AN ANALYSIS OF RAMP SERVICE TIME
DISTRIBUTIONS BY MONTE CARLO SIMULATION

William Brian Perruccio

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INTRODUCTION

The ramp-freeway merging process is one of the most complex operational problems that is encountered in analysis of freeway operations. The overall efficiency of traffic movement on the freeway, and the extent to which the overall capacity potential of the freeway can be safely realized, depends to a large extent on proper operations in the merge area. In recognition of the criticality of the merging process the Department of Civil Engineering of the University of Connecticut, in cooperation with the Connecticut State Highway Department, has undertaken a research study of several basic aspects of the problem, with a bent toward developing a merging metering and control system.

Description of Problem

This research study is concerned with the analysis of only one aspect of the ramp-merging process--namely, the distribution of service times for ramp vehicles attempting to merge with the freeway traffic stream. Service time, or the time that a vehicle spends in the first-in-line position on the ramp, is a direct indication of the rate at which ramp traffic can be accommodated in the merge process.

Service times for ramp vehicles are related to the basic components of the traffic system including the level of traffic on the freeway, the driver-vehicle units that make up the traffic, and the roadways upon which the traffic operates. The level of traffic on the freeway and the operational characteristics of the driver-vehicle units have the most direct influence on service times. The former controls the availability of gaps in the shoulder lane of the freeway; and the latter regulates the useage of the available gaps by the ramp traffic. Of course, there are numerous roadway characteristics that influence both the availability and the useage of gaps, and that thereby have an effect on the distribution of ramp service times. These characteristics include the number of lanes on the freeway, the proximity of other access and egress points on the freeway, and the ramp and freeway geometry.

Significance of Research

Although the merging of ramp and freeway traffic is a complex process, there is a possibility that it can be described as a classical queueing problem. In order to do this it is necessary to be able to mathematically describe the distribution of inter-vehicular arrival times on the ramp, the order in which ramp arrivals are allowed to enter the freeway, and the distribution of service times for ramp vehicles. If these characteristics are known, queueing equations can be derived to describe the probability that the system will be in any particular state, and to describe characteristics of the system such as the average queue length, the average number of vehicles in the system, the average waiting time of a vehicle, the average waiting time of a vehicle that waits, and the average time a vehicle spends in the system.

There are numerous probability functions that adequately describe the arrival times for ramp vehicles. The more common ones include the negative-exponential function, the hyper-exponential function, the Erlang function, and the hyperlang function. Although each of these probability distributions has particular merit, the hyperlang model appears to be the most realistic model. It is a very general model that includes the simple-exponential, the hyperexponential, and the Erlang function as special cases.

The queueing discipline is established by the geometry of the ramp area. In general, service is provided to the ramp traffic on a first come, first serve basis. That is, a trailing vehicle cannot preempt service priority and pass a leading vehicle to accept a gap in the shoulder-lane traffic stream.

The distribution of service times for ramp vehicles is not known. There has been very little field research to measure and describe this phenomenon.

Study Delimitations

Extensive research on gap availability and gap useage is already known. Because of this, and the fact that these two traffic characteristics control ramp service time, additional field studies were considered to be unnecessary. Instead, the ramp-freeway merging process was studied by means of Monte Carlo simulation on an IBM 360/65 third generation digital computer.

distributions; and the mean delay incurred by ramp vehicles was presented graphically.

Evans, Herman and Weiss (8) reported results from a simulation study of queueing at a stop sign for a main stream of traffic with random arrivals. They compared the average length of queue with results from an analytical theory and found good agreement.

Hawkes (9) established a model to study the build up of two conflicting queues at an idealized junction with random inputs. Average waiting times were computed and some numerical results were presented.

Dawson and Michael (4) utilized a digital simulation model to determine the average vehicle delay and the average queue length encountered by on-ramp vehicles merging into the freeway traffic stream.

Drew (5) suggested that if the inter-vehicle times between arrivals could be represented by an exponential function and the distribution of time spent by merging vehicles at the head of a queue could be approximated by the Erlang distribution, the entrance ramp merging operation can be considered within the context of classical queueing theory. The queueing theory approach is practical when the arrival distribution and the service time distribution are amenable mathematically, and the queue discipline is known. By assuming that the arrival distribution was exponential, Drew mathematically derived queueing formulas for the mean queue length and the mean waiting time for a queue of ramp vehicles waiting to merge. He was not able to obtain a good Erlang fit to ramp delays observed in the field, but he concluded that the conventional exponential-Erlang queueing formulas were appropriate models. Drew then used the derived queueing model to develop ramp metering techniques.

METHODOLOGY

The ramp-freeway merging process, and the associated ramp service times, were studied by means of Monte Carlo simulation on an IBM 360/65 computer. A general purpose on-ramp simulator previously developed by Dawson (2) was modified for this study.

Description of Ramp-Freeway Merge Simulator

The on-ramp traffic simulator was programmed in FORTRAN IV coding using open and closed subroutines under the control of the master program. A copy of the simulator program appears in Appendix A. Several aspects of it that were modified to reflect latest published research on freeway operations are summarized below.

Minimum Time Clearance. The minimum time that a driver demands as a buffer naturally varies from driver to driver. Instead of using a fixed average freeway vehicle-ramp vehicle buffer, this spacing was described by a normal probability distribution with a mean of 1.50 seconds and a standard deviation of 0.20 seconds.

The minimum clearance time for a ramp vehicle following another ramp vehicle through the system also varies among drivers; a normal distribution with a mean of 1.80 seconds and a standard deviation of 0.15 seconds was used to establish this spacing. This mean clearance time is related to the drivers P.I.E.V. time and the maximum flow rate of the shoulder-lane. The average P.I.E.V. time of drivers is generally considered to be 1.50 seconds, while a maximum flow rate of 2000 vph is equivalent to an average inter-vehicular spacing of 1.80 seconds. Therefore, the selection of a mean spacing of 1.80 seconds was considered justified.

Gap Acceptance. A gap acceptance model was developed from a nationwide study of gap acceptance in the freeway merging process (6). These studies showed that there is a three space function that relates the probit of gap acceptance to the log of the gap length and to the relative speed of the ramp and freeway vehicles. Probit equations were reported for several ramp configurations across the United States. A typical ramp was selected for this study and the necessary parameters were calculated to describe the appropriate gap acceptance model. The gap acceptance model is of the following form--

$$Y = a + b_1 x_0 + b_2 u_r + 5.0$$

where:

Y = probit of P, P being the probability of accepting a gap or lag t;

x_0 = log t, t being the time interval, either gap or lag;

u_r = relative speed of ramp vehicle to shoulder-lane vehicle;

b_1 = constant dependent on ramp studied;

b_2 = constant dependent on ramp studied;

a = constant dependent on ramp studied;

Headway and Vehicle Generators. Several probabilistic models are available to describe headways in the traffic stream. For the purpose of this study the shifted-exponential model was used to describe headways in the shoulder-lane stream, and the hyperlang model was used to describe ramp headways.

The shifted-exponential model is described by the mathematical model--

$$P(h \geq t) = e^{-\frac{(t - d)}{(\bar{t} - d)}}$$

where:

$P(h \geq t)$ = probability that a headway is equal to or greater than t,

t = any time,

$\bar{t}$ = average headway in stream,
= 3600/hourly volume, and

d = minimum allowable headway in stream.

The hyperlang headway distribution that was used to describe the ramp traffic stream was proposed by Dawson and Chimini (3). This distribution is based on the theory that a traffic stream is made up of two populations of vehicles, a free population and a constrained population. Each of these populations has its own distribution, the overall headway distribution is described by the model--

$$P(h \geq t) = a_1 e^{-\frac{(t - d_1)}{(\bar{t}_1 - d_1)}} + a_2 e^{-k\frac{(t - d_2)}{(\bar{t}_2 - d_2)}} \sum_{x=0}^{k-1} \left[\frac{\left[k \frac{(t - d_2)}{(\bar{t}_2 - d_2)} \right]^x}{x!} \right]$$

where:

$P(h \geq t)$ = probability that a headway is equal to or greater than t,

a_1 = proportion of free vehicles in the traffic stream,

d_1 = the minimum free headway,

$\bar{t}_1$ = the average free headway,

a_2 = proportion of constrained vehicles in the stream,

d_2 = the minimum headway in the constrained headway stream,

$\bar{t}_2$ = the average headway in the constrained headway distribution,

k = an index that indicates the degree of nonrandomness in the constrained headway distribution,

t = any time duration.

Speed Models. All ramp vehicles were given a speed of 30 mph on the assumption that ramp geometry governs speed regardless of traffic conditions. Shoulder-lane speeds (11) were described by the equation--

$$SP = 52.0 - 0.008V_s \quad : 0 \leq V_s \leq 1800$$

where:

SP = shoulder-lane speed in ramp vicinity, and

V_s = shoulder-lane volume (vph).

Use of Ramp Simulator

Simulation runs were initiated with an empty system. The simulator was pre-loaded with 300 ramp vehicles to place the system in equilibrium, but no service times were recorded during the pre-loading period. The surveillance system was actuated after the pre-loading period, and 1000 ramp vehicles were generated for observation.

Simulation runs were made at ramp volumes varying from 200-1000 vph in increments of 100 vph. For each ramp volume, shoulder-lane volume was varied from 100 vph to the highest volume at which the ramp volume could be accommodated.

These simulations runs produced service times for the individual ramp vehicles. Service times were kept separately for vehicles that were not forced to wait on the ramp for previous ramp vehicles, and for vehicles that were forced to wait for previous ramp vehicles. These service times are referred to as, service time given a zero wait and service time given a wait, respectively. When plotted in a cumulative form the distribution of service times appeared to follow the hyperlang function. To test this hypothesis a non-linear least-squares analysis was performed using Marquardt's Algorithm (13). This technique employs the method of steepest descent and the method of Gauss to converge on a set of distribution parameters that tend to minimize the sum of squares of the deviation of the service times about the hypothesized hyperlang function. The multiple correlation coefficients, R^2, were determined for each set of parameters; and, these coefficients served as a basis for the selection of the "best" set of parameters.

RESULTS AND DISCUSSION

Simulation Precision

The ramp and shoulder-lane traffic flows were generated by a Monte Carlo technique whereby probabilistic headway distributions are sampled using random numbers. Of course, the simulated stream flows were of a probabilistic nature, so that the resulting flow rates varied slightly from the flow rates that were called for at the start of each simulation run. The requested ramp volumes are compared to the generated volumes in Table 1. The small variations that resulted are due partly to sampling error and partly to errors inherent in the hyperlang model. It should be noted that the maximum variation is only slightly in excess of six percent.

Table 1

Ramp Volume Generated By
Simulator Compared With
Ramp Volume Requested

Volume (vph)	
Requested	Generated
200	202
300	292
400	392
500	468
600	575
700	661
800	764
900	857
1000	956
1050	1010

The requested and generated shoulder-lane volumes are compared in Table 2. Because the number of shoulder-lane vehicles generated was dependent on the ramp volume, the simulated shoulder-lane volumes are different for almost every run. In no case are the differences greater than two percent.

Simulation Results

The service times that were encountered by ramp vehicles fall into two classifications. The distribution of service times for those vehicles that arrived at the merge area and were not forced to wait in line for preceeding ramp vehicles is distinctly different from the distribution of service times for vehicles that had to wait in line before they were served. The service times of vehicles that wait are compounded by the effect of the minimum inter-vehicular spacing that is required by a following vehicle. For this reason it is important to note the relative proportions of ramp vehicles that wait in line, and that do not wait in line, prior to assuming the first-in-line position on the ramp.

The relationship between the portion of vehicles that do not wait and ramp volume are depicted for each shoulder-lane volumes in figure 1. As would be expected, the portion of ramp vehicles that do not have to wait decreases as ramp volume increases, and it decreases as shoulder-lane volume increases.

The Service Time Model.

The hyperlang function was selected to describe the service time distributions both for vehicles that wait and for vehicles that do not wait before being served.

