Title

BTS (version 1.0): Bottleneck Traffic Simulator User's Manual

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BTS (Version 1.0) - Bottleneck Traffic Simulator

User's Manual

by

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CHAPTER 1

INTRODUCTION

BTS -- Bottleneck Traffic Simulator -- is a macroscopic tool for simulating the performance of freeway bottlenecks. BTS can be used to measure the travel time benefits of changes in roadway design through: (1) addition of capacity, (2) increase in travel speed, or (3) improvement in roadway reliability. The unique features of BTS include:

- Allows non-standard roadway characteristics, which might be created through highway automation.
- Evaluates lane stoppages or other incidents through random simulation.
- Determines both recurrent and non-recurrent traffic delay.
- Measures impact of growth in traffic level.
- Accounts for changes in traveler behavior, including changes in departure time and changes in route.
- Interfaces with Lotus l-2-3 to provide graphs of cumulative arrivals and departure and to demonstrate queueing over time.

BTS operates on an IBM PC or compatibles with two .EXE files, three .COM files, and one .DAT file. A fully operative BTS, including output files, requires about 250K of work disk space.

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*To obtain a copy of BTS, contact Randolph Hall at the Department of Industrial Engineering & Operations Research, University of California at Berkeley, 94720.

CHAPTER 2

THEORY BEHIND BTS

BTS was developed to illustrate how a freeway bottleneck behaves over time as traffic levels and freeway performance change. By focusing on a single bottleneck, rather than an entire freeway corridor or network, BTS provides more details about roadway performance than previously possible. In particular, through randomly simulating the occurence, duration and magnitude of freeway incidents, BTS calculates average recurrent delay and average non-recurrent delay. This information is especially valuable in evaluating the merits of incident management strategies.

To run BTS, the user must first specify an initial demand pattern, as well as highway characteristics. BTS uses this input to evaluate travel time performance by time slice. If desired, BTS can iteratively adjust the demand pattern in response to the travel time data. These adjustments can include a demand increment to account for a general increase in traffic from year to year, as well as changes in route and arrival time at the bottleneck. BTS can run up to 10 iterations, representing 10 years. Travel time performance is automatically stored after each iteration for later analysis.

The following two sections explain the key phases of BTS: the performance evaluation step and the demand assignment step.

A. Performance Evaluation

Each iteration of BTS simulates traffic conditions over a period of up to 200 days (Each day will be called a run. See Table 1.1). For each day, the time, duration and magnitude of freeway

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Time Slice:	A time increment of five minutes during which arrival rates and capacities are assumed to stay constant.
Run:	A single day comprising up to 45 consecutive time slices (3 3/4 hours).
Iteration:	A set of runs during which arrival time and route assignments, as well as traffic volumes, do not change. An iteration might represent one year.

Table 1.1. Definitions

---

incidents are randomly simulated according to user specified probability distributions. The purpose of the simulation is to represent actual bottleneck capacity within each time slice on a given day, taking into account the incidents that occur on that day.

A user specified probability determines the likelihood that an incident occurs in any time slice. If an incident occurs, the duration and magnitude are simulated, and the bottleneck capacity is decremented as appropriate. However, if one incident occurs soon after another, the incident with the largest magnitude defines the capacity, until it is cleared up. To illustrate these concepts, consider the following example, pertaining to a 3-lane freeway with nominal capacity of 6000 vehicles/hour:

Time Slice	Incident	Duration (slices)	Capacity Loss	Current Capacity (veh/hr)
1	**No**	--	--	6000
2	**No**	--	--	6000
3	**Yes**	3	33%	4000
4	**No**	--	--	4000
5	**Yes**	4	20%	4000
6	**No**	--	--	4800
7	**Yes**	1	50%	3000
8	**No**	--	--	4800
9	**No**	--	--	6000
10	**No**	--	--	6000

As the example demonstrates, the current capacity is defined by the outstanding incident with the biggest capacity loss. In time slice 5, the first incident has the biggest loss, and the capacity is 4000/hour. However, the first incident is cleared at the end of slice 5, so the capacity in time slice 6 is 4800, as defined by the second incident.

The queue size at the end of a time slice is calculated in the following manner. Let:

A_i = number of arrivals in slice i
C_i = capacity in slice i (vehicles / hour)
Q_i = queue size at the end of slice i
n = number of time slices per hour
N = number of time slices in simulation.

Then:

$$Q_i = \max\{(A_i - C_i/n) + Q_{i-1},\ 0\}$$

The first part of the equation applies when the bottleneck operates at capacity and queues exist, while the second applies when the bottleneck operates below capacity.

On any day of the simulation, the total time spent waiting in queue, measured in hours, is found from a summation of the queue sizes:

$$\text{Total Time in Queue} = W = \sum_{i=1}^{N} Q_i \ (1/n)$$

The average system delay is found by averaging W over all of the days simulated. Because the simulation includes incidents, the average system delay is the sum of the average recurrent delay and the average non-recurrent delay. To calculate average recurrent delay, BTS simulates one additional day in which no incidents occur. The output from BTS provides both this value and the average system delay on a per vehicle basis. The difference between the values is the non-recurrent delay. In addition, BTS provides the average free-flow travel time, which can vary when travelers shift between routes having different travel times.

BTS has the capacity to analyze up to three parallel routes. Two of these routes are accessible to all travelers, while the third is designated as automated. The automated route is only accessible to a (user specified) portion of travelers that owns necessary equipment. BTS provides system delay, recurrent delay and free-flow travel time for each of the three routes. If desired, the third route might alternatively represent an HOV lane, accessible to a user specified portion of travelers.

