A traffic simulation model of Tokyo Metropolitan Expressway

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Master of Science in Computer Science

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Rochester Institute of Technology

School of Computer Science and Technology

A Traffic Simulation Model of Tokyo Metropolitan Expressway

A Thesis submitted in partial fulfillment of a

Master of Science in Computer Science Degree Program

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CHAPTER 1

Introduction

1.1 Introduction and ackground

Metropolitan Expressway is the motorway system constructed for the purpose of ensuring a smooth flow of traffic, maintaining and promoting metropolitan functions of T kyo Metropolis and its vicinity.

The firs Metropolitan expressway was opened on December 1962 for a distance of only 4.5 kilometers. Since th n additions to the expressway system were built and planned not only in Central Tokyo but also nearby Kaw saki and Yokohama cities This trend was give special momentum by the 18th Olympic Games in Tokyo in 1964 and by the extraordinarily rapid increase f motor traffic.

At prese t, the expressway network consists of 21 routes wi h a total length of 152.5 kilometers. The number o automobiles using them daily has reached 820.00 units on the average mainly arising from the condu t of business and the transportation of the necessit es of life.

1.2 The necess ty of Traffic Control

Thus far 152.5 kilometers of expressway system have been op ned to traffic and used by a daily

average of 800 000 vehicles. As a result, traffic congestion now occurs on expressways just as on business streets In early years congestion on the expressways wa caused for the most part by the traffic accident and breakdowns of larger vehicles. Since May of 1 69, however, with the opening of Ueno Route No.1, the daily volume of traffic has increased enormously, causing an imbalance between the capacity of Metropolitan expressways and the demand for expressway use.

Since that time, new routes have increased the volume of traffic and thus the incidents of natural congestion have tended to increase as well. At present. congestion on Metropolitan expressways occurs for the most part on inner city routes, particularly on Central Loop. Almost 80 % of this congestion was caused by the volume of traffic alone.

To ensure an adequate flow of traffic under these conditions, and to provide for the safety and convenience of drivers, a variety of measures for the traffic control. such as: the traffic information services to drivers, removal of disabled vehicles and closing or limiting access at toll gates, are conducted by Metropolitan Expressway Public Corporation (M.E.P.C) [1]

1.3 Outline of traffic control system

For efficient execution of the above traffic control service, a traffic control system is operated by an electronic computer and occasionally improved in Central Tokyo Routes of Metropolitan expressways.

The outline of the system is as follows:

1.3.1 Monitoring and communications

1.3.1.1 Vehicle detectors

Various types of detectors, for sensing the number and speed of passing cars, are installed about every 500 meters at 600 locations in the system, either on the expressway itself or at an access point.

1.3.1.2 Television monitors

Twelve monitor television receivers in the control room can show traffic conditions at any point where one of 160 cameras is installed.

1.3.1.3 Emergency telephones

A total of 620 emergency telephones are installed at intervals of 500 meters along the expressways to receive reports from drivers on accidents or disabled vehicles.

1.3.2 Information processing

The central computer receives pulse data from vehicle detectors, and calculates the volume, average speed and density of traffic on an on-line real-time basis. On the graphic panel in the control center, the condition of traffic is then shown in a three color display. The necessary processes for traffic control are registered automatically on variable message boards on the expressways.

1.3.3 Information output

There are 180 variable message board at the entrance of Metropolitan expressways and on the expressway itself, 150 variable message boards on the business streets near expressway entrances, and 77 variable regulatory signs at entrances. Staff members of the Japan Road Traffic Information Center are permanently on duty in the Corporation´s traffic control room, broadcasting information 14 times daily on weekdays on traffic accidents, disabled vehicles, driving conditions and entrance regulations.

1.3.3.1 Variable Message Boards

Information about traffic conditions on the expressway is updated automatically every five minutes, and presented in 10 or 12 character illuminated displays. Signs readable in both

directions are located at interchanges and other points; where necessary, boards are located to direct drivers to alternate routes.

1.3.3.2 Variable Message Boards on Business Streets

These boards indicate such conditions as the temporary closing of entrances and limited access to toll gates.

1.3.3.3 Variable Traffic Signs

These signs indicate the closing of entranceways because of accidents or traffic congestion, or to control the volume of traffic.

1.4 The necessity of Traffic Simulation

As mentioned in the previous paragraph, the Corporation has provided a variety of information services to the drivers. However, at present, there are still considerable complaints among drivers who use Metropolitan expressways.

Generally speaking, it is supposed that most complaints are based on the unreliability of the traffic information which the Corporation offers to them However, the reason is not so simple. The information which the Corporation offers to the driver using the latest computer system is considerably ac-

curate, the problem is that the information represents current traffic condition, which is created by using collection of the past five minutes data. Consequently, the traffic condition currently displayed on the variable message boards may change when the driver arrives at that place.

Imagine a situation that a driver who wants to go to the Tokyo International Airport enters Metropolitan expressway believing the information displayed at the toll gate. However, due to the unexpected traffic change, he missed the airplane.... .. In such a situation the kind of complaint described arises.

In 1990, due to the expansion of the Metropolitan expressway, the traffic control administration area divided into Western Tokyo area and Eastern Tokyo area. In the latter area, a new traffic control system, which is quicker and more accurate, with a one minute information update cycle has been installed. However, at present, the new system cannot resolve that kind of problem completely, because it is still based on the same algorithm of offering current information created by the collection of past data.

Now to summarize the problems of the current Traffic Control System;

(1 . Both systems offer current traffic information

created by collection of past data.

(2). Both information systems include delay time. (Western Tokyo System : 5 minutes, Eastern Tokyo System : 1 minute)

(3) This informations only represents the current length of a traffic jam, which is unfriendly for the decision-making, especially for the driver who is unfamiliar to the Metropolitan expressway.

To resolve these problems the information must include a kind of prediction of traffic flow in near future. In adding this, if the information represents the travel time to the particular destination, then it would be more friendly for the driver. It is very difficult to develop a mathematical model for a complicated traffic model such as Metropolitan expressway, then as the alternative way a Computer Simulation will give the answer for these problems.

1.5 Outline of the project

Developing a complete simulation model of the Metropolitan Expressway is evidently a very difficult job given limited time and computer storage space.

Cr the other hand, choosing a subset model and developing the simulation model for this is a reasonable thesis project.

For this thesis project, the interest is mainly placed on the traffic flow model of the Western Tokyo area which includes the Central Loop and is actually the central area of Tokyo Metropolis. In adding this, the traffic control system of the Western area has a ten ye r history from its installation, consequently a lot f statistical data for the simulator validation will be expected.

The GPSS simulation language is used with FORTRAN subroutin s for this project because of its ample features for simulation for this kind of problem.

The appl cation of this model will be considered as fol ows;

(1). Developmen of the current traffic control system's ability

The imulator will be tied up with the traffic c ntrol system using some interface and will be used for predicting the traffic flow in the near future or calculating the travel time to a particular destination.

(2). Planning and research purpose

The traffic volume prediction will be needed in case of the opening of new routes. some special event, such as the Olympic Games, and every year's traffic research etc.

In this thesis project, two kinds of simulation model are developed. Both of them are using the same algorithm. however the modeling scale is different. One model is created using 1:10 scaling where the other is using 1:100. [2]

The eason for the different scaling is based on the accu acy and run time considerations. The 1:10 scale model produces more accurate results than the 1:100 scale model, however it requires longer run time than 1:100 cale model and vice versa. Both models produce the fo lowing data and can be used in appropriate application purpose, such as travel time calculation or traffic olume research, after they are analized and validated.

The utput from the simulation models are:

(1). Traff c volume of each interval of the ex- expre sway every 1 hour. (*, ** [3]

(2). Traff c volume of each entrance and exit every 1 hour. (**)

(3 . Veloc ty level of each interval of the ex- press ay every 5 minutes. (*, **)

(4). Travel time between any combination of entrance and exit every 1 hour. (**)

(5). Traffic characteristics of selected interval (Q-K curve) every 1 simulation run. (*)

(6). Traffic volume and velocity level of each interval of the expressway with off-line processing. (*)

where: (*) : Graphical output

(**) : Numerical output

NOTE

[1] Metropolitan Expressway Public Corporation was established in 1959 to promote the construction of motorways (Metropolitan Expressways) in Central Tokyo and its vicinity. The Corporation also administrates and maintains the expressways which are already opened to traffic.

[2] In 1:10 scale model, one transaction represents ten cars where in 1:100 scale model one transaction represents one hundred cars.

[3] The output interval of (1) - (4) can be changed with a little modification of the program.

CHAPTER 2

System description

2.1 The expressway system

The expressway system of Western Tokyo consists of seven radial routes and a central loop route as its core. Most parts of the expressway are composed of two-lane, elevated-structure road.

As each route has an independent structure, vehicles can not change routes directly, for example from inner loop to outer loop without exiting and reentering.

All the traffic which goes through from one radial route to another radial route must pass the central loop route. This centralism tends to cause traffic jams in the central loop route and at the junctions of the radial routes to the central loop route.

The Metropolitan Expressway is a toll road with a flat rate toll, consequently there is a toll gate at every entrance and junction from another inter-urban expressways.

The K.K route is a free-way and strictly speaking, this route is not a part of the Metropolitan Expressway. For that reason, there is a toll gate at each junction from K.K route. However,

generally it is considered as a component of Metropolitan Expressway for it has the same road structure (two-lane elevated structure).

2.2 Traffic volumes

The traffic volume at typical commuting time in the morning reached up to 3500 - 4500 vehicles per hour at the junction of each radial route to the central loop and the loop route itself Most of the radial routes have the same traffic pattern, that is, the traffic volume begins to increase at 5 - 6 a.m. and reaches a maximum at 8 - 9 a.m. The amount of increase of the traffic volume in these periods sometimes reaches 4000 vehicles per hour.

After the traffic volume reaches its maximum, it decreases gradually but it keeps about 2000 vehicles per hour during the day time. Both loop routes usually keep about 3000 vehicles per hour during the day time.

There is another peak of traffic in the evening from central loop to each radial route and between the radial routes. However this peak does not cause as serious traffic jams as the commuting time in the morning, because of its distributive nature. Then the traffic decreases gradually and it reaches its minimum at 3 - 4 a.m.

2.3 Traffic data

The data which can be used for this simulation model are gathered both from the Traffic Computer System and variety of research which the Metropolitan Expressway Public Corporation has made. [1]

The description of each data are as follows:

2.3.1 Traffic volume

These data are obtained both from computer output [2] and O - D research data [3]. The data used in this simulation model extracted from the latter are summarized in APPENDIX 1 - APPENDIX 3.

APPENDIX 1 Traffic volume per hour in each toll gate.

APPENDIX 2 Traffic volume per hour in each exit

APPENDIX 3 Traffic volume per hour in each interval of the expressway. (link)

2.3.2 Origin - Destination (O - D) relationships

These data show the relationship between origin and destination of each vehicle at every entrance (on-ramp) and exit (off-ramp). The data used in this model represent typical commuting time (7 - 8 a.m.) and after the rapid increase of traffic volume (9 10 a.m) are summarized in APPENDIX 4

2.3.3 Branch-ratio at interchange

At the interchange of each radial route to both loop routes, the traffic branches to either the inner loop or the outer loop depending on the desired destination.

Most of the traffic choose the shorter route. For example, at HMIC (Hamazaki interchange) of Route 1-South, the traffic whose destination is Route 4 (Route Sinjuku) takes outer loop route which is shorter than to take inner loop route. However in case of a particular destination, for example Route 5 (Route Ikebukuro) at HMIC (same interchange as the above example), the traffic branches to both loop routes in certain branch ratio (detour ratio). These branch ratios are critical because they are closely related to the traffic condition.

For example, if there is a heavy traffic jam in one of the loop routes, then it is apparent that the traffic will choose the other loop route. However, there is a statistical ratio which is obtained from O - D research and it is assumed that in most cases the traffic branches follow this ratio. These ratios are summarized in APPENDIX 5 - APPENDIX 6.

Note:

[1] Refer to CHAPTER 1

[2] Toll gate traffic volume data is obtained either from Traffic Control Computer System or Toll gate Computer System.

[3] Origin to Destination Research

The O - D research is made by Metropolitan Expressway Public Corporation every two years. This research requires the co-operation of the user of Metropolitan Expressway because of its method, that is, at every entrance (toll gate) the user is handed a research card which contains several questions such as destination, what route does he or she take and time of exit etc. This card is expected to be sent back to the Corporation by mail after filling it in Although the Corporation prepares several premium or gift for the co-operation. the reply rate is rather low. (less than 35 %)

The data can be obtained from this research are:

(1). Traffic volume of each entrance.

(2). Traffic volume of each exit.

(3). Traffic volume of each interval of the expressway.

(4). Origin and destination of each vehicle in each entrance and exit.

(5). Branch ratio at each interchange.

CHAPTER 3

Traffic flow

3.1 Outline

As far as the traffic flow is concerned, there is well known traffic flow theory;

$$Q = K * V$$

where

Q : traffic volume per hour

V : average space velocity (km / hour)

K : density (traffic volume / km)

This traffic flow theory is well formed in the Metropolitan Expressway. especially in the intervals without on-ramps and off-ramps. Typical Q-K curves of the Metropolitan Expressway are shown in Fig. 3 1.1.1 and Fig. 3.1.1.2. These curves are obtained by processing output data of the Traffic Control System. Since the data which are obtained directly from the computer system are traffic volume and average velocity during five minutes. consequently density (K) must be calculated from these two data, with time conversion. The typical value of K in jam density is 240 - 360 for two lanes. which varies in the particular interval of the expressway. It is

possible t say that Q-K curve represents the nature or characte istics of the particular interval of the expressway.

Theoretic lly, the Q-K curve is treated as continous curve shown as in Fig. 3.1.2.1, however, recent research in the Metropolitan Expressway reveals that the actual Q-K curve is not continuous at the critical density, as shown in Fig. 3.1.2.2.

In Fig. 3.1.2.2 two different traffic volumes are observed at the critical density, one is on the exterior line of the smooth flow and the other is on the line of the jam flow. This means that there are two different traffic volumes against one density at the critical point.

This result of the research leads to one of the traffic control schemes: that if the smooth traffic flow can be maintained then more traffic can pass within the same time of period. The equation $Q = K * V$ shows that V is very effective for this scheme and since K can not be controlled directly then V can be the control factor for maintaining smooth flow. In the Metropolitan Expressway, the observed value of V at the critical density is 30 - 40 km / hour.

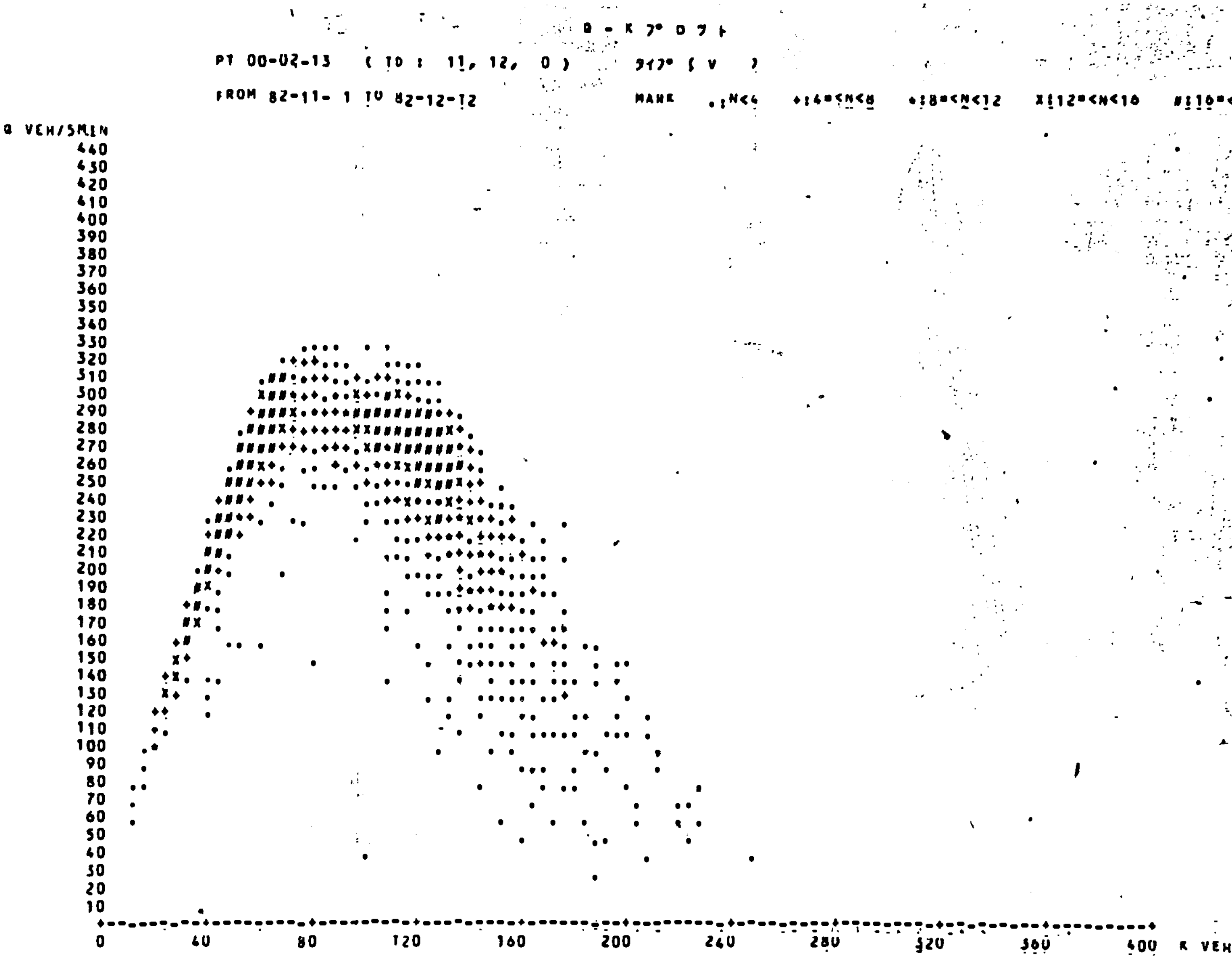

PT 00-02-13
FROM 82-11- 1 TO 82-12-12
Q VEH/5MIN
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
40
80
120
160
200
240
280
320
360
400
K VEH