Mathematically, it takes the form--

TABLE 2

Shoulder-Lane Volumes Generated by Simulator at Various Requested Combinations of Ramp and Shoulder-Lane Volumes

Shoulder-Lane Volume Requested (veh/hr)	Ramp Volume Requested (veh/hr)									
	200	300	400	500	600	700	800	900	1000	1050
100	101	102	102	103	100	98	99	98	102	101
200	205	209	204	205	202	204	204	210	205	205
300	307	308	308	313	306	311	307	305		
400	409	411	410	410	418	418	408			
500	509	511	511	512	510					
600	605	614	613	614						
700	714	713	718	716						
800	808	808	817							
900	909	911								
1000	1013	1020								
1100	1111									
1200	1215									
1300	1319									

$$P(ST \geq t) = a_1 e^{-\frac{(t - d_1)}{(\bar{t}_1 - d_1)}} + a_2 e^{-k\frac{(t - d_2)}{(\bar{t}_2 - d_2)}} \sum_{x=0}^{k-1} \left[\frac{\left[k \frac{(t - d_2)}{(\bar{t}_2 - d_2)} \right]^x}{x!} \right]$$

where:

$P(ST \geq t)$ = probability that the service time is equal to or greater than t;

a_1 = the proportion of the service time distribution explained by the exponential function;

d_1 = the minimum of the exponential function;

$\bar{t}_1$ = the average of the exponential function:

a_2 = the proportion of the service time distribution explained by the Erlang function;

d_2 = the minimum of the Erlang function;

$\bar{t}_2$ = the average of the Erlang function;

k = the index that indicates the degree of non-randomness in the Erlang function;

The hyperlang function was selected as a descriptor because it is a very general model that includes the common service time functions (exponential, Erlang, and hyper-exponential) as special cases.

Service Time Given a Wait. The parameters of the hyperlang model were evaluated for the distributions of service time given a wait, using the method of non-linear least-squares. In almost all cases the hyperlang function, in the general form, proved to

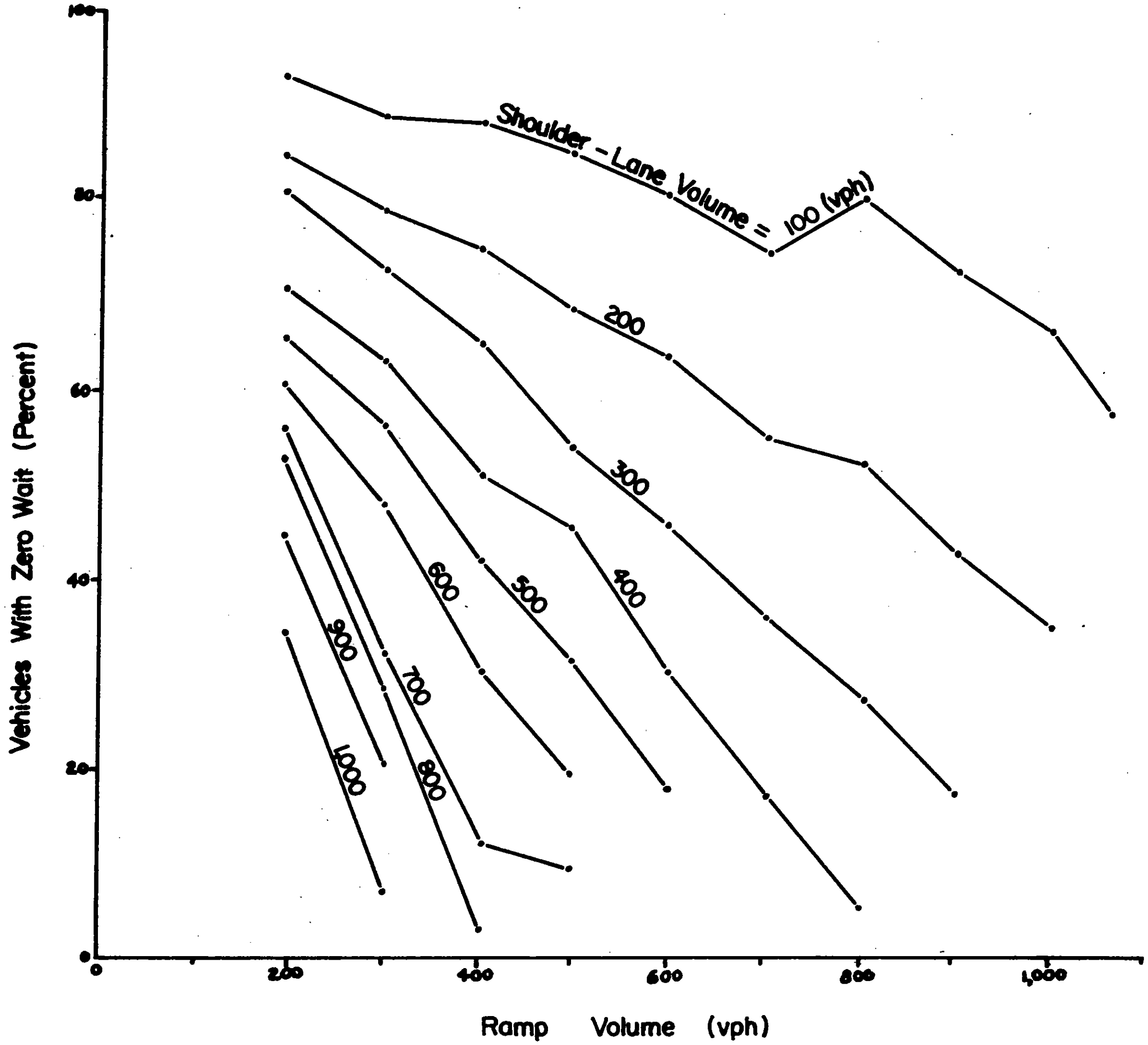

Fig. 1. Relationship Between Percent of Vehicles With Zero Wait And Ramp Volume

be a good descriptor, as was indicated by multiple correlation coefficients, R^2, that ranged from 0.9085 to 0.9997. This contradicts Drew's assumption that the Erlang function is a good general descriptor for service times.

The parameters for the models that were developed to describe service times at a ramp volume of 300vph are tabulated in Table 3, and the parameters for all ramp volumes are presented in Appendix B.

The a_1 coefficients varied from 0 percent at low shoulder-lane volume to 79 percent at high shoulder-lane volume, while a_2 varied from 100 percent to 21 percent, generally decreasing as shoulder-lane volume increased. This indicates that at low shoulder-lane volumes the service time distribution tends to be uniform as a result of large gaps in the shoulder-lane. Large gap lengths offer little resistance to vehicles as they maneuver in the merge area and consequently, the service time distribution is merely the distribution of minimum time spacings between departing ramp vehicles. As volume in the shoulder-lane increases and gaps in this lane decrease in size, the drivers waiting time becomes distinctly non-uniform as indicated by a large a_1 value.

The relationship between a_1 and shoulder-lane volume is plotted in figure 2. In general this parameter is independent of ramp volume, although there is some variation in a_1 with variation in ramp volume, at each of the different levels of flow on the shoulder-lane, there is no pattern to the variation. The differences are apparently due to random sampling error. This phenomenon merely implies that service times are dependent on available capacity in the shoulder-lane and not on the level of traffic demand on the ramp.

TABLE 3

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 300(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9889	00	..	..	10	100.0	1.84	1.35
200	.9630	00	..	..	10	100.0	1.87	1.35
300	.9956	.27	13.19	1.35	10	.73	1.80	1.35
400	.9960	.29	14.85	1.35	10	.71	1.80	1.35
500	.9934	.43	12.14	1.35	10	.57	1.80	1.35
600	.9974	.42	15.57	1.35	10	.58	1.80	1.35
700	.9976	.49	14.84	1.35	10	.51	1.80	1.35
800	.9972	.61	15.28	1.35	10	.59	1.75	1.35
900	.9991	.58	16.37	1.35	10	.42	1.78	1.35
1000	.9969	.64	17.98	1.35	10	.36	1.77	1.35
1050	.9949	.66	17.98	1.35	10	.34	1.77	1.35

