TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-82/ +292-1		

4. Title and Subtitle	5. Report Date
A Model to Calculate the Road User Costs at Work Zones	September 1982
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Jeffery L. Memmott and Conrad L. Dudek	Research Report 292-1
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843	11. Contract or Grant No. Study No. 2-18-81-292
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation Transportation Planning Division P.O. Box 5051, Austin, Texas 78763	Interim Report Sept. 1981 - Sept. 1982
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with DOT, FHWA.
Study Title: Handling Traffic in Work Zones

16. Abstract

This report presents a model, QUEWZ, which can be used to calculate the user costs resulting from lane closures through a work zone. QUEWZ calculates the delay costs and speed-change cycling costs of slowing down to go through a work zone and the change in vehicle running costs through the work zone. If a queue forms, the delay costs, speed-change cycling costs, and change in vehicle running costs in the queue are also estimated. The model also estimates the average length of queue each hour.

The model can examine a variety of lane closure strategies, which fall into two general categories; lane closures in a single direction of travel, and crossovers, where one or more lanes are closed in both directions of travel.

QUEWZ represents an improvement of previous models by using hourly traffic volumes, and recent data concerning capacities and average speeds in and around work zone sites in Texas. The increased accuracy of the user cost calculations will provide improved information for selecting the appropriate closure strategy through a work zone.

17. Key Words	18. Distribution Statement
Work Zone, Road User Costs, Lane Closure Strategy, Delay Costs, and Vehicle Operating Costs	No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Rd., Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	120	

Form DOT F 1700.7 (8-69)

A MODEL TO CALCULATE THE ROAD USER COSTS AT WORK ZONES

by

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Research Report 292-1

Sponsored by the State Department of Highways
and Public Transportation

in Cooperation with the
Federal Highway Administration
U.S. Department of Transportation

Texas Transportation Institute
Texas A&M University
College Station, Texas

September 1982

ACKNOWLEDGEMENTS

The authors wish to thank Blair Marsden and Herman Haenel (D-18T, SDHPT) for their constructive comments and suggestions during the course of the research documented herein. The authors would also like to thank Richard W. Denney for his help and comments in improvements to the computer program and the documentation.

The research direction was guided by a Technical Advisory Committee. The contributions of this Committee, whose members are listed below, are gratefully acknowledged:

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SUMMARY

This report examines a model designed to calculate the additional road user costs as a result of lane closures at highway work zones. The model, QUEWZ, is designed for evaluation of freeway work zones, but can be used for other highway types. The program presupposes a safe and adequate traffic control plan.

The major characteristics of the model include:

1. Two categories of lane closure strategies are assumed. The first type is closure of one or more lanes in a single direction of travel. The second type is a crossover, where one side of the roadway is closed and two-lane, two-way traffic is maintained on the other side of the roadway.
2. Hourly traffic volumes are used rather than ADT. This allows for a much more accurate estimate of average speeds, and the estimated queue when demand exceeds capacity.
3. A typical hourly speed-volume relationship is assumed in the model, but can be changed by the user as part of the input data.
4. Vehicle capacity through the work zone is not a constant parameter but based upon a distribution of work zone capacities in Texas. The model user can select the probability that his work zone capacity estimate will cover a certain percentage of workzone capacities observed in Texas. For those cases which are not supported by Texas data, or if Texas data are not appropriate, the user can override the program-generated work zone capacity in the input.
5. A relatively small amount of data is required to run QUEWZ. These data elements include, the lane closure strategy, total number of

lanes and the number of open lanes through the work zone, the length of closure, the hours of closure and work zone activity, and hourly traffic volumes.

6. The output from QUEWZ includes vehicle capacity and average speed through the work zone, hourly road user costs, daily user costs, and if a queue develops, the average length of queue each hour.

The user cost calculations in QUEWZ fall into three general categories. Delay costs result from slowing down and going through the work zone at a reduced speed, and if a queue develops, the delay of vehicles in the queue. Change in vehicle running costs come from a lower average running speed through the work zone and queue, if one develops. Speed-change cycling costs come from slowing down to go through the work zone and stop-and-go conditions if there is a queue. Dollar values of operating costs come from the AASHTO Redbook (1), and the values of time from the HEEM program (2). Both are updated to December 1981 values.

Several of the user costs calculations utilize information obtained from recent TTI findings regarding work zone capacities, average speeds through work zones, characteristics of queues which have formed upstream of the closure, and the effect of work activity in the work zone on vehicle reaction while going through the work zone.

The report also presents twenty sample lane closure problems. The estimates of user costs and queue length from QUEWZ are presented, along with some suggestions for using the output in decisions regarding lane closures through work zones.

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INTRODUCTION

An important aspect of a highway work zone is the lane closure strategy and the movement of traffic through the work zone. As part of the evaluation to determine the effects of different lane closure strategies (e.g., one-, two-, or three-lane closures on a four-lane section), the additional costs to vehicle users should be considered. It is therefore necessary to have a model which will improve the accuracy of user costs estimates resulting from the forced movement through a restricted work zone area.

There are several models which attempt to measure those costs (3,4,5), but each one has several limitations which prevent it from accurately calculating user costs, or are so complicated that it cannot be used very quickly or easily. Those limitations include, use of average daily traffic (ADT) volume instead of hourly traffic volumes, large amounts of required input data, no adjustment for stop-and-go conditions in a queue, and no adjustment for the effective length of reduced speed through the work zone for low traffic volumes.

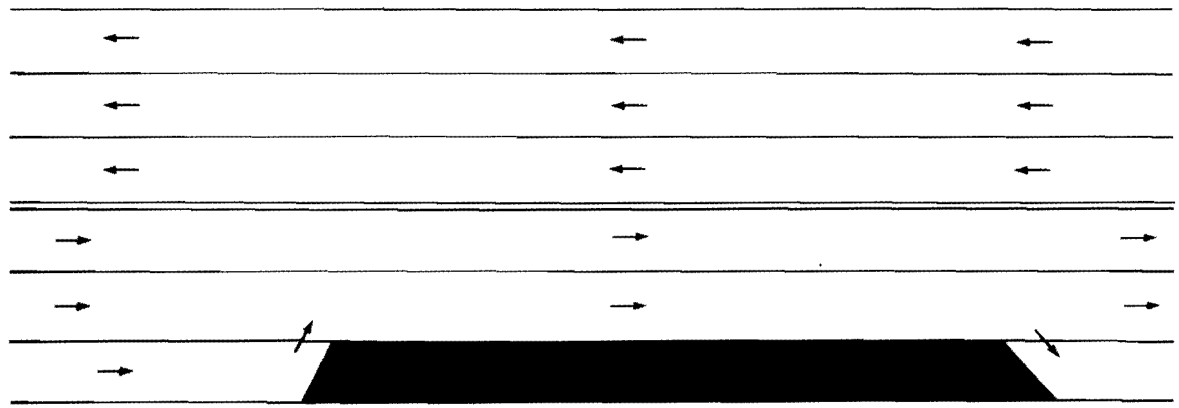
This report presents a model, QUEWZ, to estimate the additional user costs resulting from lane closures in one or both directions of travel. User costs can be estimated when one or more lanes are closed in just one direction of travel, or when a crossover is used. Hourly, as well as daily user costs are estimated, and when vehicle demand exceeds capacity, the model also estimates the length of queue. The model is designed specifically for freeway conditions, but it can be used in other situations if appropriate adjustments are made in the input data. Two vehicle types are used in the model, passenger cars and trucks.

CHARACTERISTICS OF MODEL

User costs resulting from restricted capacity through a work zone can be placed in four general categories, delay or travel time costs, vehicle running costs, speed change cycling costs, and accident costs. Delay costs result from reduced speeds through the work zone, delay in slowing down from and returning to the approach speed, and delay in a queue if demand exceeds capacity. Changes in vehicle running costs result from reduced speeds through the work zone and queue, if any. Speed change cycling costs are generated from slowing down to go through the work zone and stop-and-go conditions if a queue is present. Changes in accident costs are not calculated in this model due to the lack of data on changes in accident rates through a typical work zone.

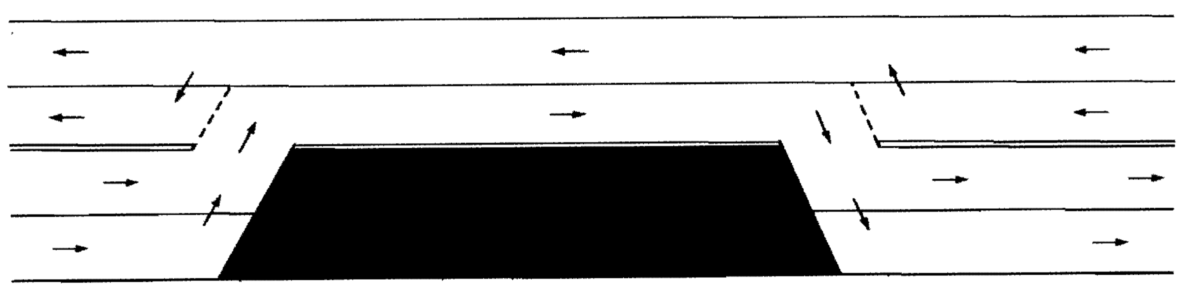
Two general configurations of lane closures through a work zone are incorporated into QUEWZ. These configurations are illustrated in Figure 1. The first configuration involves situations where one or more lanes are closed in one direction, while traffic moving in the opposite direction is not affected. The second configuration involves a crossover, where all lanes in one direction of travel are closed and two-lane, two-way traffic is maintained on the other directional lanes. A maximum of six lanes in each direction can be handled in the model.

Most other models use ADT as the input data for vehicle volume (3,4). However, the daily peaking pattern can have a significant impact on average speeds and queues during the day. Therefore hourly traffic volumes are used in this model, and the user costs are calculated for each of those hourly traffic volumes. The hourly user costs are then summed, giving the daily user costs. The input and output data for the model are listed in Table 1. Details are presented in the section entitled "Use of the Model."



LANE CLOSURE STRATEGY 1

ONE OR MORE LANES CLOSED IN ONE DIRECTION OF TRAFFIC



LANE CLOSURE STRATEGY 2

CROSSOVER ONE OR MORE LANES CLOSED IN EACH DIRECTION OF TRAVEL

FIGURE 1 TRAFFIC CLOSURE CONFIGURATION THROUGH A WORK ZONE

Table 1. Input and Output Data for QUEWZ

<u>Input Data</u>

<u>Required</u>

- Lane Closure Strategy (See Figure 1)
- Total Number of Lanes
- Number of Open Lanes Through Work Zone
- Length of Closure
- Time of Lane Closure and Work Zone Activity
- Actual Traffic Volumes by Hour

<u>Optional</u>

- Factor to Update Cost Calculations
- Percentage Trucks
- Speeds and Volumes for Speed-Volume Curve
- Capacity Estimate Risk Reduction Factor or Work Zone Capacity
- Problem Description

<u>Output Data</u>

- Vehicle Capacity
- Average Speed Through Work Zone by Hour
- Hourly User Costs
- Daily User Costs
- If a Queue Develops, Average Length of Queue each Hour

Many of the items listed on Table 1 are apparent. A few need some additional explanation.

Currently QUEWZ handles two lane closure strategies as shown in Figure 1. The user is required to identify the time when lanes will be closed and reopened. For long term road work that lasts for more than one day, the time of day when the work crews are at the site must also be specified. For short term projects the hours of restricted capacity would coincide with the work zone activity, so the hours of work zone activity could be left blank.

The factor to update cost calculations is used to update the dollar user costs to current prices. The method for determining the factor is presented in the section entitled "Use of the Model."

The QUEWZ program also allows the user to include a problem description. Such information as highway number, location of work zone, etc. can be included.

The program has constant values built into the model for all optional inputs. If the user does not specify values for the optional inputs, the program automatically uses its preset values. These program constant values, or default values, are presented in later sections of the report. Details of the user cost calculations are contained in Appendix A.

CHARACTERISTICS OF STRATEGY 1, SINGLE DIRECTION CLOSURE

The QUEWZ program assumes a typical speed-volume relationship. The user of the program has the option of defining a different speed-volume relationship by inputting the free flow speed, speed and lane volume at the dividing point between level of service D and E, speed at capacity, and lane volume at capacity.

The user has an option of including a capacity estimate risk reduction factor. Since the QUEWZ program uses a probability distribution for each type of lane closure configuration, the user can select a level of confidence that his work zone capacity estimate will cover a certain percentage of those capacities observed to date in Texas. For example, if the user selects a risk reduction factor of 100, the estimated work zone capacity will be low but the user can be assured at a 100% level of confidence that the actual work zone capacity will be equal to or larger than the estimated capacity (based on capacities observed thus far for single direction closures in Texas). A lower risk reduction factor will yield a higher estimated work zone capacity with an associated risk that the actual work zone capacity will be less than the estimated capacity (6). The program uses a preset risk factor of 60 which will give approximately the mean capacity for each closure configuration. If a lower risk reduction factor is used in the input data, the result will be a higher estimated capacity through the work zone than the mean capacity observed to date for work zones in Texas. A value more than 60 would have exactly the opposite effect on the estimated capacity. Additional information on the selection of the appropriate value is contained in Appendix A.

It should be noted that the capacity estimate risk factor is used to calibrate the program to actual conditions at a particular work zone. The level of work activity, its proximity to traffic, whether the work is short or long term, and other factors not well defined as of this writing, affect work zone capacity. In addition, the program does not account for traffic diversion. The amount of traffic diverting to alternate routes can vary from site to site. In order to properly calibrate the model, the user should check the program solutions against actual field conditions (e.g., by comparing queue length, speed, etc.), and adjust the risk factor accordingly.

For some lane closure configurations, capacity data are unavailable for Texas work zones, and default values are automatically assigned by the computer program based on NCHRP Report 1-10A (3). If these values are not appropriate, or if the Texas data do not properly describe the actual work zone capacity, then the user can specify the per lane capacity in the work zone. The specified capacity value will override the work zone capacity generated by QUEWZ.

CHARACTERISTICS OF STRATEGY 2, CROSSOVER

Due to the lack of capacity and speed data for crossover configurations, the same approach and parameters previously described for strategy 1, are used for the crossover strategy. In effect each direction of travel through the work zone is treated independently. The same speed-volume relationship is assumed for each direction of travel.

The capacity in each direction is estimated based upon the previously described Texas capacity data for closures affecting a single direction of travel. For example, a crossover for a 4-lane freeway would consist of two-lane, two-way traffic through the work zone. The capacity for each direction of travel would be estimated using the lane reduction in that direction. In this case each direction is being reduced to one lane in a single direction, which would be treated as a single direction closure for both directions of travel. This is the same way crossovers are handled in the FPS Model (3) and the EAROMAR Model (5).