Fig. 3.1.1.1

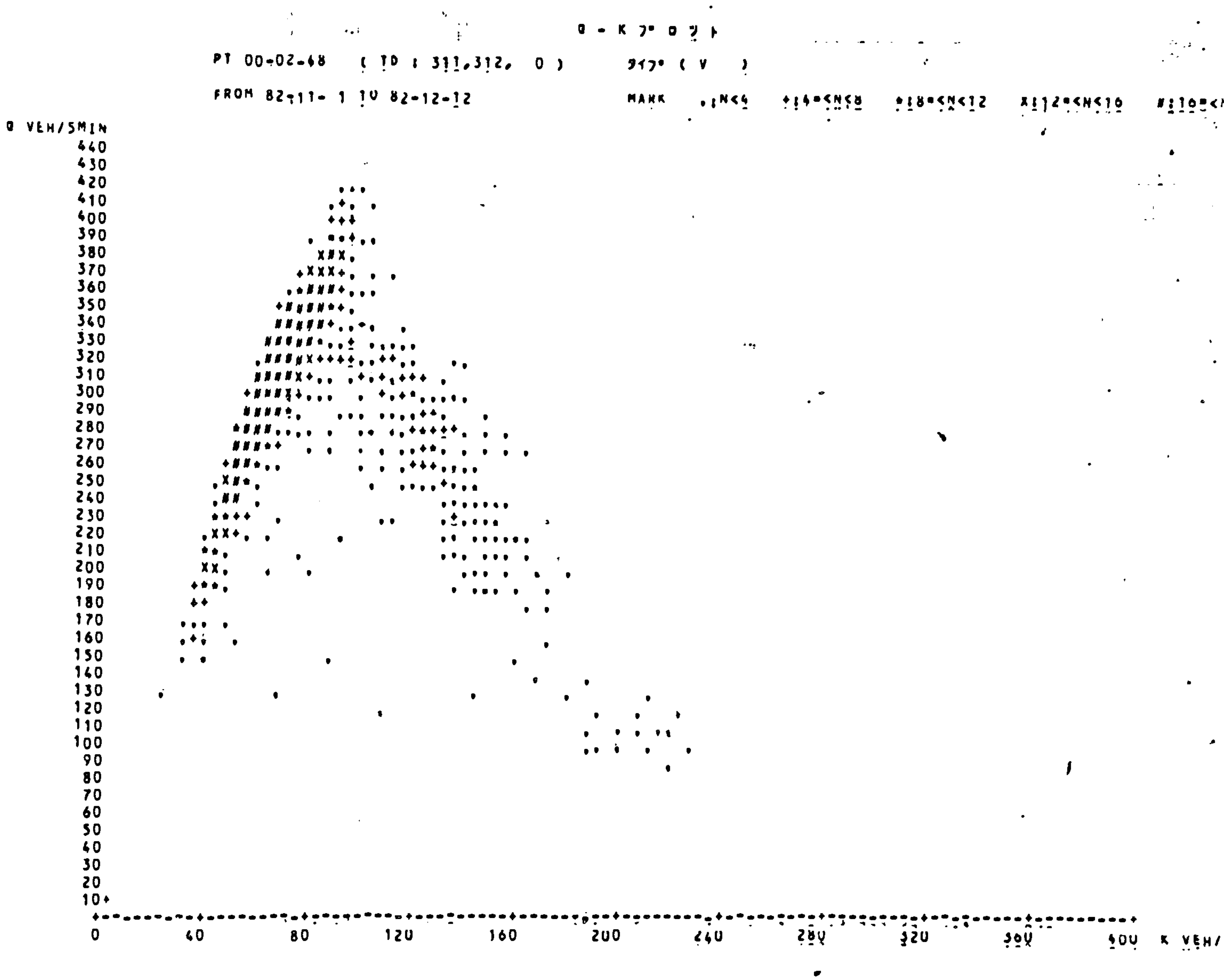

Q - K
PT 00-02-48 (TD : 311,312, 0)
FROM 82-11- 1 TO 82-12-12
MARK
Q VEH/5MIN
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 40 80 120 160 200 240 280 320 360 400 K VEH/

Fig. 3.1.1.2

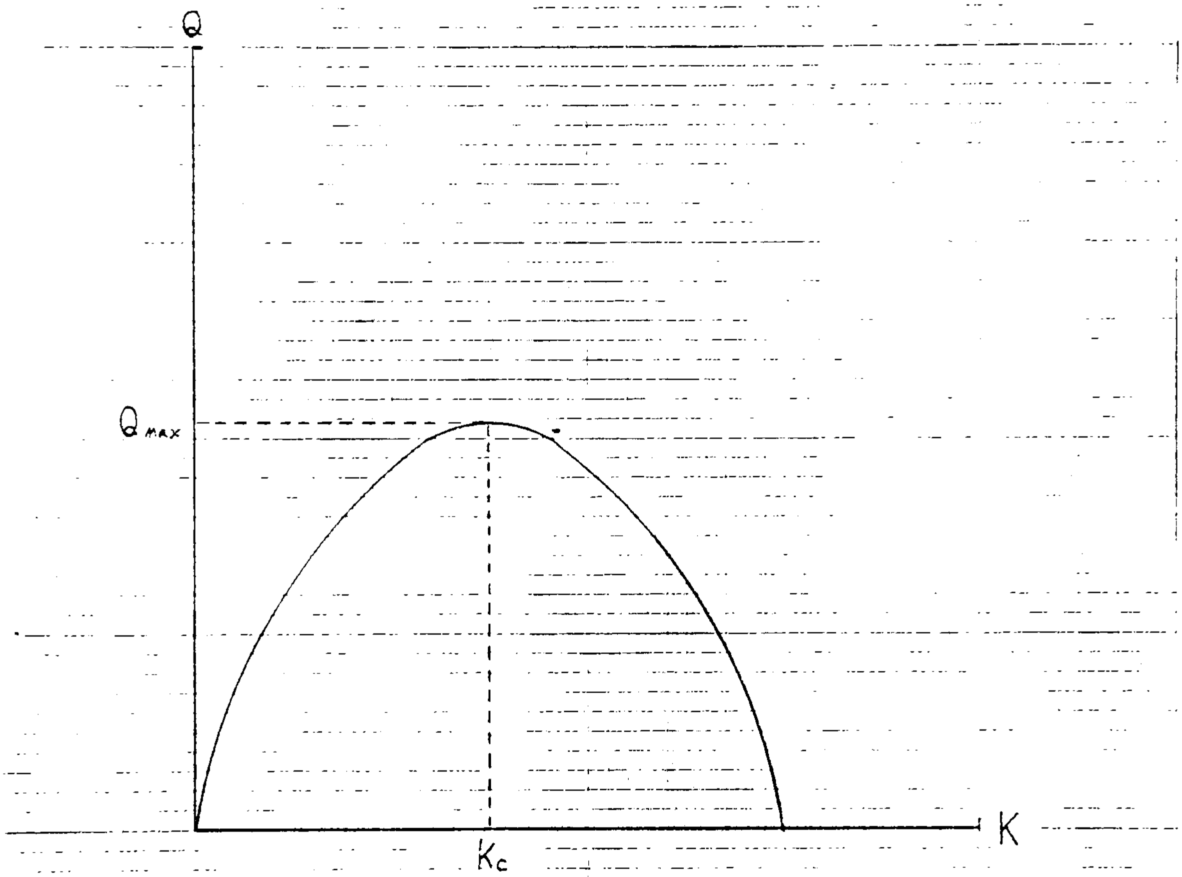


Fig. 3.1.2.1

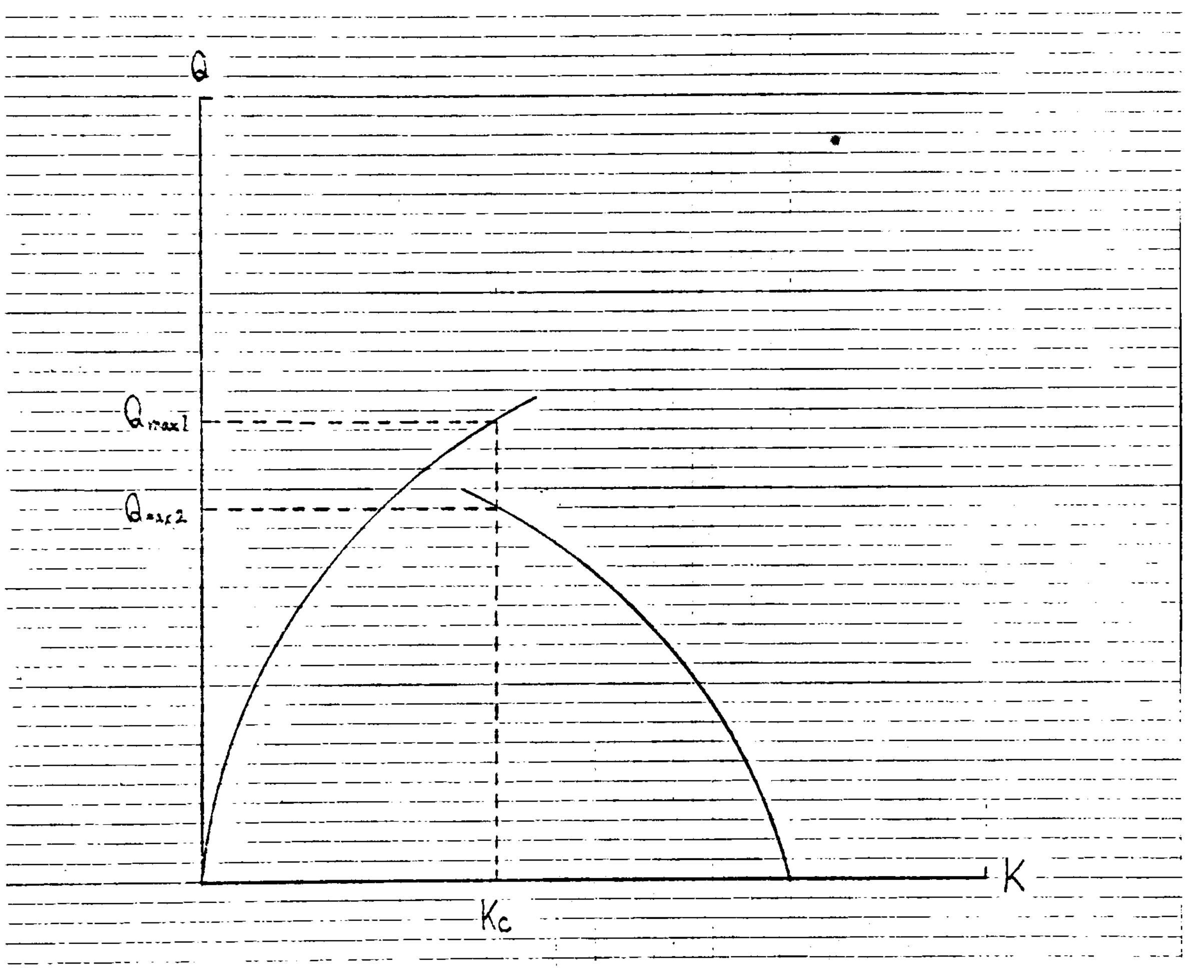


Fig. 3.1.2.2

3.2 Modeling of traffic flow

In this section several methods for modeling traffic flow are described.

In modeling the expressway using GPSS entities there is no doubt about choosing storage as the element of the simulated expressway (link). because of its properties that storage can contain many transactions within a defined capacity. The next step is to choose attributes of storage which preserve or keep the characteristics of traffic flow such as Q, K and V, as mentioned in the previous section.

For this purpose, a small GPSS model called "Q-K curve tester" is developed and the basic characteristics of storage attributes are examined.

The model consists of three separate programs; a GPSS main program and two FORTRAN subroutines which are called by main program.

The GPSS main program consists of three consecutive storages with the instruction sequence "enter-advance-leave". There are three kinds of functions: first, five different interarrival functions are defined and give different interarrival time for an eight hour simulation. Second, a built-in exponential function is used to modify the interarrival function; third, several delay functions are defined to give an appropriate delay time to each transaction while they are in each link The delay functions

can be changed depending on different capacity of storage. Each consecutive enter-advance-leave" sequence is followed by "queue", which counts the transactions passed in previous storage and after these queues. a dummy advance block is inserted to correct the down bias effect on the queue count when a transaction is denied entry to successive storage.

When a transaction enters each link (storage), the average contents of the storage which a transaction currently in it is assigned to the transaction's parameter and a delay function is invoked. passing this parameter value for its argument. The delay function returns an appropriate delay time, which forces the transaction in the link to stay for a given time period.

This model runs eight hours with five minute intervals using reset cards. The five minute interval is decided considering similarities to the data from which the Q- curve is obtained in the Traffic Control System.

Several xamples obtained from this model are shown in Fig. 3.2.2 - 3.2.3 and Table 3.2.1. Fig. 3.2.2 shows Q - K curve obtained at storage capacity = 30 and delay function = 0,40/8,60/30.400. [1] In this case it is assumed that one transaction represents ten vehicles. so from Fig. 3.2.2 the number of vehicles pa sing during five minutes (corresponds

to Q) is abo t 400 and the number of vehicles existing in the link (corresponds to K) is 300.

Fig. 3.2.3 shows another example, however in this case it is ssumed that one transaction represents one-hundred veh cles. Though the curve in Fig. 3.2.3 is very discr te, we can observe the same result at storage capacit = 3 and delay function = 0.40/3.400; the number of vehicles passing during five minutes (Q) is 400 and number of vehicles existing in the link (K) is 00.

In these xamples Q is represented by CC$ (total entries of queue) and K is represented by SA$ (average content of storage). There is another example, if we us S$ (current contents of storage) instead of SA$ hen invoking the delay function, this means when tr nsaction enters storage, the current contents of he storage is assigned to the transaction's p rameter. The result is shown in Fig. 3.2.4 The - K curve shown here is obtained at storage = 40. d lay function = 0,40/10,60/40,400. the delay function h s the same proportion to the previous example in F g. 3.2.2. However, in this case though maximum Q is about 400, it does not decrease below 250 in jam density. This series of experiment shows that it had better to use SA$ than to use S$ for the control factor of the transaction

In Table 3.2.1 a part of the GPSS statistics

is shown. The purpose here is to find out the attributes of GPSS entities such as storages and queues which represent the characteristics of traffic flow Q, K and V. In the previous example we use QC$ as Q and SA$ as K, so what attribute represents V is the question.

From the equation Q = K * V we can obtain;

V = Q / K

Since QC$ represents Q and SA$ represents K, we can calculate V from these two values.

V = QC$ * 12 / SA$

where QC$ = traffic volume / 5 minutes

For example, if we take the value of o1 in Table 3.2.1 QC$o1 = 54 and SA$o1 = 7.837 then V (km / h) = 54 * 12 / 7.837 = 82.625.

If we choose ST$ (average residence time of storage) as the time factor (second), then V (km / h) in unit length (1 km) is represented V (km / h) = 3600 * 1 / ST$. Now in Table 3.2.1 ST$o1 = 43.537, we obtain V (km / h) = 3600 * 1 / 43.537 = 82.688.