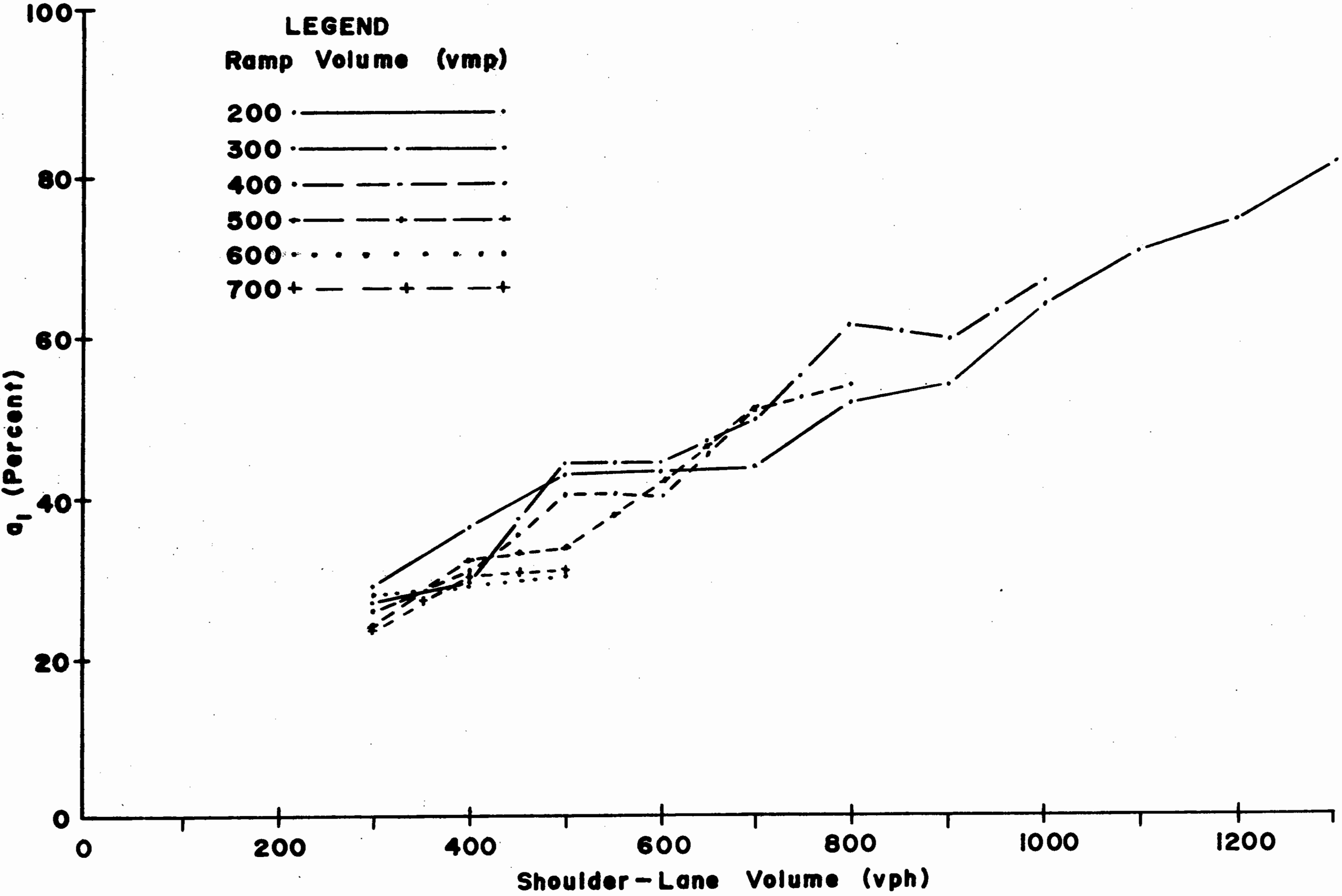

Fig. 2 RELATIONSHIP BETWEEN a_1 AND SHOULDER-LANE VOLUME FOR SERVICE TIME GIVEN A WAIT

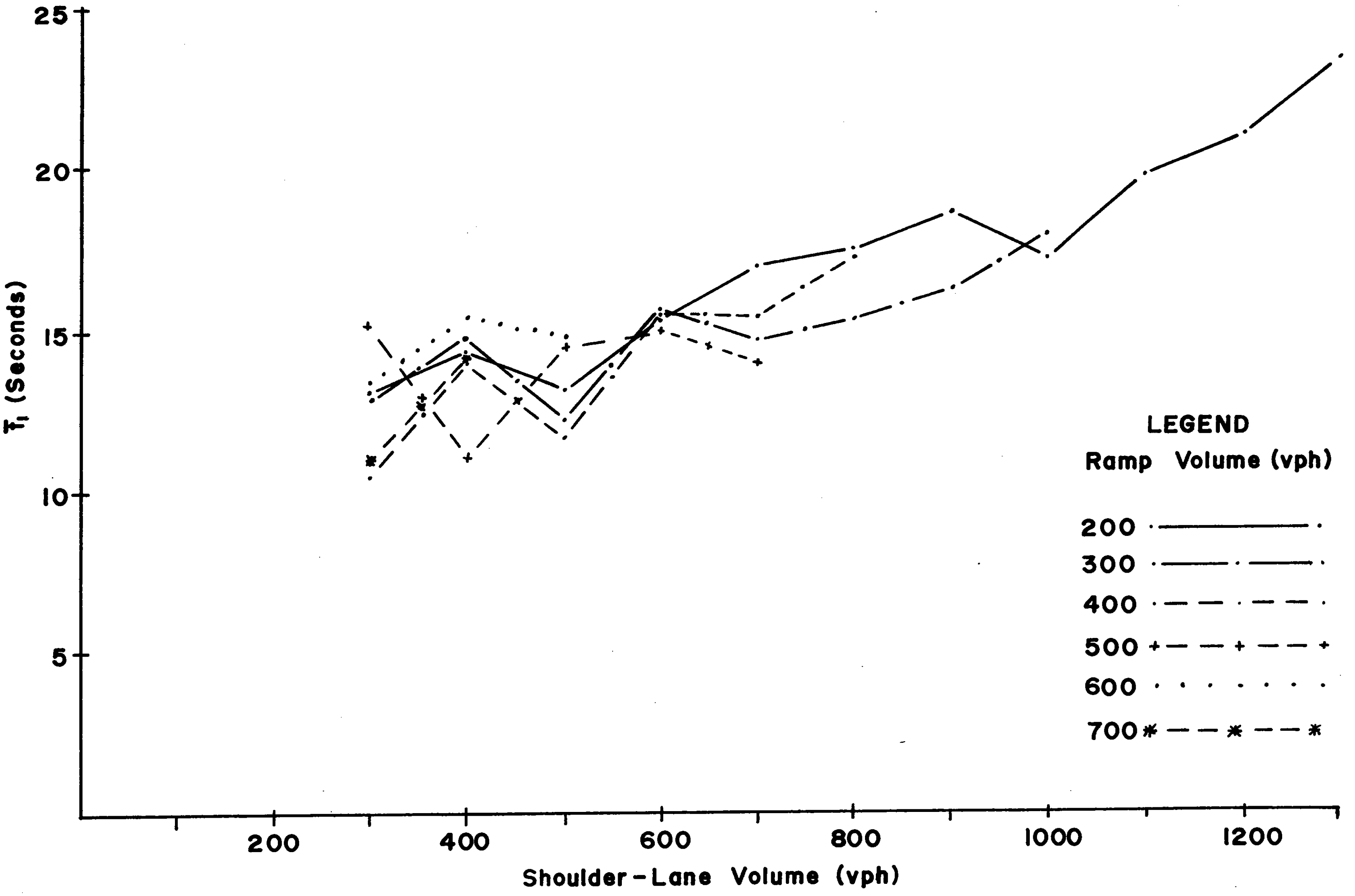

Fig. 3 RELATIONSHIP BETWEEN $\bar{t}_1$ AND SHOULDER-LANE VOLUME FOR SERVICE TIME GIVEN A WAIT

TABLE 4

Hyperlang Model Parameters For Service Time Given a Zero Wait

Ramp Volume = 300(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9858	00	..	..	1	100.0	1.06	00
200	.9759	00	..	..	1	100.0	2.16	00
300	.9652	00	..	..	1	100.0	3.32	00
400	.9754	00	..	..	1	100.0	5.16	00
500	.9800	00	..	..	1	100.0	5.93	00
600	.9773	00	..	..	1	100.0	8.49	00
700	.9838	00	..	..	1	100.0	7.93	00
800	.9765	00	..	..	1	100.0	8.36	00
900	.9976	00	..	..	1	100.0	12.72	00
1000	.9756	00	..	..	1	100.0	10.81	00

case of the hyperlang function. The R^2 values for the selected models ranged from 0.8229 to 0.9968. It is interesting to note that this is similar to the results reported by Drew (5).

The minimum service time was set equal to zero since it is possible for a vehicle to enter the freeway traffic stream immediately upon arriving in the first-in-line position.

The average for the Erlang function $\bar{t}_2$, increases in value with increasing shoulder-lane volume as shown in figure 4. However, $\bar{t}_2$ is generally constant for all ramp volumes at a particular shoulder-lane volume. Again this indicated that service time is dependent on shoulder-lane volume and independent of ramp volume.

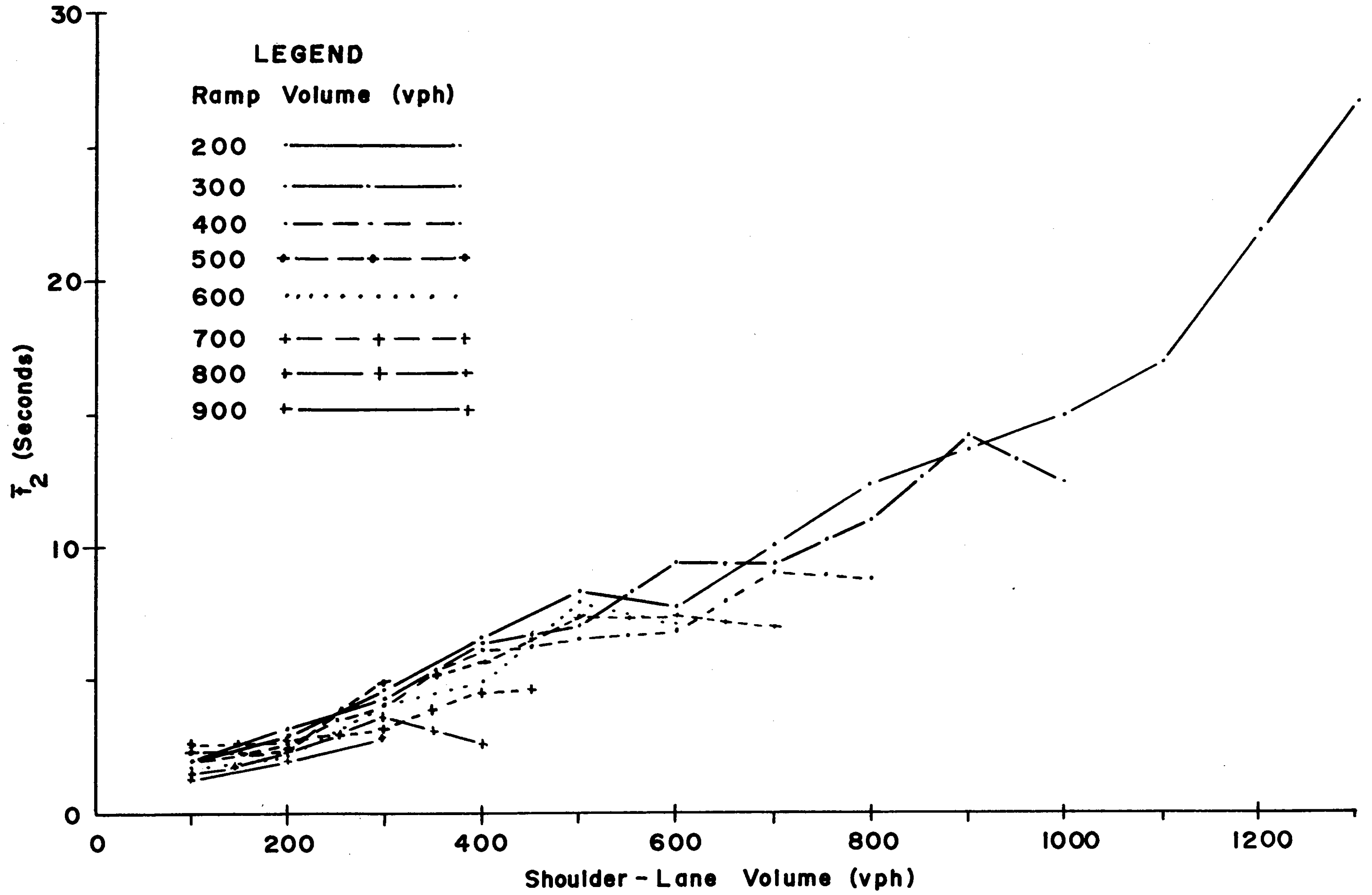

Fig. 4 RELATIONSHIP BETWEEN $\bar{t}_2$ AND SHOULDED-LANE VOLUME FOR SERVICE TIME GIVEN A ZERO WAIT

SUMMARY AND CONCLUSIONS

The service times encountered by ramp vehicles can be separated into two groups; namely, service time given a wait, and service time given a zero wait. The distributions of service times given a wait were adequately described by the general hyperlang model, but the distributions of service times given a zero wait were best described by the special exponential case of the hyperlang model. The composite description of service times could be formed by linearly combining the distribution of service times given a wait with the zero wait distribution. The resulting overall model would be a rather complex, three-term distribution that would not lend itself to the development of a queueing model. Two alternatives are then available to determine the distribution of service times; field studies and digital simulation. Simulation is perhaps the most practical way to analyze the operation of a ramp-freeway merge operation.

