table 1, is used to check the chi-square tests. For this model, the degrees of freedom is the number of time periods studied, which in this case is 20. The maximum chi-square value for the ingress-egress estimation, Matrix (GGG), is 34.2 for I_1. The The level of confidence for acceptance of this value is less than 5.00%. The maximum chi-square value for the turning movement estimation is 25.2 for X_{41}. The level of confidence for acceptance of this value is less than 25%. The maximum chi-square value for the turning movement percentage is 21.1 for X_{32}. The level of confidence for acceptance of this value is less than 50%. Therefore, the chi-square shows that the model is an unacceptable estimator for these variables for individual time periods, but is valid for estimating average percent turning.

In the next chapter, the intersection model theory described in this chapter is used to build intersection models using actual data. The results is analyzed to see if this theory is valid in practice.

Chapter Four

CASE STUDIES

In this chapter intersection turning movement models developed with actual field data, using the theory described in the previous chapter and data from previous studies conducted by the Michigan Department of Transportation will be discussed. Selected candidate locations were chosen to develop and test the models. The procedures for data collection used by the Department are similar to those described in Chapter 1. Figure 11 shows a typical hand-counted volume summary sheet. Figure 12 shows a typical machine count volume sheet. Note that the counts are tabulated in fifteen minute time periods.

Despite the large amount of collected data available, only two intersection data sets were acceptable for study. The reasons for unacceptability are many:

1. Straight-through counts were not made,
2. Machine(s) failed during the study,
3. Hand-counts were not taken at the same time as the machine counts,
4. Volumes are so low that they cannot be studied without large error,
5. There was an accident or some other disruption during the study period,

Study #203

VEHICLE VOLUME SUMMARY

1771 (11/74)

WEATHER Clear

DATE 7-26-78 DAY Wednesday COUNTY Delta TWP. VILLAGE OR CITY Escanaba

INTERSECTION OF US-2, US-41, M-35(Lincoln) @ 12th Ave. N.

TIME: 7A TO 9A; 11A TO 1P; 2P TO 6P

TIME	FROM N ON US-2,41,M-35 LEFT	STRAIGHT	RIGHT	TOTAL	FROM S ON US-2,41,M-35 LEFT	STRAIGHT	RIGHT	TOTAL	FROM E ON 12th Ave. LEFT	STRAIGHT	RIGHT	TOTAL	FROM W ON 12th Ave. LEFT	STRAIGHT	RIGHT	TOTAL	TOTAL
7-7:15A	9	116	0	125	0	97	2	99	1	0	6	7	0	0	1	1	232
30	10	106	1	117	1	111	6	118	3	0	1	4	0	0	1	1	240
45	4	132	1	137	2	146	8	156	4	0	2	6	1	0	2	3	302
8:00A	3	185	1	189	7	200	10	217	0	0	6	6	0	0	9	9	421
8-8:15A	0	110	0	110	6	99	4	109	1	0	7	8	2	0	8	10	237
30	3	93	2	98	3	89	2	94	1	0	1	2	1	0	1	2	196
45	0	105	1	106	3	85	2	90	1	0	2	3	0	0	1	1	200
9:00A	2	153	0	155	2	103	4	109	1	0	2	3	0	1	7	8	275
11-11:15A	3	145	1	149	1	154	4	159	0	0	4	4	0	0	3	3	315
30	5	154	0	159	3	168	4	175	2	3	5	10	0	1	8	9	353
45	3	127	1	131	1	137	5	143	3	0	2	5	2	0	6	8	287
12:00N	1	202	1	204	10	165	6	181	6	0	4	10	3	0	8	11	406
12-12:15P	5	290	1	296	4	193	6	203	2	0	1	3	0	0	8	8	510
30	1	200	1	202	4	184	8	196	4	0	3	7	3	1	7	11	416
45	1	195	0	196	4	191	3	198	1	0	2	3	1	0	2	3	400
1:00P	1	183	4	188	7	233	8	248	2	0	2	4	0	4	5	9	449
2-2:15P	3	169	1	173	7	226	6	239	0	1	8	9	0	1	3	4	425
30	3	172	3	178	6	222	7	235	6	0	8	14	1	0	5	6	433
45	1	174	0	175	3	229	6	238	4	1	3	8	0	0	5	5	426
3:00P	1	168	1	170	5	210	5	220	5	0	8	13	0	0	3	3	406
3-3:15P	5	312	1	318	5	153	26	184	3	0	3	6	0	0	24	24	532
30	2	189	1	192	1	210	8	219	6	0	3	9	0	1	9	10	430
45	5	219	3	227	3	217	16	236	2	0	4	6	0	0	8	8	477
4:00P	4	193	0	197	3	222	7	232	5	2	10	17	0	1	8	9	455
4-4:15P	3	234	3	240	7	216	6	229	3	0	8	11	0	0	3	3	483
30	5	189	0	194	5	250	6	261	4	0	7	11	1	0	1	2	468
45	7	253	2	262	5	254	6	265	8	0	9	17	1	0	12	13	557
5:00P	4	197	4	205	2	210	11	223	3	0	5	8	2	0	0	2	438
5-5:15P	3	193	5	201	4	301	12	317	8	0	31	39	0	0	23	23	580
30	6	129	0	135	9	196	11	216	4	0	11	15	0	0	4	4	370
45	3	174	1	178	10	222	8	240	7	1	12	20	0	1	3	4	442
6:00P	1	152	3	156	6	187	5	198	1	3	5	9	1	0	4	5	368
TOTAL 8 Hrs.	107	5613	43	5763	139	5880	228	6247	101	11	185	297	19	11	192	222	12529

Figure 11

Typical Hand Count Volume Sheet

PAGE 6 TRAFFIC RECORD PROGRAM NO 16071
COUNTY CS NO MILE PT STA NO DIRECTION
DELTA 21000 00.000 1631 WEST
ROUTE DESCRIPTION
12TH AVE 100 FEET EAST OF US-2 US-41 M-35
LANES RAMP OR CROSSOVER
ALL LANES

DAY	MON		TUE		WED		THU		FRI		SAT	
DATE	07-24		07-25		07-26		07-27		07-28		07-29	
END TIME	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1215				11	1	13						
1230			3	10	2	12						
1245				8	2	9						
0100-------			1	4		9						
0115				7		8						
0130				5	3	15						
0145			1	11		5						
0200-------				10		7						
0215				11	1	23						
0230				7		7						
0245				7		14						
0300-------				11	3	5						
0315				10								
0330				10								
0345			1	4								
0400-------				10								
0415		17		19								
0430		14		16								
0445		12		15	1							
0500-------		17		19								
0515		8	1	13								
0530		10		12								
0545		6	1	10	1							
0600-------		7		3	2							
0615		13	6	9	4							
0630		9	6	7	9							
0645		9	4	4	13							
0700-------		10	3	10	10							
0715		9	12	10	4							
0730		8	8	7	6							
0745		14	9	9	8							
0800-------		8	11	13	8							
0815		20	6	7	4							
0830		11		7	6							
0845		11	3	12	2							
0900-------		15	3	10	1							

Figure 12

Typical Machine Count Volume Sheet

6. There was only one set of data at the study intersection. Two sets of usable data are needed, one to build the model, and the other to test the model.

Of the two intersections with acceptable data for study, one is three-legged and the other is four-legged. Each was studied separately using the following procedure:

1. A model is developed, verified, and accepted using the older data set,
2. The machine counts of the newer data set are used with the model to estimate the turning movements during its study period,
3. The results are compared with the actual turning movements to see how well the model works,
4. Combining both sets of data, another intersection model is created,
5. The combined model is tested with a similar intersection's data set.

Using two sets of data and a set from another intersection allows analysis of the effects of change in machine count error and operation upon the model.

FOUR-LEGGED INTERSECTION CASE STUDY

The four-legged candidate location is the Lincoln Road (US-2, US-41, M-35) at Ludington Road (US-2, US-41) intersection in Escanaba, Michigan. Figure 13 shows the

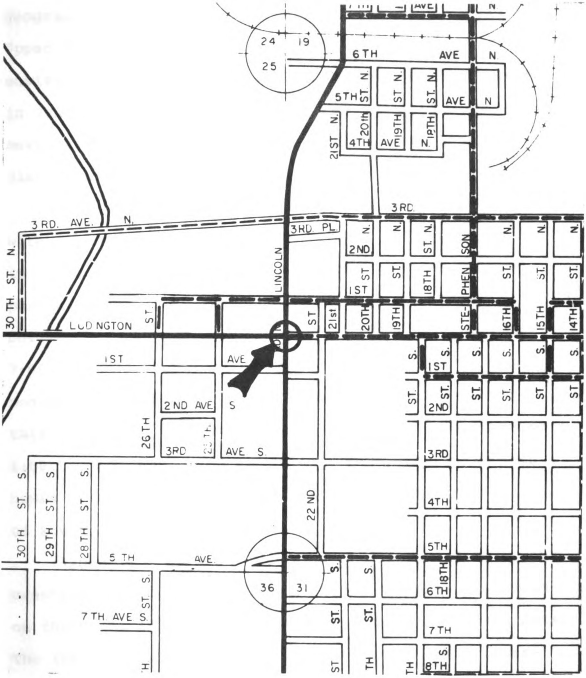


Figure 13

Lincoln Road and Ludington Road Intersection geographic location of this intersection in Michigan's Upper Peninsula. The intersection is in an urban environment in downtown Escanaba, and was studied twice, in June, 1974 and July, 1976. These two data sets meet the requirements for intersection model study as discussed in previous chapters.

Both Lincoln Road and Ludington Road are five-lane with exclusive left-hand turning lanes. The intersection is signalized with no turning prohibitions and no turn phasing. The first set of data was collected June 10, 1974 between 7:00 AM and 9:00 AM; and June 11, 1974 between 7:00 AM and 9:00 AM, 11:00 AM and 2:00 PM, and 3:00 PM and 5:00 PM. The second set of data was collected at this intersection on July 21, 1976, between 11:00 AM and 1:00 PM, and 2:00 PM and 6:00 PM. Thus, there are nine hours of study from the first data set, and six hours of study from the second data set.

Appendix C contains the input and output data in the creation and application of the intersection model based on the June, 1974 Lincoln and Ludington intersection data. The input data is Matrix (A), the hand-counted ingress-egress movements; Matrix (B) is the machine-counted ingress-egress movement; and Matrix (T) is the hand-counted turning movements, Table C-3. Table 2 on the next two pages contains the summary results for this model.

TABLE 2

RESULTS OF LINCOLN-LUDINGTON 6/74 MODEL

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN	8.42	-5.11	9.19	2.23	5.40	1.08	1.80	5.75
STAN:	9.75	26.99	7.90	8.24	7.07	8.41	9.07	8.60

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	0.00	10.23	-0.37	-2.18	-0.28	-1.48	-1.82	-1.96
STAN:	5.03	53.42	2.63	4.81	3.95	4.77	4.21	5.58

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	8.9	95.6	2.1	5.7	7.0	5.9	5.3	6.3

TABLE 2

(CONT'D)

(TE) TURNING MOVEMENT ESTIMATION ERROR

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	0.6	0.1	0.1	3.0	10.3	1.9	0.1	***	2.4	0.0	0.3	-1.0
STAN:	14.8	13.8	15.2	20.6	77.9	27.7	8.7	***	36.5	15.0	13.9	30.8

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	28.2	49.6	22.1	46.8	13.9	39.3	75.8	15.3	8.8	40.3	45.3	14.4
STAN:	6.1	7.1	7.2	10.0	4.7	9.3	6.5	6.3	3.6	9.4	9.4	4.2

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{12}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	28.3	49.7	22.1	47.9	13.4	38.7	76.7	15.1	8.3	40.6	45.6	13.8
STAN:	5.1	6.2	7.3	10.9	3.0	8.3	5.5	4.8	2.2	7.8	8.2	3.4

(TTT) CHI-SQUARE TEST TURNING MOVEMENT ESTIMATION

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	21.3	28.7	20.0	37.2	51.8	55.9	16.5	***	26.5	19.9	18.0	19.6

(PPP) CHI-SQUARE TEST TURNING MOVEMENT PERCENTAGE ESTIMATION

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	9.8	12.7	20.8	51.4	61.7	58.0	8.7	***	32.4	21.2	23.7	40.0

The error matrix, Matrix (M) is shown in Table 2. Most intersections have multi-axle vehicles traveling through them. Therefore, an overcount or positive error is expected. The intersection is typical of this positive error except for the ingress from the east, I_2. This error has a mean of -5.11% and a standard deviation of 26.99%. This abnormal error can be caused by the machine or by driver behavior. Since the standard deviation is much larger than for the other movements, a time-varying cause would be suspected. The model builder, when confronted by such a value may desire further testing, and/or new data. Since this data is the only available data, it will be used in this thesis for illustration. As will be explained in the concluding chapter, problems such as machine count inconsistency show the need for further research.

It is also important to note the large size of all the standard deviations. This makes it extremely difficult to estimate accurately any single 15 minute turning movement count. For example, if it is assumed that the machine count error is distributed normally, then for I_1 approximately one-third of the counts will be either more than 18.17% overcounted or more than 1.33% undercounted.

The machine counts are adjusted and balanced to form Matrix (D). Matrices (D) and (T) then enter the linear regression program as described in the previous chapter. Matrix (E), Table C-4, contains the regression coefficients.

In analyzing the regression coefficients, it can be seen that the intercepts are not zero. These coefficients should be zero, since if there are no ingress-egress volumes there can be no turning movements. However, the linear regression model developed in this thesis, like other linear regression models is valid only within the range of values of the independent variables upon which the model is built. Since none of the regression models built in this thesis has low values, the extension of the linear regression equation to zero values cannot be expected to give a valid solution. This does not invalidate the model, since the regression equation should give correct estimates using intersection volumes in the range upon which the model is built. Therefore, an intersection model developed with medium volumes should not be expected to give correct estimations at very low or very high volumes. More discussion of this problem is given in the next chapter.

Secondly, the signs of the coefficients are not unrealistic because of the interrelation between the ingress-egress variables. In the X_{12} equation, for example, all of the ingress coefficients are positive and all of the egress coefficients are negative. However, if any egress movement increases by 1, an ingress movement must increase by 1. Therefore, the relationship of the dependent variable, the turning movement, can be either negative or positive with any of the independent variables, the ingress-egress movements. This topic will also be discussed in further detail in the final chapter.

The estimated turning movements, Matrix (F) are produced by multiplying Matrices (D) and (E). The estimated turning movements are compared to the hand-counted turning movements to produce the error matrix, Matrix (TE). The means and standard deviations of Matrix (TE) are summarized in Table 2. This provides the first model validation check. Except for X_{23} and X_{32}, all of the errors are under 5.00%. The extremely large error found in X_{32} and the 10.3% mean error in X_{23} are due to the small turning volumes which produce large percentage errors, as was the case in our test problem of Chapter 3. With this explanation, this model check is accepted.

Using the basic intersection equations, (Equations 3-1 through 3-9), Matrix (G), the estimated ingress-egress volumes, is computed from Matrix (F). Comparing Matrices (G) and (D), the error Matrix (H) is computed and shown in Table 2. This matrix provides the second validation check. All of the mean errors are under 3.00% except I_2. The 10.23% mean error comes primarily from the 290.42% error during time period 9. Looking back at the collected data for I_2 for the time period 9, the actual ingress volume from Matrix (A) is 31 and the machine count from Matrix (B) is 7. This has caused the abnormal machine count error in Matrix (M) and the high mean error for I_2 in Matrix (H). Now the model builder must decide whether to delete the data from time period 9, accept the data as it is, or to reject the entire data set and collect new data. This study shall proceed with the data as it is, keeping in mind this source of error. This demonstrates the value of the validation checks and shows that the model analyst must understand the basic principles of the model building procedure.

Using Equation 3-28, Matrix (P), the percent turning matrix, is computed using Matrix (T). Matrix (PP), the estimated turning matrix, is also computed from Matrix (F) using Equation 3-28. The means and standard deviations from these two matrices are summarized in Table 2. They provide the third validation check. Since none of the estimated mean values is greater than 2.00% in error from the actual mean values, the validation check is accepted. The model can be accepted as an estimator for the combined performance of several time periods.

The chi-square tests are made using Equations 3-30 through 3-36, producing Matrices (GGG), (TTT), and (PPP), which are summarized in Table 2. Because of the very large chi-square values, the model's ability to estimate individual turning movements and turning movement percentages must be rejected. All of the chi-square values for the ingress-egress estimation can be accepted at a 0.995 confidence level, with degrees of freedom equal to 24, except I_2. The very high chi-square value of I_2 can be attributed to the abnormally high standard deviation of the machine count error of I_2. This demonstrates the effect that the machine count error can have on the model building process. Thus, the model must be rejected as an accurate estimator of turning movements during individual time periods. In this study, however, Matrices (M) and (E) are stored in the computer as the basic model, which will be used with the second set of data.

APPLICATION OF THE MODEL

Any new machine counts taken are adjusted by Matrix (M), and balanced, forming a (MODEL) Matrix (D). This Matrix (D) is multiplied by Matrix (E) forming a (MODEL) Matrix (F). From (MODEL) Marrix (F), an (MODEL) Matrix (G) is computed. (MODEL) Matrix (H) is created by comparing (MODEL) matrices (D) and (G). A chi-square test is performed on the ingress-egress estimation using (MODELS) Matrix (D) and (MODEL) Matrix (F), creating a (MODEL) (GGG). Matrices (GGG) and (H) give the only two validation checks for the performance of the model. A (MODEL) Matrix (PP) is computed from

(MODEL)Matrix (F). If the validation checks are accepted, the turning movement percent estimation is accepted and can be input for NETSIM or some other computer program.

This is precisely what was done with the July, 1976 data collected from the Lincoln and Ludington intersection. The computer input can be found in Appendix C and a summary is given in Table 3 on the next page. The hand-counted ingress-egress movements and the hand-counted turning movements were collected and used in this study. Normally they would not be available. Tables C-5, C-6 and C-7 show Matrices (A), (B), and (T) of the 1976 study. Matrix (B) enters the model, is adjusted by model's Matrix (M), and is balanced to form (MODEL) Matrix (D). Comparing Matrix (M) of the model, with the 1976's error matrix in Table 3, we can see a large change in the mean errors of I_1, I_2, I_3 and E_3. The effects of this change in error will be evaluated at the end of this model production run.

(MODEL) Matrix (D) is multiplied by the regression coefficients matrix, Matrix (E) producing the estimated turning movements for the 1976 study, (MODEL) Matrix (F). Looking at the mean values of (MODEL) Matrix (H), in Table 3, there are two values greater than 5.00% in absolute value. However, they are approximately 5.00%, I_1 being 5.31% and I_1 being -5.78%. The chi-square test for the ingress-egress estimation is made with the results in (MODEL) Matrix (GGG) in Table 3. With the degrees of

TABLE 3
RESULTS OF LINCOLN-LUDINGTON 6/74 MODEL
ESTIMATION OF LINCOLN-LUDINGTON 7/76 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	-5.37	4.21	17.82	1.57	5.57	-1.77	6.42	5.83
STAN:	9.01	14.54	12.42	10.91	8.83	6.71	10.81	10.68

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	5.31	-5.78	-0.11	2.79	-0.54	3.54	-0.15	0.70
STAN:	5.05	6.70	2.56	3.78	3.22	4.25	2.40	4.27

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	16.6	27.3	1.8	4.3	4.4	5.6	1.6	4.0

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	21.3	54.2	24.5	45.2	16.0	38.8	75.9	13.4	10.7	44.5	42.3	13.1
STAN:	4.8	4.6	4.7	4.8	4.1	5.9	4.2	3.3	3.1	5.1	4.5	5.0

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	21.6	57.6	20.8	39.7	15.1	45.2	77.4	12.5	10.1	37.0	43.2	19.8
STAN:	3.9	4.8	5.7	7.1	1.5	6.0	3.3	2.6	2.5	3.3	4.1	2.2

freedom equal to 24, all of the values of the chi-square can be accepted at a confidence level of at least 0.90 except I which was rejected in the original model building. Whether to accept these two checks requires the judgment and needs of the model analyst.

(MODEL) Matrix (PP) is computed next. If the model production data is accepted, this matrix is the primary output. Matrix (P), which will not normally be available, was computed for the 1976 data. The means and standard deviations of these two matrices are summarized in Table 3. Comparing Matrix (P) with Matrix (PP), the largest error in the mean values is an approximate 7.5% overestimation is the percent turning of X_{24}, and X_{41}. Since the operation of the intersection changed little, as shown by comparing Matrix (P), 1974 data, with Matrix (P), 1976 data, this error comes primarily from the difference in the machine count error. However, the error in the percent turning estimation is not large considering the magnitude of the change in the machine count error. The two mean values in (MODEL) Matrix (H), also indicated there would be some error in the estimation.

LINCOLN-LUDINGTON COMBINED DATA MODEL

The two data sets collected at the Lincoln and Ludington intersection were combined to form one data set from which a model was built. Table 4 on the next two pages gives a summary of the results of this model.

The error matrix, Matrix (M) shows the machine count error for the combined model. Matrix (TE) shows that only X_{32} has an estimation error greater than 5.00%. This is due, as was the case previously, to small volumes giving a large percent error. With this fact in mind, the first validation check is accepted.

Looking at Matrix (H), only the mean value of I_2 is greater than 5.00%. The reason is, again, the data from time period 9 from the first set (1974). Note, however, that the mean values of Matrix (H) are much closer to 0. This should be the case if the sample size increases, and the sum of squares error does not increase due to non-linearity of operation. Again, with this fact in mind, the second validation check may be accepted. Comparing the actual percent turning, Matrix (PP), with the estimated percent turning, Matrix (P), in Table 4, there is less than 1.00% difference. Therefore, this validation check is accepted.

The summary of the chi-square test matrices, (GGG) (TTT), and (PPP), are found in Table 4. Because of the very large values of the total chi-square for (TTT) and (PPP), the ability of the model to estimate turning movements and turning movement percentages is rejected. The chi-square values for the ingress-egress estimation is unacceptable for I_1 and I_2. This was the case for the previous model. Since the first model's data is included

TABLE 4

RESULTS OF LINCOLN-LUDINGTON COMBINED DATA MODEL

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	2.90	-1.38	12.64	1.97	5.47	-0.06	3.65	5.78
STAN:	11.60	23.14	10.74	9.31	7.75	7.85	9.98	9.40

(H) INGRESS-EGRESS ESTIMATION ERROR

	I1	I2	I3	I4	E1	E2	E3	E4
MEAN:	-0.18	6.41	0.78	-1.36	-0.09	-1.25	-0.48	-1.17
STAN:	7.94	44.78	4.89	5.95	2.95	3.48	5.21	5.69

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I1	I2	I3	I4	E1	E2	E3	E4
TOTAL CHISQ	45.3	86.5	9.5	14.4	7.3	6.0	13.8	11.0

TABLE 4

(CONT'D)

(TE) TURNING MOVEMENT ESTIMATION ERROR

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	0.8	0.6	0.5	2.0	13.9	1.6	0.4	***	4.5	0.5	1.2	5.9
STAN:	15.8	13.0	17.3	16.8	67.3	25.3	10.9	***	40.5	15.8	16.1	40.9

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	25.5	51.5	23.1	46.2	14.7	39.1	75.8	14.6	9.6	42.0	44.1	13.9
STAN:	6.5	6.6	6.4	8.3	4.6	8.0	5.6	5.3	3.5	8.2	7.9	4.6

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	25.5	51.8	22.8	46.7	14.6	38.7	76.6	14.3	9.2	42.0	44.6	13.4
STAN:	6.2	5.4	5.5	7.4	1.9	7.1	4.6	4.0	2.4	5.4	5.9	2.2

(TTT) CHI-SQUARE TEST TURNING MOVEMENT ESTIMATION

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	45.2	52.4	49.4	54.3	***	94.6	48.7	***	52.6	42.1	39.2	74.1

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
TOTAL CHISQ	18.5	16.5	36.4	52.4	***	77.4	12.6	***	59.7	47.3	44.5	93.9

in the combined data model, the same variables in (GGG) had high chi-square values.

The 1974 data was run through the combined model in the first production run, (MODEL). The 1976 data was run through the combined model in the second production run, (MODEL2). The results are in the summaries of Tables 5 and 6. Since the data of these two sets are embedded in the model, it should accurately estimate the turning movements and the percent turning for both sets.

Looking at (MODEL) Matrix (H), only the mean value of I_2 is greater than 5.00%. This is true, again, because of time period 9. Comparing the estimated turning percent matrix, (MODEL) Matrix (PP) with the actual percent turning matrix Matrix (P), Table 5, there is less than 2.00% difference in the mean values. This is exceptionally good for a production run. Looking at (MODEL2) Matrix (H), Table 6, the only value greater than 5.00% is I_1. The model will iterate without changing the percent turning, as was described in the previous chapter. The iterated values are important if you are interested in specific turning movements. They are not shown in the appendix. Comparing the estimated turning percent matrix, (MODEL2) Matrix (PP), with the actual percent turning matrix, Matrix (P), in Table 6, there is less than 2.00% difference in mean values. This is a considerably better estimation than was given by the first model, as should be expected. The chi-square tests for ingress-egress

TABLE 5

RESULTS OF LINCOLN-LUDINGTON COMBINED DATA MODEL
ESTIMATION OF LINCOLN-LUDINGTON 6/74 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN	8.42	-5.11	9.19	2.23	5.40	1.08	1.80	5.75
STAN:	9.75	26.99	7.90	8.24	7.07	8.41	9.07	8.60

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	-4.64	13.06	2.68	-2.15	-0.83	-2.76	-0.35	-2.89
STAN:	6.68	56.96	5.08	6.54	3.01	3.30	5.84	6.12

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	26.1	71.3	6.0	9.5	4.5	4.7	7.7	7.8

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
MEAN:	28.2	49.6	22.1	46.8	13.9	39.3	75.8	15.3	8.8	40.3	45.3	14.4
STAN:	6.1	7.1	7.2	10.0	4.7	9.3	6.5	6.3	3.6	9.4	9.4	4.2

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	28.4	49.6	22.0	48.4	13.8	37.7	76.3	15.1	8.6	41.4	46.0	12.6
STAN:	5.7	5.2	6.3	8.2	1.8	8.1	5.4	4.7	2.5	6.5	6.7	2.1

TABLE 6

RESULTS OF LINCOLN-LUDINGTON COMBINED DATA MODEL
ESTIMATION OF LINCOLN-LUDINGTON 7/76 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	-5.37	4.21	17.82	1.57	5.57	-1.77	6.42	5.83
STAN:	9.01	14.54	12.42	10.91	8.83	6.71	10.81	10.68

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	6.52	-3.54	-2.08	-0.25	1.02	1.03	-0.69	1.41
STAN:	4.02	5.76	2.83	4.73	2.51	2.35	4.20	3.83

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	19.2	15.1	3.5	4.8	2.8	1.2	6.1	3.2

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	21.3	54.2	24.5	45.2	16.0	38.8	75.9	13.4	10.7	44.5	42.3	13.1
STAN:	4.8	4.6	4.7	4.8	4.1	5.9	4.2	3.3	3.1	5.1	4.5	5.0

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	21.1	54.9	24.0	44.0	15.9	40.1	76.9	13.0	10.1	43.0	42.5	14.5
STAN:	3.8	4.1	3.9	5.1	1.5	5.0	2.8	2.0	2.0	3.0	3.6	1.9

estimation, Matrix (GGG), has, as did the combined model, high values for I_1 and I_2, and acceptable values for the other movements.

The combined model was tested using a third set of data collected at a different intersection. This intersection is Ford Road (M-153) at Newburgh Road in Westland, Michigan. This intersection's location in western Wayne County is shown in Figure 14. Ford Road is a four-lane highway with no exclusive turning lanes. Newburgh Road, which runs north-south, is two-lane with no turn lanes. The intersection is in an urban area and is signalized with no turn phasing. Intersection data was collected on May 10, 1976 from 2:00 PM to 6:00 PM and on May 11, 1976 from 7:00 AM to 9:00 AM. This data was placed in Matrices (A), (B), and (T) as is shown in Tables C-8, C-9 and C-10 respectively.

The actual error matrix, Matrix (M), Table 7, shows a high consistant overcount in all directions. The error, except for I_3, is approximately 10% greater than the error matrix of the combined model. This should cause some error in the results, but as seen with the first model it should not be extremely large.