This result shows good correspondence to the V value obtained from QC$o1 and SA$o1. Actually, if we define the variable V$o1 = 3600 / ST$o1 which represent V (km / h) and if we plot the relationship between V$o1 and SA$o1 on the graph then we can ob-

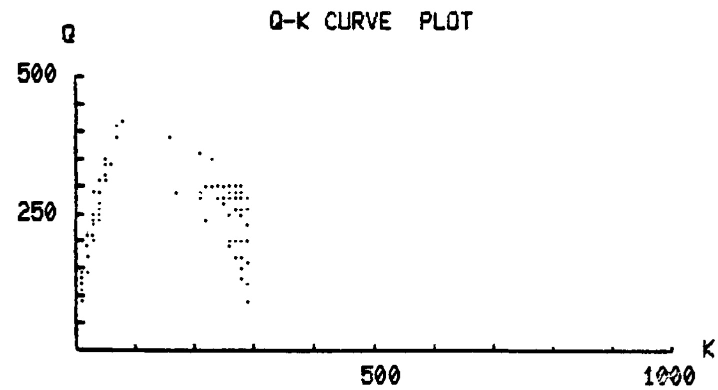
tain the result shown in Fig. 3.2.5. This result is reasonable because the equation

$$V = Q * 1 / K$$

represents a hyperbolic curve.

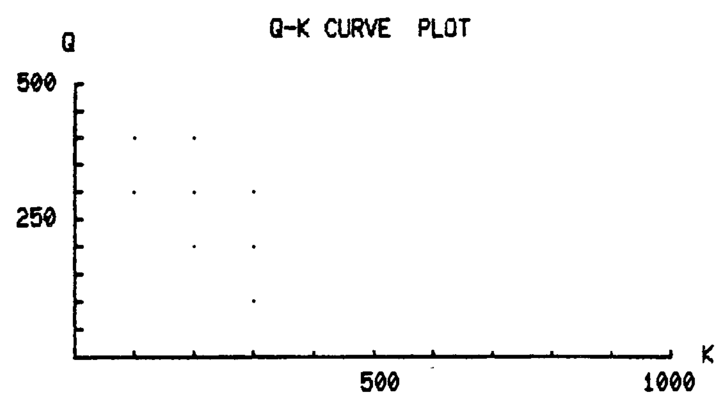
Furthermore if we define another variable V$qo1 = SA$o1 * 300 / ST$o1 which represent Q and if we plot the relationship between QC$o1 then we obtain a linear graph. which is shown in Fig. 3.2.6.

From these results, it is possible to conclude that the attributes in the model QC$, SA$ and 3600 / ST$ represent traffic characteristics Q, K and V respectively.



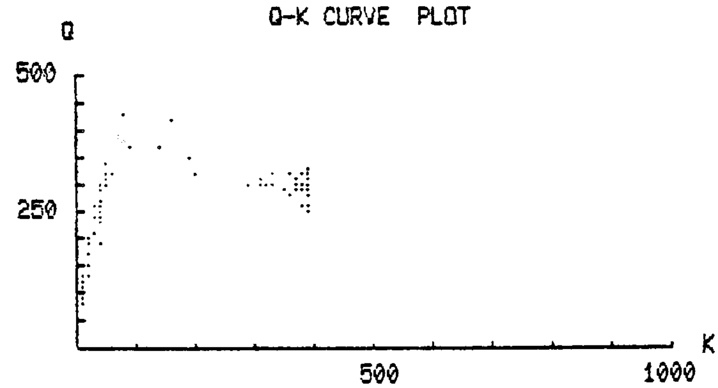
Assembly Errors: 0
Next Block Attempts: 51914
Next Block Moves: 51725
Page Faults: 485
Run Time: 00:00:43.54
Elapsed Time: 00:04:23.20

Fig. 3.2.2



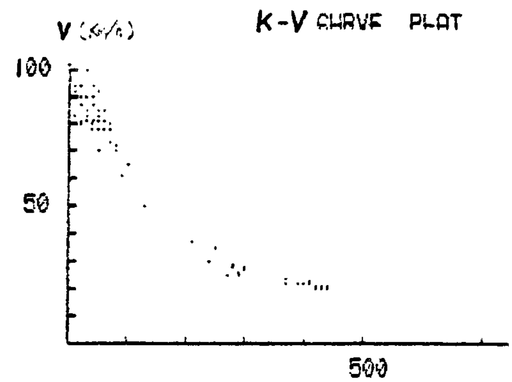
Assembly Errors: 0
Next Block Attempts: 5368
Next Block Moves: 5220
Page Faults: 351
Run Time: 00:00:10.38
Elapsed Time: 00:01:46.67

Fig. 3.2.3



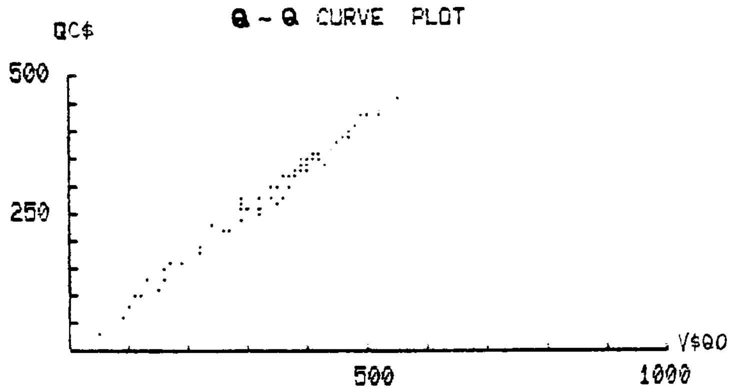
Assembly Errors: 0
Next Block Attempts: 58891
Next Block Moves: 58265
Page Faults: 444
Run Time: 00:00:46.74
Elapsed Time: 00:04:42.16

Fig. 3.2.4



Assembly Errors: 0
Next Block Attempts: 64665
Next Block Moves: 64265
Page Faults: 319
Run Time: 00:00:52.45
Elapsed Time: 00:03:21.23

Fig. 3.2.5



Assembly Errors: 0

PRINT BLOCK 26 AT CLOCK TIME 12900

STORAGE	CAPACITY	AVERAGE CONTENTS	TOTAL ENTRIES	AVERAGE TIME/TRANS	AVERAGE UTILIZ.
01	36	7.837	54	43.537	0.218
02	36	8.150	54	45.278	0.226
03	36	7.710	53	43.642	0.214

```
216                    reset
217                    start            1,np          ;44
```

TABLE 3.2.1

3.3 Implementation in the GPSS model

The results gotten in the previous section show that attributes QC$, SA$ and 3600 / ST$ in the model sequence enter - advance - leave represent traffic characteristics Q, K and V respectively.

Furthermore, attribute SA$ is better than S$ when it is used as the control factor of the transaction's delay time in each link. From these results we can draw out the basic design of the traffic flow model.

First, we use storage as the representation of a link (element of a simulated expressway) and we define the capacity of the storage, considering the length of each link. Since the unit length of a link is 1 kilometer and it must contain a maximum of 240 - 360 vehicles in it, we have to choose a maximum storage capacity 36 in 1:10 scale model and 4 in 1:100 model. In the latter case we have to choose storage capacity 3 or 4, since it is impossible to take intermediate value.

Second, we have to decide the delay function. Using the "Q - K curve tester" several delay functions are examined in previous section. However, the results gotten in the 1:10 scale model and the 1:100 scale model are somewhat different. In the 1:10 model, a three point continous delay function is used for example In the case of storage capacity

30. the delay function which produce an appropriate Q - K curve is 0,40/7,60/30,400; in the 1:100 scale model the two point function, 0,40/3,400, produces an appropriate result when the storage capacity is 3. If we use a two point function which has the same proportion of its value to the delay function in the 1:100 scale model, then the model will produce under-achievement of the passing transactions. Furthermore if we use a delay function which has the same proportion as the 1:10 scale model in the 1:100 model (in this case storage capacity 4 is chosen), then the model will produce over-achievement of the passing transactions. It is assumed that the over-achievement in 1:100 scale model is due to the discreteness of the control factor, that is, the argument value of the delay function can take only four values and adding this the probability to take value 1 is supposed to be very large. Anyway we decided to use a different type of delay function in each model. From these examples, we can also conclude that the storage capacity limits the maximum number of transactions in the link, while the function value limits or controls the number of passing transactions. Furthermore, in the case of different lengths of the link. we can draw the result that the delay function of unit length can be used, magnifying its value proportionally depending on the

length of the link. For example, if the storage capacity of unit length is 30 and the length of the link which we are going to decide the delay function is 2 kilometer then the delay function for this link would be 0,80/14,120/60,800.

Third, we have to run the model in five minute intervals using the reset card. Because the delay control factor should be SA$ and it must be reset every five minutes. If we do not use a five minute reset then, the model would produce similar results when S$ is used as the argument of the delay function.

NOTE:

[1] The function in GPSS can be defined either discrete or continuous using the following notation. For example, 0,40/8,60/30,400 represents three point continuous function, although the argument specification C" is not shown. This function returns value 40, a linear interpolated integer value between 40 and 60 and also a linear interpolated integer value between 60 and 400, corresponding to the argument value 0, 1 to 8 and 9 to 30 respectively.

CHAPTER 4

The GPSS model

4.1 Modeling strategy

In the previous section, the basic characteristics of traffic flow and the strategies of modeling traffic flow are described. In this section, we develop an expressway model based on these results.

In modeling the Tokyo Metropolitan Expressway using the GPSS simulation language, care must be taken in the following points:

4.1.1 Scaling of the model

Although it is ideal to represent one transaction vehicle by one transaction in the model, there is a GPSS restriction that prevents implementation of this strategy. In the GPSS processor there is a restriction that the number of transactions existing in the model can not exceed a certain amount. The restriction can be expanded by reallocating the resources within the GPSS processor, however, it is not enough for representing the vehicles by one transaction, even by reallocating the resources in this particular model.

For example, it is assumed that 45000 vehi-

cles can exist in the model simultaneously in the case of a traffic jam and 30000 vehicles in the case of normal conditions. Consequently, for this reason we have to de-scale the model. In this model 1:10 and 1:100 scaling are used, as mentioned in chapter 2.

4.1.2 Run time of the model

The run time of the model is closely related to the scaling factor. Generally speaking, the run time of the 1:10 scale model is almost ten times longer than the 1:100 scale model because the GPSS processor must treat ten times more transactions in the former model. It is very important to decide the run time of the model, especially in particular applications

For example, if we use this model for research purposes, such as the survey of the effect of opening a new route, then run time is not the main consideration. However, if we use this model for calculating travel time for the information service to the driver in an on-line basis, then longer run times would be fatal.

Since scaling and run time of the model are closely related to each other, we expect to find a trade-off between the accuracy and calculation speed in examining these two different scale models in a

later section.

4.2 Abbreviations in modeling

As menticned in the previous paragraph, we decide to use de-scaling in creating the expressway model, consequently we have to consider several points about the total accuracy of the model.

As far as the accuracy of this model is concerned, ten vehicles in the 1:10 scale model and one hundred vehicles in the 1:100 scale model are the limit of resolution in each model. Consequently the following abbreviations are considered:

4.2.1 Simulate two lanes by single lane

Since ten vehicles is the resolution limit, it does not make sense to simulate the particular characteristics which would occur in a two-lane model implementation, such as lane-change at the interchange etc. Furthermore, most of the interchanges in the Metropolitan Expressway from the radial route to the loop route are channelled to a single lane for smooth merging of traffic to the loop route; for this reason it is assumed that using a single lane model is not an over abbreviation.

4.2.2 Abbreviate entrances and exits with small traffic

Entrances and exits with small amounts of traffic. which have no significant effect on the main traffic flow, are put together and added to the closest entrance with a large volume of traffic.

4.2.3 Abbreviate multi-lane toll gate

Since this model treats the traffic flow as a single lane, the multi-lane toll gates, such as those at the junctions from the inter-urban expressway, are removed. All toll gates in this model are represented by a single gate block, which is placed every entrance.

Based on these modeling strategies and abbreviations, the schematic diagram of the GPSS model of Metropolitan Expressway used is shown in Fig 4.2.1.

In Fig 4.2.1, the expressway consists of a collection of links, which are represented by a rectangular shape. The number in the rectangle shows the link number, (1 to 64). The black arrow shows the on ramp with the on-ramp number, (1 to 34). The white arrow shows the off-ramp with the off-ramp number (51 to 78). At the junction from each radial route to both loop routes, and the junction from both loop routes to K.K. route, the mnemonic names of each interchange are shown. In the mnemonic

names on both loop routes, the first character represents which loop route they belong to. For example, the interchange name CHMIC shows that this particular interchange is located on the outer loop route.

Although the links between the interchanges and the loop routes are not shown in Fig 4.2.1, there exist such links. For example, in ROUTE 1-SOUTH there are links which connect between HMU1 and both loop route interchange OHMIC and IHMIC. Conversely, there are also links from the loop routes to each radial routes, such as OHMIC to HMP1 and IHMIC to HMP1.

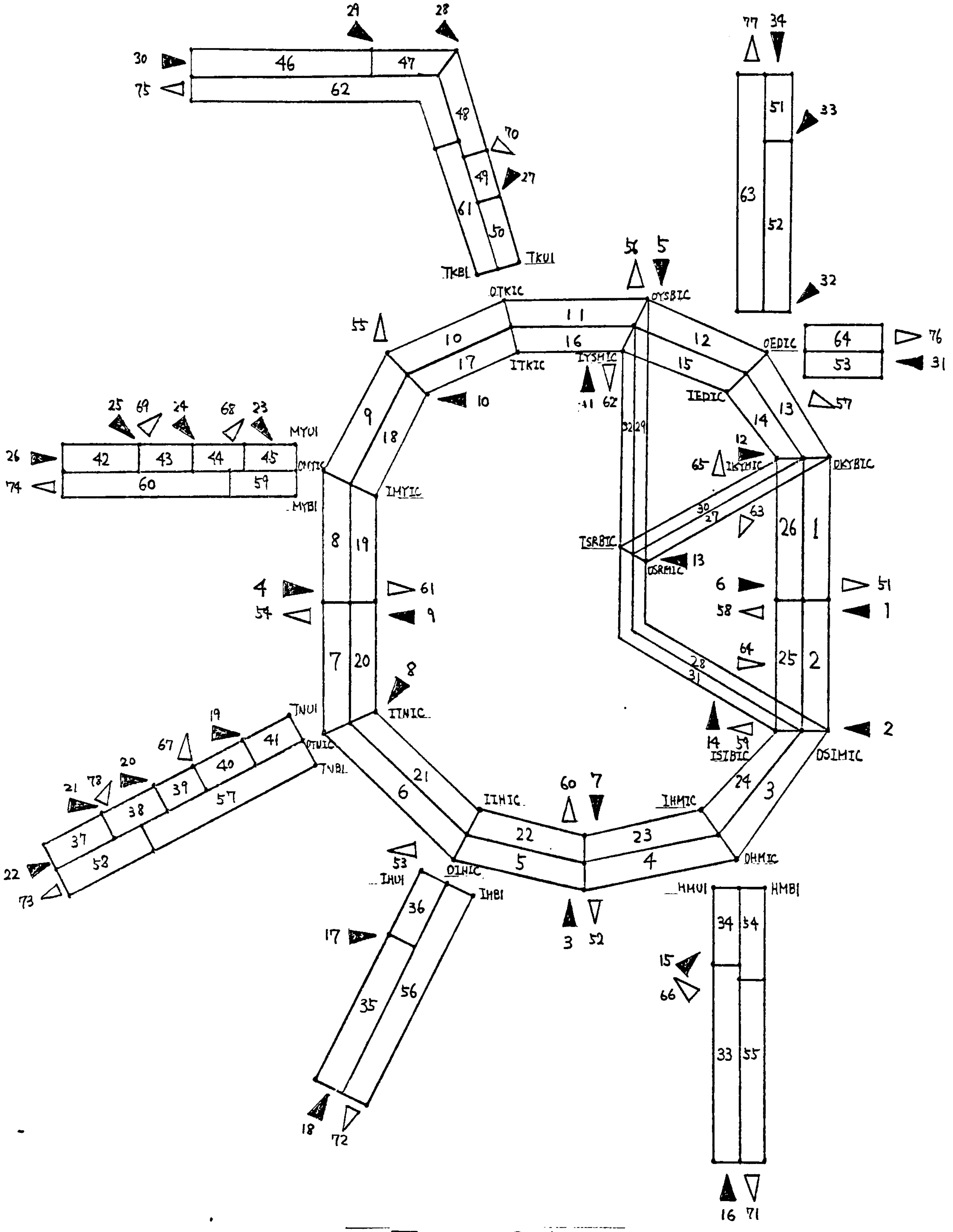

TKBI
TKUI
OTKIC
OYSBIC
OEDIC
OKYBIC
ITKIC
IYSHIC
IEDIC
IKYHIC
TSRBIC
OSRHIC
MYUI
MYBI
OMYIC
IMYIC
IINIC
INUI
INBI
ONIC
IIHIC
IHMIC
ISIBIC
OSIHIC
OHMIC
OIHIC
IHUI
IHBI
HMUI
HMBI

Fig. 4.2.1

4.3 Description of the model

4.3.1 Overview

The GPSS model of Tokyo Metropolitan Expressway is created based on the modeling strategies and abbreviations in the previous section. In this section, the GPSS model and associated FORTRAN subroutines are described.