As input to the traffic assignment phase, system travel time per vehicle is also calculated by time slice, as a function of arrival time at the bottleneck. System travel time per vehicle is found by dividing the queue size by the actual capacity for the given day and adding the free-flow time. BTS averages these waiting times among the days simulated to determine an average system waiting time by time slice. BTS also determines waiting time for a user specified percentile of the waiting time distribution.

A final feature is that BTS allows the user to specify a roadway capacity upstream from the bottleneck. For BTS to operate properly, this capacity must be larger than the nominal bottleneck capacity. In the output, BTS shows the recurrent delay upstream. This represents the minimum possible delay on the highway should the bottleneck be removed, without making ancillary improvements upstream.

B. Traffic Assignment

At the end of each iteration of BTS, waiting time data is used to revise the assignment of vehicles to arrival times and to routes. BTS allows for three types of traveler behavior:

- **Fixed arrival time** These travelers always arrive at the same time, independent of queueing. However, they will shift between routes to select the fastest available, counting both queue time and free flow time.

- **Fixed departure time** These travelers would like to depart from the bottleneck at a time that insures they will arrive at their destination at a fixed time with high probability. Travelers choose the route which allows them to leave home as late as possible, and still arrive at their destination on time with high probability.

- cost **minimizers** These travelers have a desired time to depart from the bottleneck, but are willing to depart either earlier or later if their personal cost is reduced. Travelers choose the route that offers the minimum average cost, which is the sum of an early cost, a late cost, a travel time cost, and a roadway toll (if applicable).

Based on the above criteria, as well as waiting time and free flow travel time data, BTS determines the optimal route and arrival time for each type of traveler. Travelers are automatically reassigned to their optimal *arrival time.* However, only a user specified proportion of travelers is allowed to shift between routes at any iteration. Reassignment only takes place at the end of an iteration.

B.l. Arrival Time Assignment

As an illustration of the arrival time assignment, suppose that the following travel time data is available for a route. The travel time will represent the sum of the queue time and free-flow travel time.

Time Slice	Elapsed Time End of Slice	Mean Travel Time End of Slice	90% Travel Time End of Slice
1	5 min.	2 min.	3 min.
2	10 min.	3 min.	5 min.
3	15 min.	5 min.	10 min.
4	20 min.	8 min.	17 min.
5	25 min.	10 min.	21 min.

Because Type 1 travelers have fixed arrival times, only the arrival times for Type 2 and 3 travelers are influenced by the data. In order to arrive at work on time, suppose that a Type 2 traveler must depart from the bottleneck by the end of slice 5 with 90% probability. Then the traveler must arrive at the bottleneck by the end of slice 3.

Now suppose that a Type 3 traveler desires to depart at the end of slice 5, and that its earliness cost is $5/hour, its queueing cost is $lO/hour, and its lateness cost is $20/hour and that the road has no toll. Then the optimal arrival time is found by comparing alternatives:

Arrival Time	Earliness cost	Lateness cost	Travel cost	Total cost	
5 min.	(18/60)•5	0	(2/60)•10	$1.83	
10 min.	(12/60)•5	0	(3/60)•10	$1.50	
15 min.	(5/60)•5	0	(5/60)•10	$1.25	***
20 min.	0	(3/60)•2	(8/60)•10	$2.33	
25 min.	0	(10/60)•20	(10/60)•10	$5.00	

For the example, an arrival time of 15 min, the end of slice 3, is preferred.

BTS assumes that only a portion of the travelers would own the required equipment to access the automated route. So each of the three classes is divided into two categories, designated automation equipped (AE) and not equipped (NE). The latter group chooses the optimal route among those that are accessible.

B.2. Route Assignment

To illustrate how vehicles are assigned to routes, suppose that 50% of vehicles fall in the class AE, and that 20% of vehicles are allowed to change routes at any iteration. Now, suppose that the following costs are available for Type 3 travelers:

Desired Time Slice	cost Rte 1	cost Rte 2	cost Rte 3 (auto)	Current Assignment Rte 1	Current Assignment Rte 2	Current Assignment Rte 3 (auto)
9	7	6	5	140 NE	60 NE	0 NE
				160 AE	0 AE	40 AE

For AE vehicles, Route 3 is optimal and for NE vehicles, Route 2 is optimal. Therefore, in the next iteration vehicles will be assigned as follows for the time slice:

Route 1:Not automated: 140 -.20(140) = 112 (20% shift to route 2)
Automated: 160 -.20(160) = 128 (20% shift to route 3)

Route 2:Not automated: 60 +.20(140) = 88 (20% come from route 1)
Automated: 0

Route 3:Not automated: 0
Automated: 40 +.20(160) = 72 (20% come from route 1)

The assignment to routes for Type 1 and 2 travelers is done in a similar fashion.

Running BTS over several iterations reveals how traveler behavior evolves over time. However, BTS does not guarantee that route and arrival time choices converge toward an equilibrium. Rather, BTS is designed to mimic different types of behavior, which may or may not converge.

After an iteration is completed, the number of arrivals within each class, for each time slice, is incremented by a user specified proportion representing annual growth in highway traffic. However, if desired, the number of arrivals can be held constant from iteration to iteration.

The user specifies how demand should be allocated to the different traveler types. If desired, all travelers can be allocated to the first type, in which case the distribution of arrivals among the time slices remains constant from iteration to iteration. Within each type, different travelers have different desired arrival or departure times, as specified by the user.