The machine count data from Ford and Newburgh intersection was run through the combined model in the third production run, (MODEL3). The results are found in Table 7. Looking at (MODEL3) Matrix (H), it is apparent that the model is inappropriate to the data set. There is a large error in I_1 of 50.46%. This error is consistant

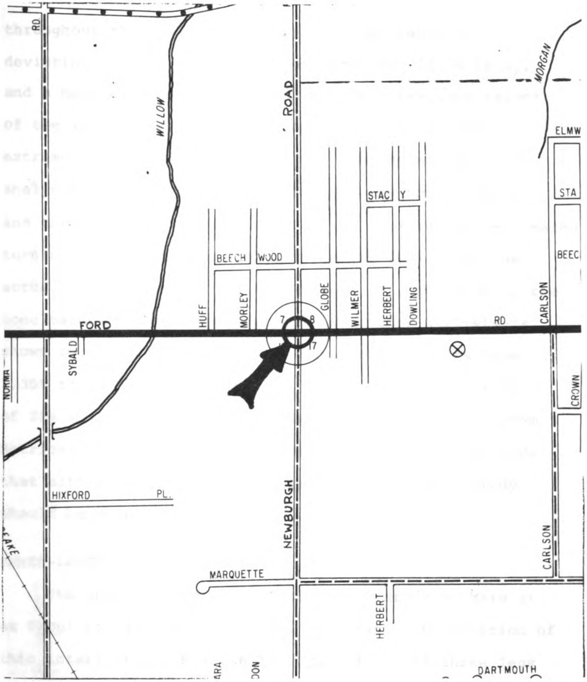


Figure 14

Ford Road and Newburgh Road Intersection throughout the data as shown by the low standard deviation. There is also a mean error of -11.34 in I_2, and a mean error of -17.05 in I_3. The chi-square values of the ingress-egress estimation, Matrix (GGG) are extremely high for I_1, I_2, and I_3. The model based on analysis of ingress-egress estimation, is not suitable and the results should be rejected. Comparing the estimated turning percent matrix, (MODEL3) Matrix (PP), with the actual turning percent matrix, Matrix (P), in Table 7, the conclusion of the ingress-egress estimation analysis is shown to be correct. The estimation error varies from 1.30% to as high as 28.5%, (X_{31}). An estimation error of 28% would generally be unacceptable. Therefore, from Matrices (H) and (GGG), the model analyst would conclude that either another model is needed or more data study should be made.

THREE-LEGGED INTERSECTION CASE STUDY

The three-legged intersection case study is Main St. at Front St. in downtown Niles, Michigan. The location of this intersection is shown in Figure 15. All three legs of the intersection are four-lane with no exclusive turn lanes. The intersection is signalized with no turn phases. The first set of data was collected October 8, 1975 from 2:00 PM to 6:00 PM and on October 9, 1975 from 7:00 AM to 8:00 AM. The second set of data was collected July 10, 1978 from 2:00 PM to 6:00 PM and on July 11, 1978 from 7:00 AM to 9:00 AM.

TABLE 7

RESULTS OF LINCOLN-LUDINGTON COMBINED DATA MODEL
ESTIMATION OF FORD-NEWBURGH 5/76 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	9.68	11.62	11.57	9.78	12.36	13.37	9.66	2.97
STAN:	14.86	14.19	21.59	13.23	18.31	15.99	14.08	12.49

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
MEAN:	50.46	-11.34	-17.05	-5.82	-0.07	-4.62	7.16	3.95
STAN:	10.24	7.37	2.01	2.17	3.99	1.01	4.33	2.68

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
TOTAL CHISQ	533.3	122.3	104.5	20.8	4.1	13.6	18.6	8.5

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:												
STAN:	23.3	61.0	15.8	14.0	15.2	70.9	52.9	31.2	15.8	8.4	79.6	11.9
	6.4	6.7	3.9	2.9	2.5	4.3	5.7	5.4	3.5	2.4	4.9	4.0

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{13}	X_{14}	X_{21}	X_{23}	X_{24}	X_{31}	X_{32}	X_{34}	X_{41}	X_{42}	X_{43}
MEAN:	30.7	44.7	24.6	30.2	13.9	55.9	24.4	42.1	33.5	16.4	67.8	15.7
STAN:	6.8	4.1	4.2	1.6	0.9	2.0	9.1	6.6	3.2	2.4	2.9	0.8

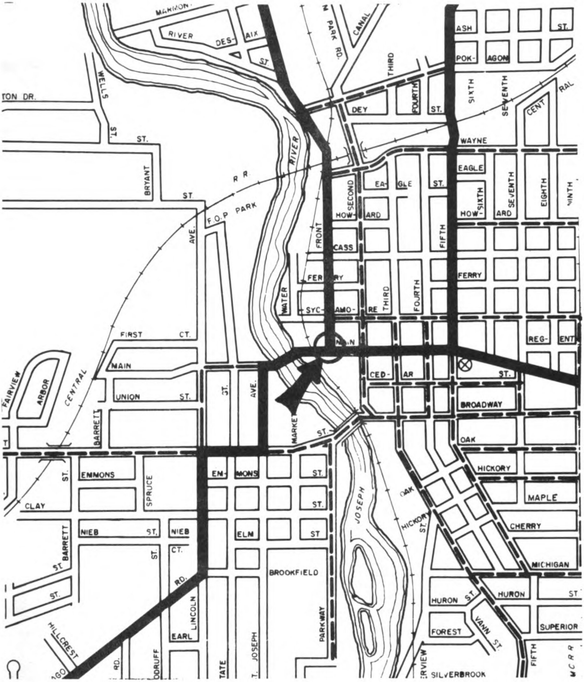


Figure 15

Main Street and Front Street Intersection

The first set of data was used to create the turning movement model shown in Appendix D with a summary in Table 8. Looking at the error matrix, Matrix (M), there are very high Matrix (M), there are extremely high errors for all move-errors for all movements except E_4, which is undercounted by a mean of 9.61%. An analyst should immediately be concerned about such large error, since it shows either large machine inaccuracy or a need to look at the intersection to reevaluate the assumption that there is no storage. However, in studying other three-legged intersections not presented in this thesis, large machine count error has been a typical characteristic. The model has to reiterate in order to reach mean error of less than 5.00% for all movements. Thus, the finished model will have two error matrices. The turning movement estimation error, Matrix (TE), Table 8, shows all mean values less than 2.00%. Thus, the first check is acceptable. The second check, however, of Matrix (H), Table 8, shows large and consistent error in E_2 and in E_4. This can best be explained by the large compensation necessary to force a mean value of approximately zero for the machine counts. The model should be rejected at this point. It will continue to be used, however, as an illustration. Comparison of the estimated turning percent error, Matrix (PP), with the actual turning movement percent error shows that the model is calibrated for its base data. However, it is unlikely the model

TABLE 8

RESULTS OF MAIN-FRONT 10/75 MODEL

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	34.05	15.19	26.68	13.88	26.14	-9.61
STAN:	15.67	16.72	20.85	15.09	24.49	14.99

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	-10.12	-0.50	-5.41	-3.46	-8.50	-2.69
STAN:	8.94	14.14	15.39	13.64	17.00	15.39

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	1.02	0.62	-0.19	-0.01	22.23	-17.04
STAN:	6.86	9.99	7.40	8.46	11.35	5.71

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_4	E_1	E_2	E_4
TOTAL CHISQ	8.9	15.8	4.2	8.4	83.8	69.1

TABLE 8

(CONT'D)

(TE) TURNING MOVEMENT ESTIMATION ERROR

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	0.5	-0.2	0.2	0.0	0.9	1.3
STAN:	14.1	15.4	10.7	17.8	23.2	23.6

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	58.6	41.4	52.3	47.7	28.6	71.4
STAN:	7.0	7.0	7.7	7.7	8.1	8.1

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	58.9	41.1	52.5	47.5	28.2	71.8
STAN:	5.7	5.7	7.3	7.3	6.1	6.1

(TTT) CHI-SQUARE TEST TURNING MOVEMENT ESTIMATION

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
TOTAL CHISQ	20.6	15.9	10.5	19.6	11.7	37.3

(PPP) CHI-SQUARE TEST TURNING MOVEMENT PERCENTAGE ESTIMATION

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
TOTAL CHISQ	9.0	13.5	4.2	5.5	36.5	9.6

will be a good estimator for other data. Matrix (F) was iterated to try and reduce the error in Matrix (G) to less than 5.00% for all mean values. It was unsuccessful in five iterations.

Although the Main-Front model was unacceptable, and should have been rejected, it was stored. The second set of data was input into the model. The results are found in Table 9. Note that the error matrix of the second set of data, Matrix (M), is very different than the model's error matrix. Analyzing (MODEL) Matrix (H), there are four unacceptably high mean error values. Comparing the estimated turning movement percent matrix, (MODEL) Matrix (PP) to the actual turning movement percent matrix, Matrix (P), Table 9, the model did much better than expected. The X_{12} and X_{14} are approximately 7.00% in error. The other movements are less than 2.00% in error. Comparing the two actual turning movement percent matrices in Tables 8 and 9, show that the actual operation of the intersection did not change significantly. Therefore, the model building technique presented in this thesis may be less sensitive to changes in machine count error than it is to changes in operation. This may be why the model performed as well as it did, even though the machine count error changed significantly.

The chi-square values of Matrix (GGG) in Table 9 are unacceptably high and should have indicated that the estimation obtained from the model would be inaccurate.

TABLE 9

RESULTS OF MAIN-FRONT 10/75 MODEL
ESTIMATION OF MAIN-FRONT 7/78 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	8.65	20.52	-7.85	8.69	3.18	4.20
STAN:	21.91	34.46	13.82	26.74	36.44	10.33

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	6.58	-7.03	-3.22	2.95	14.89	-20.72
STAN:	10.83	9.28	6.10	15.64	10.12	6.62

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_4	E_1	E_2	E_4
TOTAL CHISQ	22.2	36.3	6.3	22.1	57.6	120.9

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	61.8	38.2	55.2	44.8	25.1	74.9
STAN:	7.1	7.1	7.2	7.2	9.3	9.3

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	68.6	31.4	54.0	46.0	23.8	76.2
STAN:	9.3	9.3	5.7	5.7	10.0	10.0

The fact that the estimations of percent turning were accurate show the need for development of an accurate error estimator. This is discussed in the next chapter.

MAIN-FRONT COMBINED DATA MODEL

The two data sets were combined and used to create a combined intersection model. Table 10 contains a summary of the model's output. The error matrix, Matrix (M), shows large machine count error, except for E_4, which has an undercount mean of 2.08%. All of the standard deviations are high. The first validation check of Matrix (TE) shows that all of the mean error values are less than 5.00%. As with the previous model, there is unacceptable ingress-egress estimation error, Matrix (H). Even the combined data model would be rejected with this second validation check. However, in comparing the estimated percent turning, Matrix (PP), to the actual percent turning, Matrix (P), the error is less than 1.00% for all values.

As with the four-legged intersection combined model, both sets of data were run through the three-legged combined model. The old data was the first production run, (MODEL 2). The results are in Tables 11 and 12.

In brief, the combined model did very well in estimating the percent turning. In both cases, the estimations were less than 1.00% in error from the actual mean percent turning, despite large Matrix (H) and Matrix (GGG) errors.

TABLE 10

RESULTS OF MAIN-FRONT COMBINED DATA MODEL

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	34.05	15.19	26.68	13.88	26.14	-9.61
STAN:	15.67	16.72	20.85	15.09	24.49	14.99

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	5.76	6.69	3.10	5.63	16.43	-7.21
STAN:	12.54	15.51	9.88	20.53	12.66	4.06

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_4	E_1	E_2	E_3
TOTAL CHISQ	54.4	92.5	19.2	68.4	144.6	33.5

TABLE 10

(CONT'D)

(TE) TURNING MOVEMENT ESTIMATION ERROR

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	3.1	1.0	2.3	2.6	6.2	6.2
STAN:	20.4	17.7	19.0	22.3	33.7	30.8

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	60.3	39.7	53.9	46.1	26.7	73.3
STAN:	7.1	7.1	7.5	7.5	8.9	8.9

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	60.8	39.2	53.9	46.1	25.9	74.1
STAN:	3.9	3.9	6.0	6.0	4.5	4.5

(TTT) CHI-SQUARE TEST TURNING MOVEMENT ESTIMATION

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
TOTAL CHISQ	88.1	45.1	70.2	75.4	62.1	166.4

(PPP) CHI-SQUARE TEST TURNING MOVEMENT PERCENTAGE ESTIMATION

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
TOTAL CHISQ	40.1	49.2	18.1	20.9	109.7	45.5

TABLE 11

RESULTS OF MAIN-FRONT COMBINED DATA MODEL
ESTIMATION OF MAIN-FRONT 10/75 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN	34.05	15.19	26.68	13.88	26.14	-9.61
STAN:	15.67	16.72	20.85	15.09	24.49	14.99

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	-0.23	13.73	-1.72	2.17	17.07	-8.62
STAN:	8.56	15.56	6.84	11.25	9.89	2.94

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_4	E_1	E_2	E_4
TOTAL CHISQ	13.7	54.1	4.7	16.2	58.1	18.2

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	58.6	41.4	52.3	47.7	28.6	71.4
STAN:	7.0	7.0	7.7	7.7	8.1	8.1

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	58.8	41.2	52.8	47.2	27.9	72.1
STAN:	3.4	3.4	6.7	6.7	4.0	4.0

TABLE 12

RESULTS OF MAIN-FRONT COMBINED DATA MODEL
ESTIMATION OF MAIN-FRONT 7/78 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN	8.65	20.52	-7.85	8.69	3.18	4.20
STAN:	21.91	34.46	13.82	26.74	36.44	10.33

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	10.74	0.82	7.11	8.52	15.91	-6.03
STAN:	13.28	13.06	10.34	25.77	14.77	4.52

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I1	I2	I4	E1	E2	E4
TOTAL CHISQ	40.7	38.4	14.5	52.2	86.5	15.3

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	61.8	38.2	55.2	44.8	25.1	74.9
STAN:	7.1	7.1	7.2	7.2	9.3	9.3

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	62.5	37.5	54.9	45.1	24.1	75.9
STAN:	3.5	3.5	5.3	5.3	4.2	4.2

The combined model was tested using a third set of data collected at a different intersection. This intersection is Grand River Avenue at Golf Club Drive just east of Howell, Michigan. Its location is shown in Figure 16. Grand River Avenue is four-lane with no turning lanes. Golf Club Drive is a suburban two-lane with very low volumes. The intersection is not signalized. Data was collected at this intersection February 22, 1977 from 2:00 PM to 6:00 PM and on February 23, 1977 from 7:00 AM to 9:00 AM.

The intersection data was input into the combined model as the third production run, (MODEL 3). This input is in Tables C-7, C-8 and C-9. The output summary is in Table 13. Two differences between the model intersection and the Grand River-Golf Coub intersection are worth noting. The machine count error is significantly different and the operation is very different. The volumes on Golf Club Drive are very low as shown in Table C-7. The mean values of (MODEL 3) Matrix (H) show very large error in I_1 and E_1. The estimations produced from the combined model would be rejected on this basis. In comparing the estimated percent turning, (MODEL 3) Matrix (PP), to the actual percent turning, Matrix (P), Table 13, there is estimation error as high as 19%. The difference in operation and in machine count error was displayed in (MODEL 3) Matrix (H), and proved to be correct. The combined model was not appropriate for this intersection.

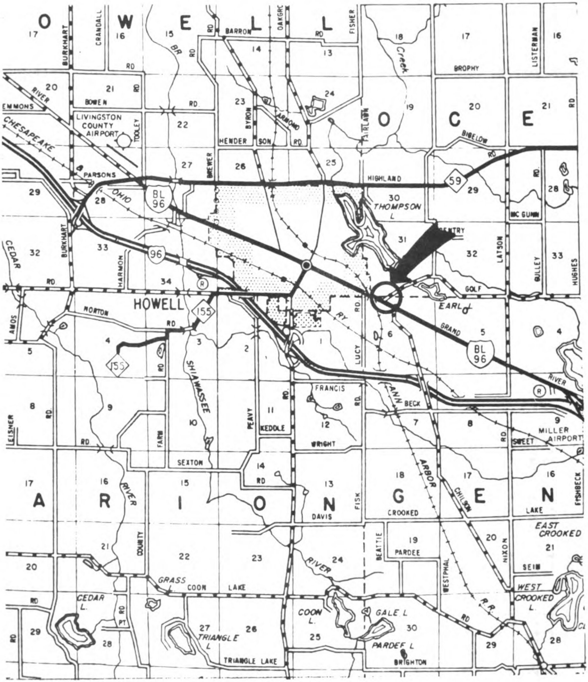


Figure 16

Grand River Ave. and Golf Club Dr. Intersection

TABLE 13

RESULTS OF MAIN-FRONT COMBINED DATA MODEL
ESTIMATION OF GRAND RIVER-GOLF CLUB 2/77 TURNING MOVEMENTS

(M) % ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	7.44	10.52	4.45	-2.21	-4.34	19.87
STAN:	20.63	39.77	10.47	20.77	11.95	34.40

(H) INGRESS-EGRESS ESTIMATION ERROR

	I_1	I_2	I_4	E_1	E_2	E_4
MEAN:	580.90	8.03	-3.82	500.10	41.42	-2.34
STAN:	261.70	7.34	1.88	452.32	21.64	3.03

(GGG) CHI-SQUARE TEST FOR INGRESS-EGRESS ESTIMATION

	I_1	I_2	I_4	E_1	E_2	E_4
TOTAL CHISQ	***	26.0	5.8	791.2	353.7	3.3

(P) ACTUAL TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	16.3	83.7	2.2	97.8	9.6	90.4
STAN:	10.0	10.0	2.1	2.1	5.2	5.2

(PP) ESTIMATED TURNING MOVEMENT PERCENTAGE

	X_{12}	X_{14}	X_{21}	X_{24}	X_{41}	X_{42}
MEAN:	37.8	62.2	21.7	78.3	20.7	79.3
STAN:	7.8	7.8	3.1	3.1	1.5	1.5

This concludes the case studies of the turning movement model theory. In the last chapter, conclusions resulting from these case studies will be presented in detail, as well as recommendations for future study.

Chapter Five

CONCLUSIONS AND RECOMMENDATIONS

The basic purpose of this thesis was to develop an an intersection turning movement modelling technique using linear-regression theory. This chapter presents the conclusions from the study and makes recommendations for future research.

This research has shown that linear regression theory can be used to build an intersection turning movement estimation model. It is important to note that two types of estimation can be made after a predictive model is built. The model can either estimate turning movements for an individual time period or it can estimate the overall turning movements for a sample of individual turning movements. The latter is generally more useful since it is rare that there is interest in one small period of the day. If this is the case, it would generally be more feasible to hand-count turning movements for the short period of time. However, overall turning movement estimation is necessary to many users, as was explained previously.

The linear regression modelling technique demonstrated in this thesis proved to be unsuccessful in accurately estimating turning movements for individual time periods.

This was true due to two factors. First, the machine count error, in general, had very large standard deviations, which caused a large amount of unexplained variance. When the machine count errors vary greatly from time period to time period, it is almost impossible to accurately estimate turning movements. The second factor is the non-linear behavior of the intersection operation.

The linear regression models were more successful in estimating turning movement percentages of the overall samples input into them. Because of the inaccuracies due to machine count error and non-linear behavior just mentioned, this type of overall performance may be the only appropriate estimation function of a linear regression technique. Even these estimations were somewhat inaccurate when the operation of the intersection changed significantly. Therefore, once a model is built, its most useful function may be to help monitor the intersection and detect significant changes in turning movements using only machine traffic counters.

From the study of the three-legged intersections, it can be concluded that the linear regression theory may not be appropriate for this type of intersection for the following reasons:

1) Machine count error at three-legged intersections appears to be larger and more unpredictable than at four-legged intersections,

2) Three-legged intersections, in general, have one leg with much smaller volumes than on the other two legs,

3) With a degree of freedom of only one, it may be more economical to have one person manually count some turning movements at the intersection than to try to build an estimation model.

It is recommended that the study of the regression technique to estimate turning movements from machine counts be pursued further. The lack of data which meets the criteria set forth previously is a major hindrance to future study. It may be worth the effort for a transportation agency to collect future intersection data so as to meet the criteria, enabling the data to be used in future turning movement estimation research.

The effect of machine count error upon turning movement estimation needs to be studied vigorously since, regardless of the estimation technique under study, machine count error has a major effect on accuracy. This effect must be studied further and its effect mitigated. If a technique is to be developed which can estimate turning movements from machine counts at an intersection never before studied, a method of estimating machine count error must be developed. It is also important to detect any changes in machine count error because of changes in traffic mixture, for example, more trucks.

Although the ingress-egress estimation matrix, Matrix (H) and the chi-square matrix, Matrix (GGG), were used as an indication of model performance, further research is needed to provide an accurate estimator of model performance. Since the estimated ingress-egress volumes should equal the volumes entering the linear regression, it should be possible to calibrate the information in Matrices (H) and (GGG), so as to indicate how accurate the model is in estimating turning movements from new data. Research is also needed to calibrate the "acceptance variables" such as the chi-square tests to meet the user's accuracy requirements.

Further research is needed to determine the cause and to measure the magnitude of the non-linear behavior of intersections. The linear regression model theory assumes fairly constant flow into and from the intersection. Time varying flow may cause some of the non-linear behavior. For example, if there are heavy turning volumes in one direction during the AM peak and heavy turning volumes in the other direction during the PM peak, linear regression may not be appropriate. The linear regression theory used in this thesis assumes that the independent variables are non-interacting. (3,11) This assumption is clearly violated since there is a definite relationship expressed in Equation 2-9, namely that the sum of ingress volumes equals the sum of the egress volumes. Further study of the effect of the non-independence of the "independent" variables is strongly recommended.

Further research may be useful in low-volume intersection turning movement estimation, but the linear regression theory presented in this thesis would probably not be appropriate. At low volume intersections, the arrivals are generally Poisson or Erlang distributed for fifteen minute time periods. The assumptions made in this study about machine count error would then probably not be valid. (5, 6)

This research provides the skeleton upon which accurate intersection turning estimation can be built. If the proposed research proves fruitful, the following future operation is envisioned. In the computer, the machine count error estimation program and several standard turning movement models would be stored. Machine counts would be taken at an intersection under study. The machine count error would be estimated and placed in an error matrix, Matrix (M). The machine count tapes would be fed directly into the computer into a Matrix (B). The computer would estimate the turning movements using all of the standard models. The estimates with the least ingress-egress error, Matrix (H), would be used. The model analyst, generally a traffic technician, would have the results in a very short time, and be able to verify or reject the estimates. The output could be used to achieve all the benefits described previously.