USE OF THE MODEL

The input data for each problem in the model consists of one card to describe the parameters, and an additional two or four cards for the hourly traffic volumes.

Card 1

Card columns	
1 - 2	problem number (1 to 99)
3	lane closure strategy; 1 indicates single direction closure, 2 indicates crossover
*4 - 7	factor to update cost calculations (default = 1.00)
*8 - 10	percentage trucks (default = 8)
*11 - 13	free flow speed in miles per hour (default = 60)
*14 - 16	LOS D/E breakpoint speed in miles per hour (default = 40)
*17 - 19	capacity speed in miles per hour (default = 30)
*20 - 23	LOS D/E breakpoint volume per lane in vehicles per hour (default = 1600)
*24 - 27	capacity volume per lane in vehicles per hour (default = 2000)
28	total number of lanes inbound direction (1-6)
29	total number of lanes outbound direction (1-6)
30 - 33	length of restricted capacity in miles
34	number of open lanes, inbound direction, through work zone. Must be equal to or less than card column 28
35	number of open lanes, outbound direction, through work zone. Must be equal to or less than card column 29
36 - 37	beginning hour of restricted capacity in military time (0 to 23)

38 - 39	ending hour of restricted capacity in military time (1 to 24), (must be greater than beginning hour of restricted capacity)
*40 - 41	beginning hour of work zone activity in military time (0 to 23), (default = beginning hour of restricted capacity)
*42 - 43	ending hour of work zone activity in military time (1 to 24), (default = ending hour of restricted capacity)
*44 - 47	capacity estimate risk reduction factor, probability that estimated capacity will be less than or equal to actual capacity (default = 60). If a user-supplied capacity is desired, the work zone capacity per lane should be specified in this field. If this value if greater than 100, the program assumes that capacity is being specified. This value should not exceed 90% of the per lane normal capacity; otherwise an error message will be displayed and the problem skipped.
*48 - 80	problem description

* indicates optional data with default values, may be left blank.

Cards 2-3 if lane closure strategy 1, single direction closure

Cards 2-5 if lane closure strategy 2, crossover

Card columns

1 - 2	problem number (must be the same as card 1)
3	direction (I-inbound or 0-outbound)
4	period (1-for first 12 hours of day, 2-second 12 hours of day)
5 - 9	total traffic volume, all lanes, in specified direction, in first hour of period (0000 to 0100 hours or 1200 to

1300 hours)

10 - 14	second hour total traffic volume (0100 to 0200 hours or 1300 to 1400 hours)
15 - 19	third hour total traffic volume (0200 to 0300 hours or 1400 to 1500 hours)
20 - 24	fourth hour total traffic volume (0300 to 0400 hours or 1500 to 1600 hours)
25 - 29	fifth hour total traffic volume (0400 to 0500 hours or 1600 to 1700 hours)
30 - 34	sixth hour total traffic volume (0500 to 0600 hours or 1700 to 1800 hours)
35 - 39	seventh hour total traffic volume (0600 to 0700 hours or 1800 to 1900 hours)
40 - 44	eighth hour total traffic volume (0700 to 0800 hours or 1900 to 2000 hours)
45 - 49	ninth hour total traffic volume (0800 to 0900 hours or 2000 to 2100 hours)
50 - 54	tenth hour total traffic volume (0900 to 1000 hours or 2100 to 2200 hours)
55 - 59	eleventh hour total traffic volume (1000 to 1100 hours or 2200 to 2300 hours)
60 - 64	twelfth hour total traffic volume (1100 to 1200 hours or 2300 to 2400 hours)

QUEWZ can be used to look at a number of different work zones at the same time, as well as different closure strategies at a single work zone. Each alternative at each work zone must be given a different problem number. The problem number can range from 1 to 99. Care must be taken that the first card for each problem specify the model correctly, and the data are in the correct card columns. Only a few of the data elements on the first card must be specified, most can be left blank. If the card columns are left blank, then the model will use the previously described default values for those data elements. To update the cost calculations to any month since December 1981, merely insert the Consumer Price Index (CPI) for that month, with 1967 = 100, into the following formula for the cost update factor (CUF),

$$CUF = \frac{CPI}{281.5}$$

Any other price index could be used by replacing 281.5 in the denominator with the index value for December 1981.

For projects lasting less than a day, just the hours of restricted capacity need to be specified, the hours of work zone activity can be left blank. For projects lasting more than 24 hours, the restricted capacity can be specified for some period greater than the hours of work zone activity. In this situation the hours of restricted capacity must be specified (which would normally be the 24 hour period), along with the hours of actual work zone activity.

The volume cards for each numbered problem can come in any order, after the first card of the problem, but there must be the right number of cards specifying the volume data. There must be two cards for lane closure strategy 1 (the lane closure in one direction problem) and four cards for lane closure strategy 2 (the crossover problem). There are no default traffic volumes, so all volumes on each card must be specified or zero will be used for that hour. Of course only traffic volumes for those hours when the lane(s) are closed would be needed for the cost calculations, so traffic volumes for hours when all lanes are open can be left blank. It would be advisable, however, to include a few hours of traffic after the lanes are open to account for the possibility of a queue at the time the lanes are opened, and the necessary additional time period(s) to relieve the congestion.

Twenty sample problems are presented in the next section using QUEWZ. The program and the complete output for each of the test problems are presented in Appendix B. The output format is basically the same for all problems, except for the treatment of the work zone capacity. If the program calculates the capacity, then the CERF factor used in the calculation is printed out. If the work zone capcity is part of the input data, then the CERF factor is not used, and therefore not printed out.

EXAMPLES OF THE MODEL'S USE

In the examples used to test the model, the same hourly traffic volumes are used for each problem. The freeway work zone is assumed to be one mile in length and work activity begins at 9:00 AM and ends at 3:00 PM. It is also assumed that the lane closures through the work zone remain closed for an entire 24 hour period for some problems, and for others it is assumed that closure begins at 8:00 AM and ends at 4:00 PM. A vehicle mix of eight percent trucks is also assumed.

Table 2 presents some summary results of twenty test problems. Complete output for each problem is contained in Appendix B. In several of the test problems, demand exceeded capacity for some hours and a queue formed. The user costs increased substantially for those hours when a queue was present, which dramatically increased the total daily user costs.

An interesting comparison can be made with problems five and six. Suppose an engineer has to perform maintenance work on a freeway and has the choice of closing one or two lanes of the three inbound lanes. If the hourly traffic volumes were similar to those assumed in these test problems, then a one lane closure would not be expected to produce any queues and a small amount of user costs. If the second lane is closed however, then very long queues could be expected, along with substantial user costs. This is the sort of situation where QUEWZ could be very useful, by providing relevant information concerning the available alternatives.

In addition, Table 2 has three problems to test the work-zone capacity as part of the input data, which replaced the computer generated capacity of 1332 vphvl. The same thing happened with problem 16. However on problem 17 the work-zone capacity was intentionally given a value greater than the restricted capacity, producing an error, and the problem was not processed. If a work-zone capacity is given as part of the input data, it cannot exceed 90% of the normal capacity per lane.

Table 2.

*** SUMMARY OF EXAMPLE PROBLEMS ***

PROB NO	TOTAL NUMBER OF LANES INB	OUTB	NUMBER OF OPEN LANES THRU WZ INB	OUTB	LENGTH OF WORK ZONE (MILES)	NORMAL CAPACITY EACH DIRECTION (VPH)	RESTRICTED CAPACITY WORK ZONE INACTIVITY HOURS (VPH) INB	OUTB	WORK ZONE ACTIVITY HOURS (VPH) INB	OUTB	HOURS OF RESTRICTED CAPACITY BEG	END	HOURS OF WORK ZONE ACTIVITY BEG	END	LONGEST EST QUEUE LENGTH (MILES) INB	OUTB	TOTAL ADD. DAILY USER COSTS DUE TO LANE CLOSURE ($)
1	2	2	1	2	1.00	4000.	1800.		1332.		8	16	9	15	1.9	0.0	17647.
2	2	2	1	1	1.00	4000.	1800.	1800.	1354.	1354.	8	16	9	15	1.7	2.9	35112.
3	2	2	1	2	1.00	4000.	1800.		1650.		0	23	9	15	1.0	0.0	11214.
4	2	2	1	1	1.00	4000.	1800.	1800.	1354.	1354.	0	23	9	15	1.7	3.7	78343.
5	3	3	2	3	1.00	6000.	3600.		2983.		8	16	9	15	0.0	0.0	546.
6	3	3	1	3	1.00	6000.	1800.		1127.		8	16	9	15	3.6	0.0	64108.
7	3	3	2	3	1.00	6000.	3600.		2983.		0	23	9	15	0.0	0.0	847.
8	3	3	1	3	1.00	6000.	1800.		1127.		0	23	9	15	4.1	0.0	120878.
9	4	4	4	3	1.00	8000.		5400.		4577.	0	23	9	15	0.0	0.0	368.
10	4	4	4	2	1.00	8000.		3600.		2968.	0	23	9	15	0.0	0.0	986.
11	4	4	4	1	1.00	8000.		1800.		1200.	0	23	9	15	0.0	3.2	101485.
12	5	5	4	5	1.00	10000.	7200.		6200.		0	23	9	15	0.0	0.0	214.
13	5	5	3	5	1.00	10000.	5400.		4500.		0	23	9	15	0.0	0.0	436.
14	5	5	2	5	1.00	10000.	3600.		2745.		0	23	9	15	0.0	0.0	1126.
15	5	5	1	5	1.00	10000.	1800.		1200.		0	23	9	15	1.7	0.0	81736.
16	6	6	5	6	1.00	12000.	9000.		8250.		9	15	9	15	0.0	0.0	58.
17	PROBLEM NOT PROCESSED																
18	6	6	3	6	1.00	12000	5400.		4500.		9	15	9	15	0.0	0.0	217.
19	6	6	2	6	1.00	12000.	3600.		2800.		9	15	9	15	0.0	0.0	551.
20	6	6	1	6	1.00	12000.	1800.		1200.		9	15	9	15	0.8	0.0	27495.

SUMMARY AND RECOMMENDATIONS

This report presents a model to calculate the additional user costs generated by restricted capacity through a work zone. The model goes through a number of calculations to estimate the various user costs associated with work zones. Those user costs, presupposing an adequate Traffic Control Plan, include delay costs and change in vehicle running costs through the work zone, speed-change cycle costs in slowing down and returning to the approach speed, and costs if a queue forms in the form of delay costs, vehicle running costs, and speed-change cycle costs. The accuracy of the cost calculations has been increased significantly over previous models by using hourly rather than daily traffic volume and by incorporating recent findings regarding work zone capacities and average speeds.

Additional work remains in order to accurately estimate the effect on average speeds from varying shoulder widths, and the change in accident rates should be the subject of further research. In addition more work should be done on the user costs generated in a queue including vehicles which divert to avoid waiting in the queue, which is not currently accounted for. This additional information would increase the accuracy of the user cost calculations, which in turn would increase the reliability of decisions regarding work zone configurations and the tradeoffs involved. The program should also be written to output alternative traffic control strategies that can improve traffic operations if excessive queues develop. This will assure that the user explores all alternatives and it increases the probability of completing the required work at minimum cost and time. A few alternative traffic control strategies include closing entrance ramps, temporary use of the shoulder as an operating lane, diverting traffic to the frontage road, and splitting traffic during middle lane closures.

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APPENDIX A

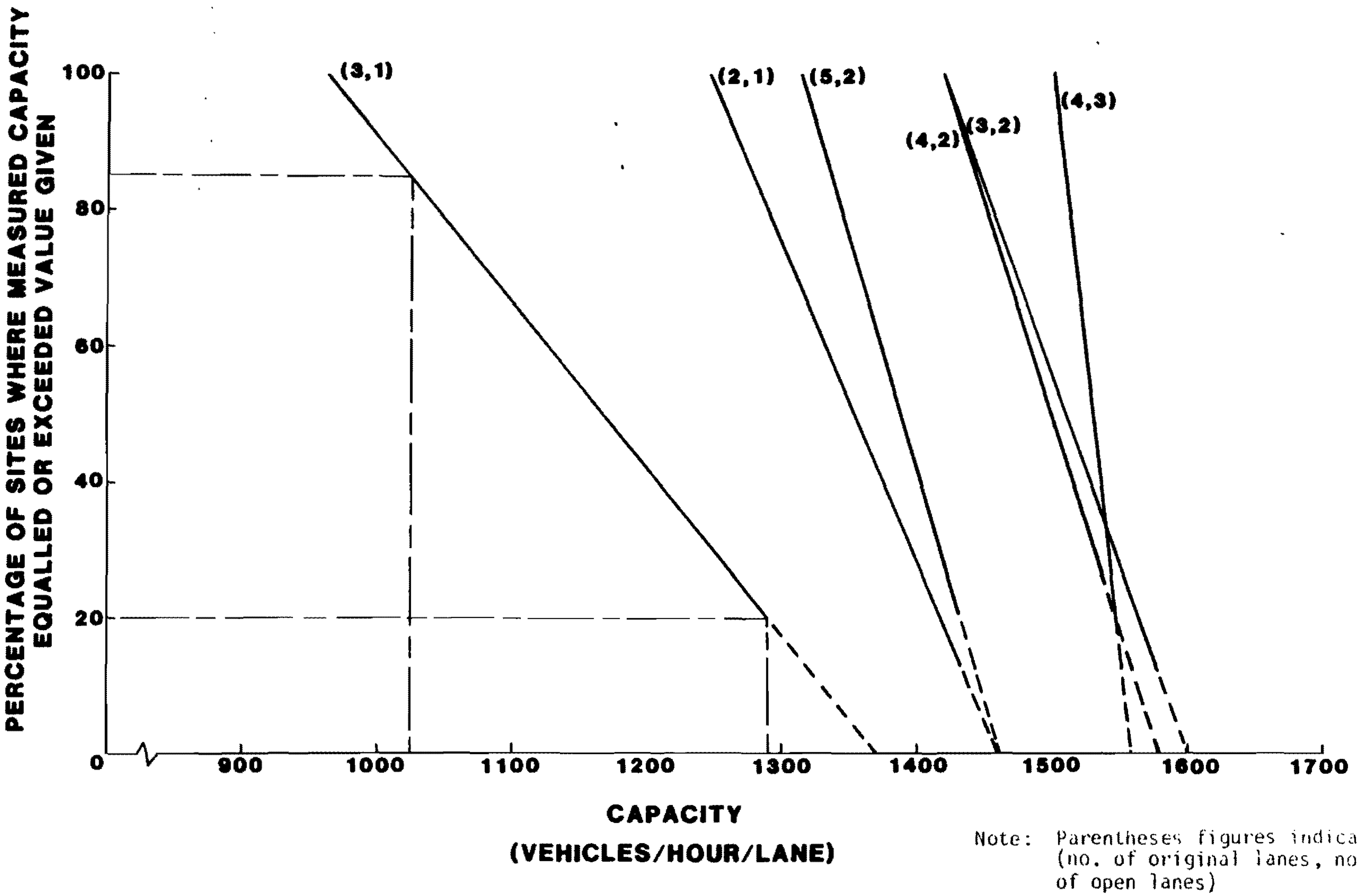
USER COST CALCULATIONS

The calculation of user costs in QUEWZ, in most respects, is typical of user cost calculations elsewhere. There are significant differences, however, for several aspects of speeds, capacities, and queues which incorporate several recent findings by TTI concerning work zones. As a result, several different equations and approaches are presented here which are not found in other models.