APPENDIX A

Computer Program for On-Ramp Simulator with Acceleration Lane

```
//D0524 JOB )0524,P000,5,11,2*,@WILLIAM  PERRUCCIO@,MSGLEVEL=1
//STEP EXEC FORTRAN,PARM.FORT=)NOSOURCE,NODECK,NCLIST,NOMAP,BCD*
//FORT.SYSIN DD *
C
C
C     ACCELERATION LANE
C
C
C     RAMP CAPACITY BY DIGITAL SIMULATION
C
C     DEFINITIONS
C
C     ACCEPT     = NAME OF SUBROUTINE TO DETERMINE IF GAP IS
C                  ACCEPTABLE TO A VEHICLE IN EITHER MOVING
C                  OR STOPPED CONDITION
C     AM         = THE DESIRED MEAN OF THE NORMAL
C                  DISTRIBUTION FOR SUBROUTINE GAUSS
C     ACPTNO     = NUMBER RETURNED BY ACCEPT.  IF ACPTNO IS
C                  MINUS OR ZERO, GAP IS ACCEPTABLE.  IF
C                  ACPTNO IS POSITIVE, GAP IS NOT ACCEPTABLE.
C     ADELAY     = ACCUMULATED DELAY TIME
C     ASG        = AVAILABLE SHOULDER LANE GAP
C     ASORT      = NAME OF SUBROUTINE THAT PERFORMS PUSH-DOWN
C                  SORT OF FLOATING POINT QUANTITIES
C     ASRTIM     = ACCUMULATED SERVICE TIMES OF ALL VEHICLES
C     ASRTM1     = ACCUMULATED SERVICE TIMES OF VEHICLES THAT
C                  DO NOT WAIT FOR QUEUE
C     ASRTM2     = ACCUMULATED SERVICE TIMES OF VEHICLES
C                  THAT WAIT FOR QUEUE
C     ASSRT1     = ACCUMULATED SQUARES OF SERVICE TIMES OF
C                  VEHICLES THAT DO NOT WAIT FOR QUEUE
C     ASSRT2     = ACCUMULATED SQUARES OF SERVICE TIMES OF
C                  VEHICLES THAT WAIT FOR QUEUE
C     ASSRTM     = ACCUMULATED SQUARES OF SERVICE TIMES OF
C                  ALL VEHICLES
C     ASSWT2     = ACCUMULATED SQUARES OF WAIT TIMES OF
C                  VEHICLES THAT WAIT FOR QUEUE
C     ASSYT1     = ACCUMULATED SQUARES OF SYSTEM TIMES OF
C                  VEHICLES THAT DO NOT WAIT FOR QUEUE
C     ASSYT2     = ACCUMULATED SQUARES OF SYSTEM TIMES OF
C                  VEHICLES THAT WAIT FOR QUEUE
C     ASSYTM     = ACCUMULATED SQUARES OF SYSTEM TIMES OF
C                  ALL VEHICLES
C     ASWAIT     = ACCUMULATED SQUARES OF WAIT TIMES OF ALL
C                  VEHICLES
C     ASWT2      = ACCUMULATED SQUARES OF SERVICE TIMES
C                  OF VEHICLES THAT WAIT
C     ASYTM1     = ACCUMULATED SYSTEM TIMES OF VEHICLES THAT
C                  DO NOT WAIT FOR QUEUE
C     ASYTM2     = ACCUMULATED SYSTEM TIME OF VEHICLES THAT
C                  WAIT FOR QUEUE
C     ASYTM      = ACCUMULATED SYSTEM TIMES OF ALL VEHICLES
C     AVLTIM     = TIME AVAILABLE BETWEEN ARRIVAL TIME INTO
C                  SYSTEM AND EARLIEST POSSIBLE DEPARTURE
C                  TIME FROM SYSTEM
C     AVQL       = AVERAGE QUEUE LENGTH
C     AVSRT1     = AVERAGE SERVICE TIME OF VEHICLES THAT DO
C                  NOT WAIT FOR QUEUE
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C      AVSRT2      = AVERAGE SERVICE TIME OF VEHICLES THAT WAIT
C                    FOR QUEUE
C      AVSRTM      = AVERAGE SERVICE TIME OF ALL VEHICLES
C      AVSYT1      = AVERAGE SYSTEM TIME OF VEHICLES THAT DO
C                    NOT WAIT FOR QUEUE
C      AVSYT2      = AVERAGE SYSTEM TIME OF VEHICLES THAT
                     WAIT FOR QUEUE
C      AVSYTM      = AVERAGE SYSTEM TIME OF ALL VEHICLES
C      AVWAIT      = AVERAGE WAIT OF ALL VEHICLES
C      AVWT1       = AVERAGE WAIT OF VEHICLES THAT DO NOT WAIT
C                    FOR QUEUE
C      AVWT2       = AVERAGE WAIT OF VEHICLES THAT WAIT FOR QUEUE
C      AWAIT       = ACCUMULATED WAIT TIMES OF ALL VEHICLES
C      BOG         = CONSTANT FOR THE PROBIT EQUATION
C      B1G         = CONSTANT FOR THE PROBIT EQUATION
C      B2G         = CONSTANT FOR THE PROBIT EQUATION
C      BOL         = INTERCEPT FOR THE PROBIT EQUATION USED
C                    TO DETERMINE GAP ACCEPTANCE
C      B1L         = SLOPE FOR THE PROBIT EQUATION
C                    TO DETERMINE GAP ACCEPTANCE
C      B2L         = SLOPE FOR PROBIT EQUATION USED
C                    TO DETERMINE GAP ACCEPTANCE
C      DDELAY(I)   = DELAY INCURRED BY THE LTH OBSERVED VEHICLE
C      DELAYM      = MEAN DELAY FOR 1000 OBSERVED VEHICLES
C      EDEPTM      = EARLIEST DEPARTURE TIME WITHOUT ENCROACHING
C                    UPON MINIMUM ALLOWABLE TIME SPACING TO
C                    LEADING RAMP VEHICLE
C      GAUSS       = NAME OF SUBROUTINE THAT COMPUTES A
C                    NORMALLY DISTRIBUTED RANDOM NUMBER
C                    WITH A GIVEN MEAN AND STANDARD DEVIATION
C      I           = INDEX OF VEHICLE GENERATED
C      IC          = INDEX OF OPERATING CONDITION
C                    1 - MOVING
C                    2 - STOPPED
C      IQ          = INDEX OF QUEUE CONDITION
C                    1 - NO QUEUE
C                    2 - QUEUE
C      IQL1        = INDEX USED IN DETERMINING QUEUE LENGTH
C      IQL2        = INDEX USED IN DETERMINING QUEUE LENGTH
C      IX*         = AN ODD INTEGER NUMBER WITH NINE
C                    OR LESS DIGITS ON THE FIRST ENTRY TO
C                    SUBROUTINE GAUSS.  THEREAFTER IT WILL CONTAIN
C                    A UNIFORMLY DISTRIBUTED INTEGER RANDOM
C                    NUMBER GENERATED BY SUBROUTINE GAUSS FOR
C                    USE ON THE NEXT ENTRY TO THE SUBROUTINE.
C                    THE SYMBOL  *  CAN TAKE ON THE LETTER A FOR
C                    THE GAP ACCEPTANCE ROUTINE, R FOR THE RAMP
C                    HEADWAY GENERATOR AND S FOR THE SHOULDER
C                    LANE HEADWAY GENERATOR.
C      IY*         = A RESULTANT INTEGER RANDOM NUMBER REQUIRED
C                    FOR THE NEXT ENTRY TO SUBROUTINE RANDU.
C                    THE RANGE OF THIS NUMBER IS BETWEEN 0
C                    AND 2**31.
C                    THE SYMBOL  *  CAN TAKE ON THE LETTER A
C                    FOR THE GAP ACCEPTANCE ROUTINE, R FOR THE
C                    RAMP HEADWAY GENERATOR AND S FOR THE
C                    SHOULDER-LANE HEADWAY GENERATOR
C      J           = INDEX FOR VEHICLES NOT WAITING FOR QUEUE
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C     K           = INDEX FOR VEHICLES WAITING FOR QUEUE
C     KK          = PARAMETER WHICH IS A POSITIVE INTEGER
C                   WHICH DETERMINES THE INDEX OF RANDOMNESS
C                   FOR THE HYPERLANG HEADWAY GENERATOR
C     L           = INDEX FOR OBSERVED VEHICLES
C     LQ(L)       = QUEUE EXISTING AS L-TH VEHICLE ENTERS SYSTEM
C     LQMAX       = MAXIMUM QUEUE OBSERVED
C     NRDEPT      = NUMBER OF RAMP VEHICLE DEPARTURES
C     NSVEH       = NUMBER OF SHOULDER LANE VEHICLES GENERATED
C                   PAST RAMP ENTRANCE
C     NVW         = NUMBER OF VEHICLES THAT WAIT FOR A QUEUE
C     NVW**       = NUMBER OF VEHICLES WAITING LONGER THAN **
C                   SECONDS WHERE ** HAS VALUES OF 30, 60,
C                   90, 120, 150 AND 180
C     NVWGT       = NAME OF SUBROUTINE TO DETERMINE NUMBER OF
C                   VEHICLES BY LENGTH OF DELAY
C     PAG         = PROBABILITY OF ACCEPTING GAP
C     PRNORM      = NAME OF SUBROUTINE THAT GENERATES A
C                   PROBABILITY TABLE TO BE USED IN A
C                   TABLE LOOKUP PROCESS
C     PROBIT      = THE ABSCISSA WHICH CORRESPONDS TO A
C                   PROBABILITY IN A NORMAL DISTRIBUTION
C                   HAVING A MEAN OF 5.0 AND A VARIANCE OF 1.0
C     PVW**       = PERCENT OF VEHICLES DELAYED LONGER THAN
C                   ** SECONDS WHERE ** HAS VALUES OF 30, 60,
C                   90, 120, 150 AND 180
C     P85         = 85-TH PERCENTILE QUEUE LENGTH
C     P90         = 90-TH PERCENTILE QUEUE LENGTH
C     P95         = 95-TH PERCENTILE QUEUE LENGTH
C                   RA1 = PORTION UNDER RESTRICTED CONDITION
C                   RT1 = MEAN RESTRICTED HEADWAY
C                   RD1 = MINIMUM RESTRICTED HEADWAY
C                   RA2 = PORTION UNDER FREE CONDITION
C                   RT2 = MEAN FREE HEADWAY
C                   RD2 = MINIMUM FREE HEADWAY
C     RANDU       = NAME OF SUBROUTINE THAT COMPUTES
C                   UNIFORMLY DISTRIBUTED RANDOM REAL NUMBERS
C                   BETWEEN 0 AND 1.0
C     RAMP        = NAME OF SUBROUTINE THAT RETURNS RAMP HEADWAYS
C     RAMVOL      = RAMP VOLUME CALLED FOR ON DATA CARD
C     RAMVPH      = RAMP VOLUME GENERATED
C     RELSP       = DIFFERENCE BETWEEN SHOULDER-LANE SPEED
C                   AND RAMP SPEED
C     RDT(I)      = TIME OF DEPARTURE OF THE I-TH VEHICLE
C                   FROM THE SYSTEM
C     RH          = RAMP HEADWAY GENERATED BY RAMP SUBROUTINE
C     RPDATA      = NAME OF SUBROUTINE THAT RETURNS RA1, RT1,
C                   RD1, RA2, RT2, AND RD2
C     RSPD        = RAMP SPEED
C     S           = THE DESIRED STANDARD DEVIATION OF THE
C                   NORMAL DISTRIBUTION FOR SUBROUTINE GAUSS
