ASSESSMENT OF COEFFICIENTS FOR INDIVIDUAL VEHICLE FROM SIMULTANEOUS EQUATION MODEL

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Abstract: Handling traffic is exclusively different from physical occurrence. To predict the normal behavior of an individual vehicle, an attempt has been made to find the linear coefficients value for each individual vehicle when they are in stream. These coefficients are helpful to find Passenger Car Unit (PCU) of mixed traffic flow. The value of coefficients is calculated by collecting the individual vehicle volumes and speeds. The study focuses on large percentage of vehicles like Cars, Buses, Two-Wheelers (TW), Light Commercial Vehicles (LCV) and Trucks compared to other vehicles that are less than two percent. Simultaneous Equation Model (SEM) is used to find coefficients values for six individual hourly data.

Key words: Coefficients, Individual Vehicle, SEM.

I. INTRODUCTION

In regression modeling, an equation is usually considered to indicate a relationship describing a fact. Several circumstances involve a set of relationships which explain the actions of certain variables. In particular, when a relationship is a part of a system, then some descriptive variables having a random probability distribution are associated with the problem. System of equations is used to solve a function when there is more than one unknown and there is sufficient information to set up equations in those unknowns. Endogenous variables are considered for finding the coefficients. These variables have always been the dependent variables of a system. Here the matrix method is the most important approach used to solve system of six simultaneous equations in circumstances where substitution and elimination approaches are either unfeasible or impossible. The powerful soft computing tool, Microsoft Excel spread sheet is used for finding required coefficients values of individual vehicle, during each hour for six hours in a day. MINVERSE function is used to find inverse value of matrix of a given array. The input array should contain only numbers and be a square matrix, with equal rows and columns. MMULT function is used for matrix multiplication of two arrays; the column count of first array should be equal to row count of second array for each individual equation.

II. OBJECTIVE OF THE STUDY

To determine the coefficients values of every individual vehicle during each individual hour for six-hour data by considering volume and speed of each vehicle in set of simultaneous equations using soft computing tool.

III. LITERATURE REVIEW

Research related to coefficients values for an individual vehicle using set of simultaneous equations has been published in very few journals. However, this concept was presented in one of M E dissertation work of Mr. Mritunjay Pratap Singh guided by Dr. Virendra Kumar and Prof. Sathishchandra, IIT, Roorkee, using Lotus software. Some articles explain supply and demand problem, rate, distance and time, planes, trains and automobiles, etc. The concept of following papers influenced to find the coefficients values of individual vehicles.

- L. Fox, H. D. Husky and J. H. Wilkinson have explained four methods to solve simultaneous equations. First three methods were performed by using regular desk computing machines and the last method by using punched card equipment, given by Hollerith. This method involves Choleski method for symmetric matrices in which the square matrix is given as a product of two triangular matrices, reciprocal of which, is comparatively an easier operation. Pivotal condensation procedure is used to report the result of simultaneous equations required for the calculation of a column matrix x, fulfilling the condition Ax = b. wherein A and b are known matrices of order n x n and 1 x n respectively. The inversion of matrix A is closely associated with the above equation as it involves the computation of a square matrix AX = I. The solution of AX = I provides a solution for n equations given by Ax = b in which b is indicating the n column of unit matrix I, then giving matrix A, which is inverse of X.

- Scott C. Himes1 and Eric T. Donnell concentrated on the association of traffic flow uniqueness on operating speeds of vehicle along multilane, limited access highways using a simultaneous equations approach. This study acknowledges both geometric design and traffic flow parameters in a simultaneous equations system, to model the mean operating speed and speed deviation on four-lane highways two lanes in each direction. Models for both left and right-lane mean speeds and speed variations were estimated. The three stage least squares estimator was used to investigate the possible endogeneity of mean speed and speed deviation in the system of equations and to account for the contemporary connection between the disturbances across the equations. The outcome indicates that different geometric design features are connected with mean speed and speed deviation in the left and right lane models. As such, it was suggested that prospect multilane highway speed models are measured using a simultaneous equations framework.

- Richard A.L. Carter and Anirudh L. Nagar clarify the measure of correlations with single equation within a simultaneous system or for the entire system which is different from Hooper's measure, particularly account for recognizing limitations. Also, the emphasis is made on asymptotic distribution to make system measures more attractive to trace correlation. Finally, they concluded single-equation measure acquires precise account of the recognized limitations on the equation of attention whereas the full systems measure takes account of such limitations for all equations of the model.

- Alok Kumar et al. used system of linear equations to define rank of matrix and to identify linearly independent and dependent variables. They made an attempt to compare rank of augmented matrix with rank of coefficient matrix and concluded if both matrices are not equal, then the system of equations are inconsistent.