Estimation of Vehicle Capacity Through Work Zone

Generally, the primary effect work zones have on traffic is the restricted capacity around the work area and the resulting effect on average speeds. The model assumes highway capacity under normal conditions will be 2,000 vehicles per hour per lane (vphpl), but this can be changed as part of the input data. When lanes are closed for prolonged periods (i.e., longer than one day), but work activity is not taking place in the work zone, previous research by TTI has found the capacity to be about 1800 vphpl, or about 90 percent of normal capacity, which is used in this model.

Data on work zone capacities during work activity hours are reported in TTI Research Report 228-6, (6). Using the data in that report, linear approximations of the cumulative distributions for each reported closure combination are estimated. These capacity approximations are depicted in Figure 2. The numbers in the parentheses indicate the number of original lanes and the number of open lanes through the work zone. The function of the Figure is to assist the users in identifying risks in using certain capacity values for a given lane closure situation to estimate the effects of the lane closures (e.g., queue lengths).



Note: Parentheses figures indicate (no. of original lanes, no. of open lanes)

FIGURE 2 CUMULATIVE DISTRIBUTION OF WORK ZONE CAPACITIES

For example, the 85th percentile for the (3,1) situation is 1030 vphpl. This means that 85% of the studies conducted on 3-lane freeway sections with 1 lane open through the work zone resulted in capacity flows equal to or greater than 1030 vphpl. The capacity flow was equal to or greater than 1290 vphpl on only 20% of the cases studied. Thus, to assume a higher capacity of 1500 vphpl (which is the mean capacity for (3,2) and (4,2) closures), for (3,1) work zones would tend to underestimate the length of queues caused by the lane reduction at the vast majority of these work zones. While this data only applies to single direction closure strategies, the same capacities are used here for the crossover strategy until capacity data are available for crossover stategies.

For those lane closure combinations which did not have capacity data (i.e., (4,1), (5,1), (5,3), (5,4), (6,1), (6,2), (6,3), (6,4) combinations), the closure capacities in NCHRP Report 1-10A (3) are used. For freeways with four, five, or six lanes in each direction, and only one lane left open through the work zone, an average capacity of 1200 vphpl is used. For five or six lanes with three lanes left open, 1500 vphpl capacity is used, for five or six lanes with four lanes left open, 1550 vphpl capacity is used, and for six lanes with five lanes left open, 1580 vphpl capacity is used. Estimated capacity is calculated in the program with the following equation,

$$CAPW = a - b(CERF)$$

where CAPW = restricted capacity during work zone activity hours

CERF = capacity estimate risk factor, probability that the estimated capacity will be less than or equal to the actual capacity.

The values for coefficients a and b are listed in Table 3. The coefficients were obtained through regression analyses of the capacity data presented in TTI Research Report 228-6 (6) and illustrated in Figure 2. The capacity estimate risk factor (CERF) in the above equation can take any value from 1 to 100. The value of CERF can be specified as part of the input data, but it is not necessary. If the value is left blank or is zero, a value of 60 will automatically be used in the model, which yields the approximate mean capacity for Texas work zones. This work zone capacity generated within the program can be overriden by a user specified capacity as part of the input data. To input the work zone capacity, it is necessary to replace the CERF number with the work zone capacity per lane. Any number in that field greater than 100 will be used as the work zone capacity, and the program generated capacity will not be used.

Calculation of Average Speeds

The average approach speed is calculated using the assumed speed-volume curve depicted in Figure 3. Truck speeds are assumed to be 90 percent of car speeds (2). The three speed parameters, SP_1, SP_2, and SP_3; along with the volume parameters, V_1, and V_2; have preset constant values or default values if the user does not specify speed and volume parameters. Those default values are given by:

SP_1 = 60 mph

SP_2 = 40 mph

SP_3 = 30 mph

V_1 = 2,000 vphpl

V_2 = 1,600 vphpl

Table 3. Restricted Capacity Coefficients During Work Zone Activity Hours

Normal Number of Open Lanes in One Direction	Open Lanes Through Work Zone in One Direction				
	Intercept Term (a)				
	1	2	3	4	5
2	1460				
3	1370	1600			
4	1200	1580	1560		
5	1200	1460	1500	1550	
6	1200	1400	1500	1550	1580
	Slope Term (b)				
	1	2	3	4	5
2	2.13				
3	4.05	1.81			
4	0.00	1.60	0.57		
5	0.00	1.46	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00

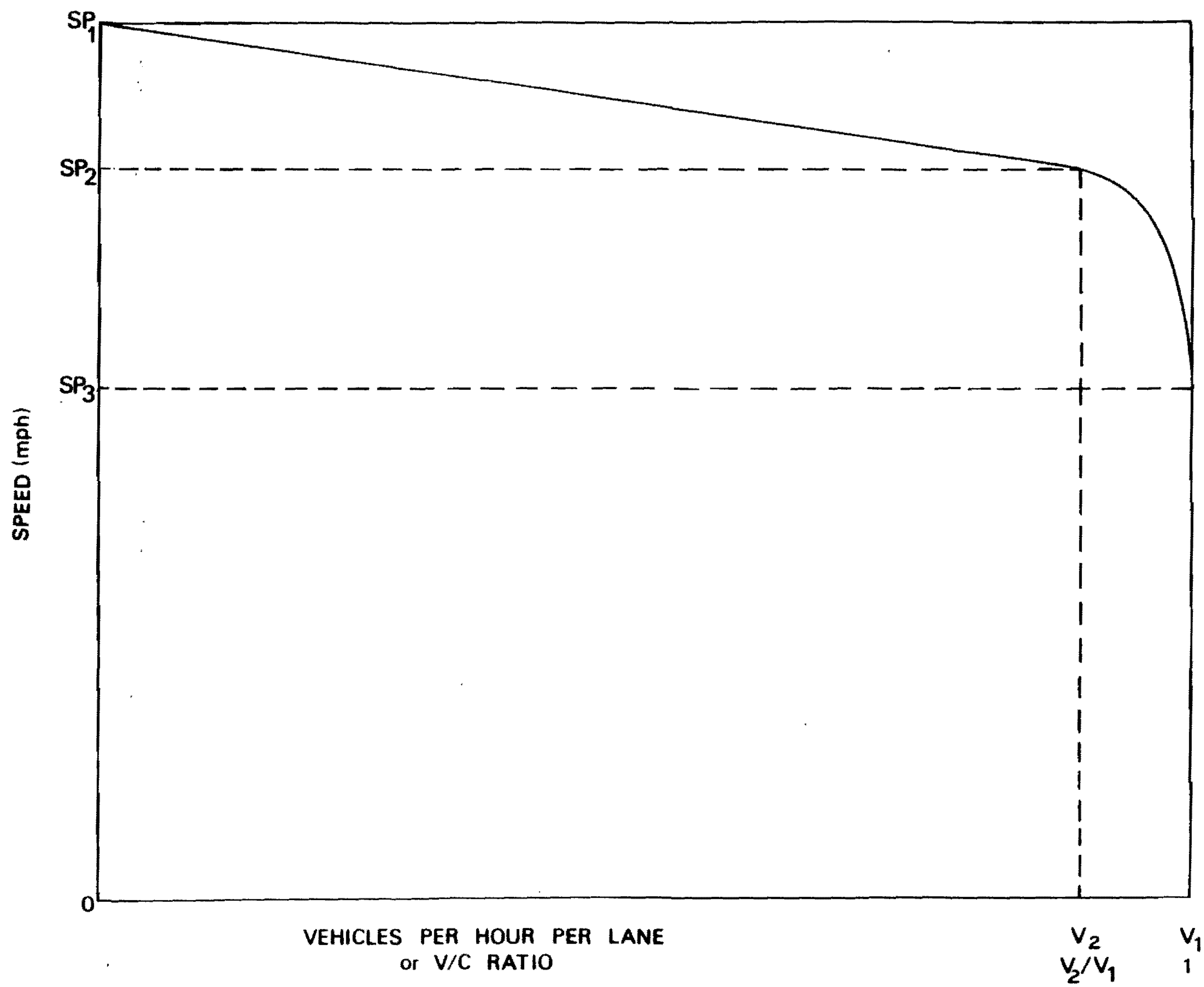


FIGURE 3 HOURLY SPEED - VOLUME CURVE

Table 4. Recommended Speeds and Volumes for Freeways of Various Lanes and Peak-Hour Factors

	Peak-Hour Factor			
4 lanes	1.00	0.91	0.83	0.77
SP_1	60	60	60	60
SP_2	37	38	41	42
SP_3	30	30	30	30
VL_2	1800	1650	1500	1400
VL_1	2000	2000	2000	2000
6 lanes				
SP_1	60	60	60	60
SP_2	37	39	41	43
SP_3	30	30	30	30
VL_2	1800	1650	1500	1400
VL_1	2000	2000	2000	2000
8 lanes				
SP_1	60	60	60	60
SP_2	37	39	42	44
SP_3	30	30	30	30
VL_2	1800	1650	1500	1400
VL_1	2000	2000	2000	2000

Table 4 gives some additional quidance for speed and volume parameters from the Highway Capacity Manual (7) which vary by the number of freeway lanes and the peak-hour factor, which is simply the ratio of the peak-hour traffic volume and the maximum 5-min. rate of flow within the peak-hour. The Highway Capacity Manual (7) recommends a peak-hour factor of 0.91 for large metropolitan areas over a million population, a peak-hour factor of 0.83 for areas between 500,000 and 1,000,000 population, and a peak-hour factor of 0.77 for areas under 500,000 population. These values may need calibration to match field conditions.

The hourly traffic volume specified by the user is converted into a V/C ratio, and the approach speed, in mph, is calculated using the following equations, which is based on the assumed speed-volume relationship. The equations are taken from the Highway Economic Evaluation Model, HEEM (2).

if $\frac{V_2}{V_1} \geq V/C$, then

$$SP = SP_1 + \frac{V_1(SP_2-SP_1)}{V_2} \cdot (V/C)$$

if $\frac{V_2}{V_1} < V/C \leq 1$, then

$$SP = SP_2 + (SP_2-SP_3)[1-(\frac{V/C-V_2/V_1}{1-V_2/V_1})^2]^{\frac{1}{2}}$$

if V/C > 1 or a queue is present, then

$SP = SP_3(2-V/C)$, with the speed constrained to the following range,

$$20 \leq SP \leq SP_3$$

The average speed through the work zone (SP_{wz}) is calculated from the same speed equations above, using the V/C ratio of the work zone area. Unpublished data on work zones in Texas, collected by TTI (8) (which will be referred to as the "work zone data" in this report), indicates the speed-volume relationship does not change if capacity is restricted through a work zone. The higher V/C ratio accounts for the lower average speeds.

That same "work zone data" also indicate that the minimum speed (SP_{mn}) of vehicles is somewhat lower than the average speed through the work zone, and can be estimated using the V/C ratio of the work zone,

$$SP_{mn} = SP_{wz} - 2.3 - 25.7(V/C_{wz})^2$$

If there is a queue, then $SP_{mn} = 0$.

Calculation of Delay Through the Lane Closure Section

The "work zone data" also indicate that the distance over which vehicles slow down through a work zone is not always the entire distance of restricted capacity. When the traffic volume is light, vehicles tend to slow down only when passing the paving machine or other major work activity. An adjustment distance of 0.1 miles on each side of the work zone is also included to account for the effects of average speed being reduced upstream of the lane closure. If the work zone closure is less than 0.1 miles, then the model assumes traffic will slow down through the entire work zone. The following equations are used to estimate the effective length of closure (CLL), in miles, of reduced average speeds,

$$CLL = 0.1 + (WZD+0.1)(V/C_{wz})$$

where WZD = length of restricted capacity around work zone, in miles.

If WZD $\leq$ 0.1, or if $V/C_{wz} > 1$, then

$$CLL = WZD + 0.2$$

The dollar delay cost of going through the work zone at reduced speed (CDWZ), is calculated with,

$$CDWZ = (CLL)\left(\frac{1}{SP_{wz}} - \frac{1}{SP_{ap}}\right)(VL)(CUF)\left(PTC \cdot VLT_c + \frac{PTT \cdot VLT_t}{0.9}\right)$$

where SP_{ap} = approach speed (mph)

VL = hourly vehicle volume (vph)

CUF = factor to update cost calculations

PTC = percentage cars ÷ 100

PTT = percentage trucks ÷ 100

VLT_c = car value of time (\$/hr.)

VLT_t = truck value of time (\$/hr.)