C     SAT1        = ARRIVAL TIME OF LAST SHOULDER LANE VEHICLE
C     SAT2        = ARRIVAL TIME OF NEXT SHOULDER LANE VEHICLE
C     SDSRT1      = STD. DEV. OF SERVICE TIMES OF VEHICLES
C                   THAT DO NOT WAIT FOR A QUEUE
C     SDSRT2      = STD. DEV. OF SERVICE TIMES OF VEHICLES
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C                    = THAT WAIT FOR A QUEUE
C      SDSRTM        = STD. DEV. OF SERVICE TIMES OF ALL OBSERVED VEHICLES
C      SDWAI1        = STD. DEV. OF WAIT TIMES OF ALL OBSERVED VEHICLES
C      SDWT1         = STD. DEV. OF WAIT TIMES OF VEHICLES THAT
C                      DO NOT WAIT FOR A QUEUE
C      SDWT2         = STD. DEV. OF WAIT TIMES OF VEHICLES THAT
C                      WAIT FOR A QUEUE
C      SDSYT1        = STD. DEV. OF SYSTEM TIMES OF VEHICLES
C                      THAT DO NOT WAIT FOR A QUEUE
C      SDSYT2        = STD. DEV. OF SYSTEM TIMES OF VEHICLES
C                      THAT WAIT FOR A QUEUE
C      SDSYTM        = STD. DEV. OF SYSTEM TIMES OF ALL OBSERVED VEHICLES
C      SERVICE TIME = TIME ON RAMP AS FIRST IN LINE VEHICLE
C                      WAITING FOR ACCEPTABLE GAP
C      SH            = SHOULDER-LANE HEADWAYS RETURNED BY SHLANE
C      SHDATA        = NAME OF SUBROUTINE THAT RETURNS THE D AND
C                      Z PARAMETERS OF THE SHOULDER LANE HEADWAY
C                      DISTRIBUTION
C      SHLANE        = NAME OF SUBROUTINE THAT RETURNS
C                      SHOULDER LANE HEADWAYS
C      SHLVOL        = SHOULDER LANE VOLUME CALLED FOR
C      SHLVPH        = SHOULDER LANE VOLUME GENERATED
C      SORT2         = NAME OF SUBROUTINE THAT PERFORMS A PUSH-DOWN
C                      SORT ON FIXED-POINT QUANTITIES
C      SRDNO         = RANDOM NUMBER RETURNED BY THE SUBROUTINE SRAND*
C      SRTIM(L)      = SERVICE TIME OF THE L-TH OBSERVED VEHICLE
C      SRTIM1(J)     = SERVICE TIME OF THE J-TH VEHICLE THAT
C                      DOES NOT WAIT FOR A QUEUE
C      SRTIM2(K)     = SERVICE TIME OF THE K-TH VEHICLE THAT
C                      WAITS FOR A QUEUE
C      SSPD          = SHOULDER LANE SPEED
C      SYSTIM(L)     = SYSTEM TIME OF THE L-TH OBSERVED VEHICLE
C      SYSTM1(J)     = SYSTEM TIME OF THE J-TH VEHICLE THAT DOES
C                      NOT WAIT FOR A QUEUE
C      SYSTM2(K)     = SYSTEM TIME OF THE K-TH VEHICLE THAT
C                      WAITS FOR A QUEUE
C      SYSTM         = TOTAL TIME A VEHICLE LOSES IN THE SYSTEM
C      TIME          = NAME OF VARIABLE USED AS CLOCK
C      V             = THE VALUE OF THE COMPUTED NORMAL RANDOM
C                      VARIABLE FROM SUBROUTINE GAUSS
C      VRSRT1        = VARIANCE OF SERVICE TIMES OF VEHICLES
C                      THAT DO NOT WAIT FOR A QUEUE
C      VRSRT2        = VARIANCE OF SERVICE TIMES OF VEHICLES
C                      THAT WAIT FOR A QUEUE
C      VRSRT         = VARIANCE OF SERVICE TIMES OF ALL OBSERVED VEHICLES
C      VRSYT1        = VARIANCE OF SYSTEM TIMES OF VEHICLES THAT
C                      DO NOT WAIT FOR A QUEUE
C      VRSYT2        = VARIANCE OF SYSTEM TIMES OF VEHICLES
C                      THAT WAIT FOR A QUEUE
C      VRSYT         = VARIANCE OF SYSTEM TIMES OF ALL OBSERVED VEHICLES
C      VRWAIT        = VARIANCE OF WAIT TIMES OF ALL OBSERVED VEHICLES
C      VRWT1         = VARIANCE OF WAIT TIMES OF VEHICLES THAT
C                      DO NOT WAIT FOR A QUEUE
C      VRWT2         = VARIANCE OF WAIT TIMES OF VEHICLES THAT
C                      WAIT FOR A QUEUE
C      W             = FLOATING POINT CONVERSION OF OBSERVED
C                      QUEUE LENGTH
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 1006 WRITE(6,1007) SHLVOL,RAMVOL
 1007 FORMAT(1H1,14X,9HSHLVOL = ,F5.0,5X,9HRAMVOL = ,F5.0)
C     INITIALIZE STORAGE
 1013 J=0
 1027 ASRTM2=0.
      NQ1 = 0
      NQ2 = 0
 1008 I=0
      LL = 0
 1009 L=0
 1010 SAT1 = 0.
 1011 SAT2=0.
 1012 WQL=0.
 1014 K=0
 1015 NRDEPT=0
 1016 NSVEH=0
 1017 NVW30=0
 1018 NVW60=0
 1019 NVW90=0
 1020 NVW120=0
 1021 NVW150=0
 1022 NVW180=0
 1023 ASRTM1=0.
 1024 ASSRT1=0.
 1025 AWAIT2=0.
 1026 ASWT2=0.
 1028 ASSRT2=0.
 1029 ASYTM1 = 0.
 1030 ASSYT1 = 0.
 1031 ASYTM2=0.
 1032 ASSYT2=0.
 1033 AWAIT=0.
 1034 ASWAIT=0.
 1035 ASRTIM=0.
 1036 ASSRTM=0.
 1037 ASYTM=0.
 1038 ASSYTM=0.
 1039 RSPD = 30.0
      ADELAY = 0.
C     CALCULATION OF CONSTANTS FOR LATER REPEATED USES
 1040 SSPD = 52.0-0.008*SHLVOL
      RELSP = SSPD-RSPD
C     OUTPUT CONSTANTS OF RAMP AND SHOULDER LANE DISTRIBUTIONS
 1061 CALL SHDATA(SHLVOL, D, Z)
 1062 WRITE(6,1063) RAMVOL,RA1,RT1,RD1,RA2,RT2,RD2,SHLVOL,D,Z
 1063 FORMAT(15X,9HRAMVOL = ,F5.0,5X,
      16HRA1 = ,F5.3,5X,6HRT1 = F6.3,5X,6HRD1 = ,F5.2 /
      234X,6HRA2 = ,F5.3,5X,6HRT2 = ,F6.3,5X,6HRD2 = ,F5.2 /
      315X,9HSHLVOL = ,F5.0,5X,4HD = ,F4.2,8X,4HZ = ,F6.2)
      WRITE(6,106)*KK
 1065 FORMAT(34X,8HKERLG = ,12)
 1064 TIMMAX = 2.*(1300./RAMVOL)
C     ROUTINE TO GENERATE FLOW OF 300 PRELIMINARY
C     VEHICLES THUS LOADING THE SIMULATOR BEFORE VEHICLES
C     FOR OBSERVATION ARE GENERATED
  800 I = I + 1
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C       GENERATE NEXT RAMP HEADWAY
  822 CALL RHEAD(RA1,RT1,RD1,RA2,RT2,RD2,KK,RH,IXR)
C       DETERMINE IF THIS IS THE FIRST VEHICLE TO BE
C       GENERATED AND PROCEED ACCORDINGLY
      IF (I-1) 825,825,826
C       CALCULATE RAMP ARRIVAL TIME
  825 RAT(1) = RH
C       CALCULATE DEPARTURE TIME
 1825 RDT(I) = RAT(I)
C       CALCULATE EARLIEST POSSIBLE DEPARTURE TIME
C       WITHOUT OVERTAKING THE LEADING RAMP VEHICLE
 2825 EDEPTM = 0.
 3825 GO TO 830
C       CALCULATE RAMP ARRIVAL TIME
  826 RAT(I) = RAT(I-1) + RH
C       CALCULATE RAMP DEPARTURE TIME IF
C       VEHICLE CAN LEAVE IMMEDIATELY
  827 RDT(I) = RAT(I)
C       CALCULATE VALUE FROM GAUSSIAN DISTRIBUTION FOR EARLIEST
C       DEPARTURE FROM LEADING RAMP VEHICLE.
      CALL GAUSS(IX,0.15,1.8,V)
C       CALCULATE EARLIEST POSSIBLE DEPARTURE TIME
C       WITHOUT OVERTAKING LEADING RAMP VEHICLE
  828 EDEPTM = RDT(I-1)  +  V
C       DETERMINE IF QUEUE EXISTS
  829 IF(RDT(I)-RDT(I-1))864,830,830
C       NO QUEUE EXISTS
  830 IQ=1
C       DETERMINE OPERATING CHARACTERISTICS WHILE IN SYSTEM
 1830 IF(RDT(I)-EDEPTM)831,4831,4831
C       VEHICLE IN STOPPED CONDITION
  831 IC = 2
C       CALCULATE RAMP DEPARTURE TIME ASSUMING VEHICLE
C       IN QUESTION WILL FOLLOW AT THE MINIMUM
C       SPACING DISTRIBUTION
 2831 RDT(I) = RDT(I-1)  +  V
C       CALCULATE TIME AVAILABLE FROM ARRIVAL ON RAMP TO NEXT
C       POSSIBLE DEPARTURE TIME
      AVLTIM = RDT(I)-RAT(I)
 3831 GO TO 832
C       VEHICLE IN MOVING CONDITION
 4831 IC = 1
C       DETERMINE IF LAG EXISTS IN SHOULDER LANE, IF ONE DOES
C       GO AHEAD TO DETERMINE LENGTH, IF NO LAG EXISTS,
C       GENERATE GAP
  832 IF(RDT(I)-SAT2)848,833,833
C       CALL IN RANDOM NUMBER TO SAMPLE SHOULDER LANE
C       DISTRIBUTION
  833 CALL RANDU(IXS,IYS,SRDNO)
      IXS = IYS
C       GENERATE NEXT SHOULDER LANE HEADWAY
  843 SH=SHLANE(SRDNO, SHLVOL, D, Z)
C       UPDATE SHOULDER-LANE ARRIVAL TIMES
  844 SAT1=SAT2
  845 SAT2=SAT2 + SH
C       INCREMENT SHOULDER LANE VOLUME COUNTER
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  846 NSVEH=NSVEH + 1
  847 GO TO 832
C     CALCULATE LENGTH OF AVAILABLE GAP
  848 ASG = SAT2-RDT(I)
C     CALL IN RANDOM NUMBER TO SAMPLE ACCEPTANCE DISTRIBUTION
      CALL RANDU(IXA,IYA,ARDNO)
      IXA = IYA
C     DETERMINE IF GAP IS ACCEPTABLE AFTER SELECTING THE
C     PROPER ACCEPTANCE MODEL DEPENDING UPON
C     THE OPERATING CONDITION OF IC
  850 GO TO(851,853),IC
  851 CALL PROBIT(ASG,RELSP,BOL,B1L,B2L,ZDEV)
      CALL ACCEPT(ZDEV,PROB,ARDNO,ACPTNO)
  852 GO TO 854
  853 CALL PROBIT(ASG,0.0,BOG, B1G,B2G,ZDEV)
      CALL ACCEPT(ZDEV,PROB,ARDNO,ACPTNO)
  854 IF(ACPTNO)884,884,855
C     CALCULATE HEADWAY THAT OBSERVED VEHICLE WILL FOLLOW
C     LEADING SHOULDER LANE VEHICLE
  855 CALL GAUSS(IX,0.20,1.50,V)
      RDT(I) = SAT2  +  V
C     DETERMINE AMOUNT OF AVAILABLE TIME TO EARLIEST
C     DEPARTURE TIME AND RESULTING OPERATING CHARACTERISTIC
  856 AVLTIM = RDT(I)-RAT(I)
  857 IF(AVLTIM)858,858,860
C     VEHICLE MOVING
  858 IC = 1
  859 GO TO 833
C     VEHICLE STOPPED
  860 IC = 2
  861 GO TO 833
C     QUEUE EXISTS
  864 IQ=2
  865 AVLTIM = EDEPTM-RAT(I)
  866 IF(AVLTIM)867,867,869
C     VEHICLE MOVING
  867 IC = 1
  868 GO TO 873
C     VEHICLE IN STOPPED CONDITION
  869 IC = 2
C     CALCULATE HEADWAY AT WHICH OBSERVED VEHICLE IS
C     FOLLOWING LEADING RAMP VEHICLE
      CALL GAUSS(IX,0.15,1.80,V)
  873 RDT(I) = RDT(I-1)  +  V
  874 GO TO 832
C     INCREMENT RAMP VOLUME COUNTER
  884 NRDEPT=NRDEPT +1
  886 TIME = RDT(I)/3600.
C     DETERMINE IF RUNNING TIME LIMIT HAS BEEN,
C     IF IT HAS BEEN OUTPUT TRAFFIC CONDITIONS AND STOP MESSAGE