The model consists of one GPSS program and collections of FORTRAN subroutines which are called from the GPSS program. The GPSS program simulates the expressway system, defining storage as its component and several functions such as: interarrival functions, destination functions, delay functions and direction functions. The GPSS program not only produces standard or selected GPSS statistics as output, but it also produces several kinds of graphical output and statistical analysis by the aid of FORTRAN subroutines. The FORTRAN subroutines also play the role of an interactive medium between the GPSS program and the user. The user can change or select several entities such as functions or queues in the GPSS program from the FORTRAN subroutines.

The hours simulated by this model are eight the hours from 4:00 a m. - 12:00 a.m . and this interval is characteristic of typical commuting times in the morning. as mentioned in chapter 2, and it is

the most interesting time period in the view of both the administrator of the expressway and its user.

4.3.2 GPSS main program

The GPSS main program consists of the following components:

4.3.2.1 Definitions

(1). Storage definitions

Storages represent each link of the expressway. and the different length of the links are represented by defining different storage capacities.

(2). Function definitions

(a). Interarrival functions

Interarrival functions are prepared for every entrance They return appropriate values when called by the generate block corresponding to each entrance in the model. The argument of these functions is an absolute clock; time unit of both the 1:10 and the 1:100 model is a second. The interarrival time of these entrances can be modified by an exponential function and the choice can be made by the user from the FORTRAN subroutines.

(b). Destination functions

Destination functions are also prepared for every entrance, and they assign appropriate values when they are invoked by the assign block in the model There are two different destination functions for each entrance and they are switched; one controls the 4:00 a.m. to 8:00 a.m. time period and the other the 9:00 a.m. to 12:00 a.m. time period.

(c). Delay functions

Delay functions return an appropriate delay time when they are invoked by the transaction entering the particular link. Different delay functions give different characteristics to each link.

(d) Direction functions

Direction functions are prepared for every interchange rom the radial routes to the loop routes and they a sign the choice of the outer or inner loop route to each transaction.

4.3.2.2 Mod 1 segment

(1). Origin segment

This segment represents each entrance or junction from a other inter-urban expressway. The generate block invok s the corresponding interarrival function

and generates the transaction. The interarrival time can be modified by the exponential function, if the user chooses modification mode from the FORTRAN subroutine. Then the transaction is assigned its origin and destination parameters, and if the link to which the transaction is going to enter is not full, then it is transfered to the corresponding expressway segment

(2). Expressway segment

This segment represents the route structure of the expressway system. Each link, the component of the expressway. consists of an enter advance-leave" sequence. An appropriate delay time is assigned to each transaction when it invokes the delay function from each link where the transaction currently exists. At the interchange or off-ramp, the destination value of each transaction is examined by the test block and if the value is equal to the particular destination then the transaction transfers to the block or. in case of an off-ramp, it terminates. In several interchanges, where no test block exists, the transaction branches according to the given branch ratio. At the interchange from each radial route to both loop routes. the direction function is invoked by the transaction and the choice of the loop route is decided. For particular destinations, a

detour ratio is used when deciding alternatives.

4.3.2.3 FORTRAN interface segment

(1). Interactive mode segment

The segment calls FORTRAN subroutines and requests to the user to input the selection or choice.

The user can choose from the following options:

(a). Display scale

One of the display scales must be selected depending on the model which is currently used. (1:10 scale or 1:100 scale)

(b). Speed level display

The user can choose 'display' or 'suppress' for graphically displaying the speed level of each link every five minutes.

(c). Q-K curve display

The user can choose "display" or "suppress" for graphically displaying Q-K curve in a user-selected link.

(d). Travel time display

The use can choose "display or suppress" for hourly ravel time calculation between any combination of entrance and exit.

(e) Modification of interarrival time

The use can choose modification options for the interarrival time functions. Modifying by a exponentia function or no modifying can be chosen.

(2). Data communication and display segment

This segment interfaces the data communications between the GPSS program and FORTRAN subroutines. This segment also calls the display subroutines when a display is requested by the user. The display of the traffic volume from simulator, with the expected value and statistical analysis between them (paired sample t-test [1]), are displayed automatically every one hour.

4.3.2.4 GPSS statistics collection segment

This segment can be used in choosing any desired GPSS statistics, such as storages and queues.

4.3.2.5 Control segment

This segment runs the model for three-eight hour simulations, using a selective reset card and a selective clear card. The output queues for the traffic volume are reset every one hour, while all the storages and queues for the Q-K curve are reset every 5 minutes.

4.3.3 FORTRAN subroutines

The associated FORTRAN subroutines. which are directly called by the GPSS program, are as follows:

4.3.3.1 Interactive mode support subroutines

As soon as the simulation begins, these subroutines are called immediately by the GPSS program and they request the user to input several selections as mentioned in the previous section. The selections are returned to the GPSS program by these subroutines.

4.3.3.2 Data communication support subroutines

These subroutines store the data from the GPSS model. or return the results from subroutines. There are two communication cycles: 300 seconds and 3600 seconds, and they can be changed depending on the user requirements.

4.3.3.3 Display subroutines

These subroutines display the data from the GPSS model either graphically or numerically in a comprehensive manner.

The traffic volume every one hour is a graphical display with output from the GPSS model and the expected values from actual data, in an arrangement so the values can be compared. In addition to this, statistical analysis is performed, using paired sample t-test in all links.

The speed level display is generated every five minutes as a graphical display with three speed levels in different colors and different line styles on the expressway map. The speed level classifications are less than 30 km/h, between 30 km/h and 60 km/h, and greater than 60 km/h. They can be changed depending on the user requirements.

The Q-K curve display of the selected links is provided for the verification of the GPSS model. This option produces the Q-K curve of a selected link at the end of an eight hour simulation.

NOTE:

[1] Paired sample t-test is used to test the difference between the two sets of data where the individual members of one sample are directly related to corresponding individual members of other sample. The traffic volume of a particular link produced by the simulation model is directly related to the corresponding traffic volume of the link of actual data.

CHAPTER 5

Results

5.1 Method of analysis

In analyzing the results of the simulation model, the method generally taken addresses the following points: verification of techniques, sensitivity with respect to variation in the components, steady state analysis and recommendations. The methods are briefly described below; the actual analysis of the results is discussed in detail in later section 5.2.

5.1.1 Verification techniques

As far as this simulation model is concerned, the actual situation is known from the data collected by the corporation, consequently the first requirement for this model is to produce results, that are as close as possible to the actual situation.

As mentioned in the previous chapter, this model is designed to conveniently compare the simulation results to actual data, though observing them directly from the graphical output. By adding this graphical output, the statistical analysis between the simulation results and actual data is produced automatically, so we can also use these statistics for

the verification of the model. The validity of the results are discussed in a later section.

5.1.2 Sensitivity analysis

Since the model consists of a collection of storages, the capacity of the storage is a sensitive component of this model. Actually in the 1:100 scale model, this factor is very sensitive, especially in passing transactions within a unit time period. From the experiment of Q-K curve in chapter 3, we have two alternatives in choosing storage capacity (storage capacity 3 or 4). In case of storage capacity 3, the model shows drastic under achievement in passing transactions in a unit time period. Consequently, we are forced to choose storage capacity 4 in the 1:100 scale model. In the 1:10 scale model several alternatives are examined.

The delay function also can be a sensitive component, as discussed in the result section below.

5.1.3 Steady state analysis

There does not appear to be a steady state for this model, since the model simulates only the 4:00 a.m. to 12:00 a.m. time period. However, it is necessary to examine the steadiness of the model when the random number sequence is changed. For this

reason, the model is run repeatedly under different random number sequences by using the clear card between each 8 hour simulation period.

5.2 Results

5.2.1 Traffic volume

Traffic volume in each link of this model is compared to the traffic volume of the actual data, either graphically or statistically, using paired sample t-test. The graphical output is very helpful not only in analyzing and examining statistical data but it also facilitated the development of this model.

In Table 5.2.1.1 the results of the paired sample t-test of the two different scale models are shown. These results are obtained by running each model under different modifications of the interarrival function. In first case, the interarrival functions are not modified and the second case they are modified by an exponential distribution function. Both of the results are obtained from their first run. The storage capacity of the links in the 1:10 scale model is chosen to be 40, since it is to be compared to the 1:100 scale model, which used storage capacity 4.

In both scale models, we can easily see that the t-value is biased to the minus side, which means

an under achievement of passing transactions. In the 1:100 scale model, most of the t-values in the early time period exceed the critical value. However, in the 1:10 scale model all t-values, except 7:00 a.m. in the exponential modification, are within the critical region. The critical t-value in this particular case is t = 2.576 (At alpha = 0.01, n = 63, two-tail test)

In the 1:10 scale model, we can observe the same trend in the t-values under different interarrival function modifications. In the case of exponential modification, the t-value begins in the minus range and changes from minus to plus between 8:00 and 9:00 and again goes back to minus region. In the case of no modification, the t-value begins in the minus range and closes to zero at 9:00 then goes back to minus and finally exceeds zero slightly at 12:00 This trend is shown in Fig 5.2.1 1.

We can see the effect of the modification of interarrival function from this figure, that is, modifying the interarrival function with exponential distribution increases the distribution of the t-value, however it does not change the basic transition pattern of the t-value. At this moment, it is assumed that the transition pattern of the t-value may be based on another factor such as the random number sequence or particular characteristics of this

model itself.

In the 1:100 scale model, modification of the interarrival function also does not have significant effect on the t-value, as can be seen in Fig 5.2.1.2

As far as the accuracy of the traffic volume of this model is concerned, the 1:100 scale model does not produce results which meet the requirements of the statistical test. The deviation of t-value is large, so we conclude that it is better not to continue attempting to change components of this model to improve it. The only way to improve this model would be to change the delay function, because increasing the storage capacity to 5 would be unrealistic given the actual situation as mentioned in chapter 3. On the other hand, the 1:10 scale model produces reasonable results which meet the statistical test, although one of the data points slightly exceeds the critical t-value.

TABLE 5.2.1.1

THE RESULT OF PAIRED SAMPLE T-TEST IN DIFFERENT SCALE AND INTERARRIVAL MODIFICATION

	1:10 SCALE		1:100 SCALE	
TIME	NO-EXPON	EXPON	NO-EXPON	EXPON
5:00	-2.000	-2.907	-2.908	-2.909
6:00	-2.536	-2.513	-2.871	-2.794
7:00	-2.542	-2.698	-2.793	-2.772
8:00	-2.176	-1.327	-3.436	-3.641
9:00	-0.742	1.268	-2.752	-2.961
10:00	-2.369	-1.705	-3.025	-3.156
11:00	-1.205	-1.062	-1.581	-1.353
12:00	0.017	-0.038	1.918	1.649

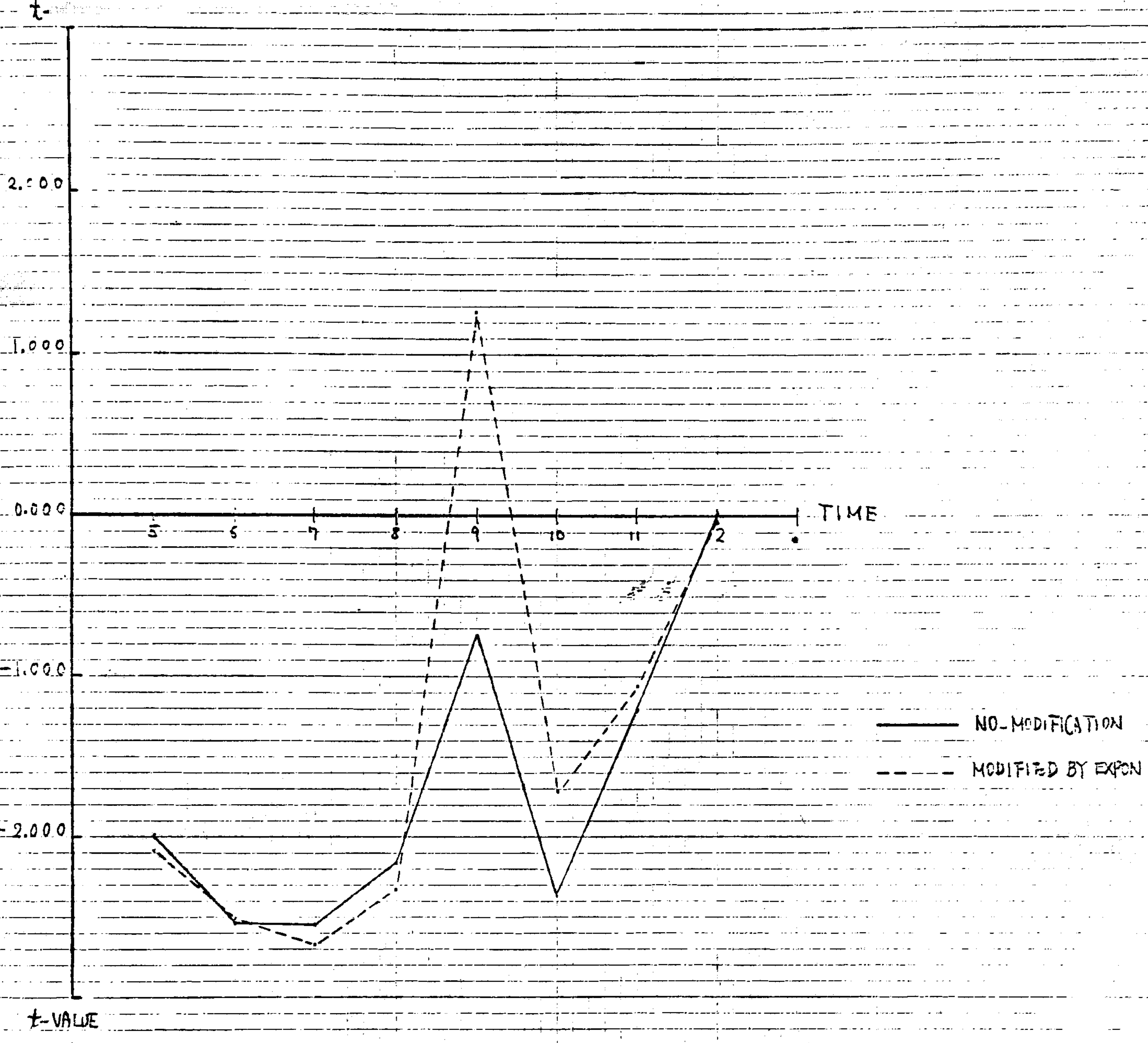


Fig 5.2.1.1 TRANSITION OF t-VALUE IN 1:10 SCALE MODEL

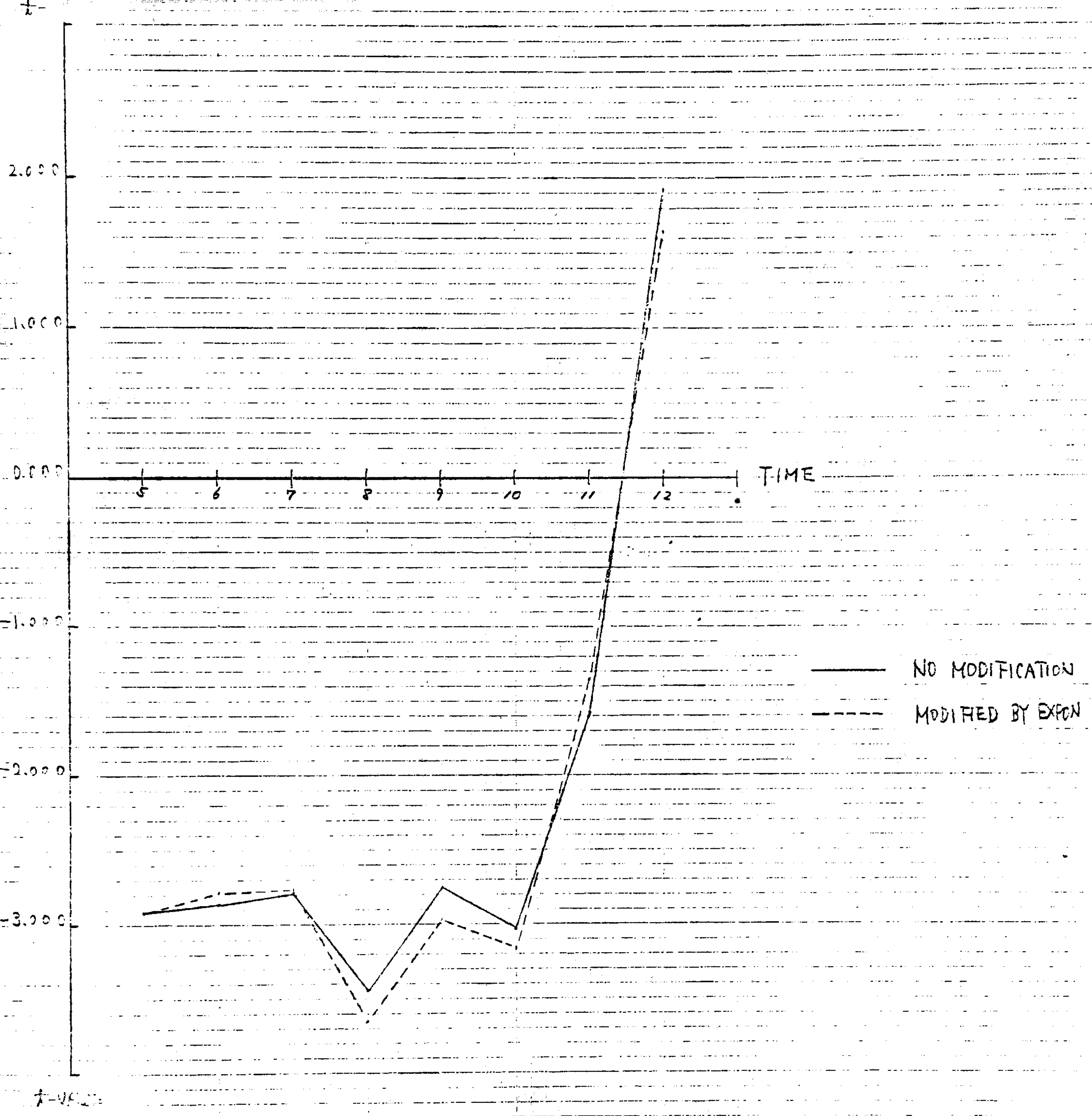


Fig 5.2.1.2 TRANSITION OF t-VALUE IN 1:100 SCALE MODEL

5.2.2 Sensitivity analysis

The sensitivity of this model can be measured by changing the components of the model. The components which directly effect the characteristics of this model are capacity of the storage and the delay function. As mentioned in chapter 3, both of these components are very important to decide the characteristics of the traffic flow, called the Q-K curve. Since the storage capacity decides the number of vehicles within the unit length of the expressway in the model, and this value lies between 250 and 360 from the observation of actual data, we decide to choose an appropriate value from the range for this analysis. Similar to the storage capacity, the delay function decides the passing of a transaction within a unit time period, and this value is decided based on the travel time of unit length of the expressway. Consequently we can not use an unrealistic value; for example, a maximum speed value greater than 120 km/h is unrealistic in the Metropolitan Expressway.