CHAPTER 3

CREATING THE INPUT DATA

The input data for BTS can be divided into five categories, route characteristics, system breakdown, driver choice behavior, traffic volume distribution, and the simulation control data. The data from the first four categories can be modified through the selection "Edit Input Data File" in the main menu of BTS. The last category can be modified before simulation by choosing the selection "Run Simulation Program." Initially, the user is provided with a set of data shown in Fig. 3.1 - 3.4. With the selection "Edit Input Data File," the user can change any data if so desired. The same basic procedure is used for making all changes. **When finished with a screen, enter 0 and all changes will be saved.**

For example, after entering the main menu of BTS, to change the capacity for Route 1 from 3600 to 4700 veh/hr, the user needs to go through the following steps:

1) Enter **1** to choose the selection "Edit Input Data File."
2) Enter 1 to choose the selection "Route Characteristics." (The panel in Fig. 3.1 will appear on the screen.)
3) Enter 5 to choose the option for changing the capacity for Route 1. The screen will prompt:

```
Data range must be from 0.00 to 99999.00
Change from 3600.00 to -->
```

4) Enter **4700**.

When the Route Characteristics screen reappears, the capacity for Route 1 is replaced by 4700. The user can change any other data shown in Fig. 3.1 to 3.4 using these steps.

* D R I V E R   C H O I C E   B E H A V I O R *

1) Arrival multiplier for each iteration: 1.05
Type 3 cost ($/hr): 2) Late: 24.00 3) Early: 6.00 4) Queue:12.00

Initial routing:

	Route	Type	Proportion
5)	1	1	0.45
6)	1	2	0.00
7)	1	3	0.00
8)	2	1	0.30
9)	2	2	0.00
10)	2	3	0.00
11)	3	1	0.25
12)	3	2	0.00
13)	3	3	0.00

Proportion of travelers that would change route:
14) Rte 1: 0.20 15) Rte 2: 0.20 16) Rte 3: 0.20
17) Pct queue for Type 2 travelers: 95 18) Prop. with automation:0.25

0= save and exit to Edit Input Data File menu
Enter a number for change (0 - 18) and press [ENTER] -->

Fig. 3.3: Selection 3: Driver Choice Behavior

* T R A F F I C   V O L U M E   D I S T R I B U T I O N *

1 time slice = 5 minute interval

Time Slice	Volumes	Time Slice	Volumes	Time Slice	Volumes
1	200.00	16	550.00	31	300.00
2	200.00	17	550.00	32	300.00
3	200.00	18	550.00	33	300.00
4	200.00	19	550.00	34	300.00
5	300.00	20	550.00	35	300.00
6	300.00	21	400.00	36	300.00
7	300.00	22	400.00	37	250.00
8	400.00	23	400.00	38	250.00
9	400.00	24	400.00	39	250.00
10	400.00	25	400.00	40	250.00
11	400.00	26	300.00	41	250.00
12	400.00	27	300.00	42	250.00
13	550.00	28	300.00		
14	550.00	29	300.00		
15	550.00	30	300.00		

0= save and exit to Edit Input Data File menu
Enter a number and press [ENTER] to change a single slice (0 - 42)
or enter 'a' for change all entries and/or number of slices -->

Fig. 3.4: Selection 4: Traffic Volume Distribution

```
*ROUTE  CHARACTERISTICS*

1) Probability that no incident occurs: 0.99

                                             Rte 1     Rte 2     Rte 3
Free flow travel time (minutes):        2) 17.50   3) 12.50  4) 7.50
Bottleneck capacity (veh/hour):         5)  3600   6)  2800  7) 2000

Upstream capacity (veh/hour):           8)  8800

Toll (dollars) :            Route     Type     Value
                       9)     1         1       0.00
                      10)     1         2       0.00
                      11)     1         3       2.00
                      12)     2         1       0.00
                      13)     2         2       0.00
                      14)     2         3       2.00
                      15)     3         1       0.00
                      16)     3         2       0.00
                      17)     3         3       2.00

 0= save and exit to Edit Input Data File menu
 Enter a number for change (0 - 17) and press [ENTER] -->
```

Fig. 3.1: Selection 1: Route Characteristics

```
*SYSTEM  BREAKDOWN  *

  Duration of breakdown (uniform distribution) :

  1) Lower bound:   1.00
  2) Upper bound:  12.00

  Capacity loss distribution
                        Level of
                      capacity loss      Probability
                  3)      10%               0.45
                  4)      20%               0.35
                  5)      30%               0.05
                  6)      40%               0.05
                  7)      50%               0.05
                  8)      60%               0.05
                  9)      70%               0 00
                 10)      80%               0 00
                 11)      90%               0 00
                 12)     100%               0 00
 0= save and exit to Edit Input Data File menu
 Enter a number for change (0 - 12) and press [ENTER] -->
```

Fig. 3.2: Selection 2: System Breakdown

In addition, the user is allowed to change the period length, and hence change the entire arrival volume distribution, in a single step. Suppose the user intends to change period length from the current 42 time slices to 12 time slices and redefine the distribution of the traffic volume as follows:

Time Slice	Volume
1	300
2	300
3	300
4	300
5	400
6	400
7	400
8	500
9	600
10	700
11	700
12	700

To do so, the following steps should be followed after entering the menu "Traffic Volume Distribution," shown in Fig. 3.4:

1) Enter a, the screen will prompt:

```
Data range must be from 10 to 45
Enter total time period -->
```

---

2) Enter 12, the screen will prompt:

```
Enter traffic volume at time slice 1 OR press [ENTER]
for default value (default = 100.00) -->
```

---

3) Enter **300**. Repeat Step 3 until done. If the default value shows the volume as wanted, press [ENTER], otherwise, enter a value.