Calculation of Queue Delay

If demand exceeds capacity of the work zone, the program assumes that a queue will form. The model also assumes there will be no change in demand as the queue forms, no traffic will divert to avoid the queue. If vehicles are assumed to arrive at a constant rate during a given hour, and enter the work zone at a constant rate during a given hour, then the average delay for each hour a queue is present (DQUE), in vehicle hours, is simply the average of the accumulated vehicles in the queue at the beginning of hour i ($ACUM_{i-1}$) and the end of the hour i ($ACUM_i$),

$$DQUE_i = \frac{ACUM_{i-1} + ACUM_i}{2}$$

where $ACUM_i = ACUM_{i-1} + VL_i - CAPW_i$

CAPW = restricted capacity through work zone (vph) for hour i

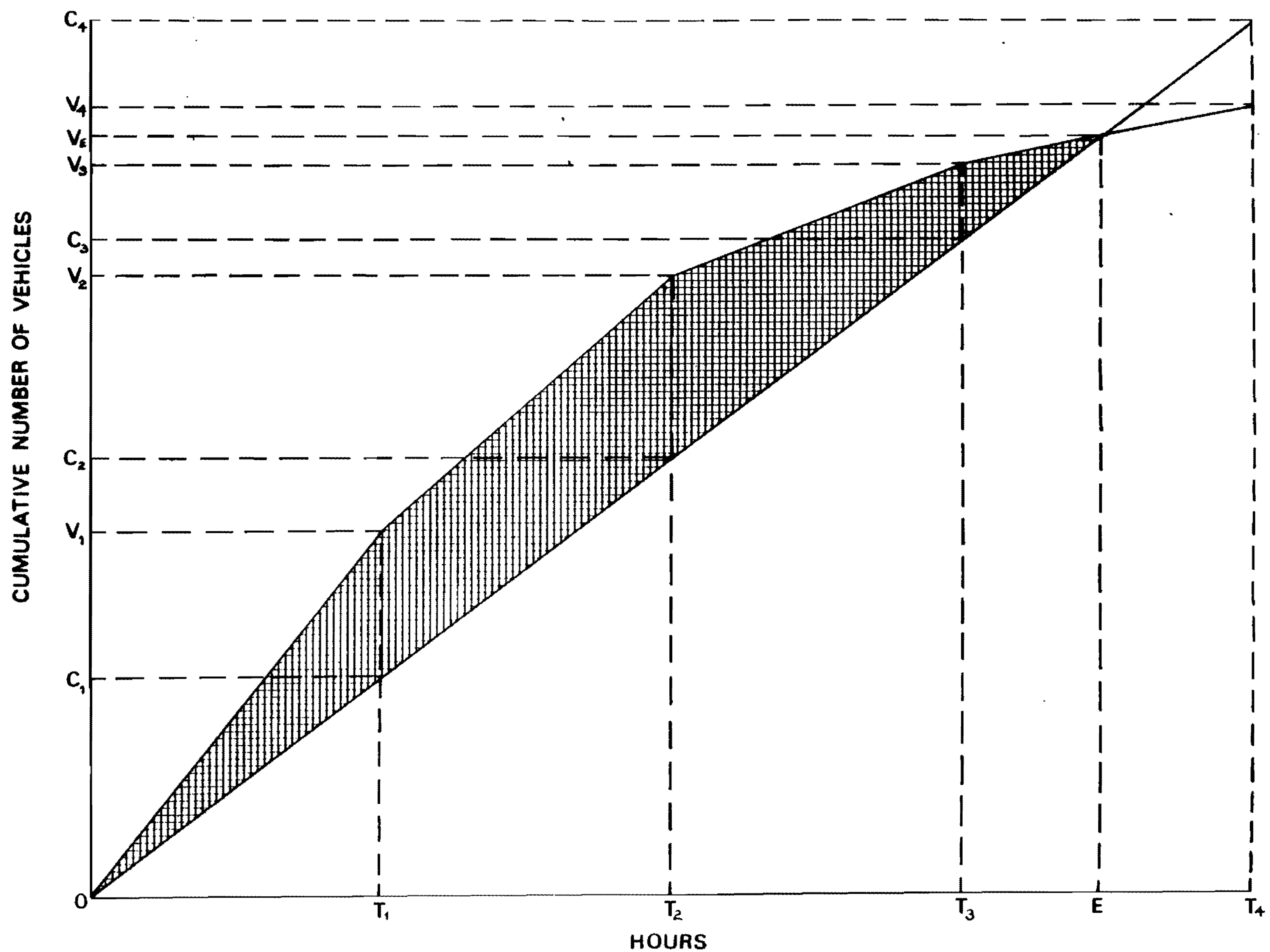
VL_i = vehicle demand during hour i

An example is presented graphically in Figure 4. The times along the horizontal axis represent hours, so T_1 = hour 1, T_2 = hour 2, etc. The V's along the vertical axis represent the number of accumulated vehicle demand at any given time. For example, V_1 represents the total number of vehicles in the first hour, V_2 represents the total number of vehicles in the first two hours, etc. The C's represent the work zone capacity. C_1 represents vehicle capacity for the first hour, C_2 represents vehicle capacity for the first two hours, etc. The shaded area represents the queue delay, the excess of vehicle demand above capacity. In the first hour, there is no queue at the beginning of the hour so $ACCUM_0 = 0$. The queue at the end of the hour, $ACCUM_1 = V_1 - C_1$, so the average delay during the first hour is

$$DQUE_1 = \frac{0 + (V_1 - C_1)}{2} = \frac{V_1 - C_1}{2}$$

The average delay for each of the next two hours can be calculated in exactly the same fashion. However, in the fourth hour the queue dissipates, therefore an adjustment must be made for that portion of the hour when the queue was present. The point E, the time when the queue dissipates, can be calculated by

FIGURE 4 CALCULATION OF QUEUE DELAY



solving the following equation. The left side of the equation is the capacity line during the fourth hour, and the right hand side is the volume demand line during the same hour.

$$(E-T_3)(C_4-C_3) = (E-T_3)(V_4-V_3) + (V_3-C_3)$$

$$(E-T_3)[(C_4-C_3)-(V_4-V_3)] = V_3 - C_3$$

$$E - T_3 = \frac{V_3 - C_3}{(C_4-C_3) - (V_4-V_3)}$$

$$E = T_3 + \frac{V_3 - C_3}{(C_4-C_3) - (V_4-V_3)}$$

Therefore if the queue dissipates during hour i, then the delay calculation must be modified by the proportion of the hour that a queue was present ($PQUE_i$).

$$PQUE_i = \frac{V_{i-1} - C_{i-1}}{(C_i-C_{i-1}) - (V_i-V_{i-1})} = \frac{ACUM_{i-1}}{CAPW_i-VL_i}$$

Average delay is then calculated as,

$$DQUE_i = \frac{ACUM_{i-1}}{2} \cdot PQUE_i$$

Once the average delay is calculated, then the cost of the delay ($CQUE_i$) is calculated as,

$$CQUE_i = (DQUE_i)(CUF)(PTC \cdot VLT_c + PTT \cdot VLT_t)$$

The average length of queue ($QUEL_i$), in miles, can also be estimated, assuming an average distance of 40 feet for each vehicle, and vehicles in the closed lane(s) will merge to the open lane(s) after the queue has formed. It appears that the number of vehicles remaining in the closed lane(s) is a function of the sight distance to the work zone and traffic volumes (9). Until more definitive data become available, the above assumption on vehicle merging will be used.

$$QUEL_i = \frac{40(DQUE_i)}{5280(TL)}$$

where TL = total number of lanes upstream of the work zone

For the hour when the queue dissipates,

$$QUEL_i = \frac{40(DQUE_i)}{5280(TL) \cdot PQUE_i}$$

Cost of Speed-Change Cycles

An additional delay cost which is included in QUEWZ is the delay cost of slowing down and returning to the approach speed, as a result of the presence of a work zone (CDSC). The "work zone data" indicates a relationship between the distance traveled, in miles, during the speed-change cycle (DSC) to be a function of the V/C ratio through the work zone,

$$DSC = 0.5 + 0.25(V/C_{wz}), \text{ with the constraint that } DSC \leq 0.75$$

If the speed is reduced and increased at an approximately constant rate, then the delay cost can be calculated from,

$$CDSC = (DSC)\left(\frac{2}{SP_{ap}+SP_{mn}} - \frac{1}{SP_{ap}}\right)(VL)(CUF)\left(PTC \cdot VLT_c + \frac{PTT \cdot VLT_t}{0.9}\right)$$

In order to estimate the change in vehicle operating costs resulting from the speed-change cycles, cost equations were developed from tabular data in the AASHTO Redbook (1) and updated to December 1981. The speed-change costs per 1000 vehicle miles for cars (SPCC) and trucks (SPCT) are calculated by,

$$SPCC = -5.2187 + 1.1241(SP_{ap}) - 1.1125(SP_{mn})$$

$$SPCT = -32.2883 + 7.1226(.9SP_{ap}) - 6.684(.9SP_{mn})$$

The additional operating cost of the speed-change cycle (CSPC) is,

$$CSPC = (\frac{VL}{1000})(CUF)(PTC \cdot SPCC + PTT \cdot SPCT)$$

If a queue is present, then additional speed-change operating costs (CSPQ) must be added. The "work zone data" indicate approximately three 0-10 mph speed-change cycles occur per mile of queue. herefore the cost can be calculated,

$$CSPQ = (\frac{VL}{1000})(CUF)(3 \cdot QUEL)(6.0223 \cdot PTC + 31.8151 \cdot PTT)$$

During the hour the queue dissipates, the above equation for CSPQ is multiplied by PQUE.

Change in Vehicle Running Costs

Vehicle running costs are also affected by changes in average speeds. The change in car running costs (VOC_c) and truck running costs (VOC_t) per 1000 vehicle miles can be calculated by the following equations. These equations were also estimated from tabular data in the AASHTO Redbook (1), updated to December 1981.

$$VOC_c = f(SP_{wz}) - f(SP_{ap})$$

$$VOC_t = g(.9SP_{wz}) - g(.9SP_{ap})$$

$$\text{where } f(SP) = (395.6898)e^{.01537(SP)}SP^{-.45525}$$

$$g(SP) = (179.1466)e^{.02203(SP)}SP^{-.35902} + (1201.8847)e^{.0322(SP)}SP^{-.79202}$$

The change in vehicle running costs (OC) is then calculated as,

$$OC = (\frac{VL}{1000})(CUF)(CLL)(VOC_c \cdot PTC + VOC_t \cdot PTT)$$

If a queue forms, the average speed through the queue (SP_q) can be calculated using a formula in TTI Research Report 165-8 (10),

$$SP_q = (\frac{SP_1}{2})[1+(1-\frac{C_{wz}}{C_{ap}})^{\frac{1}{2}}]$$

where C_{ap} = normal capacity (vph)

The cost equations are:

$$QVOC_c = f(SP_q) - f(SP_{ap})$$

$$QVOC_t = g(.9SP_q) - g(.9SP_{ap})$$

$$OCQ = (\frac{VL}{1000})(CUF)(QUEL)(QVOC_c \cdot PTC + QVOC_t \cdot PTT)$$

During the hour the queue dissipates, OCQ is multiplied by PQUE.

Total User Costs

Total hourly user costs (THC) in each direction are merely the sum of the component user costs,

$$THC = CQUE + CDWZ + CDSC + CSPC + CSPQ + OC + OCQ$$

In similar fashion, the costs can be summed up to yield the daily user costs resulting from restricted capacity through the work zone.

APPENDIX B

Program Description

QUEWZ is a computerized program written in FORTRAN IV and designed for batch input. The program was tested on a WATFIV compiler but can be run on any ANSI 77 FORTRAN compiler. QUEWZ currently uses about 20K of memory and 0.97 seconds CPU time during execution on the WATFIV compiler for the twenty test problems. The source code is 435 lines long.

QUEWZ consists of a main program where input is read, arrays set up, most cost calculations performed, and output written out. There is one subroutine, OPCOST, which is called from the main program to calculate vehicle running costs per 1000 vehicle miles, given an average speed and percentage trucks.