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APPENDICES

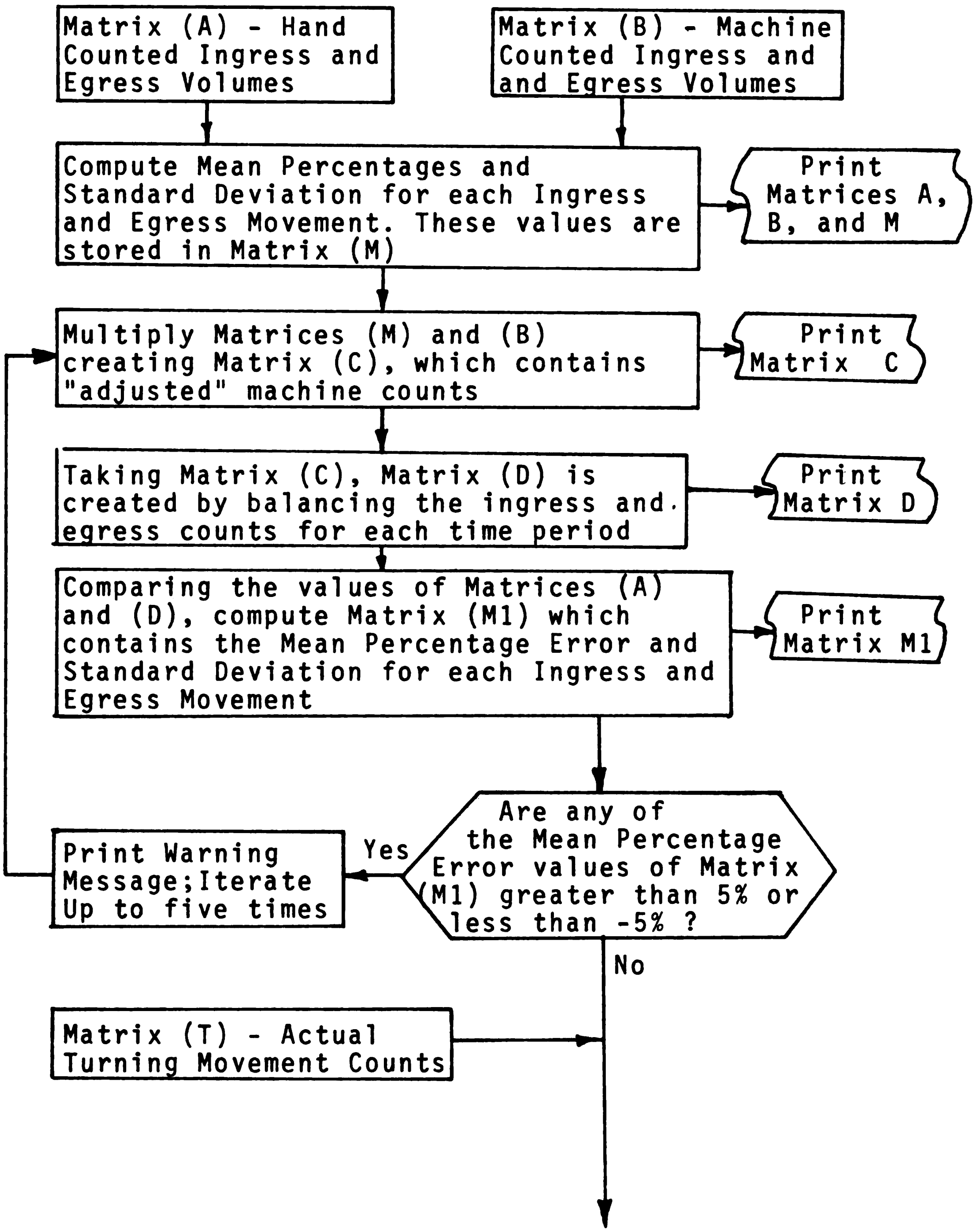
APPENDIX A

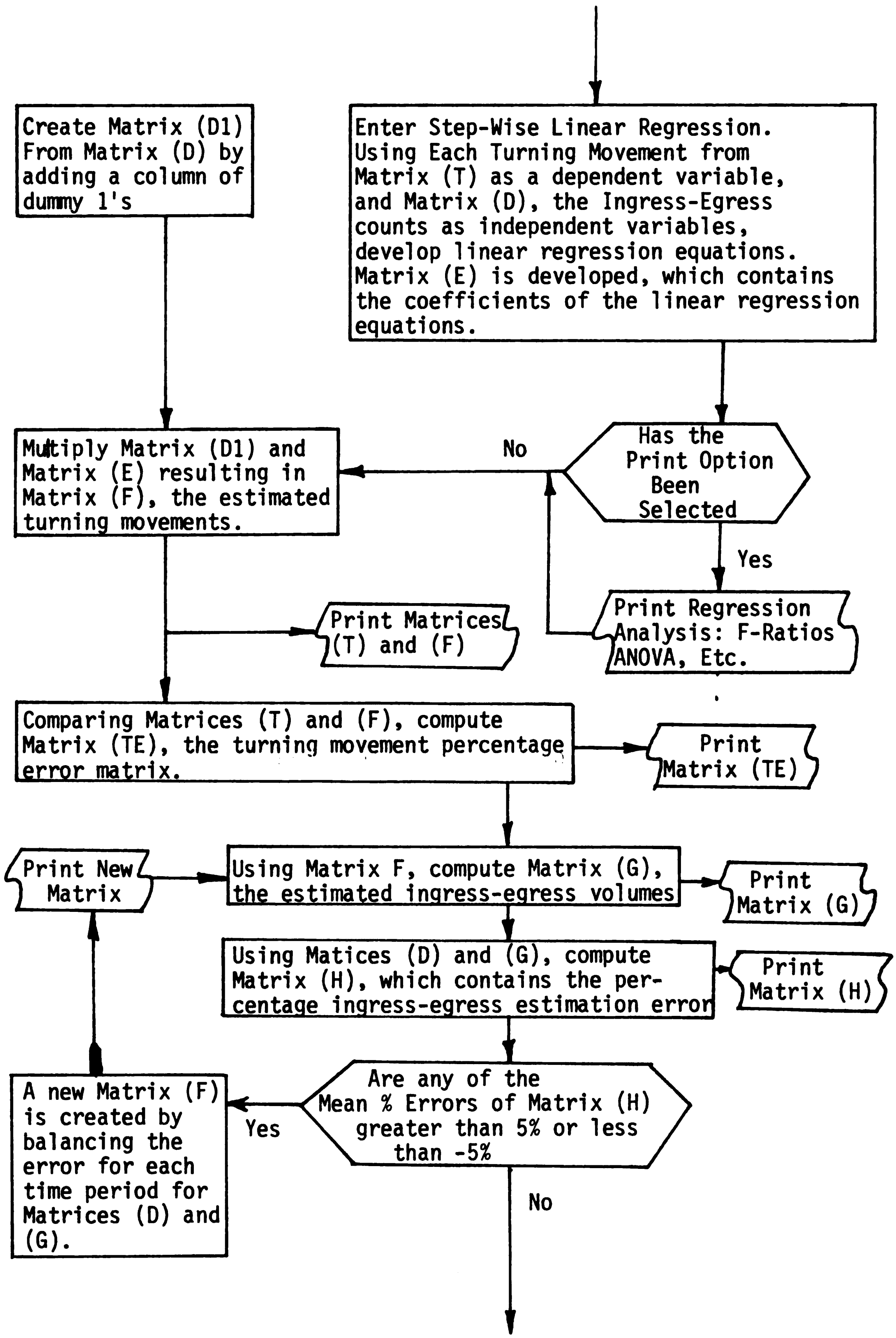
TURNING MOVEMENT MODEL

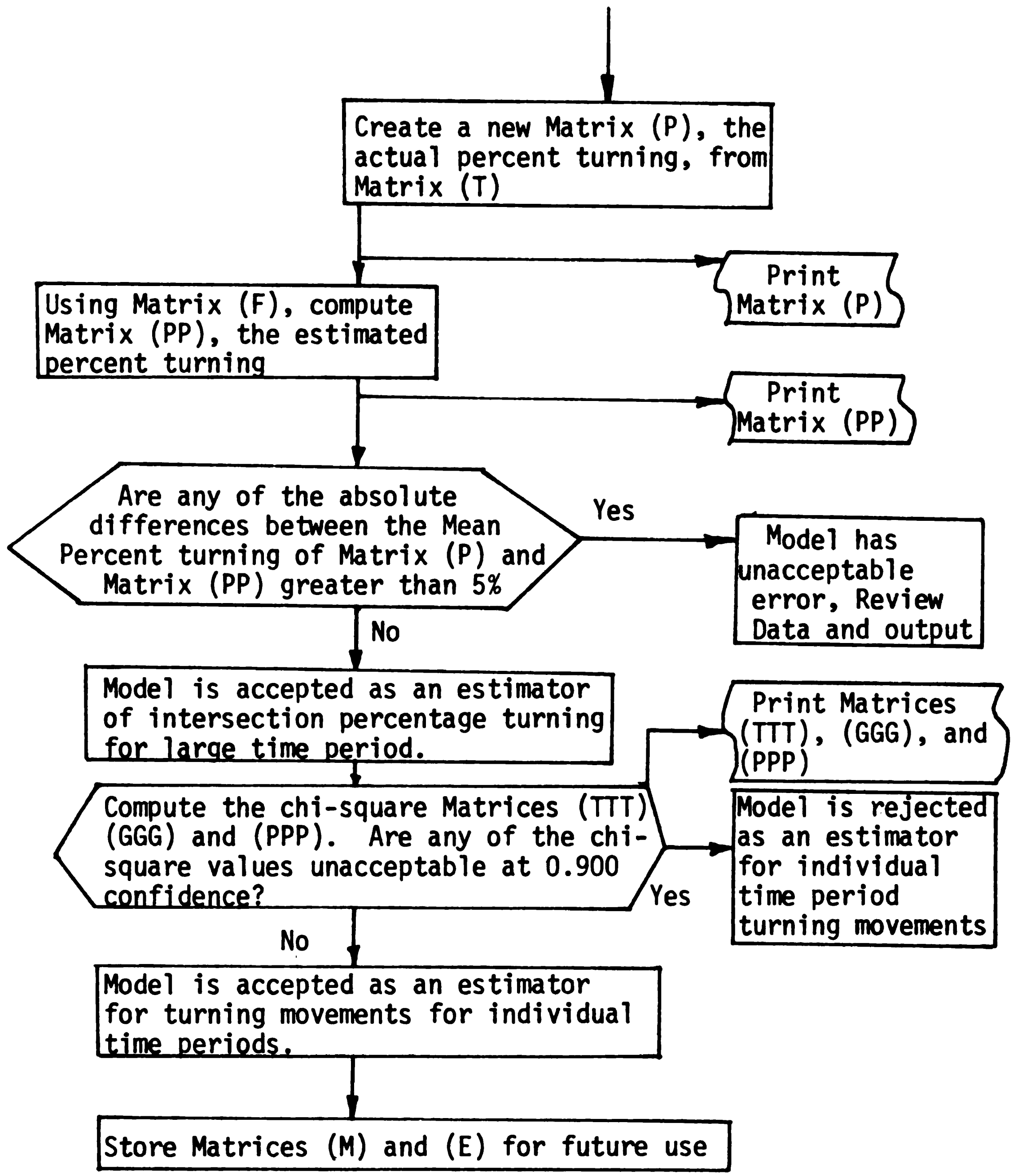
COMPUTER PROGRAM FLOW CHART

AND LISTING

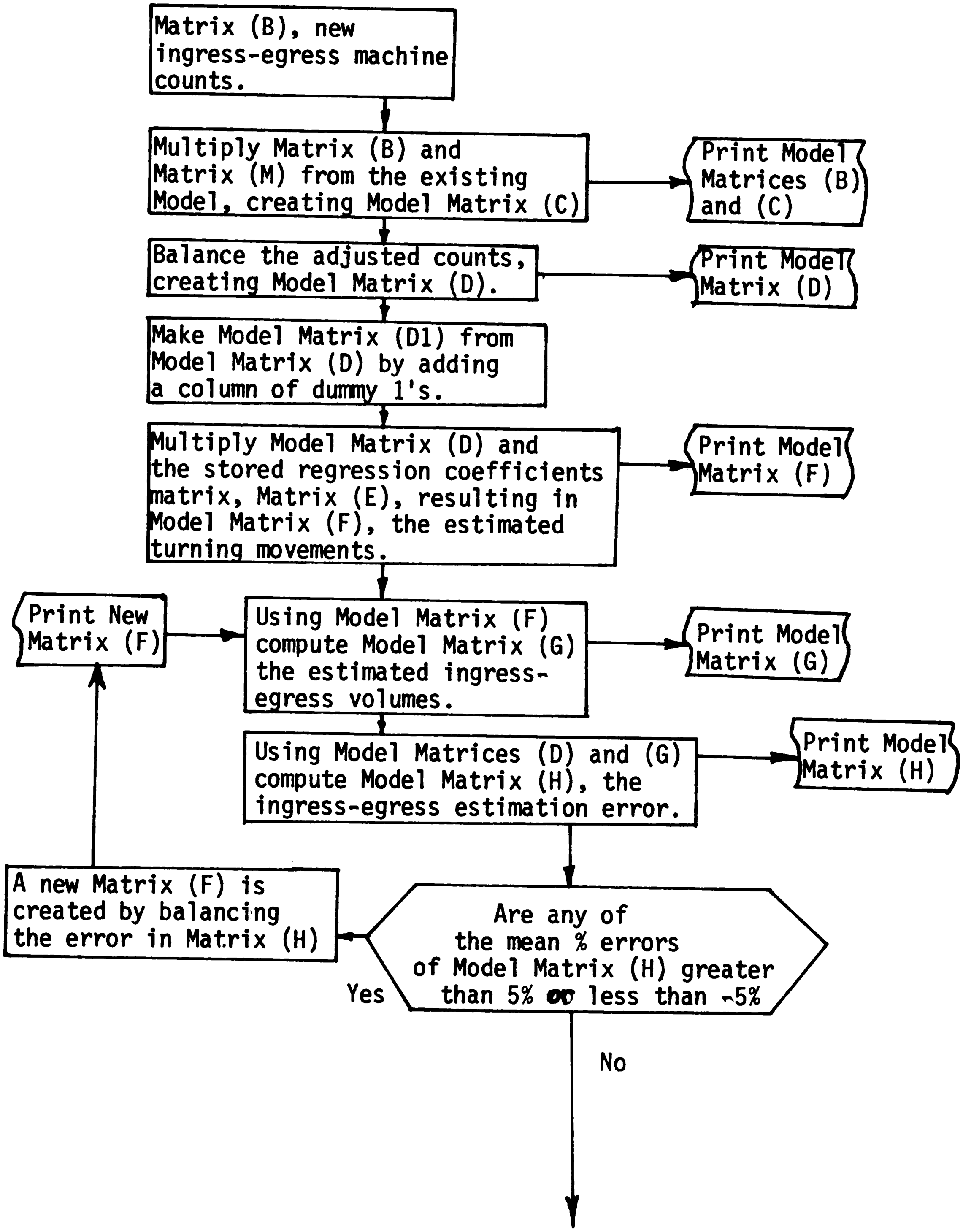
Flow Chart of Creating an Intersection Turning Movement Model

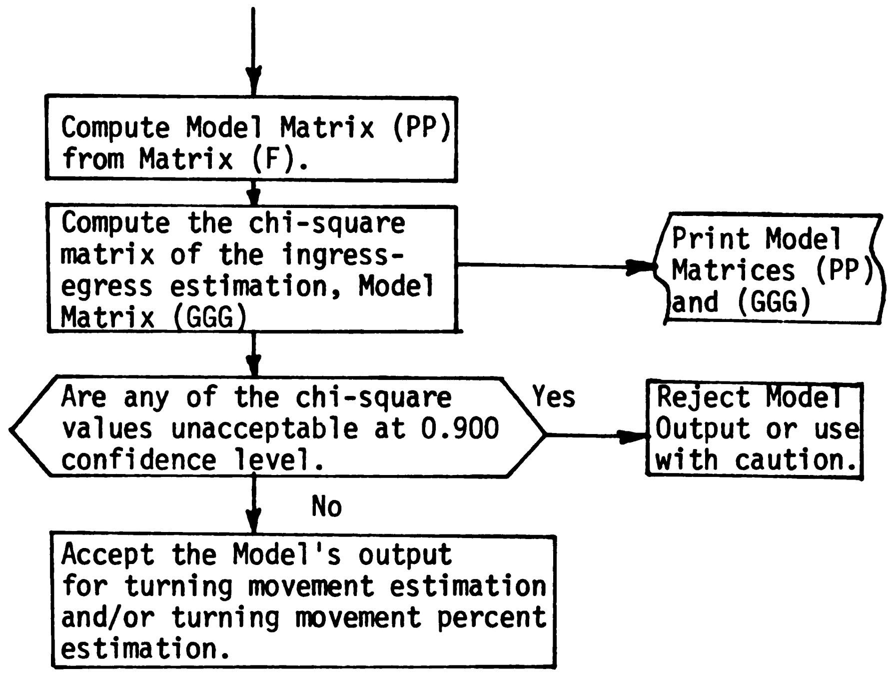



Create Matrix (D1) From Matrix (D) by adding a column of dummy 1's
Enter Step-Wise Linear Regression. Using Each Turning Movement from Matrix (T) as a dependent variable, and Matrix (D), the Ingress-Egress counts as independent variables, develop linear regression equations. Matrix (E) is developed, which contains the coefficients of the linear regression equations.
Mutiply Matrix (D1) and Matrix (E) resulting in Matrix (F), the estimated turning movements.
No
Has the Print Option Been Selected
Yes
Print Regression Analysis: F-Ratios ANOVA, Etc.
Print Matrices (T) and (F)
Comparing Matrices (T) and (F), compute Matrix (TE), the turning movement percentage error matrix.
Print Matrix (TE)
Print New Matrix
Using Matrix F, compute Matrix (G), the estimated ingress-egress volumes
Print Matrix (G)
Using Matices (D) and (G), compute Matrix (H), which contains the percentage ingress-egress estimation error
Print Matrix (H)
A new Matrix (F) is created by balancing the error for each time period for Matrices (D) and (G).
Yes
Are any of the Mean % Errors of Matrix (H) greater than 5% or less than -5%
No


Create a new Matrix (P), the actual percent turning, from Matrix (T)
Print Matrix (P)
Using Matrix (F), compute Matrix (PP), the estimated percent turning
Print Matrix (PP)
Are any of the absolute differences between the Mean Percent turning of Matrix (P) and Matrix (PP) greater than 5%
Yes
Model has unacceptable error, Review Data and output
No
Model is accepted as an estimator of intersection percentage turning for large time period.
Print Matrices (TTT), (GGG), and (PPP)
Compute the chi-square Matrices (TTT) (GGG) and (PPP). Are any of the chi-square values unacceptable at 0.900 confidence?
Yes
Model is rejected as an estimator for individual time period turning movements
No
Model is accepted as an estimator for turning movements for individual time periods.
Store Matrices (M) and (E) for future use

Flow Chart of Using An Existing Turning Movement Model




Compute Model Matrix (PP) from Matrix (F).
Compute the chi-square matrix of the ingress-egress estimation, Model Matrix (GGG)
Print Model Matrices (PP) and (GGG)
Are any of the chi-square values unacceptable at 0.900 confidence level.
Yes
Reject Model Output or use with caution.
No
Accept the Model's output for turning movement estimation and/or turning movement percent estimation.

FORTRAN COMPUTER PROGRAM LISTING

```
 $RESET FREE
FILE  1(TITLE="E/BDF/A",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,MYUSE=IN)
FILE  2(TITLE="E/BDF/B",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,MYUSE=IN)
FILE  3(TITLE="E/BDF/M",KIND=DISK,MAXRECSIZE=24,BLOCKSIZE=360,MYUSE=IO)
FILE  4(TITLE="E/BDF/O",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,MYUSE=IN)
FILE  5(TITLE="E/BDF/T",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,MYUSE=IN)
FILE  6(TITLE="E/BDF/E",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,MYUSE=IO)
FILE  7(KIND=PRINTER,MAXRECSIZE=22)
FILE  8(KIND=REMOTE, MYUSE=IO)
      INTEGER F(100,12),G(100,8),BA(12,100,9),SKNT(12),W(6,6),
     -LX(11),LY(11),LZ(11)
      REAL MEAN(12)
      COMMON E(9,12)
      DIMENSION DD(9,9),XBAR(9),BB(8),SS(8),TT(8),MM(8),LL(9),IDX(9),
     -DDD(7,7),XXBAR(7),BBB(6),SSS(6),TTT(6),MMM(6),LLL(7),IIDX(7),
     -NSTEP(5), ANS(11), SQRBAR(9), STADBR(9), COVARR(9,9), CORELL(9,9),
     -SQBAR(7), STDBAR(7), COVAR(7,7), CORREL(7,7),CHISQ(12), GG(100,8)
C     EQUIVALENCE (DD,DDD), (XBAR,XXBAR), (BB,BBB), (SS,SSS), (TT,TTT),
C    -(MM,MMM), (LL,LLL), (IDX,IIDX)
      DIMENSION A(100,8), B(100,8), C(100,8), D(100,8), C1(100,9),
     -F1(100,4), H(100,8), P(100,12), FP(100,12), T(100,12), TE(100,12),
     -T1(100,4), SUM1(12), SUM2(12), STNDEV(12), DIFF(100), AFILE(1),
     -THEJOB(3), MATRIX(41),PPP(100,12),ZZZ(100,12),GGG(100,8),
     -F01INA(5), F02INA(5), F03INN(5), F04INA(5), F05IAN(5), F06INA(5),
     -F01OUT(5), F02OUT(5), F03OUT(5), F04OUT(5), F05OUT(5), F06OUT(5)
      EQUIVALENCE  (C,C), (B,D), (C,D)
      LOGICAL HERE01,HERE02,HERE03,HERE04,HERE05,HERE06,NORMAL,ITYPE
      DATA LX/2,4,3,5,6,1,2,4,3,5,6/
      DATA LY/1,6,2,4,3,5,1,6,2,4,3/
      DATA LZ/1,2,4,3,5,6,1,2,4,3,5/
      DATA MATRIX/" <A>   <B>   <M>   <C>   <D>   <T>   <T1>  <P>  ",
     -            " <E>   <C1>  <F>   <G>   <H>   <F1>  <FF>  <TE> ",
     -            " <FF1> <FF2> <FF3> <FF4> <FF5> <M2>  <FF2> <PP3>",
     -            " <PF4> <PP5> <F2>  <F3>  <F4>  <F5>  <H2>  <H3> ",
```

```
     -            " <H4>  <H5>  <G2>  <G3>  <G4>  <G5>  <PFP> <TTT>",
     -            " <GGG>"/
      DATA F01INN/"E/BLF/",3*" ","/A."/
      DATA F02INN/"E/BLF/",3*" ","/B."/
      DATA F03INN/"E/BLF/",3*" ","/M."/
      DATA F04INN/"E/BLF/",3*" ","/O."/
      DATA F05INN/"E/BLF/",3*" ","/T."/
      DATA F06INN/"E/BLF/",3*" ","/E."/



C*************************************************************************
C*             S T A R T   O F   M A I N   P R O G R A M                 *
C*************************************************************************
      NONC=0
      NOPFT=0
      TLEG=0; IWARN=0
      WRITE(8,137)
  137 FORMAT("9Which type of Intersection do you wish to work with?",
     -/," Enter:    THREE ... for 3-legged intersection, or",
     -/,11X,"FOUR .... for 4-legged intersection:")
   11 READ(8,737,END=99) TLEG
  737 FORMAT(C1)
      JA = 8
      JC = 12
      IF ( TLEG .EQ. 198 ) GO TO 12               % F = 198
      IF ( TLEG .EQ. 227 ) GO TO 9                % T = 227
      WRITE(8,1437)
 1437 FORMAT(" Please enter: THREE or FOUR ...")
      GO TO 11
    9 JA = 6
      JC = 6
      WRITE(8,1237)
 1237 FORMAT(" For the 3-legged Model, which direction ",
```

```
     -"does not have a leg?",
     -/," Enter:    1 ... for NORTH,",
     -/,11X,"2 ... for EAST,",
     -/,11X,"3 ... for SOUTH, or",
     -/,11X,"4 ... for WEST:")
    8 READ(8,1737,END=99,DATA=7) LEG
 1737 FORMAT(I1)
      IF ( LEG .GE. 1 .AND. LEG .LE. 4 ) GO TO 12
    7 WRITE(8,1637)
 1637 FORMAT(" Please enter one of the following numbers: ",
     -"1, 2, 3, or 4 ...")
      GO TO 8
   12 WRITE(8,237)
  237 FORMAT(" Do you wish to create a new Turning Movement",
     -/," Model, or use an existing one?",
     -/," ENTER:    N ... for NEW model,"
     -/,11X,"O ... for OLD model, or",
     -/,11X,"E ... to  END program:")
    6 READ(8,337,END=99) MTYPE
  337 FORMAT(C1)
      IF(MTYPE.EQ.213) GO TO 14        % N=213
      IF(MTYPE.EQ.214) GO TO 13        % O=214
      IF(MTYPE.EQ.197) GO TO 99        % E=197
      WRITE(8,437)
  437 FORMAT(" Please enter one of the following letters: ",
     -"N, O, or E ...")
      GO TO 6
   13 NORMAL=.TRUE.
   14 WRITE(8,537)
  537 FORMAT(" Enter the JOB DESCRIPTION <up to 17 characters>:")
      READ(8,637) THEJOB
  637 FORMAT(3A6)
      IF(MTYPE.NE.214)WRITE(8,591)
  591 FORMAT(" Do you want the statistical output?",/," ENTER 'O' if YES
```

```
     +",/," ENTER '1' if NO")
      IF(MTYPE.NE.214)READ(8,592) NOPR
  592 FORMAT(I1)
      DO 18 I=2,4
      F01INN(I)=THEJOB(I-1)
      F02INN(I)=THEJOB(I-1)
      F03INN(I)=THEJOB(I-1)
      F04INN(I)=THEJOB(I-1)
      F05INN(I)=THEJOB(I-1)
   18 F06INN(I)=THEJOB(I-1)
C     CALL COMPRS (27,F01INN,F01OUT,0)
C     CALL COMPRS (27,F02INN,F02OUT,0)
C     CALL COMPRS (27,F03INN,F03OUT,0)
C     CALL COMPRS (27,F04INN,F04OUT,0)
C     CALL COMPRS (27,F05INN,F05OUT,0)
C     CALL COMPRS (27,F06INN,F06OUT,0)
      CHANGE(1,TITLE=F01INN)
      INQUIRE(1,RESIDENT=HERE01)
      CHANGE(2,TITLE=F02INN)
      INQUIRE(2,RESIDENT=HERE02)
      CHANGE(3,TITLE=F03INN)
      INQUIRE(3,RESIDENT=HERE03)
      CHANGE(4,TITLE=F04INN)
      INQUIRE(4,RESIDENT=HERE04)
      CHANGE(5,TITLE=F05INN)
      INQUIRE(5,RESIDENT=HERE05)
      CHANGE(6,TITLE=F06INN)
      INQUIRE(6,RESIDENT=HERE06)
      IF(NORMAL) GO TO 566




C*************************************************************************
```

```
C*              S T A R T   O F   N E W   M O D E L   R U N
C**********************************************************************

      IF(HERE01) GO TO 541
      WRITE(8,937) F01OUT
  937 FORMAT(" FILE NAMED: ",5A6,"IS NOT PRESENT.",
     -//," Please check your files and job description before",
     -/," attempting another run on this program. Certain files",
     -/," must be prepared and be available ahead of time. Bye.")
      GO TO 99
  541 IF(HERE02) GO TO 542
      WRITE(8,937) F02OUT
      GO TO 99
  542 IF(HERE05) GO TO 544
      WRITE(8,937) F05OUT
      GO TO 99




C**********************************************************************
C*              S T A R T   O F   P R O D U C T I O N   R U N
C**********************************************************************

  566 IF(HERE04) GO TO 341
      WRITE(8,937) F04OUT
      GO TO 99
  341 IF(HERE03) GO TO 342
      WRITE(8,937) F03OUT
      GO TO 99
  342 IF(HERE06) GO TO 343
      WRITE(8,937) F06OUT
      GO TO 99
  343 CHANGE(6,MYUSE=IN)
```

```
  544 WRITE(8,721) THEJOB
  721 FORMAT(//," JCB CESCRIPTION: ",3A6,"IS NOW EEING PRCCESSED.",//)
      IF(NORMAL) GO TO 374




C***********************************************************************
C*                              READ IN MATRIX <A>                     *
C***********************************************************************

  101 IA = IA + 1
      READ (1,/,END=81) (A(IA,J), J=1,JA)
      GO TO 101
   81 IA = IA - 1
      WRITE (7,1000) THEJOB,MATRIX(1)
 1000 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS MANUAL CCUNTS ",/
     +)
      IF(MTYPE.EQ.214) WRITE(7,9999)
 9999 FORMAT(" <MODEL>",/)
      IF (TLEG.EQ.227) GO TC 401
      WRITE (7,1001)
 1001 FORMAT(4X," TIME  I1    I2    I3    I4    E1    E2    E3    E4",
     +/,4X," PER.")
      GO TO 402
  401 IF(LEG.EQ.1)WRITE(7,4100)
      IF(LEG.EQ.2)WRITE(7,4101)
      IF(LEG.EQ.3)WRITE(7,4102)
      IF(LEG.EQ.4)WRITE(7,4103)
 4100 FORMAT(4X," TIME  I2    I3    I4    E2    E3    E4",/,4X," PER.")
 4101 FORMAT(4X," TIME  I1    I3    I4    E1    E3    E4",/,4X," PER.")
 4102 FORMAT(4X," TIME  I1    I2    I4    E1    E2    E4",/,4X," PER.")
 4103 FORMAT(4X," TIME  I1    I2    I3    E1    E2    E3",/,4X," PER.")
  402 DO 10 K=1,IA
```

```
   10 WRITE (7,2000) K, (A(K,L), L=1,JA)
 2000 FORMAT (4X,I2,1H),8(1X,I5))
      IFILE=2
      GO TO 385




C*************************************************************************
C*                             READ IN MATRIX <B>                        *
C*************************************************************************
  374 IFILE=4
  385 IB = IB + 1
      READ (IFILE,/,END=82) (B(IB,J), J=1,JA)
      GO TO 385
   82 IB = IB - 1
      IF(NORMAL) GO TO 375
      IF ( IA.NE.IB ) GO TO 777
  375 IA = IB
      WRITE (7,1002) THEJOB,MATRIX(2)
      IF(MTYPE.EQ.214) WRITE(7,9999)
 1002 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS MACHINE COUNTS ",
     +/)
      IF(TLEG.EQ.227) GO TO 403
      WRITE (7,1001)
      GO TO 404
  403 IF(LEG.EQ.1)WRITE(7,4100)
      IF(LEG.EQ.2)WRITE(7,4101)
      IF(LEG.EQ.3)WRITE(7,4102)
      IF(LEG.EQ.4)WRITE(7,4103)
  404 DO 15 K=1,IA
   15 WRITE (7,2000) K, (B(K,L), L=1,JA)
      IF(NORMAL) GO TO 376