After time slice 1, in which the default value is 100, the default value always duplicates the value in the previous time slice. For consecutive identical arrival volumes, the user needs to enter the value only once and simply press [ENTER] to duplicate thereafter. After the change, the screen in Fig. 3.4 will become:

```
* T R A F F I C   V O L U M E   D I S T R I B U T I O N *

 1 time slice = 5 minute interval

Time Slice   Volumes   Time Slice Volumes   Time Slice   Volumes
      1       300.00
      2       300.00
      3       300.00
      4       300.00
      5       400.00
      6       400.00
      7       400.00
      8       500.00
      9       600.00
     10       700.00
     11       700.00
     12       700.00

0= save and exit to Edit Input Data File menu
Enter a number and press [ENTER] to change a single slice (0 - 12)
or enter 'a' for change all entries and/or number of slices -->
```

The following is a full description of the data in each category, including the ranges, dimensions, units, and the representations:

A. Route Characteristics

- Probability that no incidents occur
  Range: 0.00 . . 1.00 Dimension: scalar Unit: none

  Probability that *no* new incident occurs in any time slice.

- Free flow travel time
  Range: 0.00 . . 99999.00 Dimension: 1..3 Unit: minute(s)

  Time required to travel through route i with ***no wait in queue.***

- Bottleneck capacity
  Range: 0.00 . . 99999.00 Dimension: 1..3 Unit: vehicles/hour

  Nominal capacity by route in the absence of incidents.

- Upstream capacity
  Range: 0.00..99999.00 Dimension: scalar Unit: vehicles/hour

Total upstream capacity among all routes. Program assumes no incidents occur upstream. The upstream capacity must exceed the combined capacity of the bottleneck routes.

- ❑ Toll cost
  Range: 0.00..99999.00 Dimension:1..3,1..3 Unit: dollar(s)

  This toll is route specific, but does not vary over time. It is used in the cost equation for Type 3 travelers (cost minimizers). Therefore, it primarily affects route choices for Type 3 travelers. (Toll can also be specific to traveler type, but the current version of BTS does not use tolls in selecting routes for Type 1 and Type 2 travelers.)

B. System Breakdown

- ❑ Duration of breakdown
  Range: 1.00..12.00 Dimension: scalar Unit:time slice

  Two parameters provide lower and upper bounds of a uniform probability distribution used to simulate incident duration.

- ❑ Capacity loss distribution
  Range: 0.00 . . 1.00 Dimension: scalar Unit: none

  The level of the capacity loss is expressed as a proportion, in 10% increments. *The sum of the proportion must equal one.*

C. Driver Choice Behavior

- ❑ Arrival multiplier per iteration
  Range: 0.00 . . 4.00 Dimension: scalar Unit: none

  The multiplier by which traffic is incremented after each iteration. The value is applied identically to each traveler type and each route at the end of each iteration, *after accounting for all shifts in arrival time and route.* For example, suppose that 400 Type 2 travelers are assigned to time slice 5 and Route 2, and that the multiplier is set to 1.1. Then the multiplier will increase the number of travelers to 440 at the start of the next iteration.

- ❑ Type 3 traveler costs
  Range: 0.00 ..99999.00 Dimension: scalar Unit:dollar(s)/hour

  Three parameters account for personal cost with respect to earliness, lateness, and queueing time per unit time, for Type 3 travelers (cost minimizers).

- Initial routing
  Range: 0.00 . . 1.00 Dimension: 1..3,1..3 Unit: none

  Nine parameters determine the initial proportional assignment of travelers to route, and type. Let

  $R_{i,j}$ = proportion of travelers that are type i and choose route j;

  $R_{i,j}$ is multiplied by the total traffic volume, specified earlier, to obtain the travelers by type and route. As an example, suppose that 400 travelers are assigned to time slice 6. with $R_{1,1} = 0.2$, $R_{1,2} = 0.2$, and $R_{2,3} = 0.6$, 160 are Type 1 travelers and 240 are Type 2 travelers. All Type 2 travelers initially choose Route 3, whereas half of the Type 1 travelers choose Route 1 and the other half choose Route 2. *The sum of the proportions must equal one.*

  As the simulation progresses, travelers are allowed to change route. However, traveler type stays the same in all iterations.

- Proportion of the vehicles that would change route
  Range: 0.00 . . 1.00 Dimension: 1..3 Unit: none

  For each route, a parameter specifies the proportion of travelers that will shift to an alternative route after an iteration, if a lower cost route is available. The same proportion is used for all traveler types.

- Percentile queue for Type 2 travelers
  Range: 0.00 . . 1.00 Dimension: scalar Unit: none

  The percentile of the waiting time distribution used by Type 2 travelers in selecting arrival time and route (The probability that Type 2 travelers depart on time). The parameter is also used to format output.

- Proportion of vehicles equipped with automation
  Range: 0.00 . . 1.00 Dimension: scalar Unit: none

  The proportion of the vehicles initially assigned to Route 1 and 2 that own the required equipment to access Route 3, the automated route. 100% of the vehicles initially assigned to Route 3 are automated.

D. Traffic Volume Distribution

- Number of travelers in slice i
  Range: 0.00 ..99999.00 Dimension: 1..45 Unit: vehicles

  Initial assignment of travelers to time slices. The volume is the sum among all vehicle types and routes, and does not distinguish between a desired arrival time and a desired departure time. Let A_i = volume in time slice i. Then if A_6 is set to 500, a total of 500 travelers desire to depart or arrive from the bottleneck at time slice 6. *Each time slice represents a five minute interval.*

E. Simulation Control Data

The following data can only be changed after selecting "Run Simulation Program."

❑ Number of runs per iteration
Range: 1..200 Dimension: scalar Unit: none

Specifies the number of runs in each iteration. Each run is equivalent to a single day of up to 45 5-minute time slices, or a maximum period of 3 hours and 45 minutes.

0 Number of iterations
Range: 1..10 Dimension: scalar Unit: none

Specifies the number of iterations per simulation. Each iteration represents a block of time (e.g., a year) over which route and arrival time choices do not change.

In addition, free flow travel time, capacities, Type 3 cost, arrival multiplier for each iteration, and percentile queue for Type 2 vehicles can be changed after selecting "Run Simulation Program."