  887 IF(TIME-TIMMAX) 888, 889, 889
C     DETERMINE IF SIMULATION LOADING IS COMPLETED
C     OUTPUT TRAFFIC DATA AND INFORMATION MESSAGE
C     WHEN TIME LIMIT IS EXCEEDED
  888 IF(I-300)800,900,900
  889 XNSVEH=NSVEH
  890 SHLVPH=XNSVEH/TIME
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  891 XNRDEP=NRDEPT
  892 RAMVPH=XNRDEP/TIME
  893 WRITE (6,401)
  894 WRITE (6,403) NSVEH, SHLVPH, NRDEPT, RAMVPH, TIME
  895 WRITE (6,896)
  896 FORMAT (1HO,/////,13X,
     154HSIMULATION RUN TERMINATED DURING LOADING OF RAMP AREA ,
     228HPREVIOUS TO ACTUAL ANALYSIS.,/
     313X,59HRE-RUN USING A RAMP VOLUME EQUAL TO THE CAPACITY
     436HINDICATED BY THE RAMVPH OF THIS RUN.  )
  898 GO TO 500
C     BEGIN SIMULATION OF 1000 VEHICLES FOR OBSERVATION
  900 CONTINUE
  915 CALL RHEAD(RA1,RT1,RD1,RA2,RT2,RD2,KK,RH,IXR)
C     INCREMENT TOTAL VEHICLE COUNTER
  916 I=I+1
C     INCREMENT OBSERVED VEHICLE COUNTER
  917 L = L + 1
C     CALCULATE RAMP ARRIVAL TIME
    1 RAT(I) = RAT(I-1)+RH
C     CALCULATE DEPARTURE TIME
    2 RDT(I) = RAT(I)
C     CALCULATE VALUE FROM GAUSSIAN DISTRIBUTION FOR EARLIEST
C     DEPARTURE FROM LEADING RAMP VEHICLE
      CALL GAUSS(IX,0.15,1.80,V)
C     CALCULATE EARLIEST POSSIBLE DEPARTURE WITHOUT
C     OVERTAKING LEADING RAMP VEHICLE
    3 EDEPTM = RDT(I-1)  +  V
C     DETERMINE IF QUEUE EXISTS
    4 IF(RDT(I)-RDT(I-1))80,6,6
C     NO QUEUE EXISTS
    6 IQ=1
C     DETERMINE OPERATING CHARACTERISTICS WHILE IN SYSTEM
 1116 IF(RDT(I)-EDEPTM)7,4117,4117
    7 CONTINUE
C     VEHICLE IN STOPPED CONDITION
 1117 IC=2
C     CALCULATE RAMP DEPARTURE TIME ASSUMING VEHICLE
C     IN QUESTION WILL FOLLOW AT THE MINIMUM
C     SPACING DISTRIBUTION
 2177 RDT(I) = RDT(I-1)  +  V
C     CALCULATE TIME AVAILABLE FROM ARRIVAL ON RAMP TO NEXT
C     POSSIBLE DEPARTURE TIME
      AVLTIM = RDT(I)-RAT(I)
 3117 GO TO 8
 4117 CONTINUE
C     VEHICLE IN MOVING CONDITION
 5117 IC=1
C     INCREMENT NON-RESTRICTED VEHICLE COUNTER
    8 J=J+1
C     ENTER QUEUE IN QUEUE LENGTH SUMMARY
    9 LQ(L)=0
C     DETERMINE IF LAG EXISTS IN SHOULDER LANE, IF ONE DOES
C     GO AHEAD TO DETERMINE LENGTH, IF NO LAG EXISTS,
C     GENERATE GAP
   12 IF(RDT(I)-SAT2)36,14,14
C     CALL IN RANDOM NUMBER TO SAMPLE SHOULDER LANE DISTRIBUTION
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  14 CALL RANDU(IXS,IYS,SRDNO)
     IXS = IYS
C    GENERATE NEXT SHOULDER-LANE HEADWAY
  26 SH=SHLANE(SRDNO, SHLVOL, D, Z)
C    UPDATE SHOULDER-LANE ARRIVAL TIMES
  28 SAT1=SAT2
  30 SAT2=SAT2+SH
C    INCREMENT SHOULDER-LANE VOLUME COUNTER
  32 NSVEH=NSVEH+1
  34 GO TO 12
C    CALCULATE LENGTH OF AVAILABLE GAP.
  36 ASG = SAT2-RDT(I)
C    CALL IN RANDOM NUMBER TO SAMPLE ACCEPTANCE DISTRIBUTION
     CALL RANDU(IXA,IYA,ARDNO)
     IXA = IYA
C    PROPER ACCEPTANCE MODEL DEPENDING UPON THE OPERATION CONDITION OF IC
  38 GO TO (39,41),IC
  39 CALL PROBIT(ASG,RELSP,B0L,B1L,B2L,ZDEV)
     CALL ACCEPT(ZDEV,PROB,ARDNO,ACPTNO)
  40 GO TO 42
  41 CALL PROBIT(ASG,0.0,B0G,B1G,B2G,ZDEV)
     CALL ACCEPT(ZDEV,PROB,ARDNO,ACPTNO)
  42 IF(ACPTNO)53,53,43
C    CALCULATE HEADWAY THAT OBSERVED VEHICLE WILL FOLLOW
C    LEADING SHOULDER LANE VEHICLE
  43 CALL GAUSS(IX,0.20,1.50,V)
     RDT(I) = SAT2 + V
C    DETERMINE AMOUNT OF AVAILABLE TIME TO EARLIEST DEPARTURE
C    TIME AND RESULTING OPERATING CHARACTERISTIC
  44 AVLTIM = RDT(I)-RAT(I)
  45 IF(AVLTIM)46,46,48
C    VEHICLE MOVING
  46 IC = 1
  47 GO TO 14
C    VEHICLE MOVING
  48 IC = 2
  49 GO TO 14
C    INCREMENT RAMP VOLUME COUNTER
  53 NRDEPT = NRDEPT+1
C    PROCEED UPON QUEUE CONDITION
  54 GO TO (55,100),IQ
C    UPDATE QUEUE-OPERATING CONDITION COUNTER
  55 NQ1 = NQ1 + 1
  59 GO TO 204
C    UPDATE WAIT-TIME, SERVICE TIME, SYSTEM-TIME AND DELAY TIME SUMMARIES
 204 WAIT(L) = 0.
 205 SRTIM1(J) = RDT(I)-RAT(I)
 206 ASRTM1=ASRTM1+SRTIM1(J)
 207 ASSRT1=ASSRT1+SRTIM1(J)**2.
 208 SRTIM(L) = SRTIM1(J)
 209 ASRTIM = ASRTIM + SRTIM(L)
 210 ASSRTM = ASSRTM + SRTIM(L)*SRTIM(L)
 211 SYSTM1(J) = RDT(I)-RAT(I)
 212 ASYTM1 = ASYTM1+SYSTM1(J)
 213 ASSYT1 = ASSYT1+SYSTM1(J)*SYSTM1(J)
 214 SYSTIM(L) = SYSTM1(J)
 215 ASYTM = ASYTM+SYSTIM(L)
 216 ASSYTM = ASSYTM + SYSTIM(L)*SYSTIM(L)
 217 DELAY = SYSTM1(J)
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 1217 ADELAY = ADELAY+DELAY
 2217 DDELAY(L) = DELAY
  218 GO TO 240
C     QUEUE EXISTS
   80 IQ=2
C     INCREMENT RESTRICTIVE VEHICLE COUNTER.
   81 K=K+1
C     DETERMINE AMOUNT OF AVAILABLE TIME TO EARLIEST DEPARTURE TIME
   82 AVLTIM = EDEPTM-RAT(I)
C     DETERMINE QUEUE LENGTH
   83 QITIME = RAT(I)
   84 DO 87 IQL1=1,1300,1
   85 IQL2 = I-IQL1
   86 IF(QITIME-RDT(IQL2))87,87,88
   87 CONTINUE
C     ENTER QUEUE LENGTH IN QUEUE LENGTH SUMMARY
   88 LQ(L) = IQL1-1
C     ACCUMULATE SUM OF QUEUE LENGTHS
   89 W = IQL1-1
   90 WQL = WQL+W
C     DETERMINE OPERATING CHARACTERISTICS
   91 IF(AVLTIM)92,92,95
C     VEHICLE IN MOVING CONDITION
   92 IC = 1
   94 GO TO 98
C     VEHICLE IN STOPPED CONDITION
   95 IC = 2
C     CALCULATE HEADWAY AT WHICH OBSERVED VEHICLE IS
C     FOLLOWING LEADING RAMP VEHICLE
      CALL GAUSS(IX,0.15,1.80,V)
C     DETERMINE NEW POSSIBLE RAMP DEPARTURE TIME
   98 RDT(I) = RDT(I-1) + V
   99 GO TO 12
C     UPDATE QUEUE-OPERATING CONDITION COUNTER
  100 NQ2 = NQ2 + 1
C     UPDATE WAIT-TIME, SERVICE TIME, SYSTEM-TIME
C     AND DELAY TIME SUMMARIES
  220 WAIT2(K) = RDT(I-1)-RAT(I)
  221 AWAIT2 = AWAIT2+WAIT2(K)
  222 ASWT2=ASWT2+WAIT2(K)*WAIT2(K)
  223 WAIT(L) = WAIT2(K)
  224 AWAIT = AWAIT + WAIT(L)
  225 ASWAIT = ASWAIT + WAIT(L)*WAIT(L)
  226 SRTIM2(K) = RDT(I)-RDT(I-1)
  227 ASRTM2=ASRTM2+SRTIM2(K)
  228 ASSRT2=ASSRT2+SRTIM2(K)*SRTIM2(K)
  229 SRTIM(L) = SRTIM2(K)
  230 ASRTIM = ASRTIM + SRTIM(L)
  231 ASSRTM = ASSRTM + SRTIM(L)*SRTIM(L)
  232 SYSTM2(K) = RDT(I)-RAT(I)
  233 ASYTM2=ASYTM2+SYSTM2(K)
  234 ASSYT2=ASSYT2+SYSTM2(K)*SYSTM2(K)
  235 SYSTIM(L) = SYSTM2(K)
  236 ASYTM = ASYTM + SYSTIM(L)
  237 ASSYTM = ASSYTM + SYSTIM(L)*SYSTIM(L)
  238 DELAY = SYSTM2(K)
 1238 ADELAY = ADELAY+DELAY
 2238 DDELAY(L) = DELAY
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C      INCREMENT DELAY-PERIOD COUNTERS
  240 CALL NVWGT(DELAY, NVW30,NVW60,NVW90,NVW120,NVW150, NVW180)
C      UPDATE TIME CLOCK
  250 TIME=RDT(I)/3600.
C      DETERMINE IF RUNNING TIME LIMIT HAS BEEN,
C      IF IT HAS BEEN OUTPUT TRAFFIC CONDITIONS AND STOP MESSAGE
  255 IF(TIME-TIMMAX)260,515,515
C      DETERMINE IF TOTAL SAMPLE HAS BEEN OBSERVED
  260 IF(NRDEPT-1300)900,264,264
C      CALCULATE PERCENTAGE BY LENGTH OF DELAY
  264 XVW30 = NVW30
      PVW30 = (XVW30/1000.)
  265 XVW60 = NVW60
      PVW60 = (XVW60/1000.)
  266 XVW90 = NVW90
      PVW90 = (XVW90/1000.)
  267 XVW120 = NVW120
      PVW120 = (XVW120/1000.)
  268 XVW150 = NVW150
      PVW150 = (XVW150/1000.)
  269 XVW180 = NVW180
      PVW180 = (XVW180/1000.)
C      CALCULATE NUMBERS OF RESTRICTIVE AND NON-RESTRICTIVE VEHICLES
  270 XK=K
  271 XJ=J
C      CALCULATE MEANS,VARIANCE AND STANDARD DEVIATIONS OF
C      WAIT-TIME, SERVICE-TIME, AND SYSTEM TIME.
  272 AVWT1=0.
  273 VRWT1=0.
  274 SDWT1=0.
  275 AVWT2=AWAIT2/XK
  276 VRWT2=(ASWT2-(AWAIT2**2.)/XK)/(XK-1.)
  277 SDWT2=SQRT(VRWT2)
  278 AVWAIT=AWAIT/1000.
  279 VRWAIT=(ASWAIT-(AWAIT**2.)/1000.)/999.
  280 SDWAIT=SQRT(VRWAIT)
  281 AVSRT1=ASRTM1/XJ
  282 VRSRT1=(ASSRT1-(ASRTM1**2.)/XJ)/(XJ-1.)
  283 SDSRT1=SQRT(VRSRT1)
  284 AVSRT2=ASRTM2/XK
  285 VRSRT2=(ASSRT2-(ASRTM2**2.)/XK)/(XK-1.)
  286 SDSRT2=SQRT(VRSRT2)
  287 AVSRT=ASRTIM/1000.
  288 VRSRT = (ASSRTM-(ASRTIM**2.)/1000.)/999.
  289 SDSRT=SQRT(VRSRT)
  290 AVSYT1 = ASYTM1/XJ
  291 VRSYT1 = (ASSYT1-(ASYTM1**2.)/XJ)/(XJ-1.)
  292 SDSYT1 = SQRT(VRSYT1)
  293 AVSYT2=ASYTM2/XK
  294 VRSYT2=(ASSYT2-(ASYTM2**2.)/XK)/(XK-1.)
  295 SDSYT2=SQRT(VRSYT2)
  296 AVSYT=ASYTM/1000.
  297 VRSYT=(ASSYTM-(ASYTM**2.)/1000.)/999.
  298 SDSYT=SQRT(VRSYT)
 1298 DELAYM = ADELAY/1000.
  299 XI=1000.
C      SORT WAIT-TIME, SERVICE TIME, SYSTEM-TIME, AND
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```
C     QUEUE LENGTH DISTRIBUTIONS INTO INCREASING ORDER.
      CALL ASORT(SRTIM1,J)
      LL = J+1
      DO 700 I = LL,1000
      SRTIM1(I) = 10000.0
  700 CONTINUE
      CALL ASORT(SYSTM1,J)
      LL = J+1
      DO 701 I=LL,1000
      SYSTM1(I) = 10000.0
  701 CONTINUE
      CALL ASORT(WAIT2,K)
      LL = K+1
      DO 702 I=LL,1000
      WAIT2(I) = 10000.0
  702 CONTINUE
      CALL ASORT(SRTIM2,K)
      LL = K+1
      DO 703 I=LL,1000
      SRTIM2(I) = 10000.0
  703 CONTINUE
      CALL ASORT(SYSTM2,K)
      LL = K+1
      DO 704 I = LL,1000
      SYSTM2(I) = 10000
  704 CONTINUE
      CALL ASORT(SRTIM,1000)
      CALL ASORT(SYSTIM,1000)
      CALL ASORT(DDELAY,1000)
  313 CALL SORT2(LQ)