```

```
C*****************************************************************************
C*   COMPUTE MATRIX <M>:   1) MEAN % ERROR;    2) STANDARD DEVIATION   *
C*****************************************************************************

      DO 25 J=1,JA
      SUM1(J) = 0; SUM2(J) = 0
      DO 20 I=1,IA
      SUM1(J) = (B(I,J) - A(I,J)) / A(I,J) * 100 + SUM1(J)
   20 SUM2(J) = ( (B(I,J)-A(I,J)) / A(I,J) * 100 )**2 + SUM2(J)
      MEAN(J) = SUM1(J) / IA
   25 STNDEV(J) = SQRT( (SUM2(J) - IA * MEAN(J)**2) / (IA-1) )
      IF (ILEG.EQ.227)GO TO 405
      WRITE (7,4000) THEJOB,MATRIX(3),(MEAN(IO),IC=1,JA),(STNDEV(IC),
     -IO=1,JA)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 4000 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR MATRIX",//
     +,8X,"      I1      I2      I3      I4      E1      E2      E3      E4",
     -/,2X,"%MEAN",
     -/, 2X,"ERROR  ",4(F7.2),4(F7.2),
     -//,2X,"STAN.",
     -/, 2X,"DEV.   ",4(F7.2),4(F7.2))
      GO TO 406
  405 IF(LEG.EQ.1)WRITE(7,4110)THEJOB,MATRIX(3),(MEAN(IO),IO=1,JA),
     +(STNDEV(IO),IC=1,JA)
      IF(LEG.EQ.2)WRITE(7,4111)THEJOB,MATRIX(3),(MEAN(IO),IO=1,JA),
     +(STNDEV(IO),IC=1,JA)
      IF(LEG.EQ.3)WRITE(7,4112)THEJOB,MATRIX(3),(MEAN(IO),IO=1,JA),
     +(STNDEV(IO),IC=1,JA)
      IF(LEG.EQ.4)WRITE(7,4113)THEJOB,MATRIX(3),(MEAN(IO),IO=1,JA),
     +(STNDEV(IO),IC=1,JA)
 4110 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR MATRIX",//
```

```
     +,8X,"      I2      I3      I4      E2      E3      E4",
     -/,2X,"%MEAN",
     -/, 2X,"ERROR   ",3(F7.2),3(F7.2),
     -//,2X,"STAN.",
     -/, 2X,"DEV.    ",3(F7.2),3(F7.2))
 4111 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR MATRIX",//
     +,8X,"      I1      I3      I4      E1      E3      E4",
     -/,2X,"%MEAN",
     -//,2X,"STAN.",
     -/, 2X,"DEV.    ",3(F7.2),3(F7.2))
 4112 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR MATRIX",//
     +,8X,"      I1      I2      I4      E1      E2      E4",
     -/,2X,"%MEAN",
     -/, 2X,"ERROR   ",3(F7.2),3(F7.2),
     -//,2X,"STAN.",
     -/, 2X,"DEV.    ",3(F7.2),3(F7.2))
 4113 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR MATRIX",//
     +,8X,"      I1      I2      I3      E1      E2      E3",
     -/,2X,"%MEAN",
     -/, 2X,"ERROR   ",3(F7.2),3(F7.2),
     -//,2X,"STAN.",
     -/, 2X,"DEV.    ",3(F7.2),3(F7.2))
  406 CONTINUE

C***********************************************************************
C*                    CREATE DISK FILE OF MATRIX <M>                   *
C***********************************************************************

      IF(HEREO3) OPEN(3)
      IF(HEREO3) PURGE (3)
      CHANGE (3,MYUSE=OUT)
  123 WRITE(3) (MEAN(IC),IO=1,JA), (STADEV(IC),IO=1,JA)
      GO TO 377
```

```
C************************************************************************
C*                          READ IN MATRIX <M>                          *
C************************************************************************

  376 CHANGE (3,MYUSE=IN)
  456 READ(3,END=378) (MEAN(IO),IO=1,JA),(STNDEV(IO),IO=1,JA)




C************************************************************************
C*                           COMPUTE MATRIX <C>                         *
C************************************************************************

  377 DO 35 I=1,IA
      DO 35 J=1,JA
   35 C(I,J) = B(I,J) - ( (MEAN(J) / 100) * B(I,J) )
      WRITE (7,1003) THEJOB,MATRIX(4)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1003 FORMAT ("1",/,1X,4A6," ADJUSTED INGRESS-EGRESS MACHINE",/,25X,
     +" COUNTS",/)
      IF(ILEG.EQ.227)GO TO 407
      WRITE (7,1001)
      GO TO 408
  407 IF(LEG.EQ.1)WRITE(7,4100)
      IF(LEG.EQ.2)WRITE(7,4101)
      IF(LEG.EQ.3)WRITE(7,4102)
      IF(LEG.EQ.4)WRITE(7,4103)
  408 DO 40 K=1,IA
   40 WRITE (7,2000) K, (C(K,L), L=1,JA)
```

```
C*****************************************************************************
C*                              COMPUTE MATRIX <D>                            *
C*****************************************************************************

      DO 60 I=1,IA
  100 SUM3 = 0; SUM4 = 0
      DO 45 J=1,JA/2
      SUM3 = C(I,J) + SUM3
   45 SUM4 = C(I,J+JA/2) + SUM4
      DIFF(I) = SUM3 - SUM4
      IF ( ABS( INT(DIFF(I)) ) .EQ. 1 ) GO TO 200
      IF ( INT(DIFF(I)) .EQ. 0 ) GO TO 60
      DO 50 J=1,JA/2
      D(I,J) = C(I,J) - ( (DIFF(I) / 2) * (C(I,J) / SUM3) )
   50 D(I,J+JA/2) = C(I,J+JA/2)+( (DIFF(I) / 2)*(C(I,J+JA/2) / SUM4) )
      GO TO 100
  200 L = 1; M = 3; N = 4
      IF ( TLEG .EQ. 198 ) GO TO 201
      L = 1; M = 2; N = 3
  201 IF (DIFF(I) .GT. 0) GO TO 300
      L = 5; M = 7; N = 8
      IF ( TLEG .EQ. 198 ) GO TO 300
      L = 4; M = 5; N = 6
  300 DO 55 K=L,M
   55 IF ( D(I,N) .LT. D(I,K) )  N = K
      D(I,N) = D(I,N) - 1
      GO TO 100
   60 CONTINUE
      WRITE (7,1004) THEJOB,MATRIX(5)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1004 FORMAT ("1",/,1X,4A6," ADJUSTED AND BALANCED INGRESS-EGRESS",/,
```

```
     +25X," MACHINE COUNTS",/)
      IF(ILEG.EQ.227)GO TO 410
      WRITE (7,1001)
      GO TO 409
  410 IF(LEG.EQ.1)WRITE(7,4100)
      IF(LEG.EQ.2)WRITE(7,4101)
      IF(LEG.EQ.3)WRITE(7,4102)
      IF(LEG.EQ.4)WRITE(7,4103)
  409 DO 65 K=1,IA
   65 WRITE (7,2000) K, (D(K,L), L=1,JA)
      IF(NORMAL) GO TO 456



C****************************************************************************
C*   COMPUTE MATRIX <M2>:   1) MEAN % ERROR;    2) STANDARD DEVIATION   *
C****************************************************************************

      ISWN=0
      DO 125 J=1,JA
      SUM1(J) = 0; SUM2(J) = 0
      DO 120 I=1,IA
      SUM1(J) = (D(I,J) - A(I,J)) / A(I,J) * 100 + SUM1(J)
  120 SUM2(J) = ( (D(I,J)-A(I,J)) / A(I,J) * 100 )**2 + SUM2(J)
      MEAN(J) = SUM1(J) / IA
      IF(ABS(MEAN(J)).GT.5.00) ISWN=1
  125 STNDEV(J) = SQRT( (SUM2(J) - IA * MEAN(J)**2) / (IA-1) )
      IF (ILEG.EQ.227)GO TO 411
      WRITE (7,4000) THEJOB,MATRIX(22),(MEAN(IO),IO=1,JA),(STNDEV(IO),
     -IO=1,JA)
      IF(MTYPE.EQ.214)WRITE(7,9999)
      IF(MTYPE.EQ.214)WRITE(7,9999)
      GO TO 412
```

```
 411 IF(LEG.EQ.1)WRITE(7,4110)THEJOB,MATRIX(22),(MEAN(IC),IO=1,JA),
    +(STNDEV(IO),IC=1,JA)
     IF(LEG.EQ.2)WRITE(7,4111)THEJOB,MATRIX(22),(MEAN(IC),IO=1,JA),
    +(STNDEV(IO),IC=1,JA)
     IF(LEG.EQ.3)WRITE(7,4112)THEJOB,MATRIX(22),(MEAN(IC),IC=1,JA),
    +(STNDEV(IO),IC=1,JA)
     IF(LEG.EQ.4)WRITE(7,4113)THEJOB,MATRIX(22),(MEAN(IC),IO=1,JA),
    +(STNDEV(IO),IC=1,JA)
     IF(MTYPE.EQ.214)WRITE(7,9999)
     IF(MTYPE.EQ.214)WRITE(7,9999)
 412 IF (ISWN .EQ. 0) GO TC 1179
     IWARN = IWARN + 1
     IF (IWARN .EQ. 1)   WRITE(8,4612)
4612 FORMAT(/," WARNING: First balancing attempt did not correct for",
    -" all",/," mean errors greater than five percent (5%)."
    -/," Program will attempt further balancing.",
    -/," PLEASE STAND BY ...... ",/)
     IF (IWARN .GE. 5)   GC TO 555
     GO TO 123


C*****************************************************************************
C*                            READ IN MATRIX <T>                             *
C*****************************************************************************

1179 IC = IC + 1
     READ (5,/,END=183) (T(IC,J), J=1,JC)
     GO TO 1179
 183 IC = IC - 1
     IF ( IA .NE. IC ) GO TO 666
     WRITE (7,1005) THEJOB,MATRIX(6)
     IF(MTYPE.EQ.214)WRITE(7,9999)
1005 FORMAT ("1",/,1X,4A6," MANUAL TURNING MOVEMENT CCUNTS "
    +,/)
```

```
      IF(TLEG.EQ.227)GO TO 112
      WRITE (7,1006)
 1006 FORMAT(3X," TIME X12  X13  X14  X21  X23  X24  X31  X32  X34  X41
     + X42  X43",/,3X," PER.")
      GO TO 113
  112 IF(LEG.EQ.1)WRITE(7,4200)
      IF(LEG.EQ.2)WRITE(7,4201)
      IF(LEG.EQ.3)WRITE(7,4202)
      IF(LEG.EQ.4)WRITE(7,4203)
 4200 FORMAT(3X," TIME X23  X24  X32  X34  X42  X43",/,3X," PER.")
 4201 FORMAT(3X," TIME X13  X14  X31  X34  X41  X43",/,3X," PER.")
 4202 FORMAT(3X," TIME X12  X14  X21  X24  X41  X42",/,3X," PER.")
 4203 FORMAT(3X," TIME X12  X13  X21  X23  X31  X32",/,3X," PER.")
  113 DO 70 K=1,IA
   70 WRITE (7,9000) K, (T(K,L), L=1,JC)
 9000 FORMAT (4X,I2,1H),12(I5))
      DO 75 I=1,IA
      DO 75 J=1,JC
      IF(T(I,J).LT.0) GO TO 999
   75 IF(T(I,J).EQ.0) T(I,J) = 0.01



C***********************************************************************
C*                        COMPUTE MATRIX <T1>                          *
C***********************************************************************

      IF ( TLEG .EQ. 198) GO TO 331
      DO 34 I=1,IA
      DO 34 K=1,3
   34 T1(I,K) = T(I,2*K-1) + T(I,2*K)
      GO TO 332
  331 DO 33 I=1,IA
      DO 33 K=1,4
```

```
   33 T1(I,K) = T(I,3*K-2) + T(I,3*K-1) + T(I,3*K)
  332 CONTINUE




C*************************************************************************
C*                         COMPUTE MATRIX <P>                            *
C*************************************************************************

      JJ = 3
      IF ( TLEG .EQ. 227 ) JJ = 2
      DO 37 K=1,JA/2
      DO 43 J=JJ*K-(JJ-1),JJ*K
      SUM1(J) = 0; SUM2(J) = 0
      DO 47 I=1,IA
      P(I,J) = T(I,J) / T1(I,K) * 100
      SUM1(J) = P(I,J) + SUM1(J)
   47 SUM2(J) = P(I,J)**2 + SUM2(J)
      MEAN(J) = SUM1(J) / IA
   43 STNDEV(J) = SCRT ( (SUM2(J) - IA * MEAN(J)**2) / (IA-1) )
   37 CONTINUE
      WRITE (7,1007) TFEJOB,MATRIX(8)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1007 FORMAT ("1",/,1X,4A6," %TURNING - MANUAL COLNTS ",/)
      IF(TLEG.EQ.227)GC TO 414
      WRITE (7,1008)
 1008 FORMAT(1X," TIME X12  X13  X14  X21  X23  X24  X31  X32  X34  X41
     + X42  X43",/,1X," PER.")
      GO TO 415
  414 IF(LEG.EQ.1)WRITE (7,4300)
      IF(LEG.EQ.2)WRITE (7,4301)
      IF(LEG.EQ.3)WRITE (7,4302)
      IF(LEG.EQ.4)WRITE (7,4303)
```

```
 4300 FORMAT(1X," TIME  X23   X24   X32   X34   X42   X43",
     +/,1X," PER.")
 4301 FORMAT(1X," TIME  X13   X14   X31   X34   X41   X43",
     +/,1X," PER.")
 4302 FORMAT(1X," TIME  X12   X14   X21   X24   X41   X42",
     +/,1X," PER.")
 4303 FORMAT(1X," TIME  X12   X13   X21   X23   X31   X32",
     +/,1X," PER.")
      DO 54 K=1,IA
   54 WRITE (7,1554) K, (P(K,L), L=1,JC)
 1554 FORMAT (2X,I2,1H),6(F6.1))
      WRITE (7,1654)(MEAN(I), I=1,6),(STNDEV(J),J=1,6)
 1654 FORMAT("OMEAN:",6(F6.1),/," STAN:",6(F6.1))
      GO TO 416
  415 DO 53 K=1,IA
   53 WRITE (7,1550) K, (P(K,L), L=1,JC)
 1550 FORMAT (2X,I2,1H),12(F5.1))
      WRITE (7,1650) MEAN,STNDEV
 1650 FORMAT("OMEAN:",12(F5.1),/," STAN:",12(F5.1))
  416 CONTINUE


C**********************************************************************
C*           LOAD <BA> WITH <D> & <T> FOR INPUT INTO REGRESSION      *
C**********************************************************************

      DO 988 K=1,JC
      DO 988 L=1,IA
      DO 989 M=1,JA
  989 BA(K,L,M) = D(L,M)+.5
  988 BA(K,L,JA+1) = T(L,K)
```

```
C*****************************************************************************
C* B E G I N   M U L T I P L E   R E G R E S S I O N   A N A L Y S I S *
C*****************************************************************************

      DO 111 IX=1,JA+1
      DO 111 IY=1,JC
  111 E(IX,IY) = 0
      NN = IA
      OO=0
      DO 91C II=1,JC
      OO=CO+1
      IF(NOPRT.EQ.1) GC TO 828
      IF(TLEG.EQ.227)GC TO 440
      IF(II.EQ.1)WRITE(7,734)
      IF(II.EQ.2)WRITE(7,735)
      IF(II.EG.3)WRITE(7,736)
      IF(II.EQ.4)WRITE(7,747)
      IF(II.EQ.5)WRITE(7,738)
      IF(II.EQ.6)WRITE(7,739)
      IF(II.EQ.7)WRITE(7,740)
      IF(II.EQ.8)WRITE(7,741)
      IF(II.EQ.9)WRITE(7,742)
      IF(II.EQ.10)WFITE(7,743)
      IF(II.EQ.11)WFITE(7,744)
      IF(II.EQ.12)WRITE(7,745)
  734 FORMAT("1",/," X12")
  735 FORMAT("1",/," X13")
  736 FORMAT("1",/," X14")
  747 FORMAT("1",/," X21")
  738 FORMAT("1",/," X23")
  739 FORMAT("1",/," X24")
  740 FORMAT("1",/," X31")
```

```
 741 FORMAT("1",/," X32")
 742 FORMAT("1",/," X34")
 743 FORMAT("1",/," X41")
 744 FORMAT("1",/," X42")
 745 FORMAT("1",/," X43")
     GO TO 445
6601 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X12")
6602 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X13")
6603 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X14")
6604 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X21")
6605 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X23")
6606 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X24")
6607 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X31")
6608 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X32")
6609 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X34")
6610 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X41")
6611 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X42")
6612 FORMAT ("      I1        I2        I3        I4        E1        E2        E3
   +      E4        X43")
 440 IF(LEG.NE.1)GO TO 441
     IF(II.EQ.1)WRITE(7,738)
     IF(II.EQ.2)WRITE(7,739)
     IF(II.EQ.3)WRITE(7,741)
```

```
      IF(II.EQ.4)WRITE(7,742)
      IF(II.EQ.5)WRITE(7,744)
      IF(II.EQ.6)WRITE(7,745)
  441 IF(LEG.NE.2)GC TC 442
      IF(II.EQ.1)WRITE(7,735)
      IF(II.EQ.2)WRITE(7,736)
      IF(II.EQ.3)WRITE(7,740)
      IF(II.EQ.4)WRITE(7,742)
      IF(II.EQ.5)WRITE(7,743)
      IF(II.EQ.6)WRITE(7,745)
  442 IF(LEG.NE.3)GC TC 443
      IF(II.EQ.1)WRITE(7,734)
      IF(II.EQ.2)WRITE(7,736)
      IF(II.EQ.3)WRITE(7,747)
      IF(II.EQ.4)WRITE(7,739)
      IF(II.EQ.5)WRITE(7,743)
      IF(II.EQ.6)WRITE(7,744)
  443 IF(LEG.NE.4)GC TC 445
      IF(II.EQ.1)WRITE(7,734)
      IF(II.EQ.2)WRITE(7,735)
      IF(II.EQ.3)WRITE(7,747)
      IF(II.EQ.4)WRITE(7,738)
      IF(II.EQ.5)WRITE(7,740)
      IF(II.EQ.6)WRITE(7,741)
  445 CONTINUE
  828 IF ( TLEG .EQ. 227 ) GO TO 9910
      DO 444 IX=1,JA+1
      IDX(IX)=0
      SQRBAR(IX)=0
      XBAR(IX)=0
      DO 444 IXX=1,JA+1
  444 DD(IX,IXX)=0
      DO 920 JJ=1,IA
      DO 920 KK=1,JA+1
```

```
      XBAR(KK)=XBAR(KK)+BA(II,JJ,KK)
  920 SQRBAR(KK)=SQRBAR(KK)+BA(II,JJ,KK)**2
      DO 940 L=1,JA+1
      XBAR(L)=XBAR(L)/NN
  940 STNDBR(L)=SQRT( (SQRBAR(L) - NN * XBAR(L)**2) / (NN-1) )
      IF(NOPRT.EQ.1) GO TO 829
      WRITE(7,6013)
 6013 FORMAT(" MEAN VALUES",/)
      IF (II.EQ.1)WRITE (7,6601)
      IF (II.EQ.2)WRITE (7,6602)
      IF (II.EQ.3)WRITE (7,6603)
      IF (II.EQ.4)WRITE (7,6604)
      IF (II.EQ.5)WRITE (7,6605)
      IF (II.EQ.6)WRITE (7,6606)
      IF (II.EQ.7)WRITE (7,6607)
      IF (II.EQ.8)WRITE (7,6608)
      IF (II.EQ.9)WRITE (7,6609)
      IF (II.EQ.10)WRITE (7,6610)
      IF (II.EQ.11)WRITE (7,6611)
      IF (II.EQ.12)WRITE (7,6612)
      WRITE(7,1246) XBAR
      WRITE(7,6014)
 6014 FORMAT(" STANDARD DEVIATIONS",/)
      IF (II.EQ.1)WRITE (7,6601)
      IF (II.EQ.2)WRITE (7,6602)
      IF (II.EQ.3)WRITE (7,6603)
      IF (II.EQ.4)WRITE (7,6604)
      IF (II.EQ.5)WRITE (7,6605)
      IF (II.EQ.6)WRITE (7,6606)
      IF (II.EQ.7)WRITE (7,6607)
      IF (II.EQ.8)WRITE (7,6608)
      IF (II.EQ.9)WRITE (7,6609)
      IF (II.EQ.10)WRITE (7,6610)
      IF (II.EQ.11)WRITE (7,6611)
```

```
      IF (II.EQ.12)WRITE (7,6612)
      WRITE(7,1246)STNDBR
  829 CONTINUE
 1246 FORMAT(" ",9(/," ",9(F8.2)),/)
      DO 960 I=1,IA
      DO 960 J=1,JA+1
      DO 960 K=1,JA+1
      DD(J,K)=DD(J,K)+((BA(II,I,J)-XBAR(J))*(BA(II,I,K)-XBAR(K)))
      COVARR(J,K)=DD(J,K)/(IA-1)
  960 CORELL(J,K)= COVARR(J,K)/(STNDBR(J)*STNDBR(K))
      IF(NOPRT.EQ.1)GO TO 838
      WRITE(7,6010)
 6010 FORMAT(" COVARIANCE MATRIX ",/)
      IF (II.EQ.1)WRITE (7,6601)
      IF (II.EQ.2)WRITE (7,6602)
      IF (II.EQ.3)WRITE (7,6603)
      IF (II.EQ.4)WRITE (7,6604)
      IF (II.EQ.5)WRITE (7,6605)
      IF (II.EQ.6)WRITE (7,6606)
      IF (II.EQ.7)WRITE (7,6607)
      IF (II.EQ.8)WRITE (7,6608)
      IF (II.EQ.9)WRITE (7,6609)
      IF (II.EQ.10)WRITE (7,6610)
      IF (II.EQ.11)WRITE (7,6611)
      IF (II.EQ.12)WRITE (7,6612)
      WRITE(7,1246) COVARR
      WRITE(7,6011)
 6011 FORMAT(" CORRELATION MATRIX ",/)
      IF (II.EQ.1)WRITE (7,6601)
      IF (II.EQ.2)WRITE (7,6602)
      IF (II.EQ.3)WRITE (7,6603)
      IF (II.EQ.4)WRITE (7,6604)
      IF (II.EQ.5)WRITE (7,6605)
      IF (II.EQ.6)WRITE (7,6606)
```

```
      IF (II.EQ.7)WRITE (7,6607)                                        00071500
      IF (II.EQ.8)WRITE (7,6608)                                        00071600
      IF (II.EQ.9)WRITE (7,6609)                                        00071700
      IF (II.EQ.10)WRITE (7,6610)                                       00071800
      IF (II.EQ.11)WRITE (7,6611)                                       00071900
      IF (II.EQ.12)WRITE (7,6612)                                       00072000
      WRITE(7,1246)CORELL                                               00072100
C     WRITE(7,1246) ((CD(I1,I2),I2=1,7),I1=1,7)                         00072200
  838 CONTINUE                                                          00072300
      IDX(9)=3                                                          00072400
      GO TO 198                                                         00072500
                                                                        00072600
 9910 DO 9444 IX=1,JA+1                                                 00072700
      IIDX(IX)=0                                                        00072800
      SQBAR(IX)=0                                                       00072900
      XXBAR(IX)=0                                                       00073000
      DO 9444 IXX=1,JA+1                                                00073100
 9444 DDD(IX,IXX)=0                                                     00073200
      DO 9920 JJ=1,IA                                                   00073300
      DO 9920 KK=1,JA+1                                                 00073400
      XXBAR(KK)=XXBAR(KK)+BA(II,JJ,KK)                                  00073500
 9920 SQBAR(KK)=SQBAR(KK)+BA(II,JJ,KK)**2                               00073600
      DO 9940 L=1,JA+1                                                  00073700
      XXBAR(L)=XXBAR(L)/NN                                              00073800
 9940 STDBAR(L)=SQRT( (SQBAR(L) - NN * XXBAR(L)**2) / (NN-1) )          00073900
      IF(NOPRT.EQ.1) GO TO 848                                          00074000
      IF(LEG.NE.1)GO TO 450                                             00074100
      IF(II.EQ.1)WRITE(7,6701)                                          00074200
      IF(II.EQ.2)WRITE(7,6702)                                          00074300
      IF(II.EQ.3)WRITE(7,6703)                                          00074400
      IF(II.EQ.4)WRITE(7,6704)                                          00074500
      IF(II.EQ.5)WRITE(7,6705)                                          00074600
      IF(II.EQ.6)WRITE(7,6706)                                          00074700
  450 IF(LEG.NE.2)GO TO 451                                             00074800
```

```
      IF(II.EQ.1)WRITE(7,6707)
      IF(II.EQ.2)WRITE(7,6708)
      IF(II.EQ.3)WRITE(7,6709)
      IF(II.EQ.4)WRITE(7,6710)
      IF(II.EQ.5)WRITE(7,6711)
      IF(II.EQ.6)WRITE(7,6712)
  451 IF(LEG.NE.3)GO TO 452
      IF(II.EQ.1)WRITE(7,6713)
      IF(II.EQ.2)WRITE(7,6714)
      IF(II.EQ.3)WRITE(7,6715)
      IF(II.EQ.4)WRITE(7,6716)
      IF(II.EQ.5)WRITE(7,6717)
      IF(II.EQ.6)WRITE(7,6718)
  452 IF(LEG.NE.4)GO TO 453
      IF(II.EQ.1)WRITE(7,6719)
      IF(II.EQ.2)WRITE(7,6720)
      IF(II.EQ.3)WRITE(7,6721)
      IF(II.EQ.4)WRITE(7,6722)
      IF(II.EQ.5)WRITE(7,6723)
      IF(II.EQ.6)WRITE(7,6724)
  453 CONTINUE
 6701 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X23")
 6702 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X24")
 6703 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X32")
 6704 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X34")
 6705 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X42")
 6706 FORMAT ("        I2              I3              I4              E2
     +         E3              E4              X43")
 6707 FORMAT ("        I1              I3              I4              E1
```

```
     +                E3                  E4                  X13")                                   00078300
6708 FORMAT ("                  I1                  I3                  I4                  E1  00078400
     +                E3                  E4                  X14")                                   00078500
6709 FORMAT ("                  I1                  I3                  I4                  E1  00078600
     +                E3                  E4                  X31")                                   00078700
6710 FORMAT ("                  I1                  I3                  I4                  E1  00078800
     +                E3                  E4                  X34")                                   00078900
6711 FORMAT ("                  I1                  I3                  I4                  E1  00079000
     +                E3                  E4                  X41")                                   00079100
6712 FORMAT ("                  I1                  I3                  I4                  E1  00079200
     +                E3                  E4                  X43")                                   00079300
6713 FORMAT ("                  I1                  I2                  I4                  E1  00079400
     +                E2                  E4                  X12")                                   00079500
6714 FORMAT ("                  I1                  I2                  I4                  E1  00079600
     +                E2                  E4                  X14")                                   00079700
6715 FORMAT ("                  I1                  I2                  I4                  E1  00079800
     +                E2                  E4                  X21")                                   00079900
6716 FORMAT ("                  I1                  I2                  I4                  E1  00080000
     +                E2                  E4                  X24")                                   00080100
6717 FORMAT ("                  I1                  I2                  I4                  E1  00080200
     +                E2                  E4                  X41")                                   00080300
6718 FORMAT ("                  I1                  I2                  I4                  E1  00080400
     +                E2                  E4                  X42")                                   00080500
6719 FORMAT ("                  I1                  I2                  I3                  E1  00080600
     +                E2                  E3                  X12")                                   00080700
6720 FORMAT ("                  I1                  I2                  I3                  E1  00080800
     +                E2                  E3                  X13")                                   00080900
6721 FORMAT ("                  I1                  I2                  I3                  E1  00081000
     +                E2                  E3                  X21")                                   00081100
6722 FORMAT ("                  I1                  I2                  I3                  E1  00081200
     +                E2                  E3                  X23")                                   00081300
6723 FORMAT ("                  I1                  I2                  I3                  E1  00081400
     +                E2                  E3                  X31")                                   00081500
6724 FORMAT ("                  I1                  I2                  I3                  E1  00081600
```

```
     +           E2               E3               X32")
      WRITE(7,9876)
 9876 FORMAT(/,3X," MEAN VALUES")
      WRITE(7,1245) XXEAR
      WRITE(7,9875)
 9875 FORMAT(/,3X," STANDARC DEVIATIONS")
      WRITE(7,1245) STCBAR
 1245 FORMAT(7(/,"0",7(F12.4,3X)),/)
  848 CONTINUE
      DO 9960 I=1,IA
      DO 9960 J=1,JA+1
      DO 9960 K=1,JA+1
      DDD(J,K)=DDD(J,K)+((BA(II,I,J)-XXBAR(J))*(BA(II,I,K)-XXBAR(K)))
      COVAR(J,K)=DDC(J,K)/(IA-1)
 9960 CORREL(J,K)= COVAR(J,K)/(STDBAR(J)*STDBAR(K))
      IF(NOPRT.EQ.1) GC TO 835
      WRITE(7,9874)
 9874 FORMAT(///,3X," COVARIANCE MATRIX")
      WRITE(7,1245) COVAR
      WRITE(7,9873)
 9873 FORMAT(///,3X," CORRELATION MATRIX")
      WRITE(7,1245) COFREL
  835 CONTINUE
      IIDX(7)=3
  198 M=JA+1
      PCT= 0.001   % AJUSTABLE TOLERANCE



C*********************************************************************
C*                    CALL SUBROUTINE STPRG                          *
C*********************************************************************

      IF(TLEG.EQ.198)CALL STPRG (M,NN,ED,XBAR,IDX,PCT,ASTEF,ANS,
```

```
     -MM,BB,SS,TT,LL,IER,II,SKNT,OO,NOFRT,TLEG,LEG)
      IF(TLEG.EQ.227)CALL STPRG (M,NN,COD,XXBAR,IIDX,FCT,NSTEP,ANS,
     -MMM,BBB,SSS,TTT,LLL,IER,II,SKNT,CO,NOPRT,TLEG,LEG)
      IF(IER.NE.0)WRITE(8,119) II
  119 FORMAT(" ***** REGRESSION #",I2," STOPPED - IER NEQ 0 *****")
      IER=0
  910 CONTINUE
      DO 1468 N=1,JC
      IF(NOPRT.EQ.1) GO TO 852
      IF(TLEG.EQ.227) GO TO 850
      IF(N.EQ.1)WRITE(7,734)
      IF(N.EQ.2)WRITE(7,735)
      IF(N.EQ.3)WRITE(7,736)
      IF(N.EQ.4)WRITE(7,747)
      IF(N.EQ.5)WRITE(7,738)
      IF(N.EQ.6)WRITE(7,739)
      IF(N.EQ.7)WRITE(7,740)
      IF(N.EQ.8)WRITE(7,741)
      IF(N.EQ.9)WRITE(7,742)
      IF(N.EQ.10)WRITE(7,743)
      IF(N.EQ.11)WRITE(7,744)
      IF(N.EQ.12)WRITE(7,745)
      GO TO 852
  850 IF(LEG.NE.1)GO TO 851
      IF(N.EQ.1)WRITE(7,738)
      IF(N.EQ.2)WRITE(7,739)
      IF(N.EQ.3)WRITE(7,741)
      IF(N.EQ.4)WRITE(7,742)
      IF(N.EQ.5)WRITE(7,744)
      IF(N.EQ.6)WRITE(7,745)
  851 IF(LEG.NE.2)GO TO 856
      IF(N.EQ.1)WRITE(7,735)
      IF(N.EQ.2)WRITE(7,736)
      IF(N.EQ.3)WRITE(7,740)
```

```
      IF(N.EQ.4)WRITE(7,742)
      IF(N.EQ.5)WRITE(7,743)
      IF(N.EQ.6)WRITE(7,745)
  856 IF(LEG.NE.3)GC TC 853
      IF(N.EQ.1)WRITE(7,734)
      IF(N.EQ.2)WRITE(7,736)
      IF(N.EQ.3)WRITE(7,747)
      IF(N.EQ.4)WRITE(7,739)
      IF(N.EQ.5)WRITE(7,743)
      IF(N.EQ.6)WRITE(7,744)
  853 IF(LEG.NE.4)GC TC 852
      IF(N.EQ.1)WRITE(7,734)
      IF(N.EQ.2)WRITE(7,735)
      IF(N.EQ.3)WRITE(7,747)
      IF(N.EQ.4)WRITE(7,738)
      IF(N.EQ.5)WRITE(7,740)
      IF(N.EQ.6)WRITE(7,741)
  852 CONTINUE
      SPREDY=0
      IF(NOPRT.EQ.1) GC TO 982
      WRITE(7,1935)
 1935 FORMAT(//," TIME           PREDICTED            ACTUAL              RESI
     +DUAL",/," PER.")
  982 CONTINUE
      DO 2480 J=1,IA
      PREDY=0
      DO 3680 I=2,JA+1
 3680 PREDY = PREDY + (E(I,N)*BA(N,J,I-1))
      PREDY = PREDY + E(1,N);     RESID=BA(N,J,JA+1)-PREDY
      IF (NOPRT.EQ.1) GO TO 845
      WRITE(7,4824)J,BA(N,J,JA+1),PREDY,RESID
 4824 FORMAT(1X,I2,")",3(9X,F9.5))
  845 CONTINUE
 2480 SPREDY=SPREDY+ ((PREDY-BA(N,J,JA+1))**2)
```

```
      STDERR= SQRT(SPREDY/(IC-SKNT(N)))
      IF(NOPRT.EQ.1)GO TO 287
      WRITE(7,9456)N,STDERR,SKNT(N)
 9456 FORMAT("OSTANDARD ERROR <MODEL #",I2,"> IS ",F10.5,"  R=",I2)
  287 CONTINUE
 1468 CONTINUE
      GO TO 572




C*****************************************************************************
C*                         READ MATRIX <E>                                   *
C*****************************************************************************
  378 CHANGE(6,MYUSE=IN)
      DO 185 K=1,JA+1
      READ (6,/,END=572) (E(K,J), J=1,6)
      IF ( TLEG .EQ. 198) READ (6,/,END=572) (E(K,J), J=7,12)
  185 CONTINUE




C*****************************************************************************
C*                        WRITE MATRIX <E>                                   *
C*****************************************************************************

  572 WRITE (7,1167) THEJOB,MATRIX(9)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1167 FORMAT ("1",/,1X,4A6," REGRESSION COEFFICIENTS MATRIX "
     +,/)
      IF(TLEG.EQ.227) GO TO 418
      WRITE (7,1168)
 1168 FORMAT("          X12        X13        X14        X21        X23
```

```
    +  X24")
      GO TO 419
  418 IF(LEG.EQ.1)WRITE(7,4310)
      IF(LEG.EQ.2)WRITE(7,4311)
      IF(LEG.EQ.3)WRITE(7,4312)
      IF(LEG.EQ.4)WRITE(7,4313)
 4310 FORMAT("          X23        X24        X32        X34        X42
    +  X43",/)
 4311 FORMAT("          X13        X14        X31        X34        X41
    +  X43",/)
 4312 FORMAT("          X12        X14        X21        X24        X41
    +  X42",/)
 4313 FORMAT("          X12        X13        X21        X23        X31
    +  X32",/)
  419 DO 893 K=1,JA+1
  893 WRITE (7,1354) K, (E(K,L), L=1,6)
      IF(TLEG.EQ.227)GO TO 417
      WRITE (7,1169)
 1169 FORMAT(//,"            X31        X32        X34        X41        X42
    +      X43")
      DO 894 K=1,JA+1
  894 WRITE (7,1354) K, (E(K,L),L=7,12)
 1354 FORMAT (2X,I2,1H),12(1X,F9.5))
  417 IF(NORMAL) GO TO 574
      IF(HERE06) OPEN(6)
      IF(HERE06) PURGE(6)
      CHANGE(6,MYUSE=OLT)
      DO 550 K=1,JA+1
  550 WRITE(6,1366) (E(K,J),J=1,JC)
 1366 FORMAT(3X,5(F10.5,","),F10.5,";",3X)
      LOCK(6)
```

```
C***********************************************************************
C*                           COMPUTE MATRIX <D1>                       *
C***********************************************************************

  574 DO 95 K=1,IA
      D1(K,1) = 1
      DO 95 L=1,JA
   95 D1(K,L+1) = D(K,L)
C     WRITE (7,1000) THEJOB,MATRIX(10)
C     DO 169 K=1,IA
C 169 WRITE (7,2002) K, (D1(K,L), L=1,JA+1)
C2002 FORMAT (/,3X,I2,1H),9X,I1,2X,8(I5,3X))




C***********************************************************************
C*                           COMPUTE MATRIX <F>                        *
C***********************************************************************

      DO 97 IX=1,IA
      DO 97 JX=1,JC
      X = 0
      DO 98 KX=1,JA+1
   98 X = D1(IX,KX) * E(KX,JX) + X
      IF(X.LT.0) X = 0
   97 F(IX,JX) = X
      IFF=IFF+1
      WRITE (7,1172) THEJOB,MATRIX(11)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1172 FORMAT ("1",/,1X,4A6," ESTIMATED TURNING MOVEMENTS ",/)
      IF(TLEG.EQ.227)GO TO 420
      WRITE (7,1216)
```

```
1216 FORMAT(3X," TIME X12  X13  X14  X21  X23  X24  X31  X32  X34  X41
    + X42  X43",/,3X," PER.")
      GO TO 421
 420  IF(LEG.EQ.1)WRITE(7,4320)
      IF(LEG.EQ.2)WRITE(7,4321)
      IF(LEG.EQ.3)WRITE(7,4322)
      IF(LEG.EQ.4)WRITE(7,4323)
4320  FORMAT(3X," TIME X23  X24  X32  X34  X42  X43",/,3X," PER.")
4321  FORMAT(3X," TIME X13  X14  X31  X34  X41  X43",/,3X," PER.")
4322  FORMAT(3X," TIME X12  X14  X21  X24  X41  X42",/,3X," PER.")
4323  FORMAT(3X," TIME X12  X13  X21  X23  X31  X32",/,3X," PER.")
 421  DO 96 K=1,IA
  96  WRITE (7,1555) K, (F(K,L), L=1,JC)
1555  FORMAT (4X,I2,1H),12(I5))


C*************************************************************************
C*   COMPUTE THE CHI-SQUARE VALUES FOR THE TURNING MOVEMENT ESTIMATION   *
C*                         MATRIX <TTT>                                  *
C*************************************************************************


 260  IF(JCHI.EQ.1.OR.MTYPE.EQ.214)GO TO 4427
      ICH11=12
      IF(TLEG.EQ.227) ICH11=6
      DO 4791 ICH12=1,ICH11
      DO 4792 ICHA=1,IA
      ZZZ(ICHA,ICH12)=((F(ICHA,ICH12)-T(ICHA,ICH12))**2)/T(ICHA,ICH12)
      CHISQ(ICH12)=CHISQ(ICH12)+ZZZ(ICHA,ICH12)
4792  CONTINUE
4791  CONTINUE
      WRITE (7,4037) THEJOB,MATRIX(40)
4037  FORMAT("1",/,1X,4A6," TURNING -CHI SQUARE TEST",/)
      IF(MTYPE.EQ.214)WRITE(7,9999)
```

```
      IF(ILEG.EQ.227)GO TO 4724
      WRITE (7,4036)
 4036 FORMAT(1X," TIME  X12   X13   X14   X21   X23   X24   X31   X32
     +X34   X41   X42   X43",/,1X," PER.")
      GO TO 4725
 4724 IF(LEG.EQ.1)WRITE (7,4380)
      IF(LEG.EQ.2)WRITE (7,4381)
      IF(LEG.EQ.3)WRITE (7,4382)
      IF(LEG.EQ.4)WRITE (7,4383)
 4380 FORMAT(1X," TIME  X23   X24   X32   X34   X42   X43",
     +/,1X," PER.")
 4381 FORMAT(1X," TIME  X13   X14   X31   X34   X41   X43",
     +/,1X," PER.")
 4382 FORMAT(1X," TIME  X12   X14   X21   X24   X41   X42",
     +/,1X," PER.")
 4383 FORMAT(1X," TIME  X12   X13   X21   X23   X31   X32",
     +/,1X," PER.")
      IF(ILEG.EQ.227) GO TO 4687
 4725 DO 4719 K=1,IA
 4719 WRITE (7,4558) K, (ZZZ(K,L), L=1,12)
 4558 FORMAT (2X,I2,1H),1X,12(F5.2,1X))
      WRITE (7,4658) (CHISQ(I),I=1,12)
 4658 FORMAT(//," TOTAL",/," CHISQ",12(F5.1,1X))
      GO TO 4688
 4687 DO 4919 KK=1,IA
 4919 WRITE (7,4958) KK, (ZZZ(KK,M), M=1,6)
 4958 FORMAT (2X,I2,1H),6(F5.2,1X))
      WRITE (7,4858) (CHISQ(II),II=1,6)