CHAPTER 4

AN EXAMPLE RUN

Before running BTS, the files, BTS.EXE, QM.EXE, INPUT.COM, VIEW.COM, EDIT.COM, and BTS.DAT, **must** be on the run-time disk. The steps to run the simulator using the data displayed in Fig. 3.1 - 3.4 in Chapter 3 are shown as follows:

1) Type command BTS and press [ENTER]. The following menu displays:

```
B O T T L E N E C K   T R A F F I C   S I M U L A T O R
==========================================================

                1. Edit Input Data File
                2. Run Simulation Program
                3. Display Output File
                0. Exit to Dos

     Enter your choice (0 - 3) and press [ENTER]   -->
```

2) Select choice two. You will see the following panel:

```
EDIT  DATA  BEFORE  SIMULATION ...

 1) Probability that no incident occurs: 0.99

                                    Rte 1      Rte 2      Rte 3
Free flow travel time (minutes):  2) 17.50   3) 12.50   4) 7.50
Bottleneck capacity (veh/hour) :  5) 3600    6) 2800    7) 2000

8) Upstream capacity (veh/hour):   8800
9) Arrival multiplier for each iteration:        1.05

Type 3 cost (dollars / hour) :
10) Late:  24.00       11) Early: 6.00      12) Queue: 12.00

13) Percentile queue for Type 2 travelers:      95

14) Number of iterations:    10
15) Number of runs in each iteration:    50

0= save and start simulation.
Enter a number for change (0 - 15) and press [ENTER] -->
```

3) At this time, you can change any data shown in the panel if so desired. When done, enter 0. All of the modified data will be saved and the simulation will start. The screen will display:

Iteration 1

wait . . .

---

4) When the simulation is done, the following panel is shown on the screen, which provides a summary of the statistics collected at the end of each iteration.

-- Summary Statistics --

Iteration	Total Arrival (vehicles)	Free Flow Travel Time Per Veh (minutes)	System Recurrent Per Veh (min)	Queue Time (per Veh) Total Average (min)	Queue Time (per Veh) Total 95% (min)	Upstream Recurrent Per Veh (min)
1	14900	13.500	0.000	0.066	0.000	0.000
2	15645	12.862	0.000	0.061	0.232	0.000
3	16427	12.352	0.558	0.822	1.808	0.000
4	17249	11.984	2.066	2.217	2.865	0.000
5	18111	11.852	3.174	3.835	7.131	0.000
6	19017	12.076	2.431	3.420	8.784	0.000
7	19967	12.198	2.844	3.670	7.560	0.034
8	20966	12.207	5.406	6.492	11.857	0.396
9	22014	12.381	5.350	6.300	11.739	0.922
10	23115	12.487	7.064	8.043	11.810	1.672

Press [ENTER] to exit -->

This data summarizes the bottleneck performance among all three routes.

5) Press [ENTER] to bring the main menu on the screen. The output files, Report.out and Lotus.prn are now created. These files provide detailed simulation output that can be used for further analysis. The user can either display the output files on the screen or print them out by selecting "Display Output File" in the main menu.

The output file Report.prn contains all of the input data as well as the summary statistics shown previously. A more detailed output is provided in the file Lotus.prn. It contains the recurrent delay, nonrecurrent delay, and a user-specified percentile delay by time slice and by route, a cumulative traffic volume by time slice and by route, an upstream delay by time slice, and a total arrival volume by time slice. This file can also be examined in Lotus 1-2-3, as discussed in the following chapter.

CHAPTER 5

EVALUATION OF BOTTLENECK PERFORMANCE WITH LOTUS 1-2-3

After the simulation is complete, system performance can be evaluated in greater detail using Lotus 1-2-3. This can be done in the following steps.

1) Return to DOS and enter your LOTUS l-2-3 program.

2) Select the /File/Retrieve option, and select Lotshell.wk1 from the drive that contains your BTS program.

3) Move the cursor to the cell that states "Import Lotus.prn here."

4) Select the /File/Import/Numbers option, and select Lotus.prn from the drive that contains your BTS program.

You will now have access to graphs and data that provide arrivals and queueing time by route, time slice and iteration. Each column is formatted as follows:

Column A:	Time Slice	
Column B:	Cumulative Arrivals	(Route 1)
Column C:	Percentile Wait per Vehicle	
Column D:	Average Wait per Vehicle	
Column E:	Recurrent Wait per Vehicle	
Column F:	Cumulative Arrivals	(Route 2)
Column G:	Percentile Wait per Vehicle	
Column H:	Average Wait per Vehicle	
Column I:	Recurrent Wait per Vehicle	
Column J:	Cumulative Arrivals	(Route 3)
Column K:	Percentile Wait per Vehicle	
Column L:	Average Wait per Vehicle	
Column M:	Recurrent Wait per Vehicle	
Column N:	Recurrent Wait per Vehicle	(Upstream)
Column 0:	Cumulative Arrivals	(Sum of Rte. 1,2,3)
Column P:	Percentile Wait per Vehicle	
Column Q:	Average Wait per Vehicle	
Column R:	Recurrent Wait per Vehicle	

The data can be analyzed through any of the regular Lotus l-2-3 features, or through the following predefined graphs. To display a graph, enter the commands:

/Graph/Name/Use

followed by the graph name. To print a graph, first save it by entering the commands /Graph/Save, followed by a graph name. The graph can later be printed from the Printgraph option of Lotus 1-2-3.