This Appendix contains a computer generated flow chart, a variable dictionary, a program listing, and output for the sample problems presented in the section "Examples of the Model's Use."

```
C
C      QUEWZ MODEL - QUEUE AND USER COST EVALUATION OF A WORK ZONE
C

EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
E      CHARACTER*1 DIR                                                        E
EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                                        I
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
.      CHARACTER*1 TIME                                                       .
.      CHARACTER*1 VT                                                         .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
                                        I
       INTEGER OTL,BHR,EHR,BHW,EHW,OOL
       DIMENSION VT(4),KPROB(4),DIR(4),TIME(4),VOL(4,12),IT(2,2),VL(2,24)
      *,CP(6,5),SLP(6,5),CAPN(2),CAPR(2),CAPW(2),VLT(2),CQUE(2,24),VC(2),
      *SP(2),QUEL(2,24),CDSC(2,24),CDWZ(2,24),CSPC(2,24),CVOC(3),OC(2,24)
      *,OCQ(2,24),SPD(2,2,24),THC(2,24),THCQ(2,24),STL(24),CHAR(9),
      *NHR(24),CAP(2,24)
                                        I
C      VALUE OF TIME FOR CARS AND TRUCKS
                                        I
       DATA VLT/9.72,17.71/
                                        I
C      VALID LETTERS TO IDENTIFY DIRECTION AND TIME OF VOLUME DATA
                                        I
       DATA VT/'I','O','1','2'/
                                        I
C      INTERCEPT TERM FOR WORK ZONE CAPACITY EQUATION
                                        I
       DATA CP/0.0,1460.,1370.,1200.,1200.,1200.,0.0,0.0,1600.,
      *1580.,1460.,1400.,0.0,0.0,0.0,1560.,1500.,1500.,0.0,
      *0.0,0.0,0.0,1550.,1550.,0.,0.,0.,0.,0.,1580./
                                        I
C      SLOPE TERM FOR WORK ZONE CAPACITY EQUATION
                                        I
       DATA SLP/0.0,2.13,4.05,0.0,0.0,0.0,0.0,0.0,0.,1.81,1.6,1.46,0.,
      *0.0,0.0,0.0,0.57,0.0,0.0,0.0,0.0,0.0,0.0,0.,0.,0.,0.,0.,0.,0.,0./
                                        I
C      SET END FLAG AND PROBLEM COUNT TO ZERO
                                        I
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
.      IEND=0
.      IPROB=0                                                                .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
                                        I
                                        OK-------------------------------------------O
                                        I                                            I
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .           I
.    5 IPROB=IPROB+1                                                                 I
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .           I
                                        I                                            I
                                        I                                            I
                                        I                                            I
                                        I                                            I
                                        I                                            I
1 2 3 4 5 6 7 8 9 0                                          . 9 . 8 . 7  6 . 5 . 4 . 3 . 2  1
```

```
C     IF CAPACITY IS RESTRICTED, INBOUND KI=1, OUTBOUND KO=1
      IF (IEND.EQ.1) GOTO 99
      KI=0
      KO=0
      ID=0
      IFLAG=0
      SUM=0.0
C     ZERO ALL VOLUME, SPEED, AND COST ARRAYS FOR EACH PROBLEM
      DO 15 M=1,2
      DO 15 N=1,24
      DO 35 L=1,2
      SPD(L,M,N)=0.0
   35 CONTINUE
      CAP(M,N)=0.0
      VL(M,N)=0.0
      CQUE(M,N)=0.0
      CDSC(M,N)=0.0
      CDWZ(M,N)=0.0
      CSPC(M,N)=0.0
      OC(M,N)=0.0
      QUEL(M,N)=0.0
      THC(M,N)=0.0
      THCQ(M,N)=0.0
   15 CONTINUE
```

```
      DO 55 IZ=1,2
      DO 55 IY=1,2
      IT(IZ,IY)=0
   55 CONTINUE
C     READ IN FIRST CARD OF PROBLEM
C     IF CERF IS GREATER THAN 100, IT IS ASSUMED TO BE THE WORK ZONE
C     CAPACITY, AND THE PROGRAM GENERATED CAPACITY WILL NOT BE USED.
      READ (5,10,END=99,ERR=30)IPROB,MODEL,CUF,PT,SPF,SPCG,SPCAP,VOLCG,
     +VOLCAP,ITL,OTL,WZD,IOL,OOL,BHR,EHR,BHW,EHW,CERF,
     +(CHAR(JJ),JJ=1,9)
   10 FORMAT(I2,I1,F4.0,4F3.0,2F4.0,2I1,F4.0,2I1,4I2,F4.0,8A4,A1)
C     SET DEFAULT VALUES IF NOT PROVIDED FROM INPUT
      IF (CUF.EQ.0.0) CUF=1.0
      IF (PT.EQ.0.0) PT=8.0
      IF (SPF.EQ.0.0) SPF=60
      IF (SPCG.EQ.0.0) SPCG=40
      IF (SPCAP.EQ.0.0) SPCAP=30
      IF (VOLCG.EQ.0.0) VOLCG=1600.
      IF (VOLCAP.EQ.0.0) VOLCAP=2000
      IF (CERF.EQ.0.0) CERF=60
      IF (BHW.GT.0..OR.EHW.GT.0.) GOTO 9
      BHW=BHR
      EHW=EHR
C     PRINT ASSUMPTIONS FOR PROBLEM
```

```
      9 WRITE (6,11) IPROB,(CHAR(JK),JK=1,9),MODEL,CUF,PT,ITL,OTL,WZD,
     +IOL,OOL,BHR,EHR,BHW,EHW

   11 FORMAT('1',' PROBLEM ',I2,1X,9A4//' MODEL',T35,I1//' COST UPDATE F
     +ACTOR',T30,F6.2//' PERCENTAGE TRUCKS',T32,F4.0//' TOTAL NUMBER OF
     +LANES'/4X,'INBOUND',T35,I1/4X,'OUTBOUND',T35,I1//' LENGTH OF WORKZ
     +ONE',T30,F6.2,' MILES'//' WORKZONE OPEN LANES'/4X,'INBOUND',T35,I1
     +/4X,'OUTBOUND',T35,I1//' HOURS OF RESTRICTED CAPACITY'/4X,'BEGINNI
     +NG',T34,I2/4X,'ENDING',T34,I2//' HOURS OF WORKZONE ACTIVITY'/4X,'B
     +EGINNING',T34,I2/4X,'ENDING',T34,I2/)

      BHW=BHW+1
      BHR=BHR+1
      EHW=EHW+1
      EHR=EHR+1
      IF(EHW.GT.24) EHW=24
      IF(EHR.GT.24) EHR=24

      GOTO 40

   20 WRITE (6,12) IPROB

   12 FORMAT(/' HOURLY VOLUME DATA CARDS MISSING, WRONG, OR OUT OF ORDER
     + FOR PROBLEM ',I2)

      GOTO 99

   30 WRITE (6,13) IPROB

   13 FORMAT(/' ERROR IN HARDWARE READ, PROBLEM ',I2)

      GOTO 99
```

```
C      CHECK FOR VALID LAND CLOSURE STRATEGY NUMBER

                                        OK
                                         I
   40 IF (MODEL.EQ.1.OR.MODEL.EQ.2) GOTO 45
                                         I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W      WRITE (6,31) IPROB                                                        W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                         I
   31 FORMAT(/' INVALID LANE CLOSURE STRATEGY NUMBER ON PROBLEM ',I2)
                                         I
       GOTO 99

C      READ NEXT TWO CARDS IF LANE CLOSURE STRATEGY 1,
C      NEXT FOUR CARDS IF LANE CLOSURE STRATEGY 2

                                        OK
                                         I
   45 IM=MODEL+2
                                         I
       DO 50 I=1,IM
                                         I
RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
R      READ (5,14,END=60,ERR=70) KPROB(I),DIR(I),TIME(I),(VOL(I,J),
R     +J=1,12)
RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
                                         I
   14 FORMAT (I2,2A1,12F5.0)
                                         I
       IF (IPROB.NE.KPROB(I)) GOTO 20
                                         I
       GOTO 50
```

```
   70 IFLAG=KPROB(I)

      WRITE (6,13) KPROB(I)

   50 CONTINUE

      GOTO 65

   60 IEND=1

C     IF ERROR IN PROBLEM, GO TO NEXT PROBLEM

   65 IF (IFLAG.NE.0) GOTO 5

C     CHECK INBOUND DIRECTION FOR CAPACITY REDUCTION

      IF (ITL-IOL) 80,100,90

   80 WRITE (6,41) IPROB

   41 FORMAT(/' RESTRICTED CAPACITY GREATER THAN TOTAL CAPACITY - ',
     +'PROBLEM ',I2,'SKIPPED')

      GOTO 5
```

```
   90 KI=1

C      CHECK OUTBOUND DIRECTION FOR CAPACITY REDUCTION

  100 IF (OTL-OOL) 110,130,120

  110 WRITE(6,41) IPROB

      GOTO 5

  120 KO=1

C      SET UP (IT) ARRAY SUCH THAT TRAFFIC VOLUME CARD NO. WILL APPEAR IN
C      FOLLOWING LOCATION IT(1,1)=INB,AM, IT(1,2)=INB,PM, IT(2,1)=OUTB,AM
C      IT(2,2)=OUTB,PM

  130 DO 140 IR=1,IM

      IF (DIR(IR) EQ VT(1)) ID=1
      IF (DIR(IR) EQ VT(2)) ID=2

      IF (TIME(IR).NE VT(3)) GOTO 135

      IT(ID,1)=IR
```

```
      GOTO 140

      OK

  135 IF (TIME(IR).NE.VT(4)) GOTO 145

      IT(ID,2)=IR

      GOTO 140

      OK

  145 WRITE (6,29) IPROB

   29 FORMAT(/' INVALID TIME OR DIRECTION CODE-PROBLEM ',I2,' SKIPPED')

      GOTO 5

      OK

  140 CONTINUE

      IF (KI.LT.1) GOTO 165

      IF (IT(I,1).LT.1) GOTO 185

      IF (IT(I,2).LT.1) GOTO 185
```

```
  165 IF (KO.LT.1) GOTO 180

      IF (IT(2,1).LT.1) GOTO 185

      IF (IT(2,2).LT.1) GOTO 185

      GOTO 180

  185 WRITE(6,49) IPROB

   49 FORMAT(/' DIRECTION ON TRAFFIC CARDS DO NOT MATCH DIRECTION OF ',
     +'RESTRICTED CAPACITY - PROBLEM ',I2,' SKIPPED')

      GOTO 5

C     SET UP INBOUND AND/OR OUTBOUND TRAFFIC ARRAYS IF CAPACITY IS
C     RESTRICTED IN THAT DIRECTION VL(KS,KV)

  180 KT=2-KI
      KU=KO+1

C     IF NO CAPACITY REDUCTION, GO TO NEXT PROBLEM

      IF (KT.LE.KU) GOTO 155

      WRITE (6,33) IPROB
```

```
   33 FORMAT(' NO CAPACITY REDUCTON, PROBLEM ',I2,' SKIPPED')
      GOTO 5
  155 DO 150 KS=KT,KU
      DO 160 KV=1,12
      VL(KS,KV)=VOL(IT(KS,1),KV)
      KW=KV+12
      VL(KS,KW)=VOL(IT(KS,2),KV)
  160 CONTINUE
  150 CONTINUE
C     CALCULATE USER COSTS IA=1 IF INBOUND COSTS, IA=2 IF OUTBOUND COSTS
      DO 200 IA=1,2
      ACUM=0.0
C     CALCULATE CAPACITIES CAPN=NORMAL CAPACITY, CAPR=RESTRICTED
C     CAPACITY DURING NONWORKZONE ACTIVITY HOURS, CAPW=CAPACITY
C     DURING WORKZONE ACTIVITY HOURS
      IF (IA-1) 175,175,170
  175 IF (KI.EQ.0) GOTO 200
```

```
      CAPN(1)=VOLCAP*ITL
      CAPR(1)=VOLCAP*IOL*0.9
      CAPW(1)=(CP(ITL,IOL)-SLP(ITL,IOL)*CERF)*IOL

C     CHECK TO SEE IF WORK ZONE CAPACITY FROM INPUT DATA IS TO BE USED
C     INSTEAD OF PROGRAM GENERATED CAPACITY

      IF (CERF.GT.100.) CAPW(1)=CERF*IOL

      WRITE (6,16) CAPN(1),CAPR(1),CAPW(1)

   16 FORMAT(' INBOUND CAPACITY'/4X,'NORMAL ',T30,F6.0,' (VPH)'/4X,
     *'RESTRICTED ',T30,F6.0,' (VPH)'/4X,'WORKING HOURS ',T30,F6.0,
     *' (VPH)'/)

C     TEST TO DETERMINE IF USER INPUT CAPACITY IS GREATER THAN
C     RESTRICTED CAPACITY.  IF IT IS, CONTROL TRANSFERS TO THE NEXT
C     PROBLEM AND AN ERROR MESSAGE IS DISPLAYED.

      IF (CAPW(1).LT.CAPR(1)) GOTO 190

      WRITE (6,43) IPROB

   43 FORMAT (/' WORK ZONE CAPACITY GREATER THAN RESTRICTED CAPACITY -',
     *' PROBLEM ',I2,' SKIPPED'//' POSSIBLE SOURCE OF ERROR: USER-',
     *'SUPPLIED CAPACITY ESTIMATE GREATER THAN 90% OF NORMAL CAPACITY')

      GOTO 5

                                OK

  170 IF (KO.EQ.0) GOTO 200

      CAPN(2)=VOLCAP*OTL
      CAPR(2)=VOLCAP*OOL*0.9
      CAPW(2)=(CP(OTL,OOL)-SLP(OTL,OOL)*CERF)*OOL
```

```
C     CHECK TO SEE IF WORK ZONE CAPACITY FROM INPUT DATA IS TO BE USED
C     INSTEAD OF PROGRAM GENERATED CAPACITY

      IF (CERF.GT 100.) CAPW(2)=CERF*OOL

      WRITE (6,17) CAPN(2),CAPR(2),CAPW(2)

   17 FORMAT(' OUTBOUND CAPACITY',/4X,'NORMAL ',T29,F7.0,' (VPH)',/4X,
     +'RESTRICTED ',T29,F7.0,' (VPH)'/4X,'WORKING HOURS ',T29,F7.0,
     +' (VPH)'/)

C     TEST TO DETERMINE IF USER INPUT CAPACITY IS GREATER THAN
C     RESTRICTED CAPACITY.  IF IT IS, CONTROL TRANSFERS TO THE NEXT
C     PROBLEM AND AN ERROR MESSAGE IS DISPLAYED.

      IF (CAPW(2).LT CAPR(2)) GOTO 190

      WRITE (6,43) IPROB

      GOTO 5

C     CALCULATE USER COSTS FOR EACH HOUR J

                                OK

  190 DO 210 J=1,24

      IHR=0
      NHR(J)=0

C     SELECT APPROPRIATE CAPACITY THROUGH WORKZONE FOR HOUR J

      IF (J.GE.BHW.AND J LE EHW) GOTO 220
```

```
      IF (J.GE.BHR.AND.J.LE.EHR) GOTO 230

      CPP=CAPN(IA)
      CAP(IA,J)=CPP

      IF (ACUM.GT.0.) GOTO 240

      NHR(J)=1

      GOTO 210

                                                  OK

  220 CPP=CAPW(IA)
      CAP(IA,J)=CPP
      IHR=2

      GOTO 240

                                                  OK

  230 CPP=CAPR(IA)
      CAP(IA,J)=CPP
      IHR=1

C     CALCULATE DELAY IN QUEUE (DQUE), COST OF QUEUE (CQUE), AND LENGTH
C     OF QUEUE (QUEL). IQUE=1 WITH QUEUE, IQUE=2 HOUR QUEUE DISSIPATES
                                                  OK

  240 IF (VL(IA,J).GT.CPP) GOTO 250
```

```
      IF (ACUM.GT 0.0) GOTO 260

      IQUE=0

      GOTO 270

                                             OK

  250 IQUE=1
      EXD=VL(IA,J)-CPP
                                             OK

  255 DQUE=ACUM+EXD/2.
      PTC=1.-PT/100
      PTT=PT/100.
                                             OK

  265 CQUE(IA,J)=DQUE+CUF+(PTC+VLT(1)+PTT+VLT(2))

      IF (IA-1) 275,275,285

  275 ALN=ITL

      GOTO 295

                                             OK

  285 ALN=OTL
```

```
 295 QUEL(IA,J)=DQUE/(ALN+132 )

     IF (IQUE.NE 2) GOTO 335

     QUEL(IA,J)=QUEL(IA,J)/PQUE

 335 ACUM=ACUM+EXD
     IF (ACUM.LT.0.0) ACUM=0.0

     GOTO 270

 260 IQUE=1
     SRP=CPP-VL(IA,J)
     PQUE=ACUM/SRP
     EXD=-SRP

     IF (ACUM.GE.SRP) GOTO 255

     DQUE=(ACUM**2)/(2 *SRP)
     IQUE=2

     GOTO 265

C    CALCUALTE PARAMETERS FOR SPEED-VOLUME EQUATIONS
```

```
  270 SLO=VOLCAP+(SPCG-SPF)/VOLCG
      CGV=VOLCG/VOLCAP
      SPE=SPCG-SPCAP

C     CALCULATE V/C RATIO AND AVERAGE SPEED FOR NORMAL CONDITONS JC=1,
C     AND FOR RESTRICTED CAPACITY JC=2

      DO 280 JC=1,2

      IF (JC.EQ.2) GOTO 300

      VC(JC)=VL(IA,J)/CAPN(IA)

      GOTO 310

  300 VC(JC)=VL(IA,J)/CPP

      IF (IQUE EQ 1) GOTO 320

  310 IF (VC(JC) GT 1 ) GOTO 320

      IF (VC(JC)-CGV) 305,305,315

  305 SP(JC)=SPF+SLO*VC(JC)
```

```
      GOTO 325

  OK

  315 SP(JC)=SPCAP*SPE*SQRT(1.-((VC(JC)-CGV)/(1.-CGV))**2)

  OK

  325 IF (IQUE.EQ.2.AND.JC.EQ.2)SP(JC)=(1.-PQUE)*SP(JC)+PQUE*SPCAP

      GOTO 280

  OK

  320 SP(JC)=SPCAP*(2.-VC(JC))
      IF (SP(JC).LT.20.) SP(JC)=20
      IF (SP(JC).GT.SPCAP) SP(JC)=SPCAP
      VC(JC)=1.

  OK

  280 CONTINUE

C     CALCULATE MINIMUM SPEED (SPMN) FOR SPEED-CYCLE COST CALCULATION

      IF (IQUE.EQ.1) GOTO 330

      SPMN=SP(2)-2.3-25.7*(VC(2)**2)
      IF (IQUE.EQ.2) SPMN=SPMN*(1.-PQUE)

      IF (SPMN.GE.0.0) GOTO 340
```

```
  330 SPMN=0.0

C      CALCULATE LENGTH OF REDUCED SPEED THROUGH WORK ZONE ARES (CLL)

  340 IF (WZD.LE.0.1) GOTO 350

      CLL=0.1+(WZD+0.1)+VC(2)

      GOTO 360

  350 CLL=WZD+0.2

C      CALCULATE DISTANCE (DSC) AND DELAY COST (CDSC) OF SLOWING DOWN AND
C      RETURNING TO APPROACH SPEED

  360 DSC=0.5+0.25+VC(2)
      PTT=PT/100.
      PTC=1.-PT/100
      CDSC(IA,J)=DSC+(2./(SP(1)+SPMN)-1./SP(1))+VL(IA,J)+CUF+
     +(PTC+VLT(1)+PTT/0.9+VLT(2))

C      CALCULATE DELAY COST OF REDUCED SPEED THROUGH WORK ZONE (CDWZ)

      CDWZ(IA,J)=CLL+(1./SP(2)-1./SP(1))+VL(IA,J)+CUF+(PTC+VLT(1)+PTT/
     + 0.9+VLT(2))

C      CALCULATE COST OF SPEED CHANGE CYCLE (CSPC)

      SPCC=-5.2187+1.1241+SP(1)-1.1125+SPMN
      IF (SPCC.LT.0.0) SPCC=0.0
      SPCT=-32.2883+7.1226+0.9+SP(1)-6.684+SPMN+0.9
      IF (SPCT.LT.0.0) SPCT=0.0
```

```
      CSPC(IA,J)=VL(IA,J)+CUF+(PTC+SPCC+PTT+SPCT)/1000.
C     ADD COST OF QUEUE CYCLING COSTS IF THERE IS A QUEUE
      IF (IQUE.EQ.0) GOTO 370
      CSPQ=(6.0223+PTC+31.8151+PTT)+CUF+VL(IA,J)+3.+QUEL(IA,J)/1000.
      IF (IQUE.EQ.2) CSPQ=CSPQ+PQUE
      CSPC(IA,J)=CSPC(IA,J)+CSPQ
C     CALCULATE RUNNING COST DIFFERENCE THROUGH WORK ZONE (OC)
  370 DO 380 IOP=1,2
      SPEED=SP(IOP)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     CALL OPCOST(SPEED,PT,VOC)                                         C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      CVOC(IOP)=VOC+VL(IA,J)/1000
  380 CONTINUE
      OC(IA,J)=(CVOC(2)-CVOC(1))+CLL+CUF
C     ADD TO RUNNING COSTS THE ADDITIONAL QUEUE RUNNING COSTS IF ANY
      IF (IQUE.EQ.0) GOTO 390
      SPE=SPF/2.+(1-SQRT(1.-CPP/CAPN(IA)))
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      CALL OPCOST(SPEED, PT,VOC)                                        C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

       CVOC(3)=VOC*VL(IA,J)/1000.
       OCQ(IA,J)=(CVOC(3)-CVOC(1))*QUEL(IA,J)*CUF
       IF (IQUE.EQ.2) OCQ(IA,J)=OCQ(IA,J)+PQUE
       OC(IA,J)=OC(IA,J)+OCQ(IA,J)

C      SUM UP COSTS TO GET TOTAL HOURLY USER COST (THC) IN EACH DIRECTION

  390 THC(IA,J)=CDSC(IA,J)+CDWZ(IA,J)+CSPC(IA,J)+OC(IA,J)+CQUE(IA,J)

C      CALCULATE HOURLY COST PER MILE QUEUE (THCQ)

       IF (QUEL(IA,J).EQ.0.0) GOTO 400

       THCQ(IA,J)=THC(IA,J)/QUEL(IA,J)

C      PUT SPEEDS INTO ARRAY FOR OUTPUT

  400 DO 410 IS=1,2

       SPD(IS,IA,J)=SP(IS)

  410 CONTINUE

C      SUM HOURLY USER COSTS INTO DAILY TOTAL

       SUM=SUM+THC(IA,J)
```

```
      210 CONTINUE

      200 CONTINUE

C     SUM HOURLY COSTS FOR EACH DIRECTION FOR TOTAL HOURLY COSTS

          DO 420 ISM=1,24

          STL(ISM)=THC(1,ISM)+THC(2,ISM)

      420 CONTINUE

C     WRITE OUT CAPACITY ESTIMATE RISK FACTOR  IF WORK ZONE CAPACITY
C     IS CALCULATED IN PROGRAM AND IS NOT PART OF INPUT DATA

          IF (CERF.GT.100.) GOTO 430

          WRITE(6,37) CERF

       37 FORMAT (' CAPACITY ESTIMATE RISK FACTOR,'/
         +' PROBABILITY THAT ESTIMATED'/' WORKING HOURS CAPACITY IS'/
         +' LESS THAN ACTUAL CAPACITY',T32,F4.0,' PERCENT'/)

C     WRITE OUT SUMMARY HEADINGS

      430 WRITE (6,18) IPROB

       18 FORMAT('1',48X,'SUMMARY OF USER COSTS - PROBLEM ',I2,//19X,
         +'*** INBOUND DIRECTION ***',18X,'*',15X,'*** OUTBOUND ',
         +'DIRECTION ***',14X,'* TOTAL ADD.')

          WRITE (6,19)
```

```
   19 FORMAT('  HOUR   VOLUME  CAPACITY  APRCH  WORK    LENGTH',
     +T51,'ADDITIONAL  +  VOLUME  CAPACITY  APRCH  WORK   LENGTH',
     +T107,'ADDITIONAL  + HOURLY USER')

      WRITE (6,21)

   21 FORMAT(9X,'(VPH)     (VPH)     SPEED  ZONE',5X,'OF',7X,'HOURLY',
     +T63,'+  (VPH)     (VPH)',4X,'SPEED  ZONE',5X,'OF',7X,'HOURLY',
     +T119,'+  COSTS DUE')

      WRITE (6,22)

   22 FORMAT(27X,'(MPH)  SPEED   QUEUE   USER COSTS  +',T84,'(MPH)',
     +2X,'SPEED   QUEUE   USER COSTS  +   TO LANE')

      WRITE (6,23)

   23 FORMAT(34X,'(MPH)  (MILES)',5X,'($)',6X,'+',T91,'(MPH)  (MILES)',
     +5X,'($)',6X,'+ CLOSURE ($)'/)
C     WRITE OUT CALCULATED USER DATA FOR EACH HOUR AND DAILY TOTAL

      DO 450 LC=1,24

      LC1=LC-1

      WRITE(6,39) LC1,LC

   39 FORMAT(1X,I2,'-',I2)

      IF(NHR(LC) EQ 1) GOTO 440

      IF (KI EQ.0) GOTO 440

      WRITE (6,24) VL(1,LC),CAP(1,LC),SPD(1,1,LC),SPD(2,1,LC),QUEL(1,LC)
```

```
   24 FORMAT('+',T9,F7.0,2X,F7.0,3X,F4.0,3X,F4.0,T41,F6.1)
                                      OK

W  440 WRITE (6,25) THC(1,LC)                                              W

   25 FORMAT('+',T52,F8.0,T63,'*')

.       IF(NHR(LC).EQ.1) GOTO 460

.       IF (KO.EQ.0) GOTO 460

W       WRITE (6,26) VL(2,LC),CAP(2,LC),SPD(1,2,LC),SPD(2,2,LC),QUEL(2,LC)W

   26 FORMAT ('+',T65,F7.0,T74,F7.0,T84,F4.0,T92,F4.0,T97,F6.1)
                                      OK

W  460 WRITE (6,27) THC(2,LC),STL(LC)                                      W

   27 FORMAT ('+',T108,F8.0,T119,'+',T121,F9.0/)

.  450 CONTINUE                                                            .

W       WRITE (6,28) SUM                                                   W

   28 FORMAT (5X,'TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE',
     *' CLOSURE = ',F10.0,/)

C       WRITE OUT WARNING IF QUEUE GREATER THAN A MILE

.       QMAX=0.                                                            .

        DO 500 I=1,2
```

```
      DO 500 J=1,24
      IF (QUEL(I,J) GT.QMAX) QMAX=QUEL(I,J)
  500 CONTINUE
      IF (QMAX.LE.1.) GOTO 480
      WRITE (6,42) QMAX
   42 FORMAT (' *** WARNING *** QUEUE ESTIMATED TO REACH ',F6.1,' MILES'
     *,' LONG.  QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY ',
     *'TO DIVERT '/'                TO OTHER ROUTES. CHECK ALTERNATE ',
     *'ROUTES - DIVERSION MAY TAKE PLACE.')
C     GO TO NEXT PROBLEM, IF ANY
  480 IF (IEND.EQ.1) GOTO 99
      GOTO 5
   99 STOP
      END
```

```
FORTCHT, VERSION A1      MAINTAINED BY DALE L. SCHAFER,    PHONE 845-1714
 E=ENTRY, T=TERMINAL, C=CALL, R=READ, W=WRITE
                        C

                        EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                        E      SUBROUTINE OPCOST(SP,PTR,CST)                                    E
                        EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                                                             I
                        C
                        C      CALCULATES RUNNING COSTS PER 1000 VEHICLE MILES, GIVEN SPEED AND
                        C      PERCENTAGE TRUCKS
                                                             I
                        .      SPC=SP                                                          .
                        .      SPT=SP*0.9                                                      .
                        .      PT=PTR/100.                                                     .
                                                             I
                        C      CAR RUNNING COSTS
                                                             I
                        .      CR=395.6898*EXP(.0157*SPC)*(SPC)**(-.45525)                     .
                                                             I
                        C      TRUCK RUNNING COSTS
                                                             I
                        .      TK=179.1466*EXP(.02203*SPT)*(SPT)**(-.35902)+(1201.8847*        .
                        .     *EXP(.0322*SPT)*(SPT)**(-.79202))                                .
                        .      CST=((1.-PT)*CR+PT*TK)                                          .
                                                             I
                        TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT
                        T      RETURN                                                          T
                        TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT

                        .      END                                                             .
```