 4858 FORMAT(//," TOTAL",/," CHISQ",6(F5.1,1X))
 4688 DO 4643 ICHI4 = 1, 12
      CHISQ(ICHI4)=0.
 4643 CONTINUE
      JCHI=1
 4427 ISW2=1
```

```
  488 NONC=NCNO+1
      IF(NCNC.EQ.1) GO TO 499
      IF(NORMAL) GO TO 382



C***************************************************************************
C*                          COMPUTE MATRIX <TE>                            *
C***************************************************************************

      DO 497 J=1,JC
      SUM1(J) = 0;  SUM2(J) = 0
      DO 498 I=1,IA
      TE(I,J) = (F(I,J) - T(I,J)) / T(I,J) * 100
      SUM1(J) = TE(I,J) + SUM1(J)
  498 SUM2(J) = TE(I,J)**2 + SUM2(J)
      MEAN(J) = SUM1(J) / IA
  497 STNDEV(J) = SQRT ( (SUM2(J) - IA * MEAN(J)**2) / (IA-1) )
      WRITE (7,1021) THEJOB,MATRIX(16)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1021 FORMAT ("1",/,1X,4A6," TURNING MOVEMENT %ERROR ",/)
      IF(TLEG.EQ.227)GO TO 430
      WRITE (7,1217)
 1217 FORMAT(1X,"  TIME  X12  X13  X14  X21  X23  X24  X31  X32  X34  X4
     +1  X42  X43",/,1X"  PER.")
      DO 59 K=1,IA
   59 WRITE (7,1444) K, (TE(K,L), L=1,JC)
 1444 FORMAT (4X,I2,1H),12(I5))
      WRITE (7,1651) MEAN,STNDEV
 1651 FORMAT("OMEAN:",12(F5.1),/," STAN:",12(F5.1))
      GO TO 431
  430 IF(LEG.EQ.1)WRITE(7,4400)
      IF(LEG.EQ.2)WRITE(7,4401)
```

```
      IF(LEG.EQ.3)WRITE(7,4402)
      IF(LEG.EQ.4)WRITE(7,4403)
 4400 FORMAT(1X,"  TIME  X23  X24  X32  X34  X42  X43",/,1X"  PER.")
 4401 FORMAT(1X,"  TIME  X13  X14  X31  X34  X41  X43",/,1X"  PER.")
 4402 FORMAT(1X,"  TIME  X12  X14  X21  X24  X41  X42",/,1X"  PER.")
 4403 FORMAT(1X,"  TIME  X12  X13  X21  X23  X31  X32",/,1X"  PER.")
      DO 89 K=1,IA
   89 WRITE (7,8444) K, (TE(K,L), L=1,JC)
 8444 FORMAT (4X,I2,1H),6(I5))
      WRITE (7,8651) (MEAN(I),I=1,6),(STNDEV(J),J=1,6)
 8651 FORMAT("OMEAN:",6(F6.1),/," STAN:",6(F6.1))
  431 CONTINUE
C**********************************************************************
C*                         COMPUTE MATRIX <G>                        *
C**********************************************************************
      KONT = 0
  382 IF ( TLEG .EQ. 198 ) GO TO 1711
      DO 1701 I=1,IA
      GG(I,1) = F(I,1) + F(I,2)
      G (I,1) = F(I,1) + F(I,2)
      GG(I,2) = F(I,3) + F(I,4)
      G (I,2) = F(I,3) + F(I,4)
      GG(I,3) = F(I,5) + F(I,6)                            % FOR 3-LEG MODEL
      G (I,3) = F(I,5) + F(I,6)
      GG(I,4) = F(I,3) + F(I,5)
      G (I,4) = F(I,3) + F(I,5)
      GG(I,5) = F(I,1) + F(I,6)
      G (I,5) = F(I,1) + F(I,6)
      GG(I,6) = F(I,2) + F(I,4)
 1701 G (I,6) = F(I,2) + F(I,4)
      GO TO 1171
 1711 DO 17 I=1,IA
      GG(I,1) = F(I,1) + F(I,2) + F(I,3)
      G (I,1) = F(I,1) + F(I,2) + F(I,3)
```

```
      GG(I,2) = F(I,4) + F(I,5) + F(I,6)
      G (I,2) = F(I,4) + F(I,5) + F(I,6)
      GG(I,3) = F(I,7) + F(I,8) + F(I,9)
      G (I,3) = F(I,7) + F(I,8) + F(I,9)
      GG(I,4) = F(I,10) + F(I,11) + F(I,12)            % FOR 4-LEG MODEL
      G (I,4) = F(I,10) + F(I,11) + F(I,12)
      GG(I,5) = F(I,04) + F(I,07) + F(I,10)
      G (I,5) = F(I,04) + F(I,07) + F(I,10)
      GG(I,6) = F(I,01) + F(I,08) + F(I,11)
      G (I,6) = F(I,01) + F(I,08) + F(I,11)
      GG(I,7) = F(I,02) + F(I,05) + F(I,12)
      G (I,7) = F(I,02) + F(I,05) + F(I,12)
      GG(I,8) = F(I,03) + F(I,06) + F(I,09)
   17 G (I,8) = F(I,03) + F(I,06) + F(I,09)
 1171 IG=IG+1
      IF(IG.EQ.1)WRITE (7,1023) THEJOB,MATRIX(12)
      IF(IG.EQ.2)WRITE (7,1023) THEJOB,MATRIX(35)
      IF(IG.EQ.3)WRITE (7,1023) THEJOB,MATRIX(36)
      IF(IG.EQ.4)WRITE (7,1023) THEJOB,MATRIX(37)
      IF(IG.EQ.5)WRITE (7,1023) THEJOB,MATRIX(38)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1023 FORMAT ("1",/,1X,4A6," ESTIMATED INGRESS-EGRESS COUNTS"
     +,/)
      IF(TLEG.EQ.227)GO TO 432
      WRITE (7,1031)
 1031 FORMAT(1X," TIME     I1     I2     I3     I4     E1     E2     E3     E4"
     +,/,1X," PER.")
      GO TO 433
  432 IF(LEG.EQ.1)WRITE(7,4440)
      IF(LEG.EQ.2)WRITE(7,4441)
      IF(LEG.EQ.3)WRITE(7,4442)
      IF(LEG.EQ.4)WRITE(7,4443)
 4440 FORMAT(1X," TIME     I2     I3     I4     E2     E3     E4",/,1X," PER.
     +")
```

```
4441 FORMAT(1X," TIME      I1     I3     I4     E1     E3     E4",/,1X," PER.
    +")
4442 FORMAT(1X," TIME      I1     I2     I4     E1     E2     E4",/,1X," PER.
    +")
4443 FORMAT(1X," TIME      I1     I2     I3     E1     E2     E3",/,1X," PER.
    +")
 433 DO 57 K=1,IA
  57 WRITE (7,2000) K, (G(K,L), L=1,JA)


C***********************************************************************
C*  COMPUTE THE CHI-SQUARE VALUES FOR THE INGRESS-EGRESS ESTIMATION    *
C*                          MATRIX <GGG>                               *
C***********************************************************************


      IF(KCHI.EQ.1)GO TO 5427
      ICH21=8
      IF(TLEG.EQ.227) ICH21=6
      DO 5791 ICH22=1,ICH21
      DO 5792 ICHA=1,IA
      GGG(ICHA,ICH22)=((GG(ICHA,ICH22)-D(ICHA,ICH22))**2)/GG(ICHA,ICH22)
      CHISQ(ICH22)=CHISQ(ICH22)+GGG(ICHA,ICH22)
5792 CONTINUE
5791 CONTINUE
      WRITE (7,5037) THEJOB,MATRIX(41)
5037 FORMAT("1",/,1X,4A6," IN - EG   -CHI SQUARE TEST",/)
      IF(MTYPE.EQ.214)WRITE(7,9999)
      IF(TLEG.EQ.227)GO TO 5724
      WRITE (7,5036)
5036 FORMAT(1X," TIME      I1     I2     I3     I4     E1     E2     E3    E4"
    +,/,1X," PER.")
      GO TO 5725
5724 IF(LEG.EQ.1)WRITE (7,5380)
```

```
      IF(LEG.EQ.2)WRITE (7,5381)
      IF(LEG.EQ.3)WRITE (7,5382)
      IF(LEG.EQ.4)WRITE (7,5383)
 5380 FORMAT(1X," TIME      I2      I3      I4      E2      E3      E4",/,1X," PER.
     +")
 5381 FORMAT(1X," TIME      I1      I3      I4      E1      E3      E4",/,1X," PER.
     +")
 5382 FORMAT(1X," TIME      I1      I2      I4      E1      E2      E4",/,1X," PER.
     +")
 5383 FORMAT(1X," TIME      I1      I2      I3      E1      E2      E3",/,1X," PER.
     +")
      IF(ILEG.EQ.227) GO TO 5687
 5725 DO 5719 K=1,IA
 5719 WRITE (7,5558) K, (GGG(K,L), L=1,8)
 5558 FORMAT (2X,I2,1H),1X,8(F5.2,1X))
      WRITE (7,5658) (CHISQ(I),I=1,8)
 5658 FORMAT(//," TOTAL",/," CHISQ",8(F5.1,1X))
      GO TO 5688
 5687 DO 5919 K=1,IA
 5919 WRITE (7,5958) K, (GGG(K,L), L=1,6)
 5958 FORMAT (2X,I2,1H),6(F5.2,1X))
      WRITE (7,5858) (CHISQ(I),I=1,6)
 5858 FORMAT(//," TOTAL",/," CHISQ",6(F5.1,1X))
 5688 DO 5643 ICHI4 = 1, 12
      CHISQ(ICHI4)=0.
 5643 CONTINUE
      KCHI=1
 5427 CONTINUE



C***********************************************************************
C*                        COMPUTE MATRIX <H>                           *
C***********************************************************************
```

```
      ISW1=0
      DO 23 J=1,JA
      SUM1(J) = 0; SUM2(J) = 0
      DO 27 I=1,IA
      H(I,J) = ( G(I,J) - D(I,J) ) / D(I,J) * 100
      SUM1(J) = H(I,J) + SUM1(J)
   27 SUM2(J) = H(I,J)**2 + SUM2(J)
      MEAN(J) = SUM1(J) / IA
      IF(ABS(MEAN(J)).GT.5.C0) ISW1=1
   23 STNDEV(J) = SQRT( (SUM2(J) - IA * MEAN(J)**2) / (IA-1) )
      IH=IH+1
      IF(IH.EQ.1)WRITE (7,1032) THEJOB,MATRIX(13)
      IF(IH.EQ.2)WRITE (7,1032) THEJOB,MATRIX(31)
      IF(IH.EQ.3)WRITE (7,1C32) THEJOB,MATRIX(32)
      IF(IH.EQ.4)WRITE (7,1032) THEJOB,MATRIX(33)
      IF(IH.EQ.5)WRITE (7,1C32) THEJOB,MATRIX(34)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 1032 FORMAT ("1",/,1X,4A6," INGRESS-EGRESS %ERROR ",/)
      IF(TLEG.EQ.227)GO TO 434
      WRITE (7,1033)
 1033 FORMAT(2X," TIME  I1     I2     I3     I4     E1     E2     E3
     + E4",/,2X," PER.")
      DO 93 K=1,IA
   93 WRITE (7,9850) K, (H(K,L), L=1,JA)
 9850 FORMAT (2X,I2,1H),8(1X,F6.2))
      WRITE (7,9950) (MEAN(IO),IO=1,JA), (STNDEV(IO),IO=1,JA)
 9950 FORMAT("OMEAN:",8(F7.2,),/," STAN:",8(F7.2))
      GO TO 435
  434 IF(LEG.EQ.1)WRITE(7,4500)
      IF(LEG.EQ.2)WRITE(7,4501)
      IF(LEG.EQ.3)WRITE(7,4502)
      IF(LEG.EQ.4)WRITE(7,4503)
 4500 FORMAT(2X," TIME  I2     I3     I4     E2     E3     E4",/,2X,
     + " PER.")
```

```
 4501 FORMAT(2X," TIME  I1      I3      I4      E1      E3      E4",/,2X,
     + " PER.")
 4502 FORMAT(2X," TIME  I1      I2      I4      E1      E2      E4",/,2X,
     + " PER.")
 4503 FORMAT(2X," TIME  I1      I2      I3      E1      E2      E3",/,2X,
     + " PER.")
      DO 63 K=1,IA
   63 WRITE (7,1850) K, (H(K,L), L=1,JA)
 1850 FORMAT (2X,I2,1H),6(1X,F6.2))
      WRITE (7,1950) (MEAN(IO),IO=1,JA), (STNDEV(IO),IO=1,JA)
 1950 FORMAT("OMEAN:",6(F7.2,),/," STAN:",6(F7.2))
C     IF(TLEG.EQ.227) GO TO 250
  435 IF(ISW1.EQ.0) GO TO 373




C**************************************************************************
C*                       COMPUTE NEW MATRIX <F>          (4-LEG)          *
C**************************************************************************
      DO 703 K=1,IA
      L=0
      DO 702 I=1,JA/2
      DO 701 J=1,JA/2
      IF ( I .EQ. J ) GO TO 701
      L = L + 1
      IF ( F(K,L) .EQ. 0 ) GO TO 701
      F(K,L)=(((D(K,I)-G(K,I))*F(K,L)/G(K,I))+((D(K,J+JA/2)-G(K,J+JA/2))
     &*F(K,L)/G(K,J+JA/2))+(2*F(K,L)))/2.
C     WRITE(8,*/)K,I,J,G(K,I),D(K,I),G(K,J+4),D(K,J+4),F(K,L)
      IF(F(K,L).LT.0) F(K,L) = 0
  701 CONTINUE
  702 CONTINUE
  703 CONTINUE
```

```
      IFF=IFF+1                                                         C0132700
      IF(IFF.EQ.1)WRITE (7,1172) THEJOB,MATRIX(11)                      00132800
      IF(IFF.EQ.2)WRITE (7,1172) THEJOB,MATRIX(27)                      00132900
      IF(IFF.EQ.3)WRITE (7,1172) THEJOB,MATRIX(28)                      00133000
      IF(IFF.EQ.4)WRITE (7,1172) THEJOB,MATRIX(29)                      00133100
      IF(IFF.EQ.5)WRITE (7,1172) THEJOB,MATRIX(30)                      C0133200
      DO 179 K=1,IA                                                     00133300
  179 WRITE (7,1555) K, (F(K,L), L=1,JC)                                00133400
      KONT=KONT+1                                                       00133500
      IF(KONT.EQ.1) GO TO 373                                           C0133600
      IF(KONT-6) 382,888,888                                            C0133700
                                                                        00133800
                                                                        C0133900
C***********************************************************************00134000
C*                    COMPUTE NEW MATRIX <F>        (3-LEG)            *00134100
C***********************************************************************00134200
                                                                        00134300
                                                                        C0134400
  250 IF(ISW3.EQ.1) GO TO 730                                           00134500
      ISW3=1                                                            00134600
      DO 251 K=1,IA                                                     00134700
                                                                        00134800
      DO 253 L=1,6                                                      C0134900
 253  W(L,L) = F(K,L)                                                   00135000
                                                                        C0135100
      DO 255 I=1,6                                                      00135200
      DO 256 J=1,6                                                      C0135300
  256 W(I,LX(J+I-1)) = D(K,LY(J+I-1)) - W(I,LZ(J+I-1))                  00135400
  255 CONTINUE                                                          00135500
      DO 257 N=1,6                                                      C0135600
      F(K,N) = 0                                                        00135700
      DO 259 M=1,6                                                      C0135800
  259 F(K,N) = F(K,N) + W(M,N)                                          00135900
      F(K,N) = F(K,N)/6.0                                               C0136000
```

```
  257 IF (F(K,N).LT.0) F(K,N)=0

  251 CONTINUE

      WRITE (7,1172) THEJOB,MATRIX(18)
      DO 679 K=1,IA
  679 WRITE (7,1555) K, (F(K,L), L=1,JC)

      GO TO 260




C***********************************************************************
C*                         COMPUTE MATRIX <F1>                         *
C***********************************************************************
  499 CONTINUE
  373 IF(TLEG.EQ.227) GO TO 730

      DO 73 I=1,IA                                    % FOR 4-LEG MODEL
      DO 73 K=1,4
   73 F1(I,K) = F(I,3*K-2) + F(I,3*K-1) + F(I,3*K)
      GO TO 473

  730 DO 273 I=1,IA                                   % FOR 3-LEG MODEL
      DO 273 K=1,3
  273 F1(I,K) = F(I,2*K-1) + F(I,2*K)

  473 CONTINUE




C***********************************************************************
```

```
C*                        COMPUTE MATRIX <PP>
C*************************************************************************
      IPP=IPP+1
      JJ = 3
      IF ( TLEG .EQ. 227 ) JJ = 2

      DO 77 K=1,JA/2

      DO 83 J=JJ*K-(JJ-1),JJ*K
      SUM1(J) = 0; SUM2(J) = 0

      DO 87 I=1,IA
      PP(I,J) = F(I,J) / F1(I,K) * 100
      SUM1(J) = PP(I,J) + SUM1(J)
   87 SUM2(J) = PP(I,J)**2 + SUM2(J)

      MEAN(J) = SUM1(J) / IA
   83 STNDEV(J) = SQRT ( (SLM2(J) - IA * MEAN(J)**2) / (IA-1) )

   77 CONTINUE
      IF(IPP.EQ.1)WRITE (7,1037) THEJOB,MATRIX(15)
      IF(IPP.EQ.2)WRITE (7,1037) THEJOB,MATRIX(23)
      IF(IPP.EQ.3)WRITE (7,1037) THEJOB,MATRIX(24)
      IF(IPP.EQ.4)WRITE (7,1037) THEJOB,MATRIX(25)
      IF(IPP.EQ.5)WRITE (7,1037) THEJOB,MATRIX(26)
      IF(MTYFE.EQ.214)WRITE(7,9999)
 1037 FORMAT ("1",/,1X,4A6," ESTIMATED %TURNING ",/)
      IF(TLEG.EQ.227)GC TO 424
      WRITE (7,1036)
 1036 FORMAT(1X," TIME X12  X13  X14  X21  X23  X24  X31  X32  X34  X41
     + X42  X43",/,1X," PER.")
      GO TO 425
  424 IF(LEG.EQ.1)WRITE (7,4330)
      IF(LEG.EQ.2)WRITE (7,4331)
```

```
      IF(LEG.EQ.3)WRITE (7,4332)
      IF(LEG.EQ.4)WRITE (7,4333)
 4330 FORMAT(1X," TIME  X23   X24   X32   X34   X42   X43",
     +/,1X," PER.")
 4331 FORMAT(1X," TIME  X13   X14   X31   X34   X41   X43",
     +/,1X," PER.")
 4332 FORMAT(1X," TIME  X12   X14   X21   X24   X41   X42",
     +/,1X," PER.")
 4333 FORMAT(1X," TIME  X12   X13   X21   X23   X31   X32",
     +/,1X," PER.")
      DO 19 K=1,IA
   19 WRITE (7,1558) K, (PP(K,L), L=1,JC)
 1558 FORMAT (2X,I2,1H),6(F6.1))
      WRITE (7,1658) (MEAN(IO),IO=1,JC), (STNDEV(IO),IC=1,JC)
 1658 FORMAT("OMEAN:",6(F6.1),/," STAN:",6(F6.1))
      GO TO 426
  425 DO 94 K=1,IA
   94 WRITE (7,2554) K, (PP(K,L), L=1,JC)
 2554 FORMAT (2X,I2,1H),12(F5.1))
      WRITE (7,2654) (MEAN(IO),IO=1,JC), (STNDEV(IO),IC=1,JC)
 2654 FORMAT("OMEAN:",12(F5.1),/," STAN:",12(F5.1))


C************************************************************************
C*  COMPUTE THE CHI-SQUARE VALUES FOR THE TURNING MOVEMENT PERCENTAGE  *
C*                 ESTIMATION  -  MATRIX <TTT>                         *
C************************************************************************


  426 IF(ICHI.EQ.1.OR.MTYPE.EQ.214)GO TO 427
      ICH1=12
      IF(TLEG.EQ.227) ICH1=6
      DO 791 ICH2=1,ICH1
      DO 792 ICH3=1,IA
```

```
      PPP(ICH3,ICH2)=((PP(ICH3,ICH2)-P(ICH3,ICH2))**2)/P(ICH3,ICH2)
      CHISQ(ICH2)=CHISQ(ICH2)+PPP(ICH3,ICH2)
  792 CONTINUE
  791 CONTINUE
      WRITE (7,7037) THEJOB,MATRIX(39)
      IF(MTYPE.EQ.214)WRITE(7,9999)
 7037 FORMAT("1",/,1X,4A6," %TURNING -CHI SQUARE TEST",/)
      IF(ILEG.EQ.227)GO TO 724
      WRITE (7,2036)
 2036 FORMAT(1X," TIME  X12   X13   X14   X21   X23   X24   X31   X32
     +X34   X41   X42   X43",/,1X," PER.")
      GO TO 725
  724 IF(LEG.EQ.1)WRITE (7,7330)
      IF(LEG.EQ.2)WRITE (7,7331)
      IF(LEG.EQ.3)WRITE (7,7332)
      IF(LEG.EQ.4)WRITE (7,7333)
 7330 FORMAT(1X," TIME  X23   X24   X32   X34   X42   X43",
     +/,1X," PER.")
 7331 FORMAT(1X," TIME  X13   X14   X31   X34   X41   X43",
     +/,1X," PER.")
 7332 FORMAT(1X," TIME  X12   X14   X21   X24   X41   X42",
     +/,1X," PER.")
 7333 FORMAT(1X," TIME  X12   X13   X21   X23   X31   X32",
     +/,1X," PER.")
      IF(ILEG.EQ.227) GO TO 687
  725 DO 719 K=1,IA
  719 WRITE (7,7558) K, (PPP(K,L), L=1,12)
 7558 FORMAT (2X,I2,1H),1X,12(F5.2,1X))
      WRITE (7,7658) (CHISQ(I),I=1,12)
 7658 FORMAT(//," TOTAL",/," CHISQ",12(F5.1,1X))
      GO TO 688
  687 DO 919 K=1,IA
  919 WRITE (7,7958) K, (PPP(K,L), L=1,6)
 7958 FORMAT (2X,I2,1H),6(F5.2,1X))
```

```
      WRITE (7,7858) (CHISQ(I),I=1,6)
 7858 FORMAT(//," TOTAL",/," CHISQ",6(F5.1,1X))
  688 DO 2643 ICHI4 = 1, 12
      CHISQ(ICHI4)=C.
 2643 CONTINUE
      ICHI=1
  427 IF(NONC.EQ.1) GO TO 488
      IF(ISW2.EQ.0.AND.TLEG.EQ.227) GO TO 260

      IF(ISW1.NE.0 .ANC. ISW3.NE.1) GO TO 382
      WRITE(8,1906)
 1906 FORMAT(/," Prcgram rur has been SUCCESSFUL. The lire-printer ",
     -"listing containing",/," data frcm this run will be routed tc ",
     -"you when you sign off. Bye .... ",//)

   99 LOCK(1)
      LOCK(2)
      LOCK(3)
      LOCK(4)
      LOCK(5)
      LOCK(6)

      STOF

  999 WRITE(8,1901)
 1901 FORMAT(/," WARNING: Turning movements CANNOT be less than ",
     -" ZERC (0).",/," Please check your input (MATRIX <T>) ",
     -"before running program again.")
      GO TO 99

  888 WRITE(8,1902)
 1902 FORMAT(/," WARNING: The attempt to balance MATRIX <F> has FAIL",
     -"ED.",/," Program must stop. Please inspect all data.",/," Poss",
     -"ible failure of model itself. GET HUMAN ASSISTANCE.",/)
```

```
      GO TO 99

  777 WRITE(8,1903)
 1903 FORMAT(/," WARNING: The number of records from <A> & <B> are ",
     -"NOT EQUAL.",/," Please check your data files before running ",
     -"program again.")
      GO TO 99

  666 WRITE(8,1904)
 1904 FORMAT(/," WARNING: The number of records from <A> & <T> are ",
     -"NOT EQUAL.",/," Please check your data files before running ",
     -"program again.")
      GO TO 99

  555 WRITE(8,1905)
 1905 FORMAT(/," WARNING: Balancing CANNOT remove a mean error greater",
     -" than FIVE PERCENT (5%).",/," Program must abort. Please check ",
     -" data for a more appropriate model.",/)
      GO TO 99

      END

C***********************************************************************
C*                        END OF HOST PROGRAM                          *
C***********************************************************************



      SUBROUTINE STFRG (M,N,D,XBAR,IDX,PCT,NSTEP,ANS,L,B,S,T,LL,IEF,
     -II,SKNT,OO,NOFRT,TLEG,LEG)

C***********************************************************************
C*                  S U B R O U T I N E   S T F R G                    *
```

```
C*********************************************************************

      COMMON E(9,12)
      DIMENSION D(1),XBAR(1),IDX(1),NSTEP(1),ANS(1),L(1),B(1),S(1),T(1),
     -LL(1)
      INTEGER SKNT(1)
C     DOUBLE PRECISION D,XBAR,ANS,B,S,T,RD,RE
      IER=0
      ONM=N-1
      NFO=0
      NVAR=0
      NSTEP(3)=0
      ANS(3)=0.0
      ANS(4)=0.0
      NSTOP=0


C*********************************************************************
C*   FIND DEPENDENT VARIABLE, NUMBER OF VARIABLES TO BE FORCED TO    *
C*   ENTER IN THE REGRESSION, AND NUMBER OF VARIABLES TO BE DELETED. *
C*********************************************************************

      DO 30 I=1,M
      LL(I)=1
      IF(IDX(I)) 30, 30, 10
   10 IF(IDX(I)-2) 15, 20, 25
   15 NFO=NFO+1
      IDX(NFO)=I
      GO TO 30
   20 NSTEP(3)=NSTEP(3)+1
      LL(I)=-1
      GO TO 30
   25 MY=I
      NSTEP(1)=MY
```

```
      LY=M*(MY-1)
      LYP=LY+MY
      ANS(5)=D(LYP)    % ANS(5) IS TOTAL SUM OF SQUARES
   30 CONTINUE
      IF(NOPRT.EQ.1) GO TO 872
      WRITE(7,810) ANS(5)
  810 FORMAT(//,"OTCTAL SUM OF SQUARES=",F10.4)
  872 CONTINUE
      NSTEP(2)=NFO


C***********************************************************************
C*                    FIND THE MAXIMUM NUMBER OF STEPS                 *
C***********************************************************************

      MX=M-NSTEP(3)-1


C***********************************************************************
C*                      START SELECTION OF VARIABLES                   *
C***********************************************************************
      NNN=0
      DO 140 NL=1,MX
      NNN=NNN+1
      RD=0
C     NFO IS THE NUMBER OF FORCED VARIABLE
      IF(NL-NFO) 35, 35, 55


C***********************************************************************
C*          SELECT NEXT VARIABLE TO ENTER AMONG FORCED VARIABLES       *
C***********************************************************************

   35 DO 50 I=1,NFO
```

```
      K=IDX(I)
      IF(LL(K)) 50, 50, 40
   40 LYP=LY+K
      IP=M*(K-1)+K
      RE=D(LYP)**2/D(IP)
      IF(RD-RE) 45, 50, 50
   45 RD=RE
      NEW=K
   50 CONTINUE
      GO TO 75


C***********************************************************************
C*         SELECT NEXT VARIABLE TO ENTER AMONG NON-FORCED VARIABLES    *
C***********************************************************************

   55 DO 70 I=1,M
      IF(I-MY) 60, 70, 60
   60 IF(LL(I)) 70, 70, 62
   62 LYP=LY+I
      IP=M*(I-1)+I
C     WRITE(8,*/) I,IP,D(IP)
      RE=D(LYP)**2/D(IP)
      IF(RD-RE) 64, 70, 70
   64 RD=RE
      NEW=I
   70 CONTINUE


C***********************************************************************
C*         TEST WHETHER THE PROPORTION OF THE SUM OF SQUARES REDUCED BY *
C*         THE LAST VARIABLE ENTERED IS GREATER THAN OR EQUAL TO THE    *
C*         SPECIFIED PROPORTION                                         *
C***********************************************************************
```

```
 75 IF(RD) 77,77,76
 76 IF(ANS(5)-(ANS(3)+RD))77,77,78
 77 IER=1
    GO TO 150
 78 RE=RD/ANS(5)
    IF(RE-PCT) 150, 80, 80


C*******************************************************************************
C*                 PROPORTION IS GREATER THAN OR EQUAL                        *
C*******************************************************************************

 80 LL(NEW)=0  % TAGS VARIABLE NOT TO BE ENTERED IN NEXT STEP.
    L(NL)=NEW
    ANS(1)=RD  % ANS(1) IS IMPROVEMENT IN UNEXPLAINED VARIANCE
               %        OF ACTUAL VS UNEXPLAINED ERROR.
    ANS(2)=RE  % ANS(2) IS PROPORTION OF TOTAL SUM OF SQUARES REDUCED.
    ANS(3)=ANS(3)+RD % ANS(3) IS CUMMULATIVE SUM OF SQUARES REDUCED
                     %           UP TO THIS STEP.
    IF(ANS(1).EQ.ANS(3)) ANS(1)=0
    RGMSQ=ANS(3)/NL % IS REGRESSION MEAN SQUARE.
    ANS53=ANS(5)-ANS(3) % RESIDUAL SUM OF SQUARES.
    NRES=N-NL-1  % DEGREES OF FREEDOM (RESIDUAL)
    RSMSQ=ANS53/NRES   % RESIDUAL MEAN SQUARE
    ANS(4)=ANS(4)+RE %ANS(4) IS COEFFICIENT OF MULTIPLE DETERMINATION.
    NSTEP(4)=NL  % NUMBER OF THE LAST STEP
    NSTEP(5)=NEW     % NSTEP(5) IS NUMBER OF LAST VARIABLE ENTERED.
    IF(NOPRT.EQ.1) GO TO 887
    IF(TLEG.EQ.227) GO TO 460
    IF (OC.EQ.1) WRITE(7,888)NNN
    IF (OC.EQ.2) WRITE(7,889)NNN
    IF (OC.EQ.3) WRITE(7,890)NNN
    IF (OC.EQ.4) WRITE(7,891)NNN
```

```
      IF (OC.EQ.5) WRITE(7,892)NNN                                     00170100
      IF (OC.EQ.6) WRITE(7,893)NNN                                     00170200
      IF (OC.EQ.7) WRITE(7,894)NNN                                     00170300
      IF (OC.EQ.8) WRITE(7,895)NNN                                     00170400
      IF (OC.EQ.9) WRITE(7,896)NNN                                     00170500
      IF (OC.EQ.10) WRITE(7,897)NNN                                    00170600
      IF (OC.EQ.11) WRITE(7,898)NNN                                    00170700
      IF (OC.EQ.12) WRITE(7,899)NNN                                    00170800
      GO TO 465                                                        00170900
  460 IF(LEG.NE.1)GO TO 462                                            00171000
      IF (OC.EQ.1) WRITE(7,892)NNN                                     00171100
      IF (OC.EQ.2) WRITE(7,893)NNN                                     00171200
      IF (OC.EQ.3) WRITE(7,895)NNN                                     00171300
      IF (OC.EQ.4) WRITE(7,896)NNN                                     00171400
      IF (OC.EQ.5) WRITE(7,898)NNN                                     00171500
      IF (OC.EQ.6) WRITE(7,899)NNN                                     00171600
  462 IF(LEG.NE.2)GO TO 463                                            00171700
      IF (OC.EQ.1) WRITE(7,889)NNN                                     00171800
      IF (OC.EQ.2) WRITE(7,890)NNN                                     00171900
      IF (OC.EQ.3) WRITE(7,894)NNN                                     00172000
      IF (OC.EQ.4) WRITE(7,896)NNN                                     00172100
      IF (OC.EQ.5) WRITE(7,897)NNN                                     00172200
      IF (OC.EQ.6) WRITE(7,899)NNN                                     00172300
  463 IF(LEG.NE.3)GO TO 464                                            00172400
      IF (OC.EQ.1) WRITE(7,888)NNN                                     00172500
      IF (OC.EQ.2) WRITE(7,890)NNN                                     00172600
      IF (OC.EQ.3) WRITE(7,891)NNN                                     00172700
      IF (OC.EQ.4) WRITE(7,893)NNN                                     00172800
      IF (OC.EQ.5) WRITE(7,897)NNN                                     00172900
      IF (OC.EQ.6) WRITE(7,898)NNN                                     00173000
  464 IF(LEG.NE.4)GO TO 465                                            00173100
      IF (OC.EQ.1) WRITE(7,888)NNN                                     00173200
      IF (OC.EQ.2) WRITE(7,889)NNN                                     00173300
      IF (OC.EQ.3) WRITE(7,891)NNN                                     00173400
```

```
      IF (OC.EQ.4) WRITE(7,892)NNN                                      00173500
      IF (OC.EQ.5) WRITE(7,894)NNN                                      00173600
      IF (OC.EQ.6) WRITE(7,895)NNN                                      00173700
  465 CONTINUE                                                          00173800
  888 FORMAT("1",/," X12    STEP  #   ",I2)                             00173900
  889 FORMAT("1",/," X13    STEP  #   ",I2)                             00174000
  890 FORMAT("1",/," X14    STEP  #   ",I2)                             00174100
  891 FORMAT("1",/," X21    STEP  #   ",I2)                             00174200
  892 FORMAT("1",/," X23    STEP  #   ",I2)                             00174300
  893 FORMAT("1",/," X24    STEP  #   ",I2)                             00174400
  894 FORMAT("1",/," X31    STEP  #   ",I2)                             00174500
  895 FORMAT("1",/," X32    STEP  #   ",I2)                             00174600
  896 FORMAT("1",/," X34    STEP  #   ",I2)                             00174700
  897 FORMAT("1",/," X41    STEP  #   ",I2)                             00174800
  898 FORMAT("1",/," X42    STEP  #   ",I2)                             00174900
  899 FORMAT("1",/," X43    STEP  #   ",I2)                             00175000
      WRITE(7,812) FGMSQ,(ANS(JMX),JMX=1,4),NSTEP(5),NSTEP(4),NRES,     00175100
     -ANS53,RSMSQ                                                       00175200
  812 FORMAT(                                                           00175300
     -  "OREGRESSION SUM OF SQUARES=____________________________  ",F10.4,00175400
     -/,"CIMPROVEMENT CF UNEXPLAINED VARIANCE THIS STEP=______  ",F10.4,C00175500
     -/,"OPRCPORTION OF TOTAL SUM OF SCUARES REDUCED=_________  ",F10.4,00175600
     -/,"CCUMULATE SUM OF SCUARES REDUCED TO THIS STEP=_______  ",F10.4,C00175700
     -/,"OCOEFFICIENT CF MULTIPLE DETERMINATION=______________  ",F8.5, C00175800
     -/,"ONUMBER OF LAST VARIABLE ENTERED=____________________  ",I2,   C00175900
     -/,"OREGRESSION DEGREES OF FREEDOM=______________________  ",I2,   00176000
     -/,"ORESIDUAL DEGREES CF FREEDOM=________________________  ",I2,   C00176100
     -/,"ORESIDUAL SUM OF SQUARES=____________________________  ",F10.4,C00176200
     -/,"ORESIDUAL MEAN SCUARE=_______________________________  ",F10.4)C00176300
  887 CONTINUE                                                          C00176400
                                                                        00176500
C***********************************************************************C00176600
C*        COMPUTE MULTIFLE CORRELATION, F-VALUE FOR ANALYSIS OF         *00176700
C*        VARIANCE, AND STANDARD ERROR OF ESTIMATE                      *C00176800
```

```
C*****************************************************************************
     
   85 ANS(6)= SQRT(ANS(4)) % ANS(6) IS MULTIFLE CCRRELATICN COEFFICIENT
      IF(NOPRT.EQ.1) GC TO 272
      WRITE(7,811) ANS(6)
  811 FORMAT(
    -  "OMULTIPLE CORFELATION COEFFICIENT=___________________   ",F8.5)
  272 CONTINUE
      RD=NL
      RE=CNM-RD
      RE=(ANS(5)-ANS(3))/RE
      ANS(7)=(ANS(3)/RC)/RE  % ANS(7) IS F-RATIO
   90 ANS(8)= SQRT(RE)       % ANS(8) IS STANDARD ESTIMATE CF ERROF
      IF(NOPRT.EQ.1) GC TO 678
      WRITE(7,813) ANS(7),ANS(8)
  813 FORMAT(
    -  "OF-RATIO=_______________________________________   ",F8.4,
    -/,"CSTANDARD ESTIMATE OF ERROR=_______________________   ",F8.5)
  678 CONTINUE
     
C*****************************************************************************
C*                  DIVIDE BY THE PIVOTAL ELEMENT                            *
C*****************************************************************************
     
      IP=M*(NEW-1)+NEW
      RD=D(IP)
      LYP=NEW-M
      DO 100 J=1,M
      LYP=LYP+M
      IF(LL(J)) 100, 94, 97
   94 IF(J-NEW) 96, 98, 96
   96 IJ=M*(J-1)+J
      D(IJ)=D(IJ)+D(LYF)*C(LYP)/RD
   97 D(LYP)=D(LYP)/RD
```

```
      GO TO 100
   98 D(IP)=1.0/RD
  100 CONTINUE


C**********************************************************************
C*                    COMPUTE REGRESSION COEFFICIENTS                 *
C**********************************************************************

      LYP=LY+NEW
      B(NL)=D(LYP)
      IF(NOPRT.EQ.1) GO TO 831
      WRITE(7,814) NEW,B(NL)
  831 CONTINUE
      IF(NL-1) 112, 112, 105
  105 ID=NL-1
      DO 110 J=1,ID
      IJ=NL-J
      KK=L(IJ)
      LYP=LY+KK
      B(IJ)=D(LYP)
      DO 110 K=1,J
      IK=NL-K+1
      MK=L(IK)
      LYP=M*(MK-1)+KK
      B(IJ)=B(IJ)-D(LYP)*B(IK) % B(IJ) IS COEFFICIENT
      IF(NOPRT.EQ.1)GO TO 110

  814 FORMAT("0VARIABLE #",I2,"     COEFFICIENT=______________________
     - ",F8.4)
  110 CONTINUE

C**********************************************************************
C*                         COMPUTE INTERCEPT                          *
```

```
C*************************************************************************

  112 ANS(9)=XBAR(MY)
      DO 115 I=1,NL
      KK=L(I)
      ANS(9)=ANS(9)-B(I)*XBAR(KK) % INTERCEPT
      IJ=M*(KK-1)+KK
  114 S(I)=ANS(8)* SQRT(D(IJ)) % S(I) IS PARTIAL REGRESSION COEFFICIENT
      T(I)=B(I)/S(I) % T(I) IS COMPUTED T-VALUE OF  COEFF/STD ERR
      IF(NOPRT.EQ.1)GO TO 115
      WRITE(7,815) L(I),S(I)
  815 FORMAT("0VARIABLE #",I2, "    PARTIAL REGRESSION COEFFICIENT______
     -  ",F8.5)
      WRITE(7,820) ANS(9)
  820 FORMAT(
     - "0INTERCEPT=________________________________________    ",F10.5)
  115 CONTINUE

C*************************************************************************
C*      PERFORM A REDUCTION TO ELIMINATE THE LAST VARIABLE ENTERED       *
C*************************************************************************

      IP=M*(NEW-1)
      DO 130 I=1,M
      IJ=I-M
      IK=NEW-M
      IP=IP+1
      IF(LL(I)) 130, 130, 120
  120 DO 126 J=1,M
      IJ=IJ+M
      IK=IK+M
      IF(LL(J)) 126, 122, 122
  122 IF(J-NEW) 124, 126, 124
  124 D(IJ)=D(IJ)-D(IP)*D(IK)
```

```
  126 CONTINUE
      D(IP)=D(IP)/(-RD)
  130 CONTINUE


C***********************************************************************
C*   ADJUST STANDARD ERROR OF THE ESTIMATE AND MULTIPLE CORRELATION    *
C*   COEFFICIENT                                                        *
C***********************************************************************

      RD=N-NSTEP(4)
      RD=CNM/RD
  132 ANS(10)=SQRT (ABS((1.0-(1.0-ANS(6)**2)*RD)))
  134 ANS(11)=ANS(8)*SQRT(RD)
      IF (NSTEP(3).NE.0) KNT=KNT-1
      IF (NSTEP(5).NE.0) KNT=KNT+1
  140 CONTINUE


C***********************************************************************
C*        LOAD <E> WITH INTERCEPT AND COEFFICIENTS FOR II-TH LOOP       *
C***********************************************************************

  150 E(1,II) = ANS(9)
      DO 222 IY=1,KNT
      E(L(IY)+1,II)=B(IY)
  222 CONTINUE
      SKNT(II)=KNT+1
      RETURN
      END
```