The following are the preset graphs, contained in the Lotshell.wk1 file:

Name	Function
CUMRT1	Cumulative arrival curve, Route 1, iterations 2,4,6,8,10
CUMRT2	Cumulative arrival curve, Route 2, iterations 2,4,6,8,10
CUMRT3	Cumulative arrival curve, Route 3, iterations 2,4,6,8,10
CUMTOT	Cumulative arrival curve, total all routes,iter.2,4,6,8,10
AWTRT1	Average system wait, Route 1, iterations 2,4,6,8,10
AWTRT2	Average system wait, Route 2, iterations 2,4,6,8,10
AWTRT3	Average system wait, Route 3, iterations 2,4,6,8,10
AWTTOT	Average system wait, total, iterations 2,4,6,8,10
PWTRT1	Percentile system wait, Route 1, iterations 2,4,6,8,10
PWTRT2	Percentile system wait, Route 2, iterations 2,4,6,8,10
PWTRT3	Percentile system wait, Route 3, iterations 2,4,6,8,10
PWTTOT	Percentile system wait, total, iterations 2,4,6,8,10
RWTRT1	Recurrent system wait, Route 1, iterations 2,4,6,8,10
RWTRT2	Recurrent system wait, Route 2, iterations 2,4,6,8,10
RWTRT3	Recurrent system wait, Route 3, iterations 2,4,6,8,10
RWTTOT	Recurrent system wait, total, iterations 2,4,6,8,10
RWTUPS	Recurrent system wait, upstream, iterations 2,4,6,8,10

Figures 5.1 - 5.5 show five preset graphs: CUMTOT, AWTTOT, RWTTOT, PWTTOT, and RWTUPS, for the example simulation. Notice that the graphs show how the queues evolve over time, both from iteration to iteration and time slice to time slice. By comparing AWTTOT to RWTTOT the extent to which incidents affect delay can also be assessed. For instance, note that incidents have a much larger impact at the end of the rush hour than at the start.

In addition to the preset graphs, users may choose to create individualized graphs. These can be saved in the Lotshell.wk1 file for reuse on different data sets. However, to reduce memory required for future simulations, do not save your simulation output under the file name Lotshell.wk1.