IV. DATA AND METHODOLOGY

Selection of road stretch

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Collection of volume of each vehicle

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Measurement of average speed of each vehicle

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Estimation of total volume of all vehicles during each hour

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Measurement of stream speed of each vehicle during each hour

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Estimation of coefficients from Simultaneous Equation Model

The study has been carried out on NH-13 of section length 300 m and road width of 5.5m with worst shoulder condition. The road is 40 m in front of Srinivasa rice mill and is 6.4 km from Shivamogga bus-stand and 250 m from Subbaiah Institute of Medical Sciences. Volume and speed of particular vehicle on the stretch which is expressed as vehicle/hour and kmph. The total duration of survey is six hours conducted in clear sunny weather from 7 am to 1 pm for six days. Average six-hour day data for individual vehicle volume and speed is estimated by taking one hour as standard counting period. The average speed of individual vehicles during each hour is calculated by taking time required to reach a trap length of 40 m distance by using digital stop watch. Table 1 shows the details of an average volume of individual vehicle and total traffic volume (N) during one hour count period and the average value of N is ascertained at the bottom of the Table 1. Table 2 presents speed of individual vehicle during one hour count period. Figure 1 and Figure 2 shows the variation in individual vehicle volume and variation in speed of the individual vehicle during one hour count period. Table 3 gives product of composition of individual vehicle and its speed during that particular hour which is presented in first 5 columns; U = ((∑N)/6)/N is constant term ascertained in sixth column. For wholesomeness the data of Table 3 is treated as matrix of order 6x6. Table 4 shows the inverse matrix of Table 3 made by using Microsoft Excel MINVERSE function. Table 5 indicates the result of the coefficients for individual vehicles and the constants U which is done by using Excel MMULT function for selecting MINVERSE matrix of order 6x6 (Table 3) and selecting speed data of particular vehicle of order 6x1 (Table 2). Table 6 highlights the details of the obtained result of coefficients of individual vehicle and its constant. SEM developed by powerful Excel tool, helps to solve complex problems in a short time. The coefficients obtained from SEM are helpful to find the stream speed of the roadway system. The matrix of specific order required is on the basis of number of variables and constant as mentioned in equations 1 to 6.

Table 1: Average volume of each vehicle and total traffic during each individual hour.

Time	Car/Jeep/Van	Bus	Two Wheelers	LCV	Truck	Total Volume *N
7am to 8am	82	37	135	27	31	312
8am to 9am	96	41	167	31	29	364
9am to 10am	103	43	179	28	28	381
10am to 11am	94	35	157	31	34	351
11am to 12am	88	29	161	33	35	346
12am to 1 pm	76	27	133	29	33	298

Average value of N = (∑N)/6 = 342

*N = Total Traffic Volume during one hour.

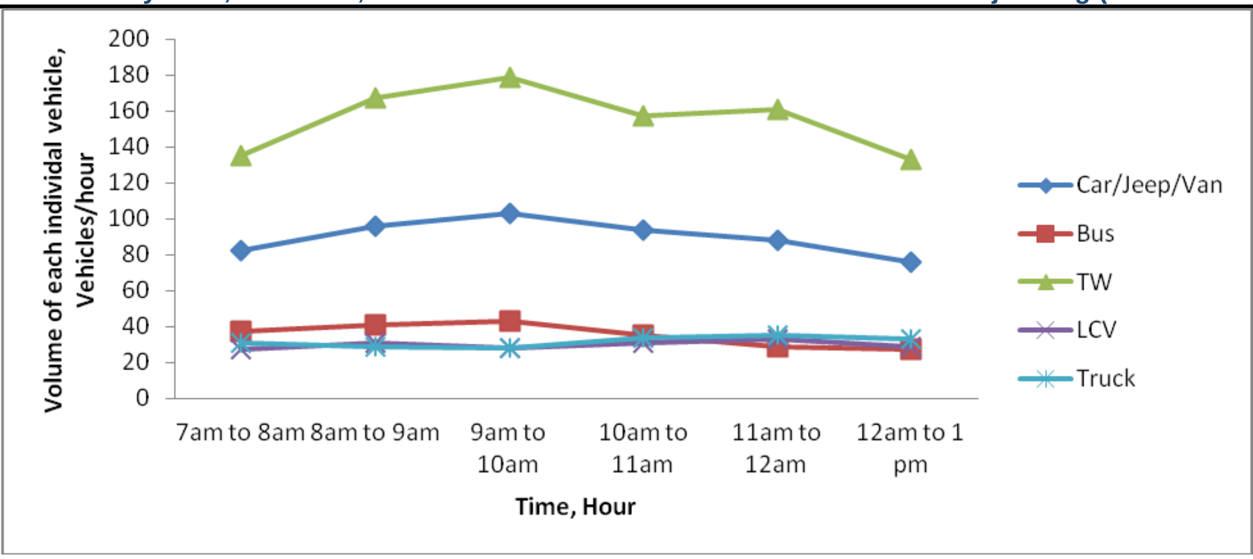

Fig 1: Variation in volume of each individual vehicle during each hour.