5.2.2.1 Effect of storage capacity

The effect of storage capacity is examined under two different storage capacities, 36 and 40, for each link. The 1:100 scale model is not used for the sensitivity analysis because of its discrete-

ness In the 1:100 scale model, we can only choose storage capacity 3 and 5 as the alternatives, and the forme shows drastic under achievement of passing transactions within a unit time period and the latter is not acceptable given the actual situation.

In Table 5.2.2.1, paired sample statistics of each storage configuration are shown. These data are extracted from their first run under the exponential modification of the interarrival function. From Table 5.2.2 1, we can observe that there is not a significant difference of t-value until 7:00 a m., the time before the heavy traffic jam begins. However, after 9:00 a.m. while the storage capacity 36 configuration continues to keep under achievement of t-value, the storage capacity 40 configuration changes its t-value from minus to plus. This change is also apparent in the graphical output which describes not only the difference but also it describes the characteristics of the change. A part of the sequence of graphical output in this situation is shown in Fig. 5.2.2.1 (storage = 36) and Fig. 5.2.2.2 (storage = 40).

TABLE 5.2.2.1

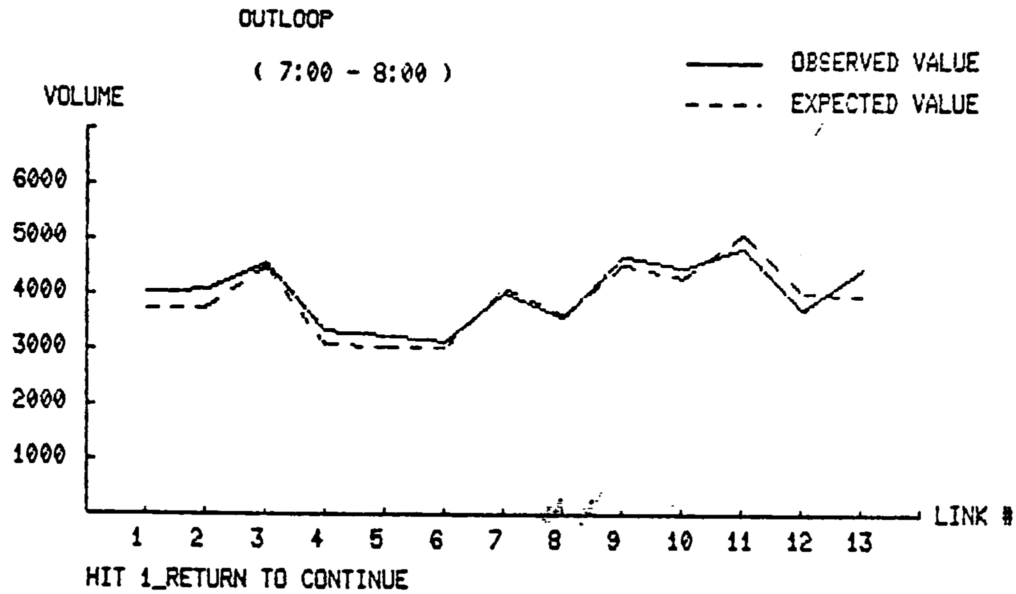
THE RESULT OF PAIRED SAMPLE T-TEST IN DIFFERENT STORAGE CAPACITY OF LINK.

TIME	CAPACITY = 36	CAPACITY = 40
5:00	-2.160	-2.097
6:00	-2.503	-2.513
7:00	-2.714	-2.688
8:00	-3.053	-1.327
9:00	-2.705	1.268

TABLE 5.2.2.2

THE RESULT OF PAIRED SAMPLE T-TEST IN DIFFERENT DELAY FUNCTION

TIME	LOWER LIMIT = 9 KM/H	LOWER LIMIT 12 KM/H
5:00	-2.160	-2.160
6:00	-2.503	-2.503
7:00	-2.714	-2.714
8:00	-3.053	-2.660
9:00	-2.705	0.604


OUTLOOP
(7:00 - 8:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
LINK #
1 2 3 4 5 6 7 8 9 10 11 12 13
HIT 1_RETURN TO CONTINUE

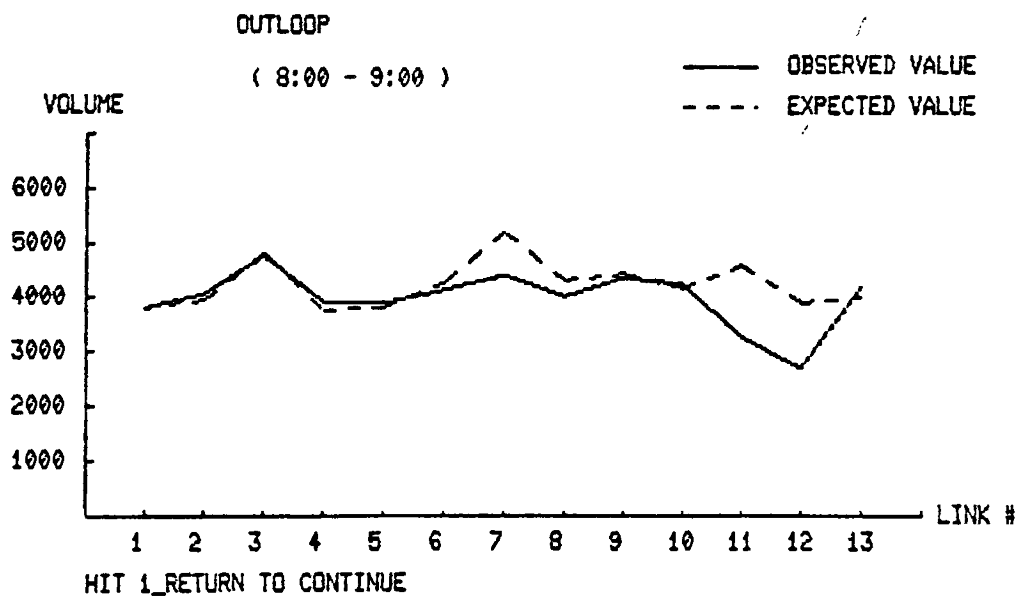
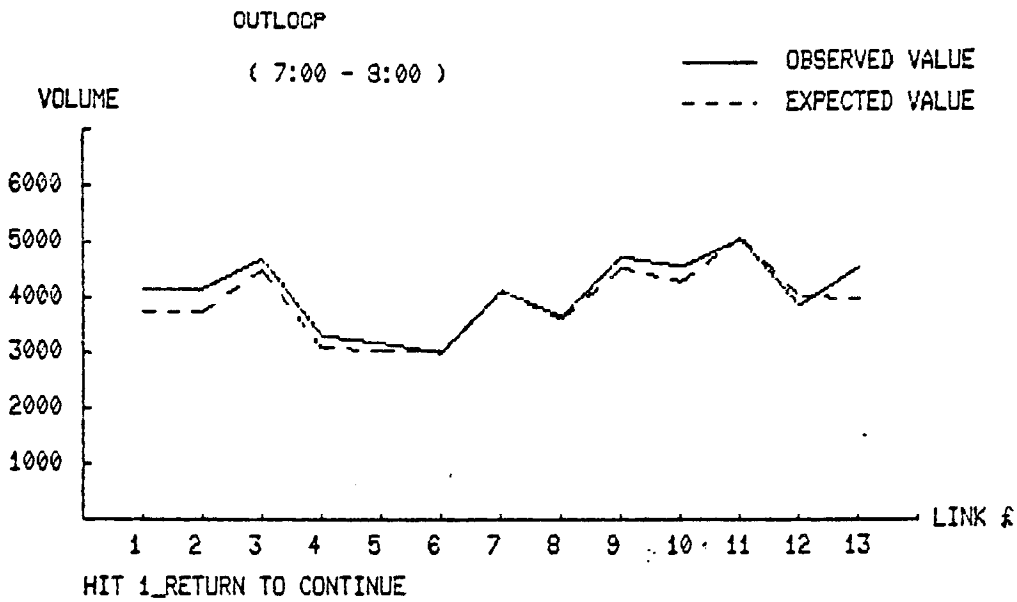

OUTLOOP
(8:00 - 9:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
LINK #
1 2 3 4 5 6 7 8 9 10 11 12 13
HIT 1_RETURN TO CONTINUE

Fig. 5.2.21


OUTLOOP
(7:00 - 8:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
LINK £
1 2 3 4 5 6 7 8 9 10 11 12 13
HIT 1_RETURN TO CONTINUE

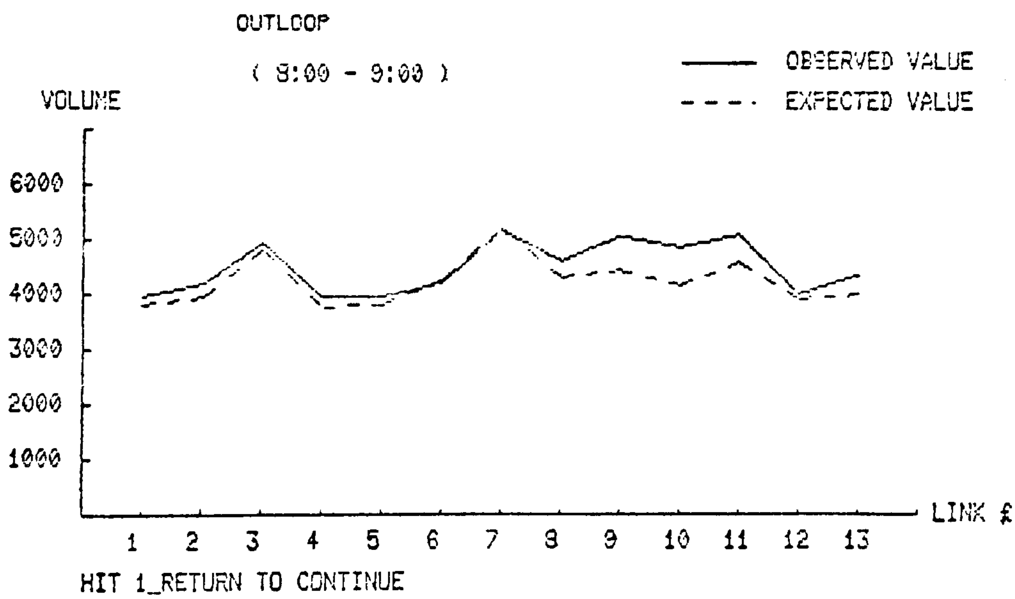
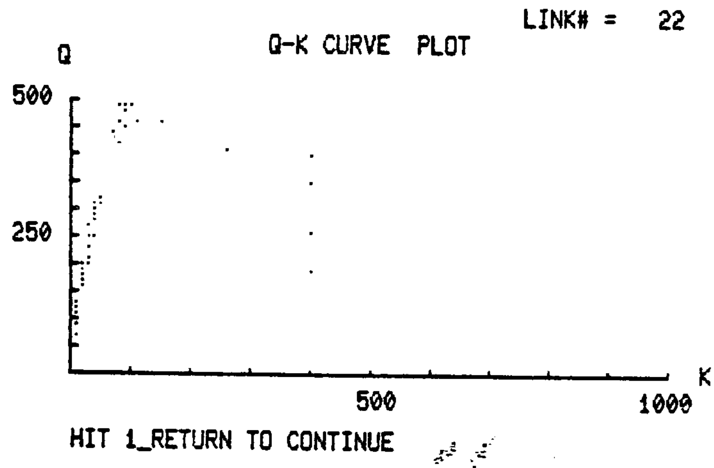

OUTLOOP
(8:00 - 9:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
LINK £
1 2 3 4 5 6 7 8 9 10 11 12 13
HIT 1_RETURN TO CONTINUE

Fig. 5.2.2.2


LINK# = 22
Q-K CURVE PLOT
Q
500
250
K
500
1000
HIT 1_RETURN TO CONTINUE

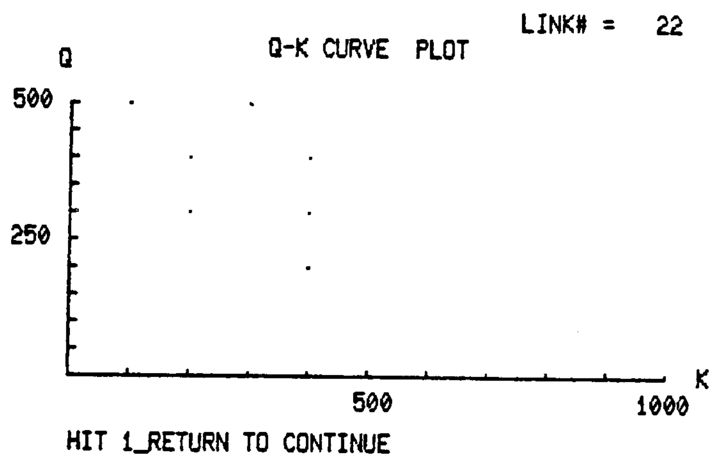

LINK# = 22
Q-K CURVE PLOT
Q
500
250
K
500
1000
HIT 1_RETURN TO CONTINUE

Fig. 5.2.2.3

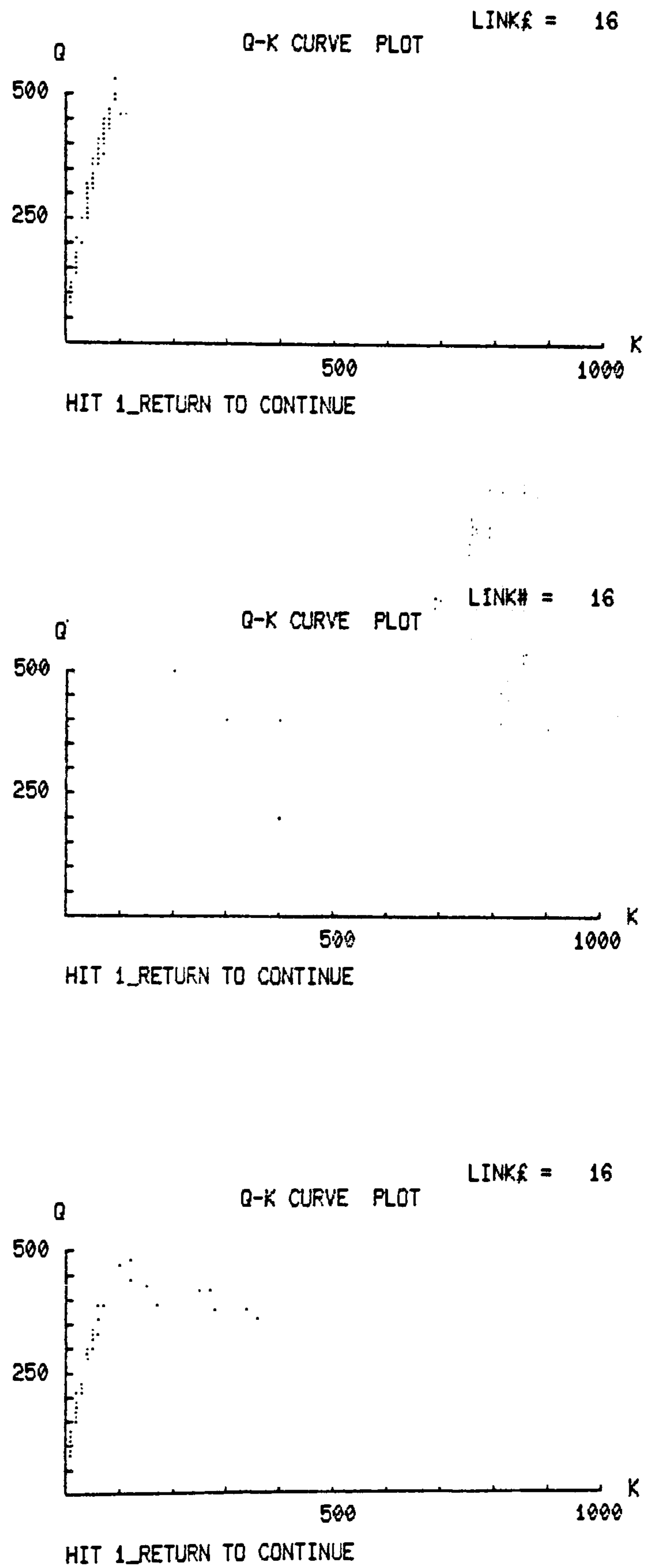

LINK£ = 16
Q-K CURVE PLOT
Q
500
250
K
500
1000
HIT 1_RETURN TO CONTINUE
LINK# = 16
Q-K CURVE PLOT
Q
500
250
K
500
1000
HIT 1_RETURN TO CONTINUE
LINK£ = 16
Q-K CURVE PLOT
Q
500
250
K
500
1000
HIT 1_RETURN TO CONTINUE

Fig. 5.2.2.4

5.2.2.2 Effect of the delay function

In examining the effect of the delay function, we choose two alternative values for the lower limit of each delay function. Lower speed limits of 9 km/h and 12 km/h are chosen for this purpose, and the 1:10 scale model with storage capacity 36 is used with exponential modification of the interarrival function.