APPENDIX B

TEST PROBLEM

INTERSECTION MODEL

TABLE B-1

TEST MATRIX (A)

INGRESS-EGRESS MANUAL COUNTS

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	125	75	99	74	163	80	75	55
2)	105	53	97	38	127	54	63	49
3)	95	84	84	51	129	71	68	46
4)	108	67	59	32	95	49	82	40
5)	107	66	70	44	114	60	76	37
6)	164	110	113	100	187	102	111	87
7)	167	110	121	95	193	110	101	89
8)	191	139	164	98	235	119	123	115
9)	177	113	119	118	178	122	126	101
10)	149	144	137	107	218	97	118	104
11)	157	252	122	240	116	244	169	242
12)	111	234	117	205	90	213	125	239
13)	116	161	117	136	90	155	115	170
14)	78	166	144	196	109	207	88	180
15)	72	183	101	154	76	161	96	177
16)	110	217	125	162	116	174	118	206
17)	106	164	91	222	80	237	100	166
18)	147	218	112	250	96	257	149	225
19)	119	158	133	217	98	238	121	170
20)	114	177	141	237	100	266	118	185

TABLE B-2

TEST MATRIX (B)
INGRESS-EGRESS MACHINE COUNTS

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	132	60	109	82	168	75	71	66
2)	126	68	96	37	136	57	72	55
3)	96	58	89	46	127	66	63	44
4)	113	62	71	37	105	53	88	38
5)	105	86	67	45	118	54	73	39
6)	160	120	136	99	199	100	124	97
7)	153	115	145	101	213	108	110	99
8)	156	144	173	99	240	113	113	113
9)	125	126	129	107	185	115	119	100
10)	137	125	149	103	208	93	118	94
11)	174	252	130	240	125	215	219	245
12)	151	234	129	205	117	225	156	237
13)	96	161	94	136	83	149	92	157
14)	89	166	155	196	91	205	107	176
15)	82	183	129	154	109	166	105	194
16)	118	257	139	193	144	203	131	226
17)	95	150	94	217	84	253	88	140
18)	143	232	113	260	95	293	148	205
19)	143	203	155	259	110	312	138	190
20)	122	198	141	230	98	267	127	173

TABLE B-3

TEST MATRIX (M)
INGRESS-EGRESS %ERROR MATRIX

	I1	I2	I3	I4	E1	E2	E3	E4
%MEAN ERROR	2.09	3.62	7.92	2.34	6.81	1.63	4.86	1.46
STAN. DEV.	15.28	15.73	10.45	8.19	13.36	10.26	12.90	9.44

TABLE B-4

TEST MATRIX (C)
ADJUSTED INGRESS-EGRESS MACHINE COUNTS

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	129	58	100	80	157	74	68	65
2)	123	66	88	36	127	56	68	54
3)	94	56	82	45	118	65	60	43
4)	111	60	65	36	98	52	84	37
5)	103	83	62	44	110	53	69	38
6)	157	116	125	97	185	98	118	96
7)	150	111	134	99	199	106	105	98
8)	153	139	159	97	224	111	108	111
9)	122	121	119	104	172	113	113	99
10)	134	120	137	101	194	91	112	93
11)	170	243	120	234	116	211	208	241
12)	148	226	119	200	109	221	148	234
13)	94	155	87	133	77	147	88	155
14)	87	160	143	191	85	202	102	173
15)	80	176	119	150	102	163	100	191
16)	116	248	128	188	134	200	125	223
17)	93	145	87	212	78	249	84	138
18)	140	224	104	254	89	288	141	202
19)	140	196	143	253	103	307	131	187
20)	119	191	130	225	91	263	121	170

TABLE B-5

TEST MATRIX (D)

ADJUSTED AND BALANCED INGRESS-EGRESS MACHINE COUNTS

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	128	57	100	80	158	74	68	65
2)	122	65	87	36	128	57	69	55
3)	96	57	83	46	116	64	59	43
4)	111	60	65	36	98	52	84	37
5)	99	80	60	42	114	55	72	40
6)	157	116	126	97	185	98	118	95
7)	152	112	135	100	196	105	103	96
8)	154	140	160	97	222	111	107	111
9)	126	125	123	108	167	110	110	96
10)	134	120	137	100	194	92	113	93
11)	172	245	121	236	116	210	207	240
12)	150	229	120	203	108	218	146	230
13)	94	155	86	132	78	147	88	155
15)	83	181	122	155	99	159	97	186
16)	116	248	128	188	134	200	125	222
17)	94	146	88	214	77	246	83	136
18)	140	223	104	254	89	289	141	202
19)	140	195	142	252	103	308	132	188
20)	118	188	128	221	93	267	123	173

TABLE B-6

TEST MATRIX (M1)

SECOND INGRESS-EGRESS %ERROR MATRIX

	I1	I2	I3	I4	E1	E2	E3	E4
%MEAN ERROR	0.12	-0.01	-0.36	0.12	-0.71	-0.19	-0.39	-0.19
STAN. DEV.	14.89	14.59	10.44	7.77	11.68	10.20	12.39	9.52

TABLE B-7

TEST MATRIX (T)