Table 2: Average speed of each vehicle during each individual hour.

Time	Average speed, kmph				
	Car/Jeep/Van	Bus	Two Wheelers	LCV	Truck
7am to 8am	51.69	49.29	43.28	43.58	32.29
8am to 9am	50.82	47.54	41.88	41.25	28.88
9am to 10am	48.44	46.86	40.95	39.56	27.85
10am to 11am	49.55	48.52	41.99	42.45	28.55
11am to 12am	50.21	49.52	43.12	44.85	30.55
12am to 1 pm	51.98	50.12	44.09	46.05	31.24

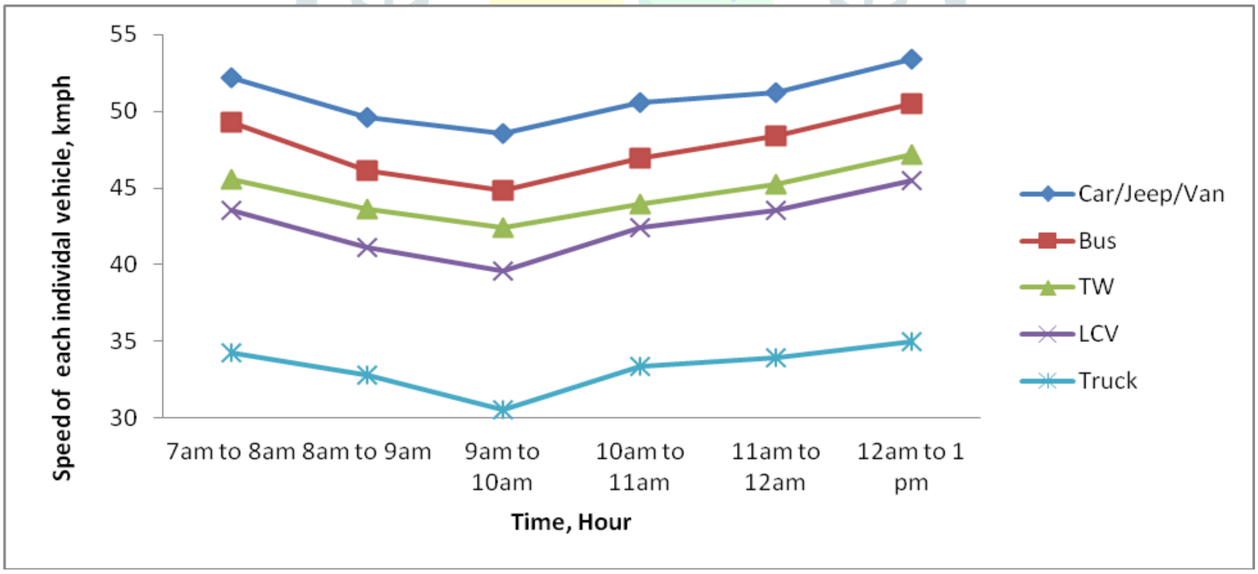

Fig 2: Variation in speed of each individual vehicle during each hour.

Table 3: Product of volume composition and speed during six hours count along with constant (Presents a matrix of order 6x6)

Volume composition*speed of vehicle					Constant (U)
Car/Jeep/Van	Bus	Two Wheelers	LCV	Truck	((∑N)/6)/N
13.72449	5.840545	19.72212	3.771346	3.407019	1.096154
13.08659	5.197088	20.01247	3.504533	2.613984	0.93956
13.11696	5.058425	19.91081	2.907297	2.24294	0.897638
13.53761	4.683618	19.66749	3.749145	3.230484	0.974359
13.02451	4.054133	21.03702	4.152659	3.43526	0.988439
13.62134	4.577315	21.0747	4.429799	3.873624	1.147651

Table 4: Inverse matrix of Table 3 data.

Car/Jeep/Van	Bus	Two Wheelers	LCV	Truck	Constant (U) ((∑N)/6)/N
-0.77173	0.159344	-0.05991	1.389046	-1.04432	0.37365
1.189243	0.300619	-0.49159	-0.69653	0.892467	-1.17479
0.403624	-0.39309	0.286408	-0.67983	0.857219	-0.44883
-1.70722	3.588675	-2.17704	0.884281	-1.63008	1.048589
2.786269	-3.19124	0.407919	-0.54821	3.296462	-2.74141
-5.81031	1.047608	4.438657	-2.78723	-11.7405	14.56967

Table 5: Result of Matrix after using MMULT function for each vehicle and constant