Variable Dictionary

Main Program

ACUM	accumulated number of vehicles in queue at beginning of hour
ALN	total number of lanes upstream of queue
BHR	beginning hour of restricted capacity
BHW	beginning hour of work zone activity
CAP(2,24)	capacity array (vph) for output, in direction IA, hour J
CAPN(2)	normal vehicle capacity (vph) in each direction
CAPR(2)	restricted vehicle capacity (vph) during work zone inactivity hours
CAPW(2)	restricted vehicle capacity (vph) during work zone activity hours
CDSC(2,24)	delay cost ($) of slowing down and returning to approach speed, direction IA, hour J
CDWZ(2,24)	delay cost ($) of reduced speed through work zone, direction IA, hour J
CERF	capacity estimate risk reduction factor or work zone capacity per lane from input
CGV	V/C ratio at LOS D/E breakpoint
CHAR(9)	array to hold problem description
CLL	length of reduced speed through work zone area (miles)
CP(6,5)	intercept term for work zone capacity equation, up to 6 total lanes and 5 open lanes through direction of closure
CPP	vehicle capacity (vph) in direction IA, hour J, which is used in user cost calculations
CQUE(2,24)	cost of queue delay ($) in direction IA, hour J
CSPQ	cost of speed-change cycles in queue ($)
CUF	cost update factor from input
CVOC(3)	hourly vehicle running cost per mile, CVOC(1) = running cost at approach speed, CVOC(2) = running cost at restricted speed, CVOC(3) = running cost at queue speed

DIR(4)	direction of traffic for each hourly traffic volume input card, DIR = I for inbound, DIR = 0 for outbound
DQUE	vehicle hours of queue delay during hour J
DSC	distance of slowing down and returning to approach speed (miles)
EHR	ending hour of restricted capacity
EHW	ending hour of work zone activity
EXD	excess demand of traffic volume during hour J
I	index for direction of travel for calculating maximum queue length, QMAX
IA	loop index to calculate user costs, IA = 1 if inbound costs, IA = 2 if outbound costs
ID	index to indicate the direction of travel for each traffic volume card, ID = 1 if inbound, ID = 2 if outbound
IEND	index to indicate end of file, IEND = 1 if end of file, IEND = 0 otherwise
IFLAG	index to indicate problem number when there is an error in the read command
IHR	index for type of capacity restriction, IHR = 1 if work zone inactivity hour, IHR = 2 if work zone activity hour, IHR = 0 if capacity not restricted during hour
IM	number of traffic volume cards to be read for problem, IM = 2 if single-lane closure, IM = 4 if crossover
IOL	number of open lanes, inbound direction
IOP	index to indicate capacity reduction for cost calculations, IOP = 1 for normal conditions, IOP = 2 for restricted capacity
IPROB	problem number from input data
IQUE	queue index, IQUE = 0 if there is no queue during hour J, IQUE = 1 if there is a queue during entire hour J, IQUE = 2 if queue dissipates during hour J
IR	index for the volume card being put into array IT(2,2)
IS	index to put speeds into final array for output
ISM	index to sum hourly user costs to daily user costs total

IT(2,2)	traffic volume card array, IT(1,1) = inbound, period 1; IT(1,2) = inbound, period 2; IT(2,1) = outbound, period 1; IT(2,2) = outbound, period 2
ITL	total number of inbound lanes
IY	index to zero out traffic card array for each problem
IZ	index to zero out traffic card array for each problem
J	loop index for each hour 1-24, to calculate hourly user costs
JC	index to calculate V/C ratio, JC = 1 for normal conditions, JC = 2 for restricted capacity
KI	index of inbound capacity restriction, KI = 1 if capacity restricted in inbound direction, KI = 0 otherwise
KO	index of outbound capacity restriction, KO = 1 if capacity restricted in outbound direction, KO = 0 otherwise
KPROB(4)	problem number on traffic volume card
KS	index for traffic card to set up traffic volume arrays
KT	lower bound to set up traffic volume arrays, KT = 1 if KI = 1, KT = 2 if KI = 0
KU	upper bound to set up traffic volume arrays, KU = 1 if KO = 0, KT = 2 if KO = 1
KV	hour index 1-12, to set up traffic volume arrays
KW	hour index 13-24, to set up traffic volume arrays
L	index to zero out accumulated arrays for each problem
LC	index to write out hourly user data
LC1	beginning of hour for hourly user cost output data
M	index to zero out accumulated arrays for each problem
MODEL	closure strategy, MODEL = 1 if single-lane closure, MODEL = 2 if crossover
N	index to zero out accumulated arrays for each problem
NHR(24)	index of capacity reduction during hour J, NHR = 1 if no capacity reduction, NHR = 0 otherwise
OC(2,24)	change in hourly running cost through work zone ($)