C     CALCULATE SIMULATION RAMP AND SHOULDER LANE VOLUMES
  330 XNSVEH=NSVEH
  332 SHLVPH = (XNSVEH/SAT2)*3600.
  336 RAMVPH = (1000./(RAT(1300)-RAT(300)))*3600.
C     CALCULATE AVERAGE, MAXIMUM, AND VARIOUS PERCENTIME
C     QUEUE LENGTHS
  341 NVW=XK
  344 AVQL=WQL/1000.
  345 P85=LQ(850)
  346 P90=LQ(900)
  347 P95=LQ(950)
  350 LQMAX = LQ(1000)
C OUTPUT FROM SIMULATION RUN
  400 WRITE(6,401)
  401 FORMAT(1H1,37X,33HRAMP CAPACITY ANALYSIS BY DIGITAL
     110HSIMULATION,//
     251X,18HACCELERATION LANE, /)
  402 WRITE (6, 403) NSVEH, SHLVPH, NRDEPT, RAMVPH, TIME
  403 FORMAT(/ 1HO,54X,12HTRAFFIC DATA, //
     113X,6HNUMBER,5X,2HOF,9X,13HSHOULDER LANE,11X,6HNUMBER,
     211X,13HRAMP  VOLUME,9X,10HSIMULATION,/
     313X,13HSHOULDER LANE,12X,6HVOLUME,14X,8HOF  RAMP,/
     415X,8HVEHICLES,12X,13HVEH. PER HOUR,10X,SHVEHICLES,
     510X,13HVEH. PER HOUR,9X,10HTIME (HRS),//
     616X,15,18X,F6.0,16X,14,16X,F5.0,12X,F8.4,/)
  404 WRITE (6,406)J,AVQL, P85, P90, P95, LQMAX
  406 FORMAT(/ 1HO,47X,23HQUEUING CHARACTERISTICS, //
```

```
   113X,11HNUMBER   OF,4X,11HAVG. LENGTH,5X,13H85 TH PERCENT,
   24X,13H90  TH PERCENT,5X,13H95 TH PERCENT,7X,7HMAXIMUM,/
   313X,11HZERO QUEUES,4X,11HOF     QUEUE,5X,13HQUEUE  LENGTH,4X,
   413HQUEUE  LENGTH,5X,13HQUEUE  LENGTH,4X,12HQUEUE LENGTH,//
   517X,13, 9X,F5.2,12X,F5.0,12X,F5.0,13X,F5.0,13X,14,/)
408 WRITE(6,410)
410 FORMAT(/1H0,48X,22HDELAY  CHARACTERISTICS )
412 WRITE(6,414)PVW30,PVW60,PVW90,PVW120,PVW150,PVW180
414 FORMAT(1H0,12X,
   151HP R O B A B I L I T Y    T H A T    D E L A Y,
   27X,37HI S       G R E A T E R    T H A N,/
   313X,10H30-SECONDS,7X,10H60-SECONDS,7X,10H90-SECONDS,
   46X,11H120-SECONDS,6X,11H150-SECONDS,6X,
   511H180-SECONDS,//3X,6F17.3,/)
416 WRITE (6,418) NVW, J, AVWAIT, AVWT2, VRWT2, SDWT2
418 FORMAT(/1H0,12X,14HWAIT TIME DATA, //
   113X,8HNO.  OF,7X,6HNO. OF,7X,9HAVG. WAIT,8X,12 HAVG.    WAIT,
   27X,12HVAR. OF WAIT,7X,12HSTD. DEV. OF,/
   313X,8HVEHICLES,8X,4HZERO,8X,9HFOR   ALL,8X,12HFOR VEHICLES,
   47X,12HFOR VEHICLES,7X,12HWAIT FOR VEH./
   513X,7HWAITING,8X,5HWAITS,8X,8HVEHICLES,9X,12HTHAT    WAIT,
   67X,12HTHAT    WAIT,7X,12HTHAT    WAIT,//
   715X,13,11X,13,10X,F7.2,11X,F7.2,13X,F6.2,13X,F6.2,/)
420 WRITE(6,401)
422 WRITE(6,410)
424 WRITE(6,426)
426 FORMAT(1H0,12X,34HSERVICE TIME  (ZERO WAIT VEHICLES))
428 WRITE(6,430)XJ,AVSRT1,VRSRT1,SDSRT1
430 FORMAT(1H0,13X,6HNUMBER,22X,7HAVERAGE,
   121X,8HVARIANCE,21X,9HSTD. DEV.,/
   216X,2HOF,24X,7HSERVICE,21X,7HSERVICE,23X,7HSERVICE,/
   313X,8HVEHICLES,22X,4HTIME,25X,4HTIME,25X,4HTIME,//
   414X,F5.0,23X,F7.2,22X,F7.2,23X,F7.2,/)
431 FORMAT(1H0,13X,6HNUMBER,22X,7HAVERAGE,
   121X,8HVARIANCE,21X,9HSTD. DEV., /
   216X,2HOF,24X,6HSYSTEM,22X,6HSYSTEM,24X,6HSYSTEM,  /
   313X,8HVEHICLES,22X,4HTIME,25X,4HTIME,25X,4HTIME,  //
   414X,F5.0,23X,F7.2,22X,F7.2,23X,F7.2, /)
432 WRITE(6,434)
434 FORMAT(/1H0,12X,32HSERVICE TIME  (WAITING VEHICLES))
436 WRITE(6,430)XK,AVSRT2,VRSRT2,SDSRT2
438 WRITE(6,440)
440 FORMAT(/1H0,12X,28HSERVICE TIME  (ALL VEHICLES))
442 WRITE(6,430)XI,AVSRT,VRSRT,SDSRT
444 WRITE(6,446)
446 FORMAT(/1H0,12X,33HSYSTEM TIME  (ZERO WAIT VEHICLES))
448 WRITE(6,431)XJ,AVSYT1,VRSYT1,SDSYT1
450 WRITE(6,452)
452 FORMAT(/1H0,12X,31HSYSTEM TIME  (WAITING VEHICLES))
454 WRITE(6,431)XK,AVSYT2,VRSYT2,SDSYT2
456 WRITE(6,458)
458 FORMAT(/1H0,12X,27HSYSTEM TIME  (ALL VEHICLES))
460 WRITE(6,431)XI,AVSYT,VRSYT,SDSYT
462 WRITE(6,464)
464 FORMAT(1H1,9X,5HINDEX,5X,4HWAIT,6X,7HSERVICE,5X,6HSYSTEM,5X,
   17HSERVICE,5X,6HSYSTEM,5X,5HTOTAL,8X,5HTOTAL,8X,5HQUEUE,5X,5HDELAY
   211X,3HFOR,6X,5HGIVEN,6X,5HGIVEN,6X,5HGIVEN,8X,4HZERO,7X,
   34HZERO,5X,7HSERVICE,6X,6HSYSTEM,7X,6HLENGTH, /
```

```
   410X,5HDIST.,5X,4HWAIT,7X,4HWAIT,8X,4HWAIT,8X,4HWAIT
   57X,4HWAIT,7X,4HTIME,8X,4HTIME,8X,7HSUMMARY,4X,5HDIST.)
465 DO 466 I = 1,1000
466 WRITE(6,468) I,WAIT2(I),SRTIM2(I),SYSTM2(I),SRTIM1(I),
   1SYSTM1(I), SRTIM(I),SYSTIM(I),LQ(I),DDELAY(I)
468 FORMAT(10X,14,2F11.2,2F12.2,2F11.2,F12.2,8X,14,5X,F6.2)
470 WRITE(6,472) RAMVOL, RA1, RT1, RD1, RA2, RT2, RD2
472 FORMAT(1H1,16X,4HRAMP,7X,7HPORTION,6X,9HAVG. FREE,
   16X,9HMIN. FREE,8X,7HPORTION,7X,9HAVG.RES.,6X,9HMIN. RES.,/
   215X,6HVOLUME,7X,4HFREE,9X,7HHEADWAY,8X,7HHEADWAY,7X,
   310HRESTRAINED,7X,7HHEADWAY,8X,7HHEADWAY,/
   416X,F5.0,7X,F4.2,10X,F5.2,10X,F4.2,12X,F4.2,11X,F5.2,
   510X,F5.2)
500 CONTINUE
    GO TO 1004
510 STOP
515 XNSVEH = NSVEH
516 SHLVPH = 3600.*XNSVEH/SAT2
517 XNRDEP = NRDEPT
518 RAMVPH = 3600.*((XNRDEP-300.)/(RDT(I)-RDT(300)))
519 WRITE(6,401)
520 WRITE(6,403) NSVEH,SHLVPH,NRDEPT,RAMVPH,TIME
525 WRITE(6,530)
530 FORMAT(1HO,/////,13X,
   148HSIMULATION RUN TERMINATED DUE TO TIME LIMITATION
535 STOP
    END
```

```
C
      SUBROUTINE ACCEPT(Z,PROB,ARDNO,ACPTNO)
C
C     SUBROUTINE TO DETERMINE IF GAP IS
C     ACCEPTABLE TO A VEHICLE IN EITHER MOVING OR STOPPED
C     CONDITION
C
      DIMENSION PROB(700)
      IF(Z+3.5)5,15,10
    5 ACPT=0
      GO TO 25
   10 IF(Z-3.5)15,15,20
   15 I=100.*Z.351.
      ACPT=PROB)I*
      GO TO 25
   20 ACPT=1.00
   25 ACPTNO = ARDNO-ACPT
      RETURN
      END
C
C
      SUBROUTINE GAUSS(IX,S,AM,V)
C
C     SUBROUTINE TO CALCULATE A NORMALLY DISTRIBUTED
C     RANDOM NUMBER WITH A GIVEN MEAN AND STANDARD
C     DEVIATION
C
      A = 0.0
      DO 50 I = 1,12
      CALL RANDU(IX,IY,Y)
      IX = IY
   50 A = A + Y
      V = (A-6.0)*S+AM
      RETURN
      END
C
C
      FUNCTION SHLANE(SRDNO,SHLVOL,D,Z)
C
C     SUBROUTINE TO CALCULATE SHOULDER-LANE HEADWAYS
      SHLANE = Z*ALOG(1.-SRDNO) ± D
      RETURN
      END
```

```
C
      SUBROUTINE NVWGT(SYSTIM,NVW30,NVW60,NVW90,NVW120,NVW150,NVW180)
C     SUBROUTINE TO DETERMINE NUMBER OF VEHICLES BY LENGTH OF DELAY
C
    1 IF(SYSTIM-180.)4,2,2
    2 NVW180 = NVW180+1
    3 GO TO 5
    4 IF(SYSTIM-150.)7,5,5
    5 NVW150=NVW150+1
    6 GO TO 8
    7 IF(SYSTIM-120.)10,8,8
    8 NVW120=NVW120+1
    9 GO TO 11
   10 IF(SYSTIM-90.)13,11,11
   11 NVW90=NVW90+1
   12 GO TO 14
   13 IF(SYSTIM-60.)16,14,14
   14 NVW60=NVW60+1
   15 GO TO 17
   16 IF(SYSTIM-30.)18,17,17
   17 NVW30=NVW30+1
   18 RETURN
      END
C
C
      SUBROUTINE SORT2(L)
C
C     SUBROUTINE TO SORT FIXED-POINT QUANTITIES
C
      DIMENSION L(1000)
    1 DO 7 I=1,999,1
      MIN = I+1
    2 DO 7 J=MIN,1000,1
    3 IF(L(I)-L(J))7,7,4
    4 LOCAL=L(I)
    5 L(I)=L(J)
    6 L(J)=LOCAL
    7 CONTINUE
   10 RETURN
      END
C
C
      SUBROUTINE SHDATA(SHLVOL, D, Z)
C
C     SUBROUTINE THAT RETURNS D AND Z PARAMETERS OF THE
C     SHOULDER-LANE HEADWAY DISTRIBUTION
C
      D=0.30 + SHLVOL/10000.
      T=3600./SHLVOL
      Z=-(T-D)
      RETURN
      END
```

```
C
      SUBROUTINE PRNORM(PROB,FUN)
C
C     SUBROUTINE TO MAKE THE CUMULATIVE STANDARD
C     NORMAL DISTRIBUTION AVAILABLE
C
      DIMENSION PROB(701)
      JNT=10
      XNT=JNT
      XO=-3.5
      YO=.0002
      PROB(1)=.0002
      DO 10 I=2,701
      ZI=I
      Z=ZI/100.-3.51
      H=(Z-XO)/XNT
      H2=H/2.
      Y=YO
      X=XO
      DO 11 J=1,JNT
      T1=H*FUN(X)
      T2=H*FUN(X+H2)
      T3=H*FUN(X+H2)
      T4=H*FUN(X+H)
      Y=Y+(T1+2.*T2+2.*T3+T4)/6.
   11 X=X+H
      PROB(I)=Y
      YO=Y
      XO=Z
   10 CONTINUE
      RETURN
      END
C
C
      FUNCTION FUN(X)
C
C     FUNCTION SUBPROGRAM TO EVALUATE THE NORMAL
C     PROBABILITY DENSITY FUNCTION
C
      FUN = (1./SORT(2.*22./7.))*EXP(-0.5*X**2)
      RETURN
      END
C
      SUBROUTINE PROBIT(X1,X2,A,B1,B2,Z)
C     SUBROUTINE THAT CALCULATES THE PROBIT EQUATION
C     FOR THE GIVEN PARAMETERS
      Z=A+B1*ALOG10(X1)+B2*X2
      RETURN
      END
```

```
C
      SUBROUTINE RHEAD(RA1,RT1,RD1,RA2,RT2,RD2,K , RH,IXR)
C
C     SUBROUTINE TO RETURN RAMP HEADWAY USING
C     HYPERLANG HEADWAY MODEL
C
      CALL RANDU(IXR,IYR,RRDNO1)
      IXR = IYR
      IF(RRDNO1-RA1)1,1,2
    1 CALL RANDU(IXR,IYR,RRDNO2)
      IXR = IYR
      RH = -(RT1-RD1)*ALOG(RRDNO2) +RD1
      GO TO 4
    2 C = K
      B=C/(RT2-RD2)
      RH = 0.
      DO 3 I = 1,K
      CALL RANDU(IXR,IYR,RRDNO2)
      IXR = IYR
      T = -ALOG(RRDNO2)/B + RD2/C
    3 RH = RH + T
    4 RETURN
      END
C
      SUBROUTINE ASORT(A, N)
C             SORT SUBROUTINE
      INTEGER A(1)   , SAVE
      NP = N
1     NP = NP/2
      IF(NP) 7,7,2
2     K = N - NP
      J = 1
3     I = J
      M = I + NP
4     IF(A(I) - A(M))6,6,5
5     SAVE = A(I)
      A(I) = A(M)
      A(M) = SAVE
      M = I
      I = I - NP
      IF(I - 1) 6,4,4
6     J = J + 1
      IF (J - K) 3,3,1
7     RETURN
      END
C
      SUBROUTINE RANDU(IX,IY,YFL)
C
C     SUBROUTINE THAT COMPUTES A RANDOM REAL
C     NUMBER BETWEEN 0 AND 1.0
C
      IY = IX*65539
      IF(IY)5,6,6
    5 IY = IY + 2147483647 + 1
    6 YFL = IY
      YFL = YFL*.4656613E-9
      RETURN
      END
```