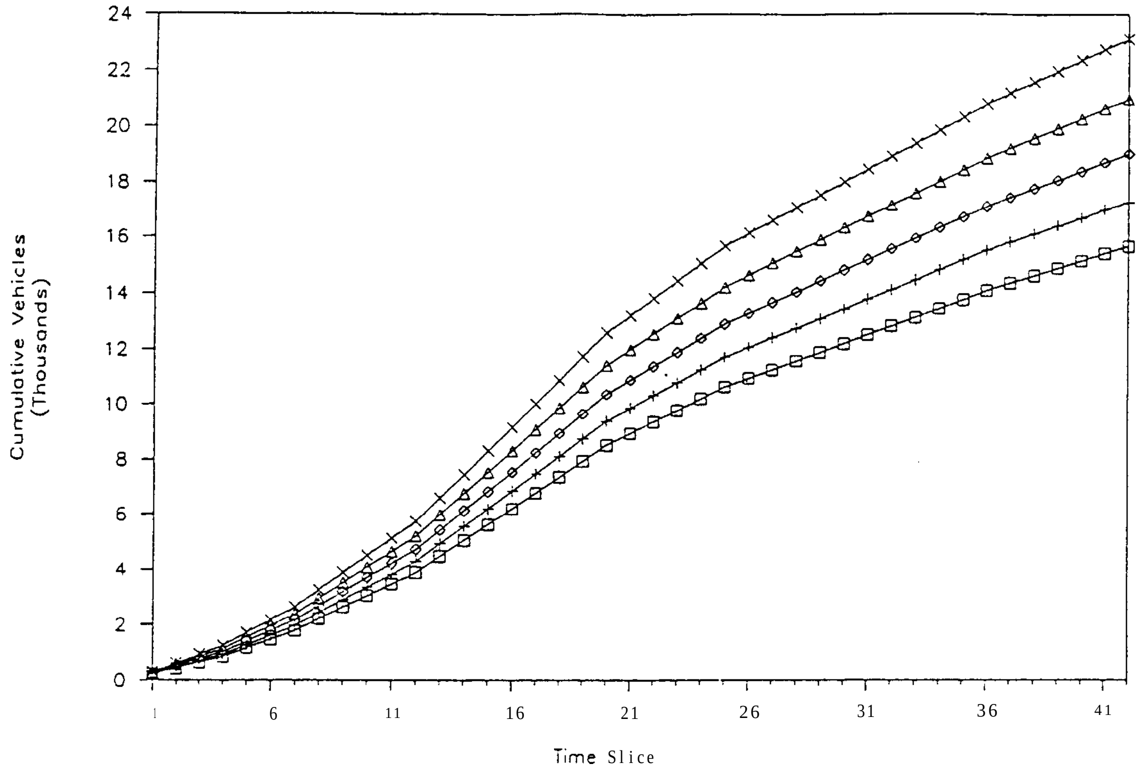

Fig. 5.1: Cumulative Arrivals: Total

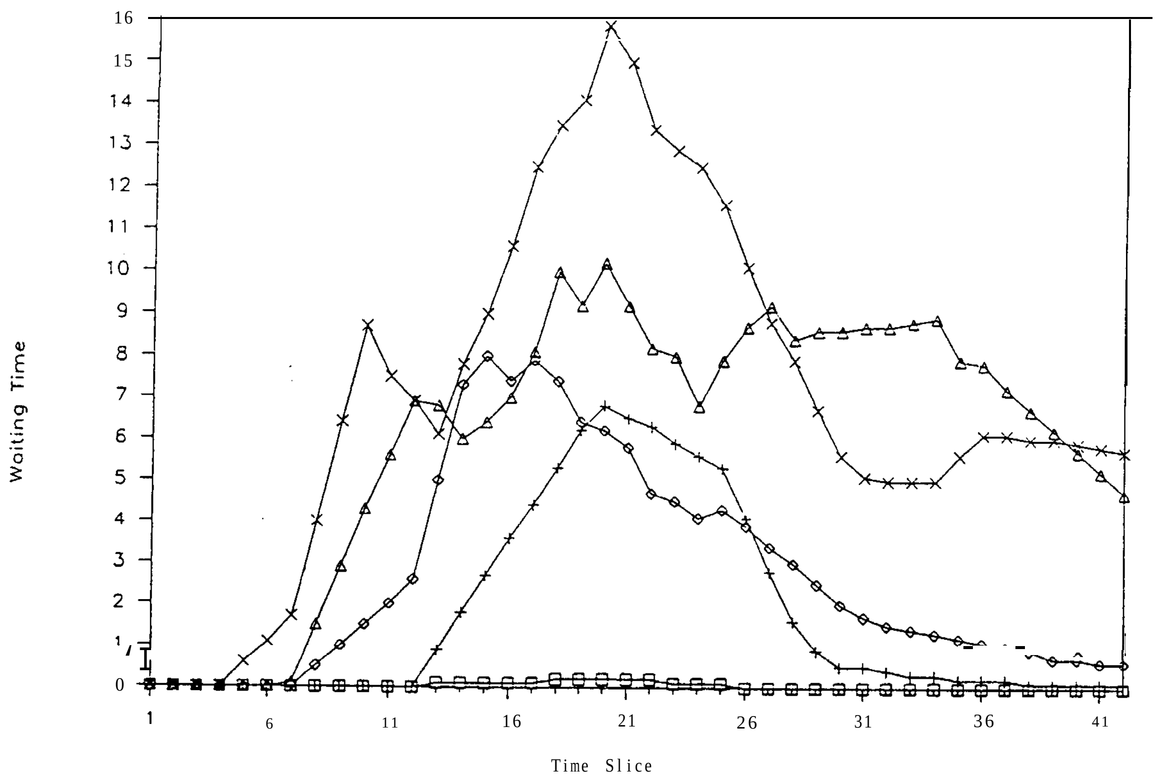

Fig. 5.2: Average Waiting Time: Total

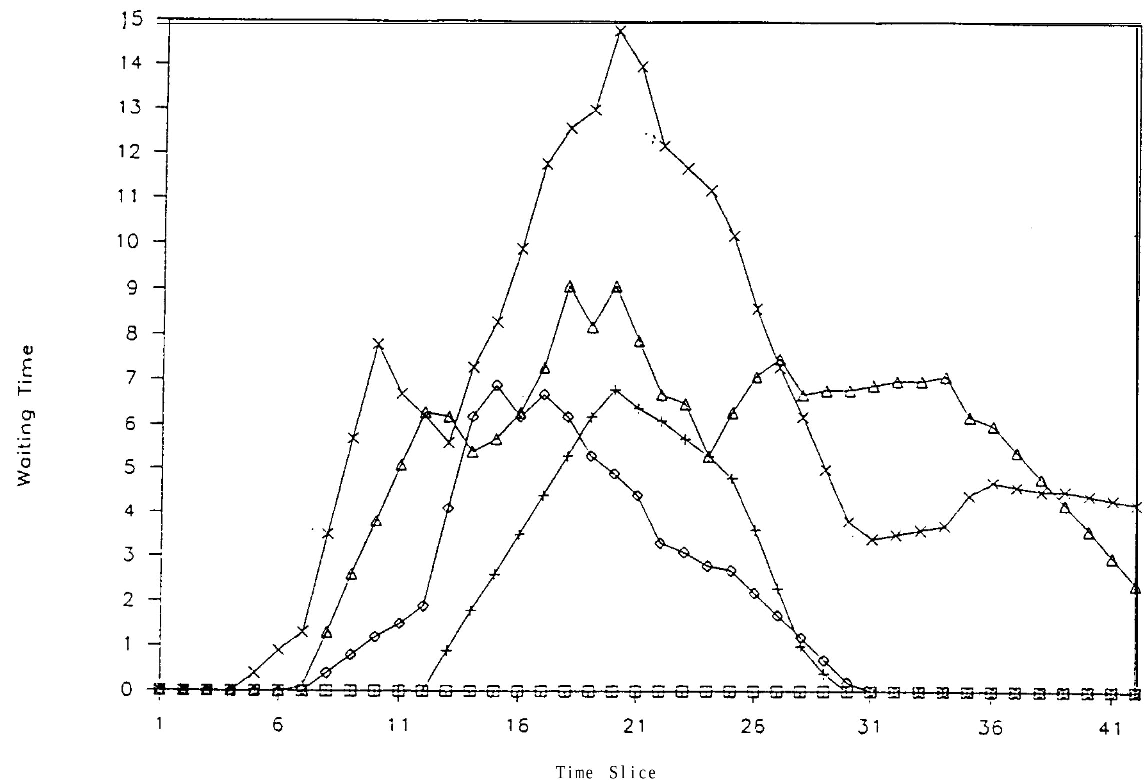

Fig. 5.3: Recurrent Waiting Time: Total

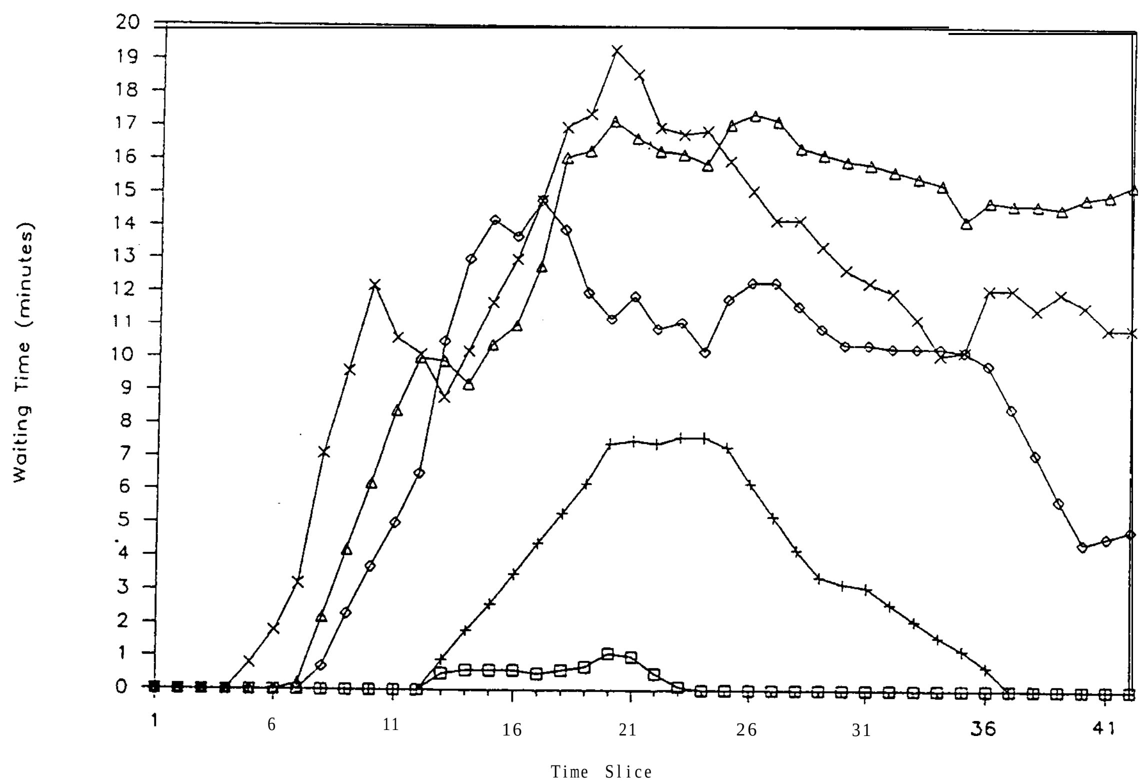

Fig. 5.4: Percentile Waiting Time: Total

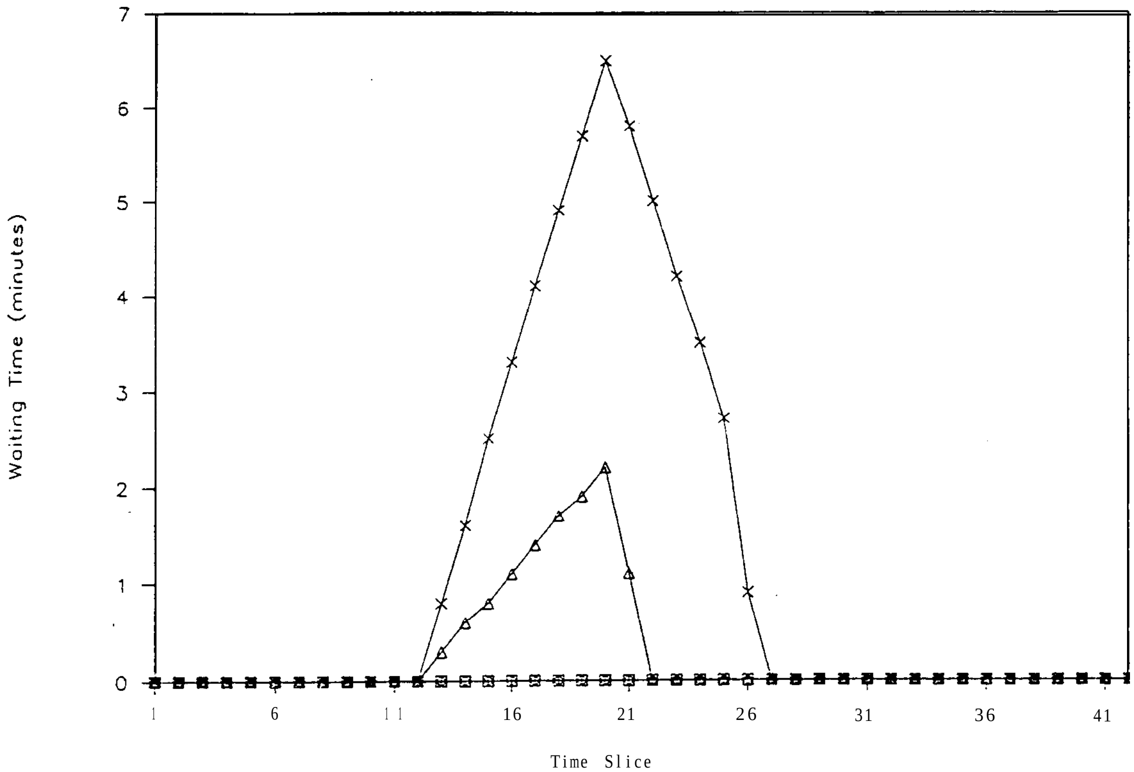

Fig. 5.5: Recurrent Waiting Time: Upstream

** Note: in Fig. 5.1 - 5.5
□ = Iteration 2
+ = Iteration 4
o = Iteration 6
Δ = Iteration 8
x = Iteration 10.

CHAPTER 6

CONCLUSION

BTS can be used to evaluate a variety of changes in highway design to improve bottlenecks, such as: (1) addition of highway lanes; (2) addition of automated or HOV lanes; or (3) incident management strategies to reduce the frequency, duration and magnitude of incidents.

The current version of BTS is experimental. In a future issue, BTS will be enhanced to include incident dependencies, weather conditions, and randomly varying traffic volumes.