OCQ(2,24)	change in hourly running cost through queue ($)
OOL	number of open lanes, outbound direction
OTL	total number of outbound lanes
PQUE	proportion of the hour the queue is present, for calculations during hour queue dissipates
PT	percentage trucks from input data
PTC	percentage cars ÷ 100
PTT	percentage trucks ÷ 100
QMAX	longest queue length during closure period (miles)
QUEL(2,24)	average length of queue (miles) in direction IA, hour J
SLO	slope term for speed-volume equation
SLP(6,5)	slope term for work zone capacity equation, up to 6 total lanes and 5 open lanes through direction of closure
SP(2)	speed through work zone (mph), SP(1) = speed with no capacity restrictions, SP(2) = speed with restricted capacity
SPCAP	capacity speed (mph) from input data
SPCC	car speed-change cycling cost per 1000 vehicles ($)
SPCG	LOS D/E breakpoint speed (mph) from input data
SPCT	truck speed-change cycling cost per 1000 vehicles ($)
SPD(2,2,24)	array of average speeds (mph) for output
SPE	difference between LOS D/E breakpoint speed and capacity speed, used in speed-volume equation
SPEED	average speed (mph) for vehicle running cost calculations
SPF	free flow speed (mph)
SPMN	minimum speed (mph) for speed-cycle cost calculations
SRP	surplus of vehicles that capacity exceeds demand for hours when queue is reduced
STL(24)	total additional hourly user costs in both directions ($)

SUM	total additional daily user costs due to lane closure ($), the sum of the hourly user costs
THC(2,24)	total additional hourly user cost in each direction ($)
THCQ(2,24)	total additional hourly cost per mile of queue ($)
TIME(4)	period index for each hourly traffic input data card, TIME = 1 for first 12 hours, TIME = 2 for second 12 hours
VC(2)	V/C ratio, VC(1) = V/C ratio for normal conditions, VC(2) = V/C ratio for restricted capacity
VL(2,24)	hourly traffic volumes for 24 hour period, each direction
VLT(2)	value of time ($/hr.), VLT(1) = car value of time, VLT(2) = truck value of time
VOC	running cost per 1000 vehicle miles ($)
VOL(4,12)	hourly traffic volumes (vph) from input data
VOLCAP	capacity volume per lane (vph)
VOLCG	LOS D/E breakpoint volume per lane (vph)
VT(4)	acceptable characters for direction and period on traffic data input cards, VT(1) = I, VT(2) = 0, VT(3) = 1, VT(4) = 2
WZD	length of work zone (miles)

Subroutine OPCOST

CR	car running cost per 1000 vehicle miles ($)
CST	total running cost per 1000 vehicle miles ($)
PT	percentage trucks ÷ 100
PTR	percentage trucks
SP	average speed (mph)
SPC	average car speed (mph)
SPT	average truck speed (mph)
TK	truck running cost per 1000 vehicle miles ($)