From the results shown in Table 5.2.2.2, we can observe that the t-values in both models are almost the same until 7:00 a.m. However, the former continues to keep under achievement of the t-value, while the latter changes its t-value from minus to plus at 9:00. Since we changed the lower limit of the delay function, the effect of this change appears apparently in the jam time period.

From the above two sensitivity analyses, we can conclude that either storage capacity or delay function is very sensitive, especially in jam condition. Therefore, care must be taken when choosing these components in a particular part of the link of this model. Since the capacity of the link is limited by the physical structure of the expressway, choosing the delay function as the variable component is a better strategy for improvement of the model.

5.2.2.3 Q - K curve

As described in the previous chapter, this model produces the Q - K curve of a selected link of the expressway at the end of an 8 hour simulation run. For examining the characteristics of particular link and verifying the traffic flow theory, two links are chosen from the inner loop route in which a large deviation of traffic volume is observed.

The Q - K curve of link 22 produced from the 1:10 scale model and the 1:100 scale model are shown in Fig. 5.2.2.3. In this figure, we can observe similar Q - K curves, as obtained from "Q - K curve tester" output, shown in Fig. 3.2.2 and Fig. 3.2.3. In these Q - K curves, since storage capacity 40 in 1:10 scale model and 4 in 1:100 scale model are used, both Q-value and K-value show slight over achievement; however, the shape of the curve represents the Q - K relationship well.

In Fig 5.2.2.4, the Q - K curves in link 16 are shown. In this case Q - K curve obtained from the different scale models appears different. The curve obtained from the 1:10 scale model shows only a smooth flow portion of traffic, while the curve obtained from 1:100 scale model shows both regions. It is interesting to compare them to another Q - K curve in the same link when storage capacity and delay function changed. The third Q - K curve in

Fig.5.2.2.4 is obtained at storage capacity 36 with a different type of delay function. The third Q - K curve shows the jam region; however, the very low Q-value when K is high does not appear in this figure. This example shows that care must be taken when employing different types of delay functions for the improvement of the model.

5.2.3 Steadiness of the model

In examining the steadiness of the model, we run the model three times using different random number sequences. For this experiment, again two different scale models are employed and are examined under exponential modification of interarrival function. The reason to choose the exponential modification is that it seems to give more distribution to t-value than no modification, as described in a previous example of this chapter.

In Table 5.2.3.1 and Table 5.2.3.2 the results of above experiments are shown From the result of 1:10 scale model in Table 5.2.3.1, we can observe the same trend of transition in t-value under different random number sequences. This trend can be seen more easily if we draw the transition pattern shown in Fig. 5.2.3.1. From this figure, we can observe that the distribution of t-value is decreased as the simulation proceeds The same trend is also

observed in the 1:100 scale model in Fig. 5.2.3.2; however the distribution of t-value is still large.

From these repeated runs of the model under different random number sequences, we can conclude that the t-value, which is assumed to represent the characteristics of the model, does not change significantly even we change the random number sequence. In another words, it is possible to conclude that the model is steady enough under different random number sequences and the characteristics of the results come from the inherent structure of the model.

TABLE 5.2.3.1

THE RESULT OF PAIRED SAMPLE T-TEST OF 1:10 SCALE MODEL UNDER DIFFERENT RANDOM NUMBER SEQUENCE

TIME	1ST RUN	2ND RUN	3RD RUN
5:00	-2.097	-2.484	-2.304
6:00	-2.513	-2.630	-2.324
7:00	-2.688	-2.506	-2.297
8:00	-1.327	-2.305	-0.602
9:00	1.268	0.314	-0.090
10:00	-1.705	0.104	0.101
11:00	-1.062	-1.543	-0.848
12:00	-0.036	-0.153	-0.007

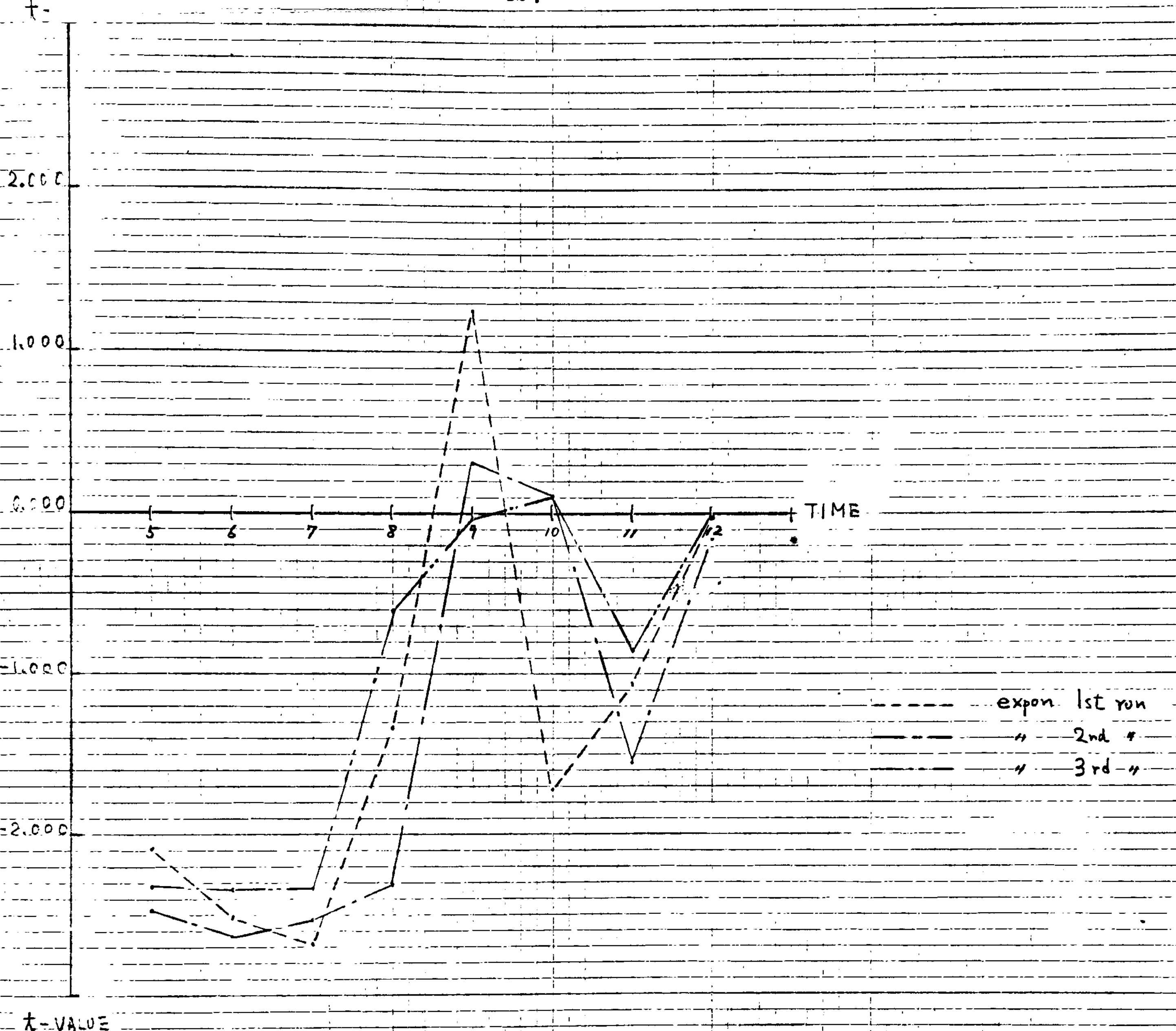


Fig 5.2.3.1 TRANSITION OF t-VALUE IN 1:10 SCALE MODEL

TABLE 5.2.3.2

THE RESULT OF PAIRED SAMPLE T-TEST OF 1:100 SCALE MODEL UNDER DIFFERENT RANDOM NUMBER SEQUENCE

TIME	1ST RUN	2ND RUN	3RD RUN
5:00	-2.908	-3.105	-2.299
6:00	-2.794	-2.290	-2.261
7:00	-2.772	-2.842	-3.041
8:00	-3.641	-3.355	-3.321
9:00	-2.961	-2.429	-2.735
10:00	-3.156	-1.970	-2.718
11:00	-1.353	-1.473	-2.627
12:00	1.649	1.286	1.550

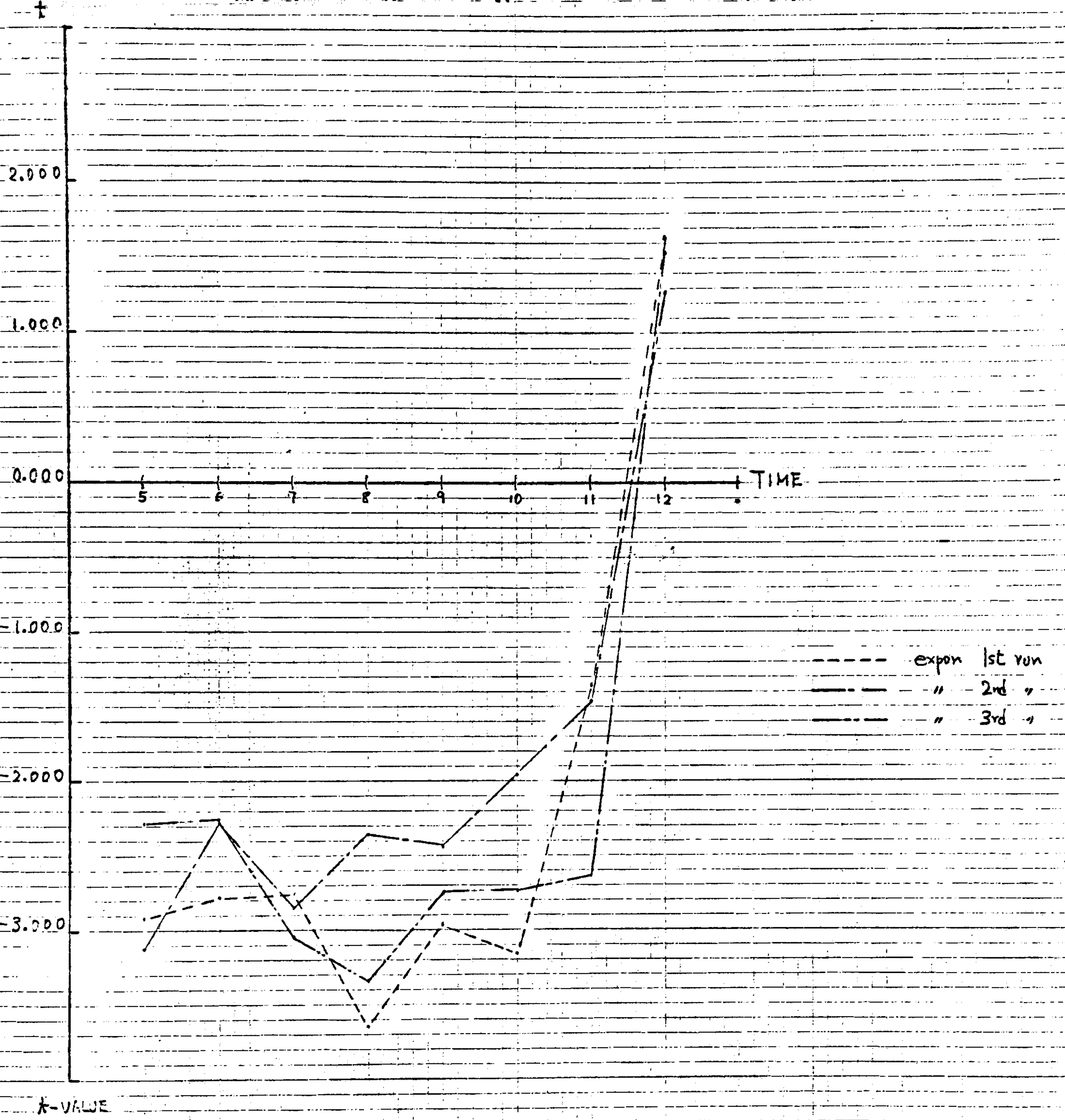


Fig 5.2.3.2 TRANSITION OF t-VALUE IN 1:100 SCALE MODEL

5.3 Case study

In this section, using an optional facility of the model, travel time between a selected entrance and exit is calculated for examining adequacy and steadiness of speed level. As described in chapter 4, this model can produce the speed level of all portions of the expressway every five minutes, however, we do not have the actual data to directly compare the model's results. Therefore, we can only determine the feasibility of the model's results.

Travel time is calculated between entrance 22, which is at the end of ROUTE 3. and exit 75 which is at the end of ROUTE 5. The distance between the two is 29.725 km, which is one of the longest distances in t is model. For this case study, the two different scale models are used and examined under exponential modification of the interarrival function. The results obtained from the 1:10 scale model and the 1:100 scale model are shown in Table 5.3.1.1 and Table 5.3.1.2 respectively.

In examining the adequacy of the travel time result, the average speed at the shortest travel time and at the longest travel time in each model is calculated. The speed range calculated from first run of the 1:10 scale model is:

maximum speed = 89.612 km/h

minimum speed = 10.923 km/h

Similarly the speed range of the 1:100 scale model is:

maximum speed = 92.413 km/h

minimum speed = 5.330 km/h

The storage capacity is 40 in the 1:10 scale model and 4 in the 1:10 scale model, and the delay function in this case represents the upper speed limit of 90 km/h and a lower speed limit of 9 km/h

From the speed range calculated in both models, the results from the 1:10 scale model shows good correspondence the maximum and minimum speed, however. the results from the 1:100 scale model exceeds both the upper and lower limits. The minimum speed calculated from its second run, 6.428 km/h, while is slightly better than that of the first run, also exceeds the limit. From these experiments, the adequacy of speed level in each model is clearly depicted. that is. the result from the 1:10 scale model shows good correspondence to the delay function used while the result from the 1:100 scale model does not.

For testing the steadiness of the travel time produced from each model. paired sample t-test is employed and the difference of the first run and the second run are tested.

The result of each paired sample t-test are shown in the following:

1:10 scale model t = 0.212

1:100 scale model t = 0.096

Since the critical t-value in this case is 1.895 (at alpha = 0.1, n = 7, two tail test), both values satisfy the test, however, care must taken in the 1:100 scale model. First, the 1:100 scale model produces "NO-TRIP" in its third run which means that there are no vehicles going from entrance 22 to exit 75 between 4:00 and 5:00, while the 1:10 scale model produces a travel time of 19.233 minutes. It is assured that this result comes from the discreteness of the 1:100 scale model; no transaction is assigned destination value 75 between 4:00 and 5:00, even though exit 75 is located at the end of ROUTE 5 and the probability of assigning this value as the destination from entrance 22 is rather high. (16.49 % ; refer to APPENDIX 4) Second, in Table 5.3 1.2 at time 10:00, the difference in the travel time between the first run and the second run exceeds 100 minutes, which is an unacceptable fluctuation. Third, the t-value obtained from the paired sample t-test is better than that of the 1:10 scale model However, care must be taken in that the paired sample t-test tends to produce a good t-value when either the

difference between paired data has a positive value or a minus value. Table 5.3.1.2 is a good example of this case. We experienced the same situation in the traffic volume paired sample t-test; however, in this case graphical output display prevents the wrong conclusion.