APPENDIX B

Tables of Model Parameters For Service Time Given A Wait

TABLE B.1

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 200(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9918	00	..	..	10	100.0	1.92	1.35
200	.9598	00	..	..	10	100.0	1.94	1.35
300	.9935	.29	13.28	1.35	10	.71	1.78	1.35
400	.9969	.36	13.98	1.35	10	.64	1.79	1.35
500	.9943	.42	13.07	1.35	10	.68	1.79	1.35
600	.9961	.42	15.25	1.35	10	.68	1.79	1.35
700	.9970	.42	16.22	1.35	10	.68	1.79	1.35
800	.9968	.51	17.47	1.35	10	.49	1.79	1.35
900	.9991	.52	18.78	1.35	10	.48	1.80	1.35
1000	.9978	.62	17.13	1.35	10	.38	1.76	1.35
1100	.9982	.70	19.44	1.35	10	.30	1.76	1.35
1200	.9985	.73	21.61	1.35	10	.27	1.76	1.35
1300	.9968	.75	23.36	1.35	10	.25	1.78	1.35
1350	.9997	.79	21.07	1.35	10	.21	1.74	1.35

TABLE B.2

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 300(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9889	00	..	..	10	100.0	1.84	1.35
200	.9630	00	..	..	10	100.0	1.87	1.35
300	.9956	.27	13.19	1.35	10	.73	1.80	1.35
400	.9960	.29	14.85	1.35	10	.71	1.80	1.35
500	.9934	.43	12.14	1.35	10	.57	1.80	1.35
600	.9974	.42	15.57	1.35	10	.58	1.80	1.35
700	.9976	.49	14.84	1.35	10	.51	1.80	1.35
800	.9972	.61	15.28	1.35	10	.59	1.75	1.35
900	.9991	.58	16.37	1.35	10	.42	1.78	1.35
1000	.9969	.64	17.98	1.35	10	.36	1.77	1.35
1050	.9949	.66	17.98	1.35	10	.34	1.77	1.35

TABLE B.3

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 400(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9789	00	..	..	10	100.0	1.83	1.35
200	.9559	00	..	..	10	100.0	1.83	1.35
300	.9974	.26	10.01	1.35	10	.74	1.80	1.35
400	.9973	.30	14.29	1.35	10	.70	1.80	1.35
500	.9963	.40	11.54	1.35	10	.60	1.78	1.35
600	.9972	.40	15.56	1.35	10	.60	1.81	1.35
700	.9969	.50	15.51	1.35	10	.50	1.78	1.35
800	.9961	.53	17.02	1.35	10	.47	1.80	1.35

TABLE B.4

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 500(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9796	00	..	..	10	100.0	1.83	1.35
200	.9742	00	..	..	10	100.0	1.84	1.35
300	.9978	.23	15.06	1.35	10	.77	1.80	1.35
400	.9964	.32	11.48	1.35	10	.68	1.77	1.35
500	.9972	.33	14.51	1.35	10	.67	1.80	1.35
600	.9970	.41	14.98	1.35	10	.59	1.78	1.35
700	.9966	.50	13.50	1.35	10	.50	1.77	1.35

TABLE B.5

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 600(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9837	00	..	..	10	100.0	1.85	1.35
200	.9613	00	..	..	10	100.0	1.85	1.35
300	.9980	.27	12.83	1.35	10	.73	1.77	1.35
400	.9976	.28	15.49	1.35	10	.72	1.80	1.35
500	.9982	.30	14.82	1.35	10	.70	1.80	1.35
550	.9977	.36	13.98	1.35	10	.64	1.80	1.35

TABLE B.6

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 700(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9968	00	..	..	10	100.0	1.83	1.35
200	.9856	00	..	..	10	100.0	1.84	1.35
300	.9950	.23	10.86	1.35	10	.77	1.80	1.35
400	.9970	.31	14.10	1.35	10	.69	1.80	1.35
450	.9946	.31	14.55	1.35	10	.69	1.80	1.35

TABLE B.7

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 800(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9968	00	..	..	10	100.0	1.83	1.35
200	.9706	00	..	..	10	100.0	1.84	1.35
300	.9480	00	..	..	10	100.0	1.85	1.35
400	.9085	00	..	..	10	100.0	1.87	1.35

TABLE B.8

Hyperlang Model Parameters For Service Time Given a Wait

Ramp Volume = 900(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9907	00	..	..	10	100.0	1.83	1.35
200	.9676	00	..	..	10	100.0	1.84	1.35
300	.9335	00	..	..	10	100.0	1.86	1.35

TABLE C.3

Hyperlang Model Parameters For Service Time Given a Zero Wait

Ramp Volume = 400(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9742	00	..	..	1	100.0	1.20	00
200	.9615	00	..	..	1	100.0	1.84	00
300	.9059	00	..	..	1	100.0	2.54	00
400	.9466	00	..	..	1	100.0	4.26	00
500	.9748	00	..	..	1	100.0	5.60	00
600	.9798	00	..	..	1	100.0	5.28	00
700	.9859	00	..	..	1	100.0	8.20	00
800	.9450	00	..	..	1	100.0	7.53	00

TABLE C.4

Hyperlang Model Parameters Service Time Given a Zero Wait

Ramp Volume = 500(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9761	00	..	..	1	100.0	1.24	00
200	.9454	00	..	..	1	100.0	1.75	00
300	.9181	00	..	..	1	100.0	3.02	00
400	.9322	00	..	..	1	100.0	4.00	00
500	.9717	00	..	..	1	100.0	6.49	00
600	.9602	00	..	..	1	100.0	6.76	00
700	.9385	00	..	..	1	100.0	5.82	00

TABLE C.5

Hyperlang Model Parameters For Service Time Given a Zero Wait

Ramp Volume = 600(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9769	00	..	..	1	100.0	1.07	00
200	.9326	00	..	..	1	100.0	1.74	00
300	.9528	00	..	..	1	100.0	2.57	00
400	.8902	00	..	..	1	100.0	3.49	00
500	.9337	00	..	..	1	100.0	7.99	00
550	.9587	00	..	..	1	100.0	6.12	00

TABLE C.6

Hyperlang Model Parameters For Service Time Given a Zero Wait

Ramp Volume = 700(vph)

Shoulder Volume	R^2	a_1	$\bar{t}_1$	d_1	k	a_2	$\bar{t}_2$	d_2
100	.9724	00	..	..	1	100.0	1.28	00
200	.9619	00	..	..	1	100.0	2.05	00
300	.9071	00	..	..	1	100.0	2.84	00
400	.9540	00	..	..	1	100.0	2.51	00
450	.9021	00	..	..	1	100.0	2.75	00

13. Moskowitz, K. "Waiting for a Gap in a Traffic Stream," *Proceedings*, Highway Research Board, Vol. 33, Washington: 1954, pp 385-394.