MANUAL TURNING MOVEMENT COUNTS

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	40	55	30	47	10	18	80	12	7	36	28	10
2)	31	51	23	29	8	16	77	10	10	21	13	4
3)	32	49	14	45	13	26	66	12	6	18	27	6
4)	26	71	11	35	6	26	45	11	3	15	12	5
5)	35	59	13	33	11	22	64	4	2	17	21	6
6)	45	79	40	53	21	36	90	12	11	44	45	11
7)	50	85	32	60	9	41	92	13	16	41	47	7
8)	53	96	42	66	19	54	118	27	19	51	39	8
9)	45	95	37	52	12	49	84	20	15	42	57	19
10)	32	79	38	66	26	52	108	15	14	44	50	13
11)	29	97	31	28	39	185	61	35	26	27	180	33
12)	20	67	24	19	28	187	58	31	28	13	162	30
13)	26	73	17	20	25	116	61	19	37	9	110	17
14)	26	44	8	14	17	135	87	20	37	8	161	27
15)	14	50	8	14	19	150	60	22	19	2	125	27
16)	19	68	23	31	30	156	63	31	31	22	120	20
17)	28	63	15	18	21	125	52	26	13	10	156	16
18)	34	98	15	15	28	175	66	30	16	15	212	23
19)	32	75	12	15	23	120	70	45	18	13	181	23
20)	28	74	12	18	21	138	71	51	19	11	203	23

TABLE B-8

TEST STATISTICAL ANALYSIS
VARIABLE RELATIONSHIP

X12

MEAN VALUES

I1	I2	I3	I4	E1	E2	E3	E4	X12
123.60	144.95	112.75	139.25	128.05	153.35	107.45	131.95	32.25

STANDARD DEVIATIONS

I1	I2	I3	I4	E1	E2	E3	E4	X12
26.15	63.23	27.19	75.13	43.76	83.50	34.13	67.37	10.17

COVARIANCE MATRIX

I1	I2	I3	I4	E1	E2	E3	E4	X12
683.62	440.45	333.84	351.37	652.44	221.52	583.72	351.45	136.74
440.45	3997.73	838.41	4232.86	-793.63	4385.65	1770.50	4159.73	-267.99
333.84	838.41	739.14	889.96	577.17	867.88	477.33	888.67	67.96
351.37	4232.86	889.96	5644.30	-1437.38	6134.07	1839.93	4600.22	-274.22
652.44	-793.63	577.17	-1437.38	1914.89	-1822.23	-17.87	-1071.68	334.83
221.52	4385.65	867.88	6134.07	-1822.23	6972.03	1732.26	4750.81	-302.51
583.72	1770.50	477.33	1839.93	-17.87	1732.26	1164.68	1793.92	-38.07
351.45	4159.73	888.67	4600.22	-1071.68	4750.81	1793.92	4538.58	-330.88
136.74	-267.99	67.96	-274.22	334.83	-302.51	-38.07	-330.88	103.46

TABLE B-8

(CONT'D)

CORRELATION MATRIX

I1	I2	I3	I4	E1	E2	E3	E4	X12
1.00	0.27	0.47	0.18	0.57	0.10	0.65	0.20	0.51
0.27	1.00	0.49	0.89	-0.29	0.83	0.82	0.98	-0.42
0.47	0.49	1.00	0.44	0.49	0.38	0.51	0.49	0.25
0.18	0.89	0.44	1.00	-0.44	0.98	0.72	0.91	-0.36
0.57	-0.29	0.49	-0.44	1.00	-0.50	-0.01	-0.36	0.75
0.10	0.83	0.38	0.98	-0.50	1.00	0.61	0.84	-0.36
0.65	0.82	0.51	0.72	-0.01	0.61	1.00	0.78	-0.11
0.20	0.98	0.49	0.91	-0.36	0.84	0.78	1.00	-0.48
0.51	-0.42	0.25	-0.36	0.75	-0.36	-0.11	-0.48	1.00

TOTAL SUM OF SQUARES= 1965.7500

TABLE B-9

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION

STEP 1

X12 STEP # 1

REGRESSION SUM OF SQUARES=	1112.3854
IMPROVEMENT OF UNEXPLAINED VARIANCE THIS STEP=	0.0000
PROPORTION OF TOTAL SUM OF SQUARES REDUCED=	0.5659
CUMULATE SUM OF SQUARES REDUCED TO THIS STEP=	1112.3854
COEFFICIENT OF MULTIPLE DETERMINATION=	0.56588
NUMBER OF LAST VARIABLE ENTERED=	5
REGRESSION DEGREES OF FREEDOM=	1
RESIDUAL DEGREES OF FREEDOM=	18
RESIDUAL SUM OF SQUARES=	853.3646
RESIDUAL MEAN SQUARE=	47.4091
MULTIPLE CORRELATION COEFFICIENT=	0.75225
F-RATIO=	23.4635
STANDARD ESTIMATE OF ERROR=	6.88543
VARIABLE # 5 COEFFICIENT=	0.1749
INTERCEPT=	9.85978

TABLE B-10

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION

STEP 2

X12 STEP # 2

REGRESSION SUM OF SQUARES=	605.8539
IMPROVEMENT OF UNEXPLAINED VARIANCE THIS STEP=	99.3224
PROPORTION OF TOTAL SUM OF SQUARES REDUCED=	0.0505
CUMULATE SUM OF SQUARES REDUCED TO THIS STEP=	1211.7078
COEFFICIENT OF MULTIPLE DETERMINATION=	0.61641
NUMBER OF LAST VARIABLE ENTERED=	8
REGRESSION DEGREES OF FREEDOM=	2
RESIDUAL DEGREES OF FREEDOM=	17
RESIDUAL SUM OF SQUARES=	754.0422
RESIDUAL MEAN SQUARE=	44.3554
MULTIPLE CORRELATION COEFFICIENT=	0.78512
F-RATIO=	13.6591
STANDARD ESTIMATE OF ERROR=	6.65999
VARIABLE # 8 COEFFICIENT=	-0.0364
INTERCEPT=	17.27754

TABLE B-11

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION
STEP 3

X12 STEP # 3	
REGRESSION SUM OF SQUARES=________________________	496.8393
IMPROVEMENT OF UNEXPLAINED VARIANCE THIS STEP=______	278.8102
PROPORTION OF TOTAL SUM OF SQUARES REDUCED=________	0.1418
CUMULATE SUM OF SQUARES REDUCED TO THIS STEP=_______	1490.5180
COEFFICIENT OF MULTIPLE DETERMINATION=_____________	0.75824
NUMBER OF LAST VARIABLE ENTERED=__________________	4
REGRESSION DEGREES OF FREEDOM=____________________	3
RESIDUAL DEGREES OF FREEDOM=______________________	16
RESIDUAL SUM OF SQUARES=__________________________	475.2320
RESIDUAL MEAN SQUARE=____________________________	29.7020
MULTIPLE CORRELATION COEFFICIENT=_________________	0.87077
F-RATIO=____	16.7275
STANDARD ESTIMATE OF ERROR=______________________	5.44995
VARIABLE # 4 COEFFICIENT=_______________________	0.1272
INTERCEPT=_______________________________________	12.29917

TABLE B-12

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION

STEP 4

X12 STEP # 4

REGRESSION SUM OF SGUARES=	386.2462
IMPRCVEMENT OF UNEXPLAINED VARIANCE TFIS STEP=	54.4666
PROPCRTION OF TOTAL SUM OF SQUARES RECUCED=	0.0277
CUMULATE SUM OF SQUARES REDUCED TO THIS STEP=	1544.9846
COEFFICIENT OF MULTIPLE DETERMINATION=	0.78595
NUMBEP OF LAST VARIABLE ENTERED=	1
REGRESSION DEGREES CF FREEDOM=	4
RESIDUAL DEGREES OF FREEDOM=	15
RESIDUAL SUM OF SQUARES=	420.7654
RESIDUAL MEAN SQUARE=	28.0510
MULTIPLE CORRELATION COEFFICIENT=	0.88654
F-RATIC=	13.7694
STANDARD ESTIMATE OF ERROR=	5.29632
VARIABLE # 1 COEFFICIENT=	0.0968
INTERCEPT=	8.77278

TABLE B-13

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION

STEP 5

X12 STEP # 5	
REGRESSION SUM OF SQUARES=______________________	310.5069
IMPROVEMENT OF UNEXPLAINED VARIANCE THIS STEP=______	7.5501
PROPORTION OF TOTAL SUM OF SQUARES REDUCED=________	0.0038
CUMULATE SUM OF SQUARES REDUCED TO THIS STEP=______	1552.5347
COEFFICIENT OF MULTIPLE DETERMINATION=___________	0.78979
NUMBER OF LAST VARIABLE ENTERED=________________	7
REGRESSION DEGREES OF FREEDOM=_________________	5
RESIDUAL DEGREES OF FREEDOM=__________________	14
RESIDUAL SUM OF SQUARES=_____________________	413.2153
RESIDUAL MEAN SQUARE=_______________________	29.5154
MULTIPLE CORRELATION COEFFICIENT=______________	0.88870
F-RATIO=___________________________________	10.5202
STANDARD ESTIMATE OF ERROR=___________________	5.43281
VARIABLE # 7 COEFFICIENT=____________________	-0.0526
INTERCEPT=________________________________	7.84385

TABLE B-14

TEST MATRIX (E)

REGRESSION COEFFICIENTS MATRIX

	X12	X13	X14	X21	X23	X24
1)	7.84385	15.98703	-11.93341	5.65569	3.51781	18.64822
2)	0.13931	-2.00579	-0.07367	-0.19182	-0.14885	0.00000
3)	0.00000	-1.75932	-0.19379	0.00000	-0.03816	0.23549
4)	0.00000	-2.25867	-0.28942	-0.13714	-0.21425	0.00000
5)	0.11028	-2.01044	0.00000	0.03083	0.00000	0.00000
6)	0.12895	2.26241	0.42140	0.45427	0.17428	-0.32175
7)	0.00000	2.11802	0.04499	0.00000	0.03900	0.00000
8)	-0.05258	2.38692	0.14779	0.18111	0.17555	0.00000
9)	-0.14424	1.68236	0.20668	-0.10993	0.12662	0.60453

	X31	X32	X34	X41	X42	X43
1)	20.32588	-11.38115	6.59075	-17.45783	30.31404	8.85247
2)	-0.04033	-0.04298	-0.09196	-0.07130	-0.14637	-0.78920
3)	0.00000	0.00000	-0.10325	-0.09719	0.00000	-0.78319
4)	0.50568	0.08884	0.09965	-0.17287	0.00000	-0.62910
5)	0.00000	-0.23930	-0.08546	0.08618	0.87802	-0.58976
6)	0.14081	0.00000	0.00000	0.42339	-0.27362	0.63947
7)	0.00000	0.28664	0.00000	0.00000	0.00000	0.60972
8)	0.00000	0.17072	0.00000	0.15434	0.00000	0.83710
9)	-0.12684	0.00000	0.28615	0.00000	0.00000	0.80592

TABLE B-15

TEST STATISTICAL ANALYSIS OF STEP-WISE REGRESSION
ACTUAL VS. PREDICTED VALUES

X12

TIME PER.	PREDICTED	ACTUAL	RESIDUAL
1)	40.00000	41.92196	-1.92196
2)	31.00000	33.75503	-2.75503
3)	32.00000	31.94491	0.05509
4)	26.00000	30.16165	-4.16165
5)	35.00000	31.41305	3.58695
6)	45.00000	44.36254	0.63746
7)	50.00000	46.05971	3.94029
8)	53.00000	46.98644	6.01356
9)	45.00000	39.21218	5.78782
10)	32.00000	43.20118	-11.20118
11)	29.00000	27.28937	1.71063
12)	20.00000	24.20321	-4.20321
13)	26.00000	18.57067	7.42933
14)	26.00000	20.79321	5.20679
15)	14.00000	17.33815	-3.33815
16)	19.00000	23.42329	-4.42329
17)	28.00000	30.48793	-2.48793
18)	34.00000	30.28571	3.71429
19)	32.00000	34.36302	-2.36302
20)	28.00000	29.22677	-1.22677

STANDARD ERROR <MODEL # 1> IS 5.43281 R= 6

TABLE B-16

TEST MATRIX (F)

ESTIMATED TURNING MOVEMENTS

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	41	58	31	46	11	21	79	5	10	34	38	8
2)	33	57	19	36	7	25	70	10	10	20	8	5
3)	31	54	15	36	7	20	69	9	8	18	24	6
4)	30	63	13	32	9	23	57	10	4	15	19	6
5)	31	70	17	40	12	24	57	7	2	20	21	4
6)	44	84	37	56	17	44	91	17	11	43	41	10
7)	45	79	38	58	16	40	98	17	13	44	42	9
8)	47	83	40	65	16	46	112	22	17	49	32	8
9)	39	81	30	53	18	52	88	18	12	37	60	12
10)	43	83	37	62	18	40	99	16	13	45	45	12
11)	27	99	31	27	37	183	60	31	26	26	180	35
12)	24	74	22	16	28	177	61	31	29	14	157	25
13)	18	51	10	13	19	123	51	17	23	3	111	18
14)	20	45	8	14	18	134	77	28	30	5	159	27
15)	17	49	13	19	22	142	69	21	32	8	127	24
16)	23	77	24	30	30	167	71	28	30	20	142	22
17)	30	63	11	17	20	110	54	25	12	10	183	17
18)	30	87	17	15	28	164	54	37	17	14	208	22
19)	34	77	14	16	21	144	77	45	19	14	203	21
20)	29	73	10	17	21	137	71	39	19	11	182	21

TABLE B-17

TEST MATRIX (TE)

TURNING MOVEMENT ESTIMATION ERROR

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	3	5	3	-2	10	17	-1	-58	43	-6	36	-20
2)	6	12	-17	24	-13	56	-9	0	0	-5	-38	25
3)	-3	10	7	-20	-46	-23	5	-25	33	0	-11	0
4)	15	-11	18	-9	50	-12	27	-9	33	0	58	20
5)	-11	19	31	21	9	9	-11	75	0	18	0	-33
6)	-2	6	-8	6	-19	22	1	42	0	-2	-9	-9
7)	-10	-7	19	-3	78	-2	7	31	-19	7	-11	29
8)	-11	-14	-5	-2	-16	-15	-5	-19	-11	-4	-18	0
9)	-13	-15	-19	2	50	6	5	-10	-20	-12	5	-37
10)	34	5	-3	-6	-31	-23	-8	7	-7	2	-10	-8
11)	-7	2	0	-4	-5	-1	-2	-11	0	-4	0	6
12)	20	10	-8	-16	0	-5	5	0	4	8	-3	-17
13)	-31	-30	-41	-35	-24	6	-16	-11	-38	-67	1	6
14)	-23	2	0	0	6	-1	-11	40	-19	-38	-1	0
15)	21	-2	63	36	16	-5	15	-5	68	300	2	-11
16)	21	13	4	-3	0	7	13	-10	-3	-9	18	10
17)	7	0	-27	-6	-5	-12	4	-4	-8	0	-7	6
18)	-12	-11	13	0	0	-6	-18	23	6	-7	-2	-4
19)	6	3	17	7	-9	20	10	0	6	8	12	-9
20)	4	-1	-17	-6	0	-1	0	-24	0	0	-10	-9
MEAN:	0.7	-0.2	1.5	-0.7	2.6	1.8	0.4	1.6	3.5	9.5	0.6	-2.7
STAN:	16.3	11.7	22.4	15.3	29.0	18.0	11.1	28.9	24.4	70.7	20.0	17.0

TABLE B-18

TEST MATRIX (G)
ESTIMATED INGRESS-EGRESS MOVEMENTS

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	130	78	94	80	159	84	77	62
2)	109	68	90	33	126	51	69	54
3)	100	63	86	48	123	64	67	43
4)	106	64	71	40	104	59	78	40
5)	118	76	66	45	117	59	86	43
6)	165	117	119	94	190	102	111	92
7)	162	114	128	95	200	104	104	91
8)	170	127	151	89	226	101	107	103
9)	150	123	118	109	178	117	111	94
10)	163	120	128	102	206	104	113	90
11)	157	247	117	241	113	238	171	240
12)	120	221	121	196	91	212	127	228
13)	79	155	91	132	67	146	88	156
14)	73	166	135	191	96	207	90	172
15)	79	183	122	159	96	165	95	187
16)	124	227	129	184	121	193	129	221
17)	104	147	91	210	81	238	100	133
18)	134	207	108	244	83	275	137	198
19)	125	181	141	238	107	282	119	177
20)	112	175	129	214	99	250	115	166

TABLE B-19

TEST MATRIX (H)

INGRESS-EGRESS % ERROR

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	1.22	35.73	-5.76	0.53	0.92	13.14	13.28	-5.27
2)	-10.51	5.09	3.12	-7.50	-1.86	-10.21	-0.56	-1.64
3)	4.54	10.74	3.11	4.99	5.73	0.29	13.73	0.90
4)	-4.19	7.10	8.60	10.70	6.28	13.17	-6.83	6.83
5)	18.94	-4.99	10.85	6.11	2.54	7.05	19.35	7.84
6)	4.99	0.84	-5.28	-3.08	2.78	4.02	-5.61	-3.44
7)	6.61	1.40	-5.49	-5.05	2.18	-0.72	0.79	-5.40
8)	10.68	-9.01	-5.74	-8.46	1.61	-8.63	0.09	-6.98
9)	18.73	-1.88	-3.77	1.05	6.47	6.66	1.11	-1.62
10)	21.79	-0.17	-6.50	1.63	6.03	13.43	0.43	-3.05
11)	-8.47	1.01	-2.92	2.13	-2.34	13.29	-17.37	0.08
12)	-19.99	-3.40	0.42	-3.49	-15.36	-2.85	-13.21	-0.98
13)	-15.74	0.14	5.40	-0.36	-13.60	-0.64	0.29	0.58
14)	-14.79	5.53	-3.79	1.50	11.26	0.89	-13.10	-2.52
15)	-4.34	0.87	-0.15	2.78	-2.87	3.86	-2.25	0.54
16)	7.33	-8.36	0.79	-2.38	-9.84	-3.35	3.51	-0.31
17)	10.50	0.48	3.90	-2.07	4.69	-3.24	20.85	-2.46
18)	-4.16	-7.29	3.94	-3.77	-6.38	-4.72	-2.84	-2.12
19)	-10.51	-7.27	-0.98	-5.69	4.13	-8.33	-9.57	-5.68
20)	-4.84	-6.93	0.83	-3.31	6.79	-6.23	-6.23	-4.07
MEAN:	0.39	0.98	0.03	-0.69	0.46	1.35	-0.21	-1.44
STAN:	12.11	9.81	5.01	4.75	7.09	7.72	10.41	3.75

TABLE B-20

TEST MATRIX (P)

% TURNING - MANUAL COUNTS

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	32.0	44.0	24.0	62.7	13.3	24.0	80.8	12.1	7.1	48.6	37.8	13.5
2)	29.5	48.6	21.9	54.7	15.1	30.2	79.4	10.3	10.3	55.3	34.2	10.5
3)	33.7	51.6	14.7	53.6	15.5	31.0	78.6	14.3	7.1	35.3	52.9	11.8
4)	24.1	65.7	10.2	52.2	9.0	38.8	76.3	18.6	5.1	46.9	37.5	15.6
5)	32.7	55.1	12.1	50.0	16.7	33.3	91.4	5.7	2.9	38.6	47.7	13.6
6)	27.4	48.2	24.4	48.2	19.1	32.7	79.6	10.6	9.7	44.0	45.0	11.0
7)	29.9	50.9	19.2	54.5	8.2	37.3	76.0	10.7	13.2	43.2	49.5	7.4
8)	27.7	50.3	22.0	47.5	13.7	38.8	72.0	16.5	11.6	52.0	39.8	8.2
9)	25.4	53.7	20.9	46.0	10.6	43.4	70.6	16.8	12.6	35.6	48.3	16.1
10)	21.5	53.0	25.5	45.8	16.1	36.1	78.8	10.9	10.2	41.1	46.7	12.1
11)	18.5	61.8	19.7	11.1	15.5	73.4	50.0	28.7	21.3	11.3	75.0	13.8
12)	18.0	60.4	21.6	8.1	12.0	79.9	49.6	26.5	23.9	6.3	79.0	14.6
13)	22.4	62.9	14.7	12.4	15.5	72.0	52.1	16.2	31.6	6.6	80.9	12.5
14)	33.3	56.4	10.3	8.4	10.2	81.3	60.4	13.9	25.7	4.1	82.1	13.8
15)	19.4	69.4	11.1	7.7	10.4	82.0	59.4	21.8	18.8	1.3	81.2	17.5
16)	17.3	61.8	20.9	14.3	13.8	71.9	50.4	24.8	24.8	13.6	74.1	12.3
17)	26.4	59.4	14.2	11.0	12.8	76.2	57.1	28.6	14.3	4.5	88.3	7.2
18)	23.1	66.7	10.2	6.9	12.8	80.3	58.9	26.8	14.3	6.0	84.8	9.2
19)	26.9	63.0	10.1	9.5	14.6	75.9	52.6	33.8	13.5	6.0	83.4	10.6
20)	24.6	64.9	10.5	10.2	11.9	78.0	50.4	36.2	13.5	4.6	85.7	9.7
MEAN:	25.7	57.4	16.9	30.7	13.4	55.8	66.2	19.2	14.6	25.2	62.7	12.1
STAN:	5.2	7.2	5.6	21.7	2.9	22.3	13.4	8.7	7.6	20.0	19.9	2.9

TABLE B-21

TEST MATRIX (PP)
ESTIMATED % TURNING

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	31.5	44.6	23.8	59.0	14.1	26.9	84.0	5.3	10.6	42.5	47.5	10.0
2)	30.3	52.3	17.4	52.9	10.3	36.8	77.8	11.1	11.1	60.6	24.2	15.2
3)	31.0	54.0	15.0	57.1	11.1	31.7	80.2	10.5	9.3	37.5	50.0	12.5
4)	28.3	59.4	12.3	50.0	14.1	35.9	80.3	14.1	5.6	37.5	47.5	15.0
5)	26.3	59.3	14.4	52.6	15.8	31.6	86.4	10.6	3.0	44.4	46.7	8.9
6)	26.7	50.9	22.4	47.9	14.5	37.6	76.5	14.3	9.2	45.7	43.6	10.6
7)	27.8	48.8	23.5	50.9	14.0	35.1	76.6	13.3	10.2	46.3	44.2	9.5
8)	27.6	48.8	23.5	51.2	12.6	36.2	74.2	14.6	11.3	55.1	36.0	9.0
9)	26.0	54.0	20.0	43.1	14.6	42.3	74.6	15.3	10.2	33.9	55.0	11.0
10)	26.4	50.9	22.7	51.7	15.0	33.3	77.3	12.5	10.2	44.1	44.1	11.8
11)	17.2	63.1	19.7	10.9	15.0	74.1	51.3	26.5	22.2	10.8	74.7	14.5
12)	20.0	61.7	18.3	7.2	12.7	80.1	50.4	25.6	24.0	7.1	80.1	12.8
13)	22.8	64.6	12.7	8.4	12.3	79.4	56.0	18.7	25.3	2.3	84.1	13.6
14)	27.4	61.6	11.0	8.4	10.8	80.7	57.0	20.7	22.2	2.6	83.2	14.1
15)	21.5	62.0	16.5	10.4	12.0	77.6	56.6	17.2	26.2	5.0	79.9	15.1
16)	18.5	62.1	19.4	13.2	13.2	73.6	55.0	21.7	23.3	10.9	77.2	12.0
17)	28.8	60.6	10.6	11.6	13.6	74.8	59.3	27.5	13.2	4.8	87.1	8.1
18)	22.4	64.9	12.7	7.2	13.5	79.2	50.0	34.3	15.7	5.7	85.2	9.0
19)	27.2	61.6	11.2	8.8	11.6	79.6	54.6	31.9	13.5	5.9	85.3	8.8
20)	25.9	65.2	8.9	9.7	12.0	78.3	55.0	30.2	14.7	5.1	85.0	9.8
MEAN:	25.7	57.5	16.8	30.6	13.1	56.2	66.7	18.8	14.6	25.4	63.0	11.6
STAN:	4.0	6.3	4.9	21.8	1.5	22.3	12.9	8.1	6.9	20.7	20.7	2.4

TABLE B-22

TEST MATRIX (GGG)

CHI-SQUARE INGRESS-EGRESS ESTIMATION

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	0.02	5.41	0.35	0.00	0.01	1.13	1.06	0.19
2)	1.50	0.16	0.08	0.22	0.05	0.66	0.00	0.01
3)	0.19	0.59	0.08	0.11	0.36	0.00	0.98	0.00
4)	0.20	0.28	0.45	0.37	0.36	0.80	0.42	0.16
5)	2.99	0.21	0.63	0.15	0.07	0.26	2.26	0.23
6)	0.37	0.01	0.37	0.10	0.14	0.15	0.39	0.12
7)	0.62	0.02	0.43	0.27	0.09	0.01	0.01	0.30
8)	1.58	1.24	0.56	0.76	0.06	0.90	0.00	0.58
9)	3.73	0.05	0.18	0.01	0.66	0.46	0.01	0.03
10)	5.22	0.00	0.62	0.03	0.67	1.46	0.00	0.09
11)	1.34	0.02	0.11	0.10	0.07	3.28	7.56	0.00
12)	7.49	0.27	0.00	0.26	3.00	0.18	2.94	0.02
13)	2.76	0.00	0.24	0.00	1.66	0.01	0.00	0.01
14)	2.20	0.46	0.21	0.04	0.98	0.02	2.05	0.12
15)	0.16	0.01	0.00	0.12	0.08	0.23	0.05	0.01
16)	0.58	1.89	0.01	0.11	1.44	0.23	0.15	0.00
17)	0.94	0.00	0.13	0.09	0.16	0.27	2.98	0.08
18)	0.25	1.28	0.16	0.37	0.39	0.67	0.12	0.09
19)	1.73	1.11	0.01	0.86	0.17	2.33	1.33	0.64
20)	0.29	0.97	0.01	0.25	0.40	1.10	0.51	0.30
TOTAL CHISQ	34.2	14.0	4.6	4.2	10.8	14.1	22.8	3.0

TABLE B-23

TEST MATRIX (TTT)

CHI-SQUARE TURNING MOVEMENT ESTIMATION

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	0.03	0.16	0.03	0.02	0.10	0.50	0.01	4.08	1.29	0.11	3.57	0.40
2)	0.13	0.71	0.70	1.69	0.13	5.06	0.64	0.00	0.00	0.05	1.92	0.25
3)	0.03	0.51	0.07	1.89	2.77	1.38	0.14	0.75	0.67	0.00	0.33	0.00
4)	0.62	0.99	0.36	0.26	1.50	0.35	3.20	0.09	0.33	0.00	4.08	0.20
5)	0.46	2.05	1.23	1.48	0.09	0.18	0.77	2.25	0.00	0.53	0.00	0.67
6)	0.02	0.32	0.23	0.17	0.76	1.78	0.01	2.08	0.00	0.02	0.36	0.09
7)	0.50	0.42	1.13	0.07	5.44	0.02	0.39	1.23	0.56	0.22	0.53	0.57
8)	0.68	1.76	0.10	0.02	0.47	1.19	0.31	0.93	0.21	0.08	1.26	0.00
9)	0.80	2.06	1.32	0.02	3.00	0.18	0.19	0.20	0.60	0.60	0.16	2.58
10)	3.78	0.20	0.03	0.24	2.46	2.77	0.75	0.07	0.07	0.02	0.50	0.08
11)	0.14	0.04	0.00	0.04	0.10	0.02	0.02	0.46	0.00	0.04	0.00	0.12
12)	0.80	0.73	0.17	0.47	0.00	0.53	0.16	0.00	0.04	0.08	0.15	0.83
13)	2.46	6.63	2.88	2.45	1.44	0.42	1.64	0.21	5.30	4.00	0.01	0.06
14)	1.38	0.02	0.00	0.09	0.06	0.01	1.15	3.20	1.32	1.13	0.02	0.00
15)	0.64	0.02	3.13	1.79	0.47	0.43	1.35	0.05	8.89	18.00	0.03	0.33
16)	0.84	1.19	0.04	0.03	0.09	0.78	1.02	0.29	0.03	0.18	4.03	0.20
17)	0.14	0.00	1.07	0.06	0.05	1.80	0.08	0.04	0.08	0.00	0.86	0.06
18)	0.47	1.23	0.27	0.00	0.00	0.69	2.18	1.63	0.06	0.07	0.08	0.04
19)	0.13	0.05	0.33	0.07	0.17	4.80	0.70	0.00	0.06	0.08	2.67	0.17
20)	0.04	0.01	0.33	0.06	0.00	0.01	0.00	2.82	0.00	0.00	2.17	0.17
TOTAL CHISQ	14.1	19.0	13.4	10.7	19.0	22.9	14.7	20.4	19.5	25.2	22.8	6.8

TABLE B-24

TEST MATRIX (PPP)