From these results, we conclude that the 1:10 scale model produces adequate travel time, corresponding to the given delay function, and it also produces steady data under different random number sequences. On the other hand, the 1:100 scale model produces unrealistic travel times and the deviation in travel times using different random number sequences is large.

TABLE 5.3.1.1

TRAVEL TIME (22 - 75) 1:10 SCALE MODEL

TIME	1ST RUN	2ND RUN	3RD RUN
5:00	19.233	19.300	19.233
6:00	31.167	26.533	35.933
7:00	48.933	44.000	37.917
8:00	46.617	46.483	42.717
9:00	68.000	66.617	61.067
10:00	119.700	118.500	119.550
11:00	145.900	170.600	155.800
12:00	159.250	162.150	158.200

TABLE 5.3.1.2

TRAVEL TIME (22 - 75) 1:100 SCALE MODEL

TIME	1ST RUN	2ND RUN	3RD RUN
5:00	18.650	19.400	NO-TRIP
6:00	27.967	58.950	22.350
7:00	35.250	51.850	41.233
8:00	63.183	90.000	86.983
9:00	125.717	80.583	77.367
10:00	161.733	264.600	192.933
11:00	266.967	203.533	653.150
12:00	323.333	268.967	213.267

CHAPTER 6

Analysis and recommendations

6.1 Review and analysis

As far as this simulation model is concerned, neither special tuning for good correspondence to the actual situ tion nor modification of source data is made Th s model is created based simply on traffic flow th ory, employing the delay function as a control f ctor and produces reasonable results corresponding to the given source data. For this reason, thi model represents the inherent characteristics of th algorithm well. Let's begin review and analysis f the results found in the previous chapter.

6.1.1 Stati tic l output analysis

As how in the results in the previous chapter th t affic volume of each model has a tendency for nde achievement, especially in the 1:100 scale mode More precisely, both models have the tendency of un er achievement in the early simulation period. before 9:00 a.m. in the 1:10 scale model and before 11:00 i the 1:100 scale model. The main reason for t is problem is the under achievement of the interarriva function. In the 1:10 scale model,

all statistics of the up-radial route are minus until 8:00 a.m. and hange to plus after 8:00 a.m. In the 1:100 sca e model, there is a same tendency, however the tur ing point is around 9:00 a.m.

Since t e up-radial route is the main source of transactions in this model, under achievement of this route has a direct effect on the traffic volume. However, in the 1:10 scale model this effect is not so serious as in the 1:100 scale model because most of the t-values are within the critical region and the correspondence of the traffic volume to the actual data is good enough, as can be observed from graphical output. On the other hand, in the 1:100 scale model another problem with the interarrival function made the situation worse. Since one transaction represents one hundred vehicles in the 1:100 scale model, interarrival function in the early time period of the simulation has a very large interarrival time. Although the interarrival function changes every one hour, the GPSS processor schedules the transaction whenever the interarrival function is called. Consequently, when the interarrival function with the very large interarrival time is called, the transaction is scheduled and remains in future event chain and it comes out to current event chain much later, even though the original interarrival function has hanged in the meantime This

fact causes over achievement in a later time period of the simulation in the 1:100 scale model. The under achievement of traffic volume in the 1:100 scale model can also be observed from the Q - K curve and the travel time calculation. The Q - K curve in link 16 shows that the 1:100 scale model tends to cause trafic jams more than the 1:10 scale model, using the same combination of storage and delay functions. In the travel time calculation, the 1:100 scale model produces a very low speed which is unrealistic under the given delay function. Both of the above problem are assumed to be caused by the discreteness of the control factor of the delay function in the 1:100 scale model.

6.1.2 Graphical output analysis

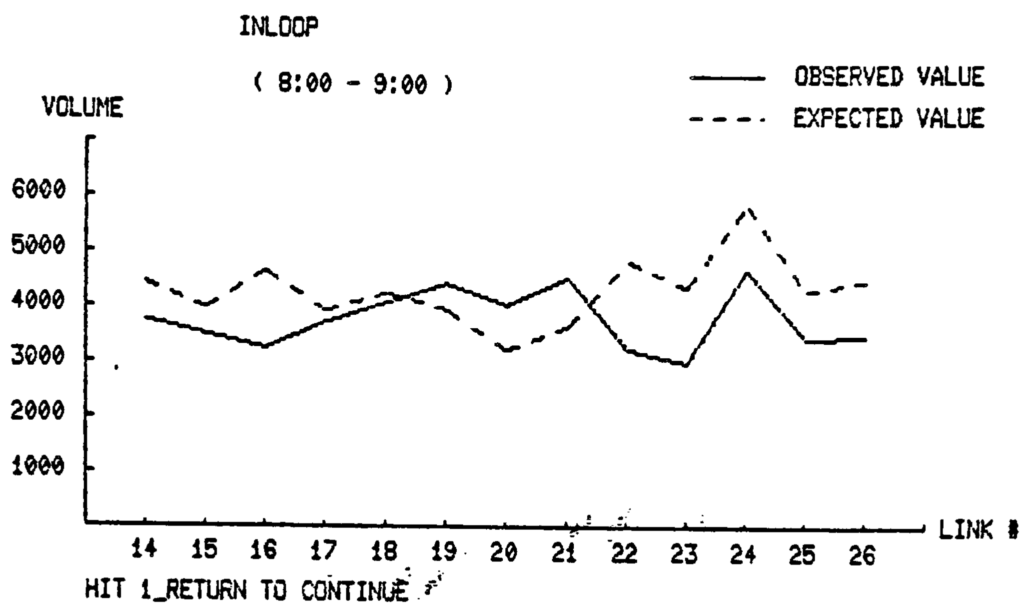
In both scale models, especially in a heavy traffic jam condition, the correspondence of traffic volume between the simulation output and the actual data is lost, as shown in the first figure of Fig. 6.1.1. This type of figure only appears in heavy traffic jam conditions and never appears in the model in which the Q - K curve has the pattern as shown in Fig 3 2.4 in chapter 3. The second curve in Fig. 6.1.1 shows the example in which the Q - K curve has the pattern similar to in Fig. 3.2.4. Both figures in Fig. 6.1.1 are obtained using the same storage

capacity, but different delay functions.

The reason for this type of phenomenon is believed to be caused by the blocking effect of the very high density link. Actually, the same kind of phenomenon is observed in the "Q - K curve tester" under heavy traffic jam conditions. In "Q - K curve tester", as the number of transactions entering to the chained storage increases, first, the contents of the front-end storage increases rapidly while the contents of the consecutive two storages do not increase as much. However, as the simulation proceeds, the situation changes and sometimes the middle storage has the larger contents and sometimes the rear-end storage has the larger contents This phenomenon appears as if traffic jam moving around in the three consecutive storages.

This behavior is not completely resolved in this model. however we can point out several strategies to avoid this effect.. Since this phenomenon appears only under the heavy traffic jam condition, we can avoid it by choosing an appropriate combination of storage capacity and delay function which does not cause heavy traffic jams. However we can not choose storage capacity and delay functions which are unrealistic when compared to actual situation, consequently we have to determine the trade-off. From the results in the previous chapter, the ap-

propriate combination of storage capacity and delay function in the 1:10 scale model assumed that the storage capacity is 36 to 40 and lower limit of delay function which has the significant effect in causing traffic jam is 9 km/h to 12 km/h.


INLOOP
(8:00 - 9:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
14 15 16 17 18 19 20 21 22 23 24 25 26
LINK #
HIT 1_RETURN TO CONTINUE

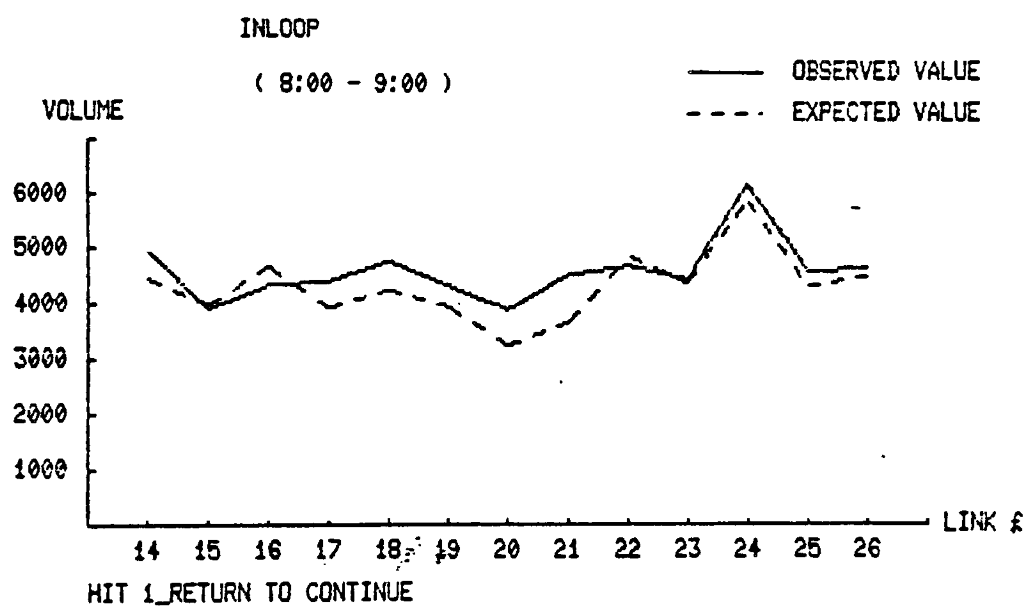

INLOOP
(8:00 - 9:00)
OBSERVED VALUE
EXPECTED VALUE
VOLUME
6000
5000
4000
3000
2000
1000
14 15 16 17 18 19 20 21 22 23 24 25 26
LINK £
HIT 1_RETURN TO CONTINUE

Fig. 6.1.1

6.2 Recommendations

The two different scale models are developed and examined in this project for finding out the strategies for a complete model. Although the difference between the two models is only a scaling factor, the results gotten from each model are quite different

However, the difference is reasonable because it depends on the resolution factor of each model. The 1:100 scale model produces the results which involve under achievement of traffic volume, or unrealistic value for the travel time. It does show steadiness under the different random number sequences. These results prove the correctness or the adequacy of the algorithm used in this model. As the result, when we change the scaling factor from 1:100 to 1:10. the model produces a fair result. Since only one random generator is used as the argument of the destination function in this model when we choose no modification of interarrival function, it is fairly clear that the difference between the two models is simply due to the discreteness in assigning the destination value to each transaction.

As mentioned in chapter 1, the purpose of this project is not creating a complete model but creating a subset and examining the basic nature of the traffic flow model and as a consequence obtaining

the strategy for a complete model. For this reason, no special tuning is made on this model because it is assumed to be harmful at this point. Although there is a problem not completely solved at this point, such as transition of traffic jam under the heavy jam condition, if the following things are applied on this model then the results improve.

6.2.1 Recommended tunings of the model:

1. Use a distinct storage capacity for each link.

   (In this model several abbreviations are made for the simplicity.)

2. Prepare distinct delay function for each link.

   (Similar to above.)

3. Prepare Origin-Destination function every 1 hour.

   (In this model, only two different O - D functions are used to represent the entire 8 hour simulation. Consequently, it might assign inadequate destination during particular time period.)

4. Change the branch ratio at interchange to the ratio which represents every different time period or create an algorithm which detects jam in the model and then decides the branch ratio in light of the

jam.

(In this model only one fixed ratio is used. It is unrealistic for a long time simulation such as 24 hours.)

6.2.2 Scale recommendation

We recommend the 1:10 scale model for practical use based on the following reason:

1. Adequate resolution for practical use

In practical use, it is necessary to represent not only the traffic volume of the link but it is also necessary to depict the traffic volume of each entrance and exit. These typical traffic volumes in entrances or exits are in units of one hundred. Consequently, the resolution limit of 10 vehicles in the 1:10 scale model is sufficient for this requirement.

2. Reasonable run time.

The actual run time of the 1:10 scale model for an 8 hour simulation run is 25 11 minutes, which is short enough both for on-line information service and research purposes

3. Data consistency

While the 1:100 scale model tends to produce a large deviation in the data, the 1:10 scale model produces data which satisfies the statistical tests.

4. Steadiness

The algorithm used in this model is quite steady under different random number sequences.

6.3 Future enhancements

The one problem which was not analyzed in this model is the transition of the traffic jam. In the speed level display of all links, which is produced every five minutes, we can see this traffic jam transition as the transition of speed level as shown in Fig. 6.3.1. The traffic jam transition in this model tends to occur between 8:00 and 9:00 when traffic volume increases rapidly. The low speed level, which is displayed yellow or red, appears frequently on the loop route during this time period

Since we do not have traffic speed level data for each link during a short time period for direct comparison to the output of this model, this problem is left for the future. For solving this problem, it is assumed that the analysis must be done using actual data in an on-line basis.

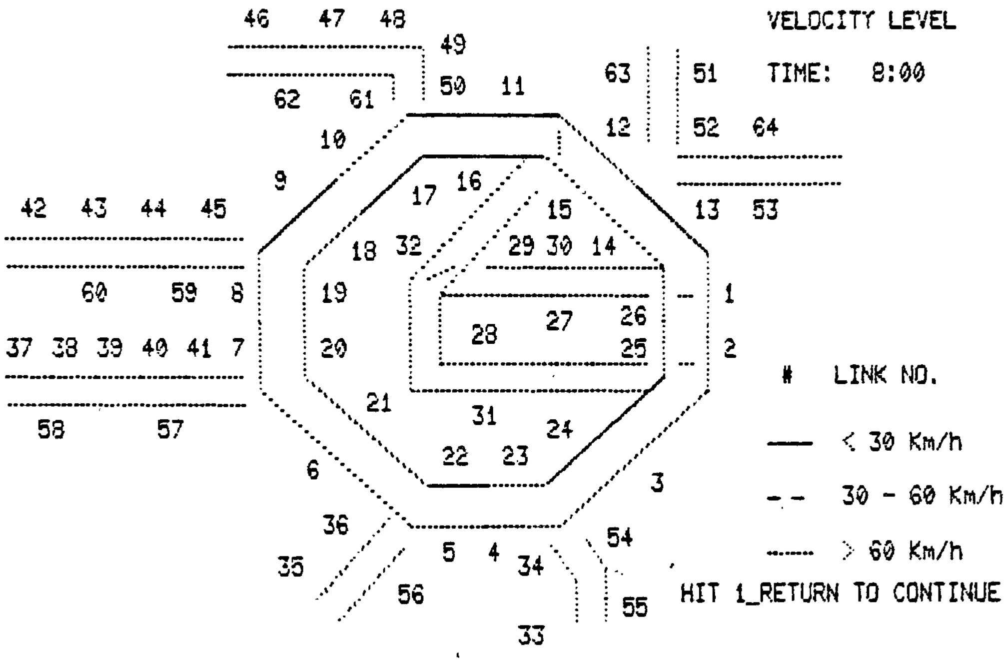

46 47 48
49
50 11
63
51
VELOCITY LEVEL
TIME: 8:00
62 61
10
12
52 64
9
17 16
15
13 53
42 43 44 45
18 32
29 30 14
60 59 8
19
1
28 27 26
25
37 38 39 40 41 7
20
2
LINK NO.
21
31
24
58 57
22 23
— < 30 Km/h
6
3
- - 30 - 60 Km/h
36
54
······ > 60 Km/h
35
5 4 34
56
55
HIT 1_RETURN TO CONTINUE
33

Fig. 6.3.1

APPENDIX 1

TRAFFIC VOLUME IN EACH ENTRANCE PER HOUR

ENTRANCES

TIME	OGINON	SODMON	OSIBON	OKSMON	OKANON
4 - 5	76	59	22	77	30
5 - 6	94	69	39	66	38
6 - 7	176	67	105	147	69
7 - 8	300	156	172	249	153
8 - 9	504	393	287	355	258
9 -10	701	392	478	546	273
10-11	846	642	589	775	584
11-12	611	495	250	748	586

ENTRANCES

TIME	IGINON	ISIBON	IIKRON	IKSMON	KITMON
4 - 5	124	32	22	46	22
5 - 6	148	56	17	34	30
6 - 7	138	79	47	138	95
7 - 8	194	110	68	208	229
8 - 9	376	152	137	295	382
9 -10	422	274	144	430	694
10-11	327	300	197	698	253
11-12	274	228	180	738	4

TRAFFIC VOLUME IN EACH ENTRANCE PER HOUR

ENTRANCES

TIME	IKANON	TAKRON	NGINON	DPSION	USIBON
4 - 5	60	18	4	19	43
5 - 6	87	20	5	44	88
6 - 7	189	59	28	82	165
7 - 8	358	89	42	123	241
8 - 9	490	150	79	264	430
9 -10	849	336	170	515	465
10-11	18	382	282	440	502
11-12	520	283	258	318	38