Program Listing

```
C
C     QUEWZ MODEL - QUEUE AND USER COST EVALUATION OF A WORK ZONE
C
      CHARACTER*1 DIR
      CHARACTER*1 TIME
      CHARACTER*1 VT
      INTEGER OTL,BHR,EHR,BHW,EHW,OOL
      DIMENSION VT(4),KPROB(4),DIR(4),TIME(4),VOL(4,12),IT(2,2),VL(2,24)
     *,CP(6,5),SLP(6,5),CAPN(2),CAPR(2),CAPW(2),VLT(2),CQUE(2,24),VC(2),
     *SP(2),QUEL(2,24),CDSC(2,24),CDWZ(2,24),CSPC(2,24),CVOC(3),OC(2,24)
     *,OCQ(2,24),SPD(2,2,24),THC(2,24),THCQ(2,24),STL(24),CHAR(9),
     *NHR(24),CAP(2,24)
C     VALUE OF TIME FOR CARS AND TRUCKS
      DATA VLT/9.72,17.71/
C     VALID LETTERS TO IDENTIFY DIRECTION AND TIME OF VOLUME DATA
      DATA VT/'I','O','1','2'/
C     INTERCEPT TERM FOR WORK ZONE CAPACITY EQUATION
      DATA CP/0.0,1460.,1370.,1200.,1200.,1200.,0.0,0.0,1600.,
     *1580.,1460.,1400.,0.0,0.0,0.0,1560.,1500.,1500.,0.0,
     *0.0,0.0,0.0,1550.,1550.,0.,0.,0.,0.,0.,1580./
C     SLOPE TERM FOR WORK ZONE CAPACITY EQUATION
      DATA SLP/0.0,2.13,4.05,0.0,0.0,0.0,0.0,0.,1.81,1.6,1.46,0.,
     *0.0,0.0,0.0,0.57,0.0,0.0,0.0,0.0,0.0,0.0,0.,0.,0.,0.,0.,0.,0.,0./
C     SET END FLAG AND PROBLEM COUNT TO ZERO
      IEND=0
      IPROB=0
    5 IPROB=IPROB+1
C     IF CAPACITY IS RESTRICTED, INBOUND KI=1, OUTBOUND KO=1
      IF (IEND.EQ.1) GOTO 99
      KI=0
      KO=0
      ID=0
      IFLAG=0
      SUM=0.0
C     ZERO ALL VOLUME, SPEED, AND COST ARRAYS FOR EACH PROBLEM
      DO 15 M=1,2
      DO 15 N=1,24
      DO 35 L=1,2
      SPD(L,M,N)=0.0
   35 CONTINUE
      CAP(M,N)=0.0
      VL(M,N)=0.0
      CQUE(M,N)=0.0
      CDSC(M,N)=0.0
      CDWZ(M,N)=0.0
      CSPC(M,N)=0.0
      OC(M,N)=0.0
      QUEL(M,N)=0.0
      THC(M,N)=0.0
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      THCQ(M,N)=0.0
   15 CONTINUE
      DO 55 IZ=1,2
      DO 55 IY=1,2
      IT(IZ,IY)=0
   55 CONTINUE
C     READ IN FIRST CARD OF PROBLEM
C     IF CERF IS GREATER THAN 100, IT IS ASSUMED TO BE THE WORK ZONE
C     CAPACITY, AND THE PROGRAM GENERATED CAPACITY WILL NOT BE USED.
      READ (5,10,END=99,ERR=30)IPROB,MODEL,CUF,PT,SPF,SPCG,SPCAP,VOLCG,
     *VOLCAP,ITL,OTL,WZD,IOL,OOL,BHR,EHR,BHW,EHW,CERF,
     *(CHAR(JJ),JJ=1,9)
   10 FORMAT(I2,I1,F4.0,4F3.0,2F4.0,2I1,F4.0,2I1,4I2,F4.0,8A4,A1)
C     SET DEFAULT VALUES IF NOT PROVIDED FROM INPUT
      IF (CUF.EQ.0.0) CUF=1.0
      IF (PT.EQ.0.0) PT=8.0
      IF (SPF.EQ.0.0) SPF=60.
      IF (SPCG.EQ.0.0) SPCG=40.
      IF (SPCAP.EQ.0.0) SPCAP=30.
      IF (VOLCG.EQ.0.0) VOLCG=1600.
      IF (VOLCAP.EQ.0.0) VOLCAP=2000.
      IF (CERF.EQ.0.0) CERF=60.
      IF (BHW.GT.0..OR.EHW.GT.0.) GOTO 9
      BHW=BHR
      EHW=EHR
C     PRINT ASSUMPTIONS FOR PROBLEM
    9 WRITE (6,11) IPROB,(CHAR(JK),JK=1,9),MODEL,CUF,PT,ITL,OTL,WZD,
     *IOL,OOL,BHR,EHR,BHW,EHW
   11 FORMAT('1',' PROBLEM ',I2,1X,9A4//' MODEL',T35,I1//' COST UPDATE F
     *ACTOR',T30,F6.2//' PERCENTAGE TRUCKS',T32,F4.0//' TOTAL NUMBER OF
     *LANES'/4X,'INBOUND',T35,I1/4X,'OUTBOUND',T35,I1//' LENGTH OF WORKZ
     *ONE',T30,F6.2,' MILES'//' WORKZONE OPEN LANES'/4X,'INBOUND',T35,I1
     */4X,'OUTBOUND',T35,I1//' HOURS OF RESTRICTED CAPACITY'/4X,'BEGINNI
     *NG',T34,I2/4X,'ENDING',T34,I2//' HOURS OF WORKZONE ACTIVITY'/4X,'B
     *EGINNING',T34,I2/4X,'ENDING',T34,I2/)
      BHW=BHW+1
      BHR=BHR+1
      EHW=EHW+1
      EHR=EHR+1
      IF(EHW.GT.24) EHW=24
      IF(EHR.GT.24) EHR=24
      GOTO 40
   20 WRITE (6,12) IPROB
   12 FORMAT(/' HOURLY VOLUME DATA CARDS MISSING, WRONG, OR OUT OF ORDER
     * FOR PROBLEM ',I2)
      GOTO 99
   30 WRITE (6,13) IPROB
   13 FORMAT(/' ERROR IN HARDWARE READ, PROBLEM ',I2)
      GOTO 99
```

```
C     CHECK FOR VALID LAND CLOSURE STRATEGY NUMBER
   40 IF (MODEL.EQ.1.OR.MODEL.EQ.2) GOTO 45
      WRITE (6,31) IPROB
   31 FORMAT(/' INVALID LANE CLOSURE STRATEGY NUMBER ON PROBLEM ',I2)
      GOTO 99
C     READ NEXT TWO CARDS IF LANE CLOSURE STRATEGY 1,
C     NEXT FOUR CARDS IF LANE CLOSURE STRATEGY 2
   45 IM=MODEL*2
      DO 50 I=1,IM
      READ (5,14,END=60,ERR=70) KPROB(I),DIR(I),TIME(I),(VOL(I,J),
     *J=1,12)
   14 FORMAT (I2,2A1,12F5.0)
      IF (IPROB.NE.KPROB(I)) GOTO 20
      GOTO 50
   70 IFLAG=KPROB(I)
      WRITE (6,13) KPROB(I)
   50 CONTINUE
      GOTO 65
   60 IEND=1
C     IF ERROR IN PROBLEM, GO TO NEXT PROBLEM
   65 IF (IFLAG.NE.0) GOTO 5
C     CHECK INBOUND DIRECTION FOR CAPACITY REDUCTION
      IF (ITL-IOL) 80,100,90
   80 WRITE (6,41) IPROB
   41 FORMAT(/' RESTRICTED CAPACITY GREATER THAN TOTAL CAPACITY - ',
     *'PROBLEM ',I2,'SKIPPED')
      GOTO 5
   90 KI=1
C     CHECK OUTBOUND DIRECTION FOR CAPACITY REDUCTION
  100 IF (OTL-OOL) 110,130,120
  110 WRITE(6,41) IPROB
      GOTO 5
  120 KO=1
C     SET UP (IT) ARRAY SUCH THAT TRAFFIC VOLUME CARD NO. WILL APPEAR IN
C     FOLLOWING LOCATION IT(1,1)=INB,AM, IT(1,2)=INB,PM, IT(2,1)=OUTB,AM
C     IT(2,2)=OUTB,PM
  130 DO 140 IR=1,IM
      IF (DIR(IR).EQ.VT(1)) ID=1
      IF (DIR(IR).EQ.VT(2)) ID=2
      IF (TIME(IR).NE.VT(3)) GOTO 135
      IT(ID,1)=IR
      GOTO 140
  135 IF (TIME(IR).NE.VT(4)) GOTO 145
      IT(ID,2)=IR
      GOTO 140
  145 WRITE (6,29) IPROB
   29 FORMAT(/' INVALID TIME OR DIRECTION CODE-PROBLEM ',I2,' SKIPPED')
      GOTO 5
  140 CONTINUE
```

```
      IF (KI.LT.1) GOTO 165
      IF (IT(1,1).LT.1) GOTO 185
      IF (IT(1,2).LT.1) GOTO 185
  165 IF (KO.LT.1) GOTO 180
      IF (IT(2,1).LT.1) GOTO 185
      IF (IT(2,2).LT.1) GOTO 185
      GOTO 180
  185 WRITE(6,49) IPROB
   49 FORMAT(/' DIRECTION ON TRAFFIC CARDS DO NOT MATCH DIRECTION OF ',
     *'RESTRICTED CAPACITY - PROBLEM ',I2,' SKIPPED')
      GOTO 5
C     SET UP INBOUND AND/OR OUTBOUND TRAFFIC ARRAYS IF CAPACITY IS
C     RESTRICTED IN THAT DIRECTION VL(KS,KV)
  180 KT=2-KI
      KU=KO+1
C     IF NO CAPACITY REDUCTION, GO TO NEXT PROBLEM
      IF (KT.LE.KU) GOTO 155
      WRITE (6,33) IPROB
   33 FORMAT(' NO CAPACITY REDUCTON, PROBLEM ',I2,' SKIPPED')
      GOTO 5
  155 DO 150 KS=KT,KU
      DO 160 KV=1,12
      VL(KS,KV)=VOL(IT(KS,1),KV)
      KW=KV+12
      VL(KS,KW)=VOL(IT(KS,2),KV)
  160 CONTINUE
  150 CONTINUE
C     CALCULATE USER COSTS IA=1 IF INBOUND COSTS, IA=2 IF OUTBOUND COSTS
      DO 200 IA=1,2
      ACUM=0.0
C     CALCULATE CAPACITIES CAPN=NORMAL CAPACITY, CAPR=RESTRICTED
C     CAPACITY DURING NONWORKZONE ACTIVITY HOURS, CAPW=CAPACITY
C     DURING WORKZONE ACTIVITY HOURS
      IF (IA-1) 175,175,170
  175 IF (KI.EQ.0) GOTO 200
      CAPN(1)=VOLCAP*ITL
      CAPR(1)=VOLCAP*IOL*0.9
      CAPW(1)=(CP(ITL,IOL)-SLP(ITL,IOL)*CERF)*IOL
C     CHECK TO SEE IF WORK ZONE CAPACITY FROM INPUT DATA IS TO BE USED
C     INSTEAD OF PROGRAM GENERATED CAPACITY
      IF (CERF.GT.100.) CAPW(1)=CERF*IOL
      WRITE (6,16) CAPN(1),CAPR(1),CAPW(1)
   16 FORMAT(' INBOUND CAPACITY'/4X,'NORMAL ',T30,F6.0,' (VPH)'/4X,
     *'RESTRICTED ',T30,F6.0,' (VPH)'/4X,'WORKING HOURS ',T30,F6.0,
     *' (VPH)'/)
C     TEST TO DETERMINE IF USER INPUT CAPACITY IS GREATER THAN
C     RESTRICTED CAPACITY.  IF IT IS, CONTROL TRANSFERS TO THE NEXT
C     PROBLEM AND AN ERROR MESSAGE IS DISPLAYED.
      IF (CAPW(1).LT.CAPR(1)) GOTO 190
```

```
      WRITE (6,43) IPROB
   43 FORMAT (/' WORK ZONE CAPACITY GREATER THAN RESTRICTED CAPACITY -',
     *' PROBLEM ',I2,' SKIPPED'//' POSSIBLE SOURCE OF ERROR: USER-',
     *'SUPPLIED CAPACITY ESTIMATE GREATER THAN 90% OF NORMAL CAPACITY')
      GOTO 5
  170 IF (KO.EQ.0) GOTO 200
      CAPN(2)=VOLCAP*OTL
      CAPR(2)=VOLCAP*OOL*0.9
      CAPW(2)=(CP(OTL,OOL)-SLP(OTL,OOL)*CERF)*OOL
C     CHECK TO SEE IF WORK ZONE CAPACITY FROM INPUT DATA IS TO BE USED
C     INSTEAD OF PROGRAM GENERATED CAPACITY
      IF (CERF.GT.100.) CAPW(2)=CERF*OOL
      WRITE (6,17) CAPN(2),CAPR(2),CAPW(2)
   17 FORMAT(' OUTBOUND CAPACITY',/4X,'NORMAL ',T29,F7.0,' (VPH)',/4X,
     *'RESTRICTED ',T29,F7.0,' (VPH)'/4X,'WORKING HOURS ',T29,F7.0,
     *' (VPH)'/)
C     TEST TO DETERMINE IF USER INPUT CAPACITY IS GREATER THAN
C     RESTRICTED CAPACITY.  IF IT IS, CONTROL TRANSFERS TO THE NEXT
C     PROBLEM AND AN ERROR MESSAGE IS DISPLAYED.
      IF (CAPW(2).LT.CAPR(2)) GOTO 190
      WRITE (6,43) IPROB
      GOTO 5
C     CALCULATE USER COSTS FOR EACH HOUR J
  190 DO 210 J=1,24
      IHR=0
      NHR(J)=0
C     SELECT APPROPRIATE CAPACITY THROUGH WORKZONE FOR HOUR J
      IF (J.GE.BHW.AND.J.LE.EHW) GOTO 220
      IF (J.GE.BHR.AND.J.LE.EHR) GOTO 230
      CPP=CAPN(IA)
      CAP(IA,J)=CPP
      IF (ACUM.GT.0.) GOTO 240
      NHR(J)=1
      GOTO 210
  220 CPP=CAPW(IA)
      CAP(IA,J)=CPP
      IHR=2
      GOTO 240
  230 CPP=CAPR(IA)
      CAP(IA,J)=CPP
      IHR=1
C     CALCULATE DELAY IN QUEUE (DQUE), COST OF QUEUE (CQUE), AND LENGTH
C     OF QUEUE (QUEL). IQUE=1 WITH QUEUE, IQUE=2 HOUR QUEUE DISSIPATES
  240 IF (VL(IA,J).GT.CPP) GOTO 250
      IF (ACUM.GT.0.0) GOTO 260
      IQUE=0
      GOTO 270
  250 IQUE=1
      EXD=VL(IA,J)-CPP
```

```
  255 DQUE=ACUM+EXD/2.
      PTC=1.-PT/100.
      PTT=PT/100.
  265 CQUE(IA,J)=DQUE*CUF*(PTC*VLT(1)+PTT*VLT(2))
      IF (IA-1) 275,275,285
  275 ALN=ITL
      GOTO 295
  285 ALN=OTL
  295 QUEL(IA,J)=DQUE/(ALN*132.)
      IF (IQUE.NE.2) GOTO 335
      QUEL(IA,J)=QUEL(IA,J)/PQUE
  335 ACUM=ACUM+EXD
      IF (ACUM.LT.0.0) ACUM=0.0
      GOTO 270
  260 IQUE=1
      SRP=CPP-VL(IA,J)
      PQUE=ACUM/SRP
      EXD=-SRP
      IF (ACUM.GE.SRP) GOTO 255
      DQUE=(ACUM**2)/(2.*SRP)
      IQUE=2
      GOTO 265
C     CALCUALTE PARAMETERS FOR SPEED-VOLUME EQUATIONS
  270 SLO=VOLCAP*(SPCG-SPF)/VOLCG
      CGV=VOLCG/VOLCAP
      SPE=SPCG-SPCAP
C     CALCULATE V/C RATIO AND AVERAGE SPEED FOR NORMAL CONDITONS JC=1,
C     AND FOR RESTRICTED CAPACITY JC=2
      DO 280 JC=1,2
      IF (JC.EQ.2) GOTO 300
      VC(JC)=VL(IA,J)/CAPN(IA)
      GOTO 310
  300 VC(JC)=VL(IA,J)/CPP
      IF (IQUE.EQ.1) GOTO 320
  310 IF (VC(JC).GT.1.) GOTO 320
      IF (VC(JC)-CGV) 305,305,315
  305 SP(JC)=SPF+SLO*VC(JC)
      GOTO 325
  315 SP(JC)=SPCAP+SPE*SQRT(1.-((VC(JC)-CGV)/(1.-CGV))**2)
  325 IF (IQUE.EQ.2.AND.JC.EQ.2)SP(JC)=(1.-PQUE)*SP(JC)+PQUE*SPCAP
      GOTO 280
  320 SP(JC)=SPCAP*(2.-VC(JC))
      IF (SP(JC).LT.20.) SP(JC)=20.
      IF (SP(JC).GT.SPCAP) SP(JC)=SPCAP
      VC(JC)=1.
  280 CONTINUE
C     CALCULATE MINIMUM SPEED (SPMN) FOR SPEED-CYCLE COST CALCULATION
      IF (IQUE.EQ.1) GOTO 330
      SPMN=SP(2)-2.3-25.7*(VC(2)**2)
```

```
      IF (IQUE.EQ.2) SPMN=SPMN*(1.-PQUE)
      IF (SPMN.GE.0.0) GOTO 340
  330 SPMN=0.0
C     CALCULATE LENGTH OF REDUCED SPEED THROUGH WORK ZONE ARES (CLL)
  340 IF (WZD.LE.0.1) GOTO 350
      CLL=0.1+(WZD+0.1)*VC(2)
      GOTO 360
  350 CLL=WZD+0.2
C     CALCULATE DISTANCE (DSC) AND DELAY COST (CDSC) OF SLOWING DOWN AND
C     RETURNING TO APPROACH SPEED
  360 DSC=0.5+0.25*VC(2)
      PTT=PT/100.
      PTC=1.-PT/100.
      CDSC(IA,J)=DSC*(2./(SP(1)+SPMN)-1./SP(1))*VL(IA,J)*CUF*
     *(PTC*VLT(1)+PTT/0.9*VLT(2))
C     CALCULATE DELAY COST OF REDUCED SPEED THROUGH WORK ZONE (CDWZ)
      CDWZ(IA,J)=CLL*(1./SP(2)-1./SP(1))*VL(IA,J)*CUF*(PTC*VLT(1)+PTT/
     * 0.9*VLT(2))
C     CALCULATE COST OF SPEED CHANGE CYCLE (CSPC)
      SPCC=-5.2187+1.1241*SP(1)-1.1125*SPMN
      IF (SPCC.LT.0.0) SPCC=0.0
      SPCT=-32.2883+7.1226*0.9*SP(1)-6.684*SPMN*0.9
      IF (SPCT.LT.0.0) SPCT=0.0
      CSPC(IA,J)=VL(IA,J)*CUF*(PTC*SPCC+PTT*SPCT)/1000.
C     ADD COST OF QUEUE CYCLING COSTS IF THERE IS A QUEUE
      IF (IQUE.EQ.0) GOTO 370
      CSPQ=(6.0223*PTC+31.8151*PTT)*CUF*VL(IA,J)*3.*QUEL(IA,J)/1000.
      IF (IQUE.EQ.2) CSPQ=CSPQ*PQUE
      CSPC(IA,J)=CSPC(IA,J)+CSPQ
C     CALCULATE RUNNING COST DIFFERENCE THROUGH WORK ZONE (OC)
  370 DO 380 IOP=1,2
      SPEED=SP(IOP)
      CALL OPCOST(SPEED,PT,VOC)
      CVOC(IOP)=VOC*VL(IA,J)/1000.
  380 CONTINUE
      OC(IA,J)=(CVOC(2)-CVOC(1))*CLL*CUF
C     ADD TO RUNNING COSTS THE ADDITIONAL QUEUE RUNNING COSTS IF ANY
      IF (IQUE.EQ.0) GOTO 390
      SPE=SPF/2.*(1-SQRT(1.-CPP/CAPN(IA)))
      CALL OPCOST(SPEED, PT,VOC)
      CVOC(3)=VOC*VL(IA,J)/1000.
      OCQ(IA,J)=(CVOC(3)-CVOC(1))*QUEL(IA,J)*CUF
      IF (IQUE.EQ.2) OCQ(IA,J)=OCQ(IA,J)*PQUE
      OC(IA,J)=OC(IA,J)+OCQ(IA,J)
C     SUM UP COSTS TO GET TOTAL HOURLY USER COST (THC) IN EACH DIRECTION
  390 THC(IA,J)=CDSC(IA,J)+CDWZ(IA,J)+CSPC(IA,J)+OC(IA,J)+CQUE(IA,J)
C     CALCULATE HOURLY COST PER MILE QUEUE (THCQ)
      IF (QUEL(IA,J).EQ.0.0) GOTO 400
      THCQ(IA,J)=THC(IA,J)/QUEL(IA,J)
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C     PUT SPEEDS INTO ARRAY FOR OUTPUT
  400 DO 410 IS=1,2
      SPD(IS,IA,J)=SP(IS)
  410 CONTINUE
C     SUM HOURLY USER COSTS INTO DAILY TOTAL
      SUM=SUM+THC(IA,J)
  210 CONTINUE
  200 CONTINUE
C     SUM HOURLY COSTS FOR EACH DIRECTION FOR TOTAL HOURLY COSTS
      DO 420 ISM=1,24
      STL(ISM)=THC(1,ISM)+THC(2,ISM)
  420 CONTINUE
C     WRITE OUT CAPACITY ESTIMATE RISK FACTOR  IF WORK ZONE CAPACITY
C     IS CALCULATED IN PROGRAM AND IS NOT PART OF INPUT DATA
      IF (CERF.GT.100.) GOTO 430
      WRITE(6,37) CERF
   37 FORMAT (' CAPACITY ESTIMATE RISK FACTOR,'/
     *' PROBABILITY THAT ESTIMATED'/' WORKING HOURS CAPACITY IS'/
     *' LESS THAN ACTUAL CAPACITY',T32,F4.0,' PERCENT'/)
C     WRITE OUT SUMMARY HEADINGS
  430 WRITE (6,18) IPROB
   18 FORMAT('1',48X,'SUMMARY OF USER COSTS - PROBLEM ',I2,//19X,
     *'*** INBOUND DIRECTION ***',18X,'*',15X,'*** OUTBOUND ',
     *'DIRECTION ***',14X,'* TOTAL ADD.')
      WRITE (6,19)
   19 FORMAT('  HOUR   VOLUME  CAPACITY  APRCH  WORK   LENGTH',
     *T51,'ADDITIONAL  *  VOLUME  CAPACITY  APRCH  WORK   LENGTH',
     *T107,'ADDITIONAL  * HOURLY USER')
      WRITE (6,21)
   21 FORMAT(9X,'(VPH)     (VPH)     SPEED  ZONE',5X,'OF',7X,'HOURLY',
     *T63,'*  (VPH)     (VPH)',4X,'SPEED  ZONE',5X,'OF',7X,'HOURLY',
     *T119,'*  COSTS DUE')
      WRITE (6,22)
   22 FORMAT(27X,'(MPH)  SPEED   QUEUE   USER COSTS  *',T84,'(MPH)',
     *2X,'SPEED   QUEUE   USER COSTS  *   TO LANE')
      WRITE (6,23)
   23 FORMAT(34X,'(MPH)  (MILES)',5X,'($)',6X,'*',T91,'(MPH)  (MILES)',
     *5X,'($)',6X,'* CLOSURE ($)'/)
C     WRITE OUT CALCULATED USER DATA FOR EACH HOUR AND DAILY TOTAL
      DO 450 LC=1,24
      LC1=LC-1
      WRITE(6,39) LC1,LC
   39 FORMAT(1X,I2,'-',I2)
      IF(NHR(LC).EQ.1) GOTO 440
      IF (KI.EQ.0) GOTO 440
      WRITE (6,24) VL(1,LC),CAP(1,LC),SPD(1,1,LC),SPD(2,1,LC),QUEL(1,LC)
   24 FORMAT('+',T9,F7.0,2X,F7.0,3X,F4.0,3X,F4.0,T41,F6.1)
  440 WRITE (6,25) THC(1,LC)
   25 FORMAT('+',T52,F8.0,T63,'*')
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      IF(NHR(LC).EQ.1) GOTO 460
      IF (KO.EQ.0) GOTO 460
      WRITE (6,26) VL(2,LC),CAP(2,LC),SPD(1,2,LC),SPD(2,2,LC),QUEL(2,LC)
   26 FORMAT ('+',T65,F7.0,T74,F7.0,T84,F4.0,T92,F4.0,T97,F6.1)
  460 WRITE (6,27) THC(2,LC),STL(LC)
   27 FORMAT ('+',T108,F8.0,T119,'*',T121,F9.0/)
  450 CONTINUE
      WRITE (6,28) SUM
   28 FORMAT (5X,'TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE',
     *' CLOSURE = ',F10.0,/)
C     WRITE OUT WARNING IF QUEUE GREATER THAN A MILE
      QMAX=0.
      DO 500 I=1,2
      DO 500 J=1,24
      IF (QUEL(I,J).GT.QMAX) QMAX=QUEL(I,J)
  500 CONTINUE
      IF (QMAX.LE.1.) GOTO 480
      WRITE (6,42) QMAX
   42 FORMAT (' *** WARNING *** QUEUE ESTIMATED TO REACH ',F6.1,' MILES'
     *,' LONG.  QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