1.393167	0.265606	0.742365	1.058662	0.866727
0.914979	1.50978	0.73339	0.564112	1.623764
1.029246	1.435146	1.057424	0.778238	0.422806
0.518481	-0.41136	1.160505	1.445682	3.573677
1.623076	3.467381	0.562831	1.710909	1.056865
-0.02611	-1.62333	3.611859	-0.7974	-11.409

Table 6: Coefficients values of each individual vehicle when they are in stream

		Vehicle Type					Constant
		Car	Bus	Two wheeler	LCV	Truck	U
Coefficients	1	1.393167	0.914979	1.029246	0.518481	1.623076	-0.02611
	2	0.265606	1.50978	1.435146	-0.41136	3.467381	-1.62333
	3	0.742365	0.73339	1.057424	1.160505	0.562831	3.611859
	4	1.058662	0.564112	0.778238	1.445682	1.710909	-0.7974
	5	0.866727	1.623764	0.422806	3.573677	1.056865	-11.409

The following equations are used to find coefficients value of individual vehicle for stream speed of car during six individual hourly volumes.

$Vc_1 = c_1 Vc_1 nc_1 + c_2 V_{B1} n_{B1} + c_3 V_{TW1} n_{TW1} + c_4 V_{L1} n_{L1} + c_5 V_{T1} n_{T1} + c_6 (U_1)$ -- 01

$Vc_2 = c_1 Vc_2 nc_2 + c_2 V_{B2} n_{B2} + c_3 V_{TW2} n_{TW2} + c_4 V_{L2} n_{L2} + c_5 V_{T2} n_{T2} + c_6 (U_2)$ -- 02

$Vc_3 = c_1 Vc_3 nc_3 + c_2 V_{B3} n_{B3} + c_3 V_{TW3} n_{TW3} + c_4 V_{L3} n_{L3} + c_5 V_{T3} n_{T3} + c_6 (U_3)$ -- 03

$Vc_4 = c_1 Vc_4 nc_4 + c_2 V_{B4} n_{B4} + c_3 V_{TW4} n_{TW4} + c_4 V_{L4} n_{L4} + c_5 V_{T4} n_{T4} + c_6 (U_4)$ -- 04

$Vc_5 = c_1 Vc_5 nc_5 + c_2 V_{B5} n_{B5} + c_3 V_{TW5} n_{TW5} + c_4 V_{L5} n_{L5} + c_5 V_{T5} n_{T5} + c_6 (U_5)$ -- 05

$Vc_6 = c_1 Vc_6 nc_6 + c_2 V_{B6} n_{B6} + c_3 V_{TW6} n_{TW6} + c_4 V_{L6} n_{L6} + c_5 V_{T6} n_{T6} + c_6 (U_6)$ -- 06

In the above equations

$Vc_1, V_{B1}, V_{TW1}, V_{L1}, V_{T1}$ …………… V_{T6} are speeds of Car, Bus, Two Wheeler, LCV and Trucks from first hour to sixth hour.

$nc_1, n_{B1}, n_{TW1}, n_{L1}, n_{T1}$ ……….. n_{T6} are composition of (Specific vehicle/Total vehicles) Car, Bus, Two Wheeler, LCV and Trucks from first hour to sixth hour.

c_1, c_2, c_3, c_4, c_5 are coefficients for Car, Bus, Two Wheeler, LCV and Trucks when all vehicles are in stream, for stream speed of car and c_6 is coefficient of constant U.

U_1, U_2, U_3, U_4, U_5 and U_6 are Constant terms from first hour to sixth hour calculated from ratio of total average volume of six hours to total vehicle volume during each hour.

To determine coefficients c_1 to c_6 for stream speed of Car, the matrix of size 6x6 (right of equation) equated to matrix of size 6x1(left of equation). Same procedure is repeated to other four vehicles by equating the same matrix of size 6x6 to corresponding stream speed of each vehicle of matrix size 6x1.

V. RESULTS AND DISCUSSION

From Table 2, speed of vehicles subsequently reduces for all type of vehicles due to worst shoulder condition and it will be higher for two wheelers. This is due to the presence of a maximum composition of two wheelers and is constrained to travel within 5.5 m wide roadway.

The result presented in Table 5 highlights the coefficients of individual vehicle when all vehicles are in stream. The coefficients value during each hour may be positive or negative i.e., it's purely on the basis of speed variation and volume composition of each vehicle. These obtained coefficients values are helpful to find the dynamic PCU value of individual vehicle.

VI. CONCLUSIONS

SEM is formed by series of set of linear equations. Usually regression model is useful tool for single equation corresponds to changes in response variable (Y) due to changes in explanatory variable (X) whereas SEM can apply to more than two equations i.e. more than two variables. SEM is used to accomplish the final result for variables when they are combined in stream. Matrix of order nxm is used to solve multiple equations with multiple unknowns; here n is the number of rows corresponding to number of equations and m is the number of columns corresponding to the number of unknown variables.

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