ENTRANCES

TIME	HEIWAR	TENGON	SIROGR	TAKGON	SBYAON
4 - 5	555	26	160	37	31
5 - 6	1163	47	409	39	54
6 - 7	2255	126	795	95	119
7 - 8	3339	224	2079	186	241
8 - 9	3213	336	3035	274	473
9 -10	3284	390	2598	143	453
10-11	2813	362	2015	239	218
11-12	2555	292	1653	204	170

TRAFFIC VOLUME IN EACH ENTRANCE PER HOUR

ENTRANCES

TIME	SNCHCN	YOUGAR	UGENCN	SINJON	HATGON
4 - 5	54	959	34	63	27
5 - 6	80	1509	40	118	60
6 - 7	174	2294	96	284	168
7 - 8	573	3215	98	543	311
8 - 9	1014	3133	72	616	150
9 -10	554	2264	111	625	178
10-11	372	2187	74	434	118
11-12	260	2105	81	379	73

ENTRANCES

TIME	EIFUKR	NKANON	GOKKCN	IKEBON	SIMRAR
4 - 5	329	33	55	73	602
5 - 6	698	45	150	145	1312
6 - 7	1920	94	310	500	2496
7 - 8	3863	131	484	757	2546
8 - 9	2490	158	815	581	2155
9 -10	2287	233	928	332	1868
10-11	1890	221	749	7	1699
11-12	1552	9	685	271	1205

TRAFFIC VOLUME IN EACH ENTRANCE PER HOUR

	ENTRANCES			
TIME	RT679	ENCEON	LENOCN	KUENCE
4 - 5	1172	17	23	235
5 - 6	2252	30	39	479
6 - 7	4320	53	96	915
7 - 8	5285	116	372	975
8 - 9	4782	171	488	1020
9 -10	4036	321	521	1021
10-11	3331	344	418	968
11-12	2623	264	237	836

APPENDIX 2

TRAFFIC VOLUME IN EACH EXIT PER HOUR

EXIT

TIME	TAKRCF	CGINOF	HGINOF	SMPSCF	OSIPCF
4 - 5	16	294	9	19	7
5 - 6	57	364	25	28	11
6 - 7	109	259	27	141	102
7 - 8	399	290	93	207	199
8 - 9	367	294	134	101	240
9 -10	219	347	132	201	130
10-11	201	211	76	193	117
11-12	84	231	67	153	141

EXIT

TIME	TIKRCF	OKSMOF	DIKNOF	OKANOF	SODMOF
4 - 5	0	0	10	39	210
5 - 6	42	57	9	126	384
6 - 7	19	201	58	215	263
7 - 8	198	744	237	1042	383
8 - 9	245	1261	286	1264	503
9 -10	217	966	193	724	397
10-11	189	556	117	491	250
11-12	122	317	93	421	299

TRAFFIC VOLUME IN EACH EXIT PER HOUR

			EXIT		
TIME	IGINOF	SKYBOF	IKANOF	IKSMOF	ISIBOF
4 - 5	85	1	41	46	6
5 - 6	141	11	20	71	41
6 - 7	187	70	70	280	149
7 - 8	423	321	301	965	584
8 - 9	559	570	439	1077	640
9 -10	442	410	212	832	467
10-11	296	286	162	357	238
11-12	301	277	146	232	240

APPENDIX 3

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

	LINK				
TIME	# 1	# 2	# 3	# 4	# 5
4 - 5	921	716	830	459	474
5 - 6	1815	1558	1809	909	937
6 - 7	3023	2934	3363	2019	2022
7 - 8	3721	3748	4492	3069	3042
8 - 9	3798	3906	4795	3733	3780
9 -10	4447	4521	5383	4075	4423
10-11	4048	4206	5674	4149	4621
11-12	3541	3517	4649	3233	3342

	LINK				
TIME	# 6	# 7	# 8	# 9	# 10
4 - 5	371	758	835	1069	1059
5 - 6	743	1213	1222	1555	1546
6 - 7	1879	2301	2247	3066	3028
7 - 8	3001	4103	3608	4535	4298
8 - 9	4246	5188	4282	4422	4136
9 -10	4549	4640	4220	4102	3909
10-11	4526	4050	4269	3586	3469
11-12	3193	3051	3482	3079	2985

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

LINK

TIME	# 11	# 12	# 13	# 14	# 15
4 - 5	1091	1035	953	1018	916
5 - 6	2176	1945	1867	1749	1707
6 - 7	3938	3386	3111	2904	3138
7 - 8	5095	4036	3972	3934	3949
8 - 9	4558	3895	3962	4419	3969
9 -10	4145	3606	4446	4666	3290
10-11	3692	3443	3873	4162	2750
11-12	3009	2949	3339	3556	2019

LINK

TIME	# 16	# 17	# 18	# 19	# 20
4 - 5	1032	951	964	742	751
5 - 6	1905	1655	1685	1422	1385
6 - 7	3705	3654	3692	3243	3158
7 - 8	4565	4278	4456	4580	3874
8 - 9	4646	3924	4247	3940	3217
9 -10	4628	3902	4534	3815	3475
10-11	3262	2453	2683	2312	2576
11-12	2742	2158	2158	1975	2495

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

LINK

TIME	# 21	# 22	# 23	# 24	# 25
4 - 5	753	843	869	1227	961
5 - 6	1258	1522	1537	2191	1692
6 - 7	2388	2591	2527	3593	2838
7 - 8	3757	4376	3902	5214	3910
8 - 9	3629	4848	4360	5869	4315
9 -10	3016	4120	3927	5353	3923
10-11	2795	3459	3521	4501	3331
11-12	2587	3299	3287	4007	3042

LINK

TIME	# 26	# 27	# 28	# 29	# 30
4 - 5	1027	10	68	54	1
5 - 6	1731	14	210	198	36
6 - 7	2975	66	503	419	116
7 - 8	3938	141	795	683	472
8 - 9	4476	132	714	571	569
9 -10	4153	147	671	407	821
10-11	3527	226	1019	560	677
11-12	3174	135	790	397	628

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

LINK

TIME	# 31	# 32	# 33	# 34	# 35
4 - 5	68	67	555	570	160
5 - 6	169	131	1163	1242	408
6 - 7	574	449	2255	2355	795
7 - 8	1044	564	3339	3427	2079
8 - 9	1314	633	3213	3506	3035
9 -10	1543	714	3284	3569	2598
10-11	1360	666	2813	3163	2015
11-12	984	351	2555	2416	1653

LINK

TIME	# 36	# 37	# 38	# 39	# 40
4 - 5	186	959	1013	1044	1021
5 - 6	455	1509	1599	1643	1594
6 - 7	921	2294	2404	2523	2427
7 - 8	2303	3215	3665	3906	3649
8 - 9	3371	3133	3940	4413	4094
9 -10	2999	2264	2659	3112	2842
10-11	2377	2187	2434	2653	2428
11-12	1935	2125	2189	2359	2145

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

LINK

TIME	# 41	# 42	# 43	# 44	# 45
4 - 5	1038	328	340	403	448
5 - 6	1633	698	745	863	900
6 - 7	2522	1920	1906	2190	2200
7 - 8	3835	3863	3565	4108	3613
8 - 9	4358	2480	2291	2907	2452
9 -10	2995	2287	2091	2716	2369
10-11	2667	1890	1569	2003	1685
11-12	2349	1552	1198	1567	1379

LINK

TIME	# 46	# 47	# 48	# 49	# 50
4 - 5	602	675	735	712	745
5 - 6	1312	1457	1622	1614	1659
6 - 7	2496	2996	3387	3300	3394
7 - 8	2546	3303	3947	3509	3730
8 - 9	2155	2736	3563	3274	3432
9 -10	1868	2200	3115	2937	3170
10-11	1699	1706	2520	2336	2557
11-12	1205	1476	2246	2147	2156

TRAFFIC VOLUME IN EACH INTERVAL CF EXPRESSWAY PER HOUR

LINK

TIME	# 51	# 52	# 53	# 54	# 55
4 - 5	235	258	1172	590	509
5 - 6	478	517	2252	1489	1352
6 - 7	915	1011	4320	2633	2324
7 - 8	975	1347	5285	3534	3091
8 - 9	1020	1462	4782	3260	2627
9 -10	1021	1526	4096	3450	3175
10-11	968	1352	3331	3708	3464
11-12	836	989	2623	3112	3014

LINK

TIME	# 56	# 57	# 58	# 59	# 60
4 - 5	199	671	671	336	354
5 - 6	343	1307	1288	832	840
6 - 7	839	2916	2933	1937	1789
7 - 8	1527	2919	2670	2562	2448
8 - 9	1441	3141	2952	2519	2473
9 -10	1541	3497	3333	3206	3151
10-11	1609	3231	3214	2739	2771
11-12	1260	2559	2543	1965	2075

TRAFFIC VOLUME IN EACH INTERVAL OF EXPRESSWAY PER HOUR

LINK

TIME	# 61	# 62	# 63	# 64
4 - 5	905	907	353	1255
5 - 6	1289	1267	572	2249
6 - 7	2622	2488	757	4458
7 - 8	3263	2949	1308	4658
8 - 9	3513	3247	1432	4434
9 -10	3798	3566	1669	4335
10-11	3370	3285	1330	4297
11-12	3020	3052	1136	3731

APPENDIX 4

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m - 8:00 a.m.)

FROM ROUTE 1_SOUTH

TO	TRAFFIC VOLUME	%
ROUTE 2	67	1.96
ROUTE 3	101	2.95
ROUTE 4	379	11.07
ROUTE 5	634	18.52
ROUTE 6,7,9	889	25.97
ROUTE 1_NORTH	518	15.13
LOOP ROUTE	835	24.40
TOTAL	3423	100.00

FROM ROUTE 2

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	82	3.56
ROUTE 3	108	4.69
ROUTE 4	161	6.99
ROUTE 5	418	18.15
ROUTE 6,7,9	524	22.76
ROUTE 1_NORTH	294	12.77
LOOP ROUTE	716	31.09
TOTAL	2303	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM ROUTE 3

TO	TRAFFIC VOLUME	%
ROUTE 1 SOUTH	253	6.60
ROUTE 2	75	1.96
ROUTE 4	64	1.67
ROUTE 5	632	16.49
ROUTE 6,7,9	970	25.29
ROUTE 1 NORTH	335	8.73
LOOP ROUTE	1506	39.26
TOTAL	3835	100.00

FROM ROUTE 4

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	587	16.24
ROUTE 2	110	3.04
ROUTE 3	69	1.90
ROUTE 5	210	5.82
ROUTE 6,7,9	1067	29.53
ROUTE 1_NORTH	79	2.20
LOOP ROUTE	1491	41.27
TOTAL	3613	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m - 9:00 a.m.)

FROM ROUTE 5

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	869	23.30
ROUTE 2	341	9.14
ROUTE 3	560	15.01
ROUTE 4	180	4.83
ROUTE 6,7,9	912	24.45
ROUTE 1_NORTH	16	0.43
LOOP ROUTE	852	22.84
TOTAL	3730	100.00

FROM ROUTE 6,7,9

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	814	15.40
ROUTE 2	482	9.12
ROUTE 3	1114	21.08
ROUTE 4	1064	20.13
ROUTE 5	984	18.62
ROUTE 1_NORTH	3	0.06
LOOP ROUTE	824	15.59
TOTAL	5285	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM ROUTE 1 NORTH

TO	TRAFFIC VOLUME	%
ROUTE 1 SOUTH	599	40.94
ROUTE 2	221	15.11
ROUTE 3	376	25.71
ROUTE 4	112	7.66
ROUTE 5	0	0.00
ROUTE 6,7,9	13	0.88
LOOP ROUTE	142	9.70
TOTAL	1463	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (OGINON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	85	28.33
ROUTE 2	71	23.67
ROUTE 3	90	30.00
ROUTE 4	49	16.33
ROUTE 5	5	1.67
ROUTE 6,7,9	0	0.00
ROUTE 1_NORTH	0	0.00
TOTAL	300	100.00

FROM LOOP ROUTE (SODMON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	45	28.84
ROUTE 2	25	16.03
ROUTE 3	27	17.31
ROUTE 4	46	29.49
ROUTE 5	13	8.33
ROUTE 6,7,9	0	0.00
ROUTE 1_NORTH	0	0.00
TOTAL	156	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (NGINON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	17	40.48
ROUTE 2	4	9.52
ROUTE 3	4	9.52
ROUTE 4	8	19.05
ROUTE 5	4	9.52
ROUTE 6.7.9	5	11.91
ROUTE 1_NORTH	0	0.00
TOTAL	42	100.00

FROM LOOP ROUTE (OSIEON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	0	0.00
ROUTE 2	11	6.40
ROUTE 3	69	40.12
ROUTE 4	58	33.72
ROUTE 5	30	17.44
ROUTE 6.7,9	4	2.32
ROUTE 1 NORTH	0	0.00
TOTAL	172	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (OKSMON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	0	0.00
ROUTE 2	0	0.00
ROUTE 3	6	2.46
ROUTE 4	138	56.56
ROUTE 5	67	27.46
ROUTE 6,7,9	33	13.52
ROUTE 1_NORTH	0	0.00
TOTAL	244	100.00

FROM LOOP ROUTE (OKANON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	43	28.11
ROUTE 2	19	12.42
ROUTE 3	14	9.15
ROUTE 4	0	0.00
ROUTE 5	12	7.84
ROUTE 6,7,9	65	42.48
ROUTE 1_NORTH	0	0.00
TOTAL	153	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (DESION)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	0	0.00
ROUTE 2	0	0.00
ROUTE 3	8	6.50
ROUTE 4	8	6.50
ROUTE 5	45	36.60
ROUTE 6,7,9	28	22.76
ROUTE 1_NORTH	34	27.64
TOTAL	123	100.00

FROM LOOP ROUTE (IGINON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	17	8.99
ROUTE 2	0	0.00
ROUTE 3	0	0.00
ROUTE 4	23	12.17
ROUTE 5	80	42.33
ROUTE 6,7,9	53	28.04
ROUTE 1_NORTH	16	8.47
TOTAL	189	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (TAKRON)

TO	TRAFFIC VOLUME	%
ROUTE 1 SOUTH	4	4.49
ROUTE 2	0	0.00
ROUTE 3	9	10.11
ROUTE 4	38	42.70
ROUTE 5	5	5.62
ROUTE 6.7,9	33	37.08
ROUTE 1 NORTH	0	0.00
TOTAL	89	100.00

FROM LOOP ROUTE (IKANON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	10	2.80
ROUTE 2	21	5.87
ROUTE 3	99	27.65
ROUTE 4	160	44.69
ROUTE 5	59	16.48
ROUTE 6,7,9	9	2.51
ROUTE 1 NORTH	0	0.00
TOTAL	358	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (KITMON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	14	6.11
ROUTE 2	42	18.34
ROUTE 3	108	47.16
ROUTE 4	65	28.39
ROUTE 5	0	0.00
ROUTE 6.7,9	0	0.00
ROUTE 1 NORTH	0	0.00
TOTAL	229	100.00

FROM LOOP ROUTE (IKSMON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	22	10.58
ROUTE 2	25	12.02
ROUTE 3	156	75.00
ROUTE 4	5	2.40
ROUTE 5	0	0.00
ROUTE 6.7,9	0	0.00
ROUTE 1_NORTH	0	0.00
TOTAL	208	100.00

RELATION OF ORIGIN AND DESTINATION OF TRAFFIC

(7:00 a.m. - 8:00 a.m.)

FROM LOOP ROUTE (IIKRON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	32	47.06
ROUTE 2	13	19.12
ROUTE 3	0	0.00
ROUTE 4	4	5.88
ROUTE 5	0	0.00
ROUTE 6.7.9	19	27.94
ROUTE 1_NORTH	0	0.00
TOTAL	68	100.00

FROM LOOP ROUTE (ISIRON)

TO	TRAFFIC VOLUME	%
ROUTE 1_SOUTH	41	37.27
ROUTE 2	0	0.00
ROUTE 3	0	0.00
ROUTE 4	0	0.00
ROUTE 5	22	20.00
ROUTE 6.7.9	34	30.91
ROUTE 1 NORTH	13	11.82
TOTAL	110	100.00

APPENDIX 5

BRANCH RATIO AT INTERCHANGE TO LOOP ROUTE

(%)

DESTINATION

INTERCHANGE	RT1	RT2	RT3	RT4	RT5	RT6,7,9
HMIC	-	97.6	97.7	96.5	83.5*	97.8
IHIC	98.7	-	94.3	96.1	93.6	94.3
TNIC	97.5	89.1	-	97.7	97.7	57.6*
MYIC	97.4	96.6	93.8	-	97.3	96.0
TKIC	80.4*	89.3	94.7	93.2		98.4
EDIC	97.4	94.1	65.7*	95.2	99.4	-

Note: * These detour ratio are considered in GPSS model.

APPENDIX 6

BRANCH RATIO AT INTERCHANGE IN LOOP ROUTE

(%)

	DESTINATION	
INTERCHANGE	LOOP_ROUTE	K.K._ROUTE
OYSPIC	86.0	14.0
CKYBIC	96.6	3.4
ISIBIC	87.4	12.6
ISBBIC	50.0	50.0

Note: These ratios are used in GPSS model.

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