CHI-SQUARE % TURNING ESTIMATION

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	0.01	0.01	0.00	0.22	0.04	0.36	0.13	3.82	1.80	0.78	2.47	0.91
2)	0.02	0.29	0.91	0.06	1.53	1.43	0.03	0.06	0.06	0.52	2.90	2.03
3)	0.21	0.11	0.00	0.24	1.23	0.02	0.04	1.02	0.65	0.14	0.16	0.05
4)	0.74	0.61	0.42	0.10	2.91	0.21	0.21	1.12	0.06	1.88	2.67	0.03
5)	1.27	0.32	0.42	0.14	0.05	0.09	0.28	4.19	0.01	0.87	0.02	1.65
6)	0.02	0.16	0.16	0.00	1.09	0.73	0.13	1.27	0.02	0.07	0.04	0.01
7)	0.16	0.09	0.96	0.25	4.19	0.13	0.00	0.60	0.71	0.23	0.56	0.60
8)	0.00	0.04	0.11	0.29	0.08	0.18	0.07	0.22	0.01	0.17	0.37	0.08
9)	0.01	0.00	0.04	0.19	1.52	0.03	0.23	0.14	0.47	0.08	0.94	1.61
10)	1.12	0.03	0.31	0.74	0.52	0.21	0.03	0.22	0.00	0.22	0.15	0.01
11)	0.09	0.03	0.00	0.00	0.02	0.01	0.03	0.17	0.04	0.02	0.00	0.04
12)	0.22	0.03	0.50	0.10	0.04	0.00	0.01	0.03	0.00	0.10	0.01	0.24
13)	0.01	0.04	0.27	1.31	0.69	0.74	0.29	0.37	1.27	2.85	0.13	0.10
14)	1.06	0.49	0.05	0.00	0.04	0.00	0.19	3.38	0.47	0.52	0.01	0.01
15)	0.22	0.79	2.57	0.98	0.26	0.23	0.14	0.96	2.92	10.73	0.02	0.34
16)	0.09	0.00	0.12	0.08	0.03	0.04	0.43	0.39	0.10	0.54	0.13	0.01
17)	0.22	0.02	0.90	0.03	0.05	0.03	0.08	0.04	0.08	0.01	0.01	0.11
18)	0.02	0.05	0.60	0.02	0.04	0.01	1.35	2.09	0.15	0.01	0.00	0.00
19)	0.00	0.03	0.12	0.05	0.60	0.17	0.07	0.11	0.00	0.00	0.04	0.30
20)	0.07	0.00	0.24	0.02	0.00	0.00	0.44	0.97	0.12	0.05	0.00	0.00
TOTAL CHISQ	5.6	3.2	8.7	4.8	14.9	4.6	4.2	21.1	9.0	19.8	10.7	8.1

APPENDIX C

FOUR-LEGGED INTERSECTION

MODEL DATA

TABLE C-1

INGRESS-EGRESS MANUAL COUNTS
LINCOLN-LUDINGTON INTERSECTION 6/74

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	125	75	99	74	163	80	75	55
2)	105	53	97	38	127	54	63	49
3)	95	84	84	51	129	71	68	46
4)	108	67	59	32	95	49	82	40
5)	107	66	70	44	114	60	76	37
6)	116	68	95	44	127	72	82	42
7)	85	52	45	31	77	50	52	34
8)	96	52	42	37	74	52	63	38
9)	78	31	71	42	110	30	41	41
10)	43	24	64	35	85	30	21	30
11)	67	24	72	50	97	45	40	31
12)	104	45	160	93	210	60	95	37
13)	77	41	72	58	81	54	54	59
14)	63	43	46	61	73	39	45	56
15)	78	47	91	53	102	67	45	55
16)	85	53	79	65	101	61	71	49
17)	108	95	74	77	124	93	70	67
18)	122	103	77	72	136	92	90	56
19)	97	98	95	71	142	82	66	71
20)	127	125	109	83	170	97	81	96
21)	170	132	122	113	191	125	134	87
22)	108	96	82	70	137	91	69	59
23)	144	121	97	103	162	95	119	89
24)	152	109	131	89	175	111	113	82
25)	168	141	116	103	171	145	118	94
26)	97	101	81	66	129	99	52	65
27)	136	131	88	81	157	86	100	93
28)	123	102	69	69	134	99	68	62
29)	158	114	94	70	152	89	104	91
30)	131	122	97	84	161	79	89	105
31)	162	110	96	85	144	93	113	103
32)	152	140	97	82	161	94	108	108
33)	163	131	119	99	165	128	125	94
34)	151	125	88	88	152	88	104	108
35)	172	143	115	110	187	107	130	116
36)	144	134	95	95	150	90	115	113

TABLE C-2

INGRESS-EGRESS MACHINE COUNTS
LINCOLN-LUDINGTON INTERSECTION 6/74

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	132	60	109	82	168	75	71	66
2)	126	68	96	37	136	57	72	55
3)	96	58	89	46	127	66	63	44
4)	113	62	71	37	105	53	88	38
5)	105	86	67	45	118	54	73	39
6)	99	58	97	37	129	63	65	43
7)	115	83	57	32	96	64	63	39
8)	101	71	41	35	73	54	65	40
9)	98	7	71	41	105	33	46	45
10)	49	18	73	37	95	29	20	30
11)	72	29	83	62	108	46	46	34
12)	115	26	177	90	219	62	95	41
13)	83	32	82	63	90	58	58	62
14)	69	25	49	54	78	37	46	58
15)	84	27	89	54	98	60	43	55
16)	104	45	91	75	119	70	76	61
17)	111	68	88	82	128	96	68	67
18)	119	85	85	73	138	90	79	55
19)	120	118	94	76	150	85	76	89
20)	132	106	124	90	182	98	76	100
21)	178	105	126	103	186	116	130	82
22)	118	98	96	76	154	99	71	65
23)	140	118	105	100	147	84	112	88
24)	169	129	160	90	209	119	117	97
25)	169	129	116	101	168	142	112	86
26)	119	108	92	68	140	112	63	78
27)	143	127	87	82	156	84	105	87
28)	143	136	85	67	136	104	72	70
29)	170	109	100	77	163	90	110	94
30)	141	110	107	88	178	81	86	114
31)	178	116	103	85	141	98	118	107
32)	163	141	108	87	174	93	103	109
33)	156	119	128	104	176	130	121	100
34)	155	142	96	96	164	78	100	109
35)	173	111	123	99	190	102	128	116
36)	168	161	107	93	161	90	126	115

TABLE C-3

MANUAL TURNING MOVEMENT COUNTS
LINCOLN-LUDINGTON INTERSECTION 6/74

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	40	55	30	47	10	18	80	12	7	36	28	10
2)	31	51	23	29	8	16	77	10	10	21	13	4
3)	32	49	14	45	13	26	66	12	6	18	27	6
4)	26	71	11	35	6	26	45	11	3	15	12	5
5)	35	59	13	33	11	22	64	4	2	17	21	6
6)	38	64	14	42	9	17	68	16	11	17	18	9
7)	32	39	14	29	8	15	36	4	5	12	14	5
8)	28	47	21	30	8	14	29	10	3	15	14	8
9)	21	31	26	15	6	10	64	2	5	31	7	4
10)	10	18	15	12	1	11	52	8	4	21	12	2
11)	18	31	18	13	1	10	62	7	3	22	20	8
12)	17	69	18	30	3	12	139	14	7	41	29	23
13)	13	38	26	14	7	20	51	8	13	16	33	9
14)	11	31	21	9	7	27	38	0	8	26	28	7
15)	21	37	20	15	4	28	65	19	7	22	27	4
16)	20	44	21	17	15	21	56	16	7	28	25	12
17)	40	48	20	43	14	38	53	12	9	28	41	8
18)	33	67	22	54	17	32	59	16	2	23	43	6
19)	24	45	28	52	12	34	69	17	9	21	41	9
20)	38	51	38	62	18	45	82	14	13	26	45	12
21)	54	95	21	53	23	56	93	19	10	45	52	16
22)	38	54	16	52	6	38	58	19	5	27	34	9
23)	40	74	30	47	26	48	76	10	11	39	45	19
24)	49	79	24	47	19	43	92	24	15	36	38	15
25)	62	88	18	56	19	66	80	26	10	35	57	11
26)	40	29	28	53	15	33	60	17	4	16	42	8
27)	41	71	24	58	17	56	60	15	13	39	30	12
28)	47	47	29	60	13	29	45	20	4	29	32	8
29)	41	86	31	52	10	52	70	16	8	30	32	8
30)	32	63	36	45	14	63	76	15	6	40	32	12
31)	39	81	42	39	18	53	76	12	8	29	42	14
32)	38	79	35	59	16	65	68	21	8	34	35	13
33)	42	96	25	59	17	55	76	29	14	30	57	12
34)	35	64	52	57	19	49	67	14	7	28	39	21
35)	44	87	41	55	26	62	88	14	13	44	49	17
36)	30	80	34	49	18	67	72	11	12	29	49	17

TABLE C-4

REGRESSION COEFFICIENTS MATRIX
LINCOLN-LUDINGTON INTERSECTION 6/74

	X12	X13	X14	X21	X23	X24
1)	-3.08063	-3.83479	5.77608	-4.42185	-2.60810	-10.55331
2)	1.41263	0.17831	0.20474	0.26674	0.00000	0.00000
3)	1.08723	-0.03567	0.00000	0.37699	0.00000	0.00000
4)	0.88400	0.04552	-0.03955	-0.10478	-0.06490	-0.14786
5)	1.08422	0.00000	0.10546	0.22106	0.07203	0.15319
6)	-0.95884	0.00000	0.00000	0.18484	0.00000	0.00000
7)	-0.79391	0.00000	-0.19707	0.00000	0.05869	0.10323
8)	-1.18210	0.67256	-0.20450	-0.33772	0.09751	0.16941
9)	-1.31749	-0.19441	0.35434	-0.33923	0.04935	0.39040

	X31	X32	X34	X41	X42	X43
1)	2.28782	-1.82950	1.41965	-3.18869	1.96494	-1.25226
2)	0.01744	-0.06739	-0.46862	0.38092	-0.26708	-0.08269
3)	-0.16109	0.00000	-0.42117	0.06485	-0.05474	0.03849
4)	0.41786	0.12708	-0.25057	0.00000	0.00000	0.06652
5)	0.00000	-0.08774	-0.47848	0.52360	0.28921	0.13133
6)	0.31228	-0.01948	0.32027	0.00000	-0.06929	0.00000
7)	-0.15282	0.23566	0.44130	-0.29580	0.36443	-0.09980
8)	0.13236	0.00000	0.47805	-0.20631	0.18552	0.12923
9)	0.00000	0.03293	0.54267	-0.22683	0.16582	0.00000

TABLE C-5

INGRESS-EGRESS MANUAL COUNTS
LINCOLN-LUDINGTON INTERSECTION 7/76

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	138	99	97	79	140	78	109	86
2)	138	116	106	79	189	78	106	66
3)	149	78	90	83	147	85	97	71
4)	158	106	123	84	182	89	129	71
5)	192	147	130	89	212	98	163	85
6)	164	110	113	100	187	102	111	87
7)	167	110	121	95	193	110	101	89
8)	191	139	164	98	235	119	123	115
9)	177	113	119	118	178	122	126	101
10)	149	144	137	107	218	97	118	104
11)	132	111	110	91	184	75	111	74
12)	142	107	117	104	197	91	87	95
13)	186	118	134	95	199	109	119	106
14)	215	146	112	97	187	99	149	135
15)	175	112	100	83	153	95	117	105
16)	172	121	123	108	193	90	122	119
17)	176	122	126	98	189	93	114	126
18)	137	92	94	95	153	89	102	74
19)	214	152	80	110	160	104	149	143
20)	214	116	105	105	166	85	168	121
21)	223	157	129	122	221	89	196	125
22)	183	126	117	99	177	86	141	121
23)	159	87	87	79	142	68	115	87
24)	139	91	107	65	157	51	104	90

TABLE C-6

INGRESS-EGRESS MACHINE COUNTS
LINCOLN-LUDINGTON INTERSECTION 7/76

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	137	111	136	83	179	83	108	93
2)	140	102	112	80	183	72	114	64
3)	143	103	117	99	173	95	113	80
4)	168	100	153	76	187	83	124	76
5)	189	150	126	85	205	91	188	88
6)	160	120	136	99	199	100	124	97
7)	153	115	145	101	213	108	110	99
8)	156	144	173	99	240	113	113	113
9)	125	126	129	107	185	115	119	100
10)	137	125	149	103	208	93	118	94
11)	138	126	160	110	216	79	120	76
12)	140	117	131	110	210	95	102	106
13)	163	126	144	81	205	103	119	112
14)	198	142	156	92	187	108	150	126
15)	160	134	123	94	184	91	120	131
16)	169	120	135	105	185	83	130	116
17)	166	106	144	112	200	100	129	121
18)	161	130	107	120	178	88	147	87
19)	203	124	104	97	165	89	163	152
20)	181	129	129	106	182	87	169	126
21)	204	156	137	111	215	87	206	102
22)	162	111	130	106	171	77	132	143
23)	156	99	107	73	148	63	117	108
24)	131	81	117	62	153	53	114	106

TABLE C-7

MANUAL TURNING MOVEMENT COUNTS
LINCOLN-LUDINGTON INTERSECTION 7/76

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	29	73	36	46	19	34	66	15	16	28	34	17
2)	32	80	26	61	22	33	89	10	7	39	36	4
3)	40	80	29	39	11	28	62	14	14	46	31	6
4)	30	97	31	48	25	33	96	20	7	38	39	7
5)	41	125	26	66	27	54	107	18	5	39	39	11
6)	45	79	40	53	21	36	90	12	11	44	45	11
7)	50	85	32	60	9	41	92	13	16	41	47	7
8)	53	96	42	66	19	54	118	27	19	51	39	8
9)	45	95	37	52	12	49	84	20	15	42	57	19
10)	32	79	38	66	26	52	108	15	14	44	50	13
11)	28	71	33	55	25	31	87	13	10	42	34	15
12)	31	68	43	53	12	42	93	14	10	51	46	7
13)	49	101	36	50	11	57	99	22	13	50	38	7
14)	49	110	56	58	22	66	83	16	13	46	34	17
15)	36	91	48	45	18	49	70	22	8	38	37	8
16)	28	90	54	54	18	49	95	12	16	44	50	14
17)	32	85	59	54	17	51	93	17	16	42	44	12
18)	29	77	31	46	14	32	67	16	11	40	44	11
19)	47	111	56	55	18	79	60	12	8	45	45	20
20)	27	130	57	48	17	51	80	12	13	38	46	21
21)	25	141	57	66	32	59	102	18	9	53	46	23
22)	37	96	50	44	27	55	91	10	16	42	39	18
23)	32	86	41	38	13	36	66	11	10	38	25	16
24)	18	78	43	42	16	33	85	8	14	30	25	10

TABLE C-8

INGRESS-EGRESS MANUAL COUNTS
FORD-NEWBURGH INTERSECTION 5/76

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	94	191	103	168	100	192	108	156
2)	99	172	111	152	88	182	96	168
3)	107	214	141	212	123	236	120	195
4)	83	169	95	165	98	169	90	155
5)	145	216	134	187	127	223	133	199
6)	132	252	120	202	113	210	163	220
7)	130	157	131	167	116	192	127	150
8)	153	228	137	227	130	246	155	214
9)	160	263	156	257	141	284	173	238
10)	110	207	116	173	108	186	130	182
11)	156	239	99	198	89	228	143	232
12)	159	242	205	254	194	241	194	231
13)	162	266	158	202	142	220	194	232
14)	160	243	190	256	165	270	188	226
15)	180	312	159	203	144	237	202	271
16)	110	217	125	162	116	174	118	206
17)	106	164	91	222	80	237	100	166
18)	147	218	112	250	96	257	149	225
19)	119	158	133	217	98	238	121	170
20)	114	177	141	237	100	266	118	185
21)	122	151	91	215	93	220	115	151
22)	91	155	100	171	84	187	91	155
23)	84	134	93	169	80	191	75	134
24)	83	149	88	123	78	140	81	144

TABLE C-9

INGRESS-EGRESS MACHINE COUNTS
FORD-NEWBURGH INTERSECTION 5/76

TIME PER.	I1	I2	I3	I4	E1	E2	E3	E4
1)	95	190	107	181	113	201	114	146
2)	125	207	132	171	107	227	120	190
3)	119	228	142	209	122	241	127	200
4)	128	235	127	209	112	238	138	191
5)	153	241	129	190	130	224	142	204
6)	153	283	128	224	142	249	178	220
7)	169	236	167	228	149	262	170	211
8)	160	257	158	265	137	263	171	230
9)	151	240	137	220	133	240	162	218
10)	132	234	138	226	134	235	162	202
11)	151	260	188	235	158	282	162	232
12)	190	270	156	247	169	231	195	230
13)	169	275	179	216	151	278	200	225
14)	153	253	191	243	173	237	178	239
15)	178	307	151	205	162	224	195	264
16)	118	257	139	193	144	203	131	226
17)	95	150	94	217	84	253	88	140
18)	143	232	113	260	95	293	148	205
19)	143	203	155	259	110	312	138	190
20)	122	198	141	230	98	267	127	173
21)	139	140	99	227	97	231	123	131
22)	85	160	98	168	79	203	93	140
23)	84	166	114	194	88	241	80	153
24)	104	178	116	163	104	194	97	150

TABLE C-10

MANUAL TURNING MOVEMENT COUNTS
FORD-NEWBURGH INTERSECTION 5/76

TIME PER.	X12	X13	X14	X21	X23	X24	X31	X32	X34	X41	X42	X43
1)	23	52	19	35	36	120	52	34	17	13	135	20
2)	29	50	20	27	24	121	52	41	18	9	121	22
3)	26	62	19	28	42	144	77	39	25	18	178	16
4)	27	43	13	29	31	109	52	24	19	17	132	16
5)	32	83	30	37	29	150	77	40	17	13	153	21
6)	22	93	17	38	35	179	64	37	19	11	156	35
7)	28	80	22	23	30	104	76	37	18	17	133	17
8)	26	89	38	31	37	160	79	30	28	20	178	29
9)	36	94	30	37	42	184	80	58	18	24	196	37
10)	22	73	15	33	36	138	60	34	22	15	137	21
11)	28	105	23	30	27	182	37	40	22	22	165	11
12)	30	106	23	32	31	179	139	44	22	23	174	57
13)	29	111	22	34	50	182	83	54	21	25	144	33
14)	21	112	27	34	34	175	101	59	30	30	184	42
15)	26	124	30	41	48	223	89	48	22	14	159	30
16)	19	68	23	31	30	156	63	31	31	22	120	20
17)	28	63	15	18	21	125	52	26	13	10	196	16
18)	34	98	15	15	28	175	66	30	16	15	212	23
19)	32	75	12	15	23	120	70	45	18	13	181	23
20)	28	74	12	18	21	138	71	51	19	11	203	23
21)	33	76	13	27	21	103	49	27	15	17	180	18
22)	26	53	12	17	26	112	49	34	17	18	141	12
23)	26	43	15	23	17	94	45	34	14	12	142	15
24)	34	38	11	26	23	100	41	37	10	11	92	20

APPENDIX D

THREE-LEGGED INTERSECTION

MODEL DATA

TABLE D-1

INGRESS-EGRESS MANUAL COUNTS

MAIN-FRONT INTERSECTION 10/75

TIME PER.	I1	I2	I4	E1	E2	E4
1)	94	84	50	57	72	99
2)	97	89	53	83	71	85
3)	99	100	57	73	74	109
4)	120	110	57	74	81	132
5)	120	111	73	81	107	116
6)	98	79	58	62	88	85
7)	113	121	100	81	128	125
8)	90	105	81	63	94	119
9)	116	110	84	84	108	118
10)	131	133	88	100	100	152
11)	97	74	49	61	73	86
12)	104	121	63	83	78	127
13)	150	128	63	76	126	139
14)	143	129	75	88	109	150
15)	89	110	65	70	96	98
16)	119	105	56	69	74	137
17)	36	44	24	34	33	37
18)	52	45	35	36	49	47
19)	65	63	92	39	109	72
20)	77	64	109	57	117	76

TABLE D-2

INGRESS-EGRESS MACHINE COUNTS

MAIN-FRONT INTERSECTION 10/75

TIME PER.	I1	I2	I4	E1	E2	E4
1)	134	88	68	66	110	85
2)	137	114	67	96	87	84
3)	142	118	91	85	110	109
4)	167	126	80	84	81	103
5)	141	108	85	84	111	100
6)	143	97	78	75	110	91
7)	178	122	121	79	130	111
8)	120	123	93	76	130	97
9)	186	106	92	88	120	96
10)	182	140	92	103	122	106
11)	146	118	94	93	123	91
12)	117	120	88	78	119	99
13)	167	143	73	83	107	151
14)	164	140	77	87	140	115
15)	125	130	78	74	103	106
16)	140	113	72	71	124	98
17)	43	68	31	50	48	24
18)	60	50	38	42	68	49
19)	97	76	114	50	111	82
20)	100	69	120	63	119	75

TABLE D-3

MANUAL TURNING MOVEMENT COUNTS

MAIN-FRONT INTERSECTION 10/75

TIME PER.	X12	X14	X21	X24	X41	X42
1)	58	36	43	41	14	36
2)	54	43	58	31	25	28
3)	59	40	50	50	23	34
4)	74	46	52	58	22	35
5)	66	54	61	50	20	53
6)	53	45	47	32	15	43
7)	63	50	59	62	22	78
8)	61	29	47	58	16	65
9)	65	51	57	53	27	57
10)	90	41	71	62	29	59
11)	56	41	44	30	17	32
12)	70	34	64	57	19	44
13)	69	81	58	70	18	45
14)	89	54	68	61	20	55
15)	43	46	55	55	15	50
16)	83	36	51	54	18	38
17)	24	12	31	13	3	21
18)	29	23	27	18	9	26
19)	33	32	24	39	15	77
20)	39	38	27	37	30	79

TABLE D-4

INGRESS-EGRESS MANUAL COUNTS
MAIN-FRONT INTERSECTION 7/78

TIME PER.	I1	I2	I4	E1	E2	E4
1)	114	105	85	89	133	82
2)	110	128	76	90	139	85
3)	105	106	105	73	154	89
4)	103	135	71	83	116	110
5)	124	122	87	101	129	103
6)	124	131	66	90	124	107
7)	103	115	85	73	134	96
8)	144	120	92	85	156	115
9)	104	134	73	89	130	92
10)	129	118	90	83	151	103
11)	131	112	99	76	152	114
12)	123	134	95	91	141	120
13)	162	129	74	100	133	132
14)	108	138	68	95	107	112
15)	104	120	78	94	124	84
16)	87	111	72	83	110	77
17)	42	46	33	44	40	37
18)	61	56	76	49	87	57
19)	58	61	88	38	114	55
20)	76	64	143	74	154	55
21)	73	77	82	54	114	64
22)	87	68	71	56	120	50
23)	80	83	55	58	101	59
24)	91	66	72	54	115	60

TABLE D-5

INGRESS-EGRESS MACHINE COUNTS
MAIN-FRONT INTERSECTION 7/78

TIME PER.	I1	I2	I4	E1	E2	E4
1)	144	150	76	105	133	98
2)	107	144	80	99	120	69
3)	180	127	73	101	133	110
4)	146	128	85	64	175	115
5)	168	134	87	43	113	105
6)	144	125	63	44	139	112
7)	121	153	76	54	153	117
8)	104	150	93	101	134	109
9)	63	58	69	101	152	94
10)	116	103	84	87	115	96
11)	142	155	90	95	124	133
12)	136	112	87	97	113	116
13)	155	120	86	108	130	127
14)	112	123	67	99	106	109
15)	111	109	71	112	120	90
16)	83	134	81	81	109	73
17)	46	92	33	43	101	36
18)	59	98	51	53	107	58
19)	66	99	73	60	91	59
20)	88	83	97	83	108	61
21)	79	91	69	70	103	63
22)	87	109	60	72	99	51
23)	82	95	42	77	104	64
24)	102	101	65	73	120	71

TABLE D-6

MANUAL TURNING MOVEMENT COUNTS
MAIN-FRONT INTERSECTION 7/78

TIME PER.	X12	X14	X21	X24	X41	X42
1)	71	43	66	39	23	62
2)	80	30	73	55	17	59
3)	64	41	58	48	15	90
4)	65	38	63	72	20	51
5)	79	45	64	58	37	50
6)	78	46	70	61	20	46
7)	60	43	62	53	11	74
8)	88	56	61	59	24	68
9)	73	31	73	61	16	57
10)	90	39	54	64	29	61
11)	78	53	51	61	25	74
12)	69	54	68	66	23	72
13)	92	70	67	62	33	41
14)	64	44	70	68	25	43
15)	63	41	77	43	17	61
16)	59	28	62	49	21	51
17)	21	21	30	16	14	19
18)	25	36	35	21	14	62
19)	40	18	24	37	14	74
20)	43	33	42	22	32	111
21)	46	27	40	37	14	68
22)	62	25	43	25	13	58
23)	53	27	51	32	7	48
24)	55	36	42	24	12	60

TABLE D-7

INGRESS-EGRESS MANUAL COUNTS
GRAND RIVER-GOLF CLUB INTERSECTION 2/77

TIME PER.	I1	I2	I4	E1	E2	E4
1)	24	149	161	18	149	167
2)	13	151	142	17	132	157
3)	17	123	169	15	158	136
4)	13	141	188	19	176	147
5)	20	170	250	31	228	181
6)	22	79	144	14	138	93
7)	20	76	253	24	240	85
8)	10	119	143	18	129	125
9)	19	200	243	29	225	208
10)	21	161	158	26	135	179
11)	15	193	163	23	143	205
12)	15	188	180	35	155	193
13)	20	191	192	46	160	197
14)	16	132	132	31	109	140
15)	13	173	121	26	101	180
16)	14	140	118	24	96	152
17)	12	45	77	4	76	54
18)	14	55	86	4	84	67
19)	17	83	108	4	108	96
20)	21	159	125	3	124	178
21)	12	97	123	8	120	104
22)	17	73	93	2	94	87
23)	17	99	88	6	84	114
24)	16	118	100	6	97	131

TABLE D-8

INGRESS-EGRESS MANUAL COUNTS

GRAND RIVER-GOLF CLUB INTERSECTION 2/77

TIME PER.	I1	I2	I4	E1	E2	E4
1)	27	143	153	19	132	169
2)	14	153	151	15	125	164
3)	14	144	171	13	131	173
4)	16	140	209	22	189	158
5)	19	136	217	27	178	164
6)	14	179	170	14	162	196
7)	23	169	213	17	181	189
8)	13	169	196	26	162	198
9)	19	146	234	29	180	162
10)	18	169	156	21	146	187
11)	21	204	178	21	130	245
12)	14	211	190	30	147	227
13)	24	216	207	42	146	241
14)	17	201	136	37	110	210
15)	18	191	134	24	96	217
16)	14	132	128	29	87	154
17)	17	35	77	4	77	57
18)	13	46	92	4	87	64
19)	13	66	118	3	87	95
20)	27	139	130	3	120	180
21)	13	91	125	6	117	117
22)	21	63	96	3	92	92
23)	16	95	96	6	81	121
24)	16	115	93	4	97	151

TABLE D-9

MANUAL TURNING MOVEMENT COUNTS

GRAND RIVER - GOLF CLUB INTERSECTION 2/77

TIME PER.	X12	X14	X21	X24	X41	X42
1)	4	20	2	147	16	145
2)	2	11	5	146	12	130
3)	3	14	1	122	14	155
4)	5	8	2	139	17	171
5)	4	16	5	165	26	224
6)	4	18	4	75	10	134
7)	5	15	6	70	18	235
8)	3	7	1	118	17	126
9)	5	14	6	194	23	220
10)	0	21	3	158	23	135
11)	0	15	3	190	20	143
12)	1	14	9	179	26	154
13)	3	17	11	180	35	157
14)	1	15	7	125	24	108
15)	2	11	4	169	22	99
16)	0	14	2	138	22	96
17)	2	10	1	44	3	74
18)	2	12	0	55	4	82
19)	4	13	0	83	4	104
20)	2	19	0	159	3	122
21)	4	8	1	96	7	116
22)	3	14	0	73	2	91
23)	2	15	0	99	6	82
24)	2	14	1	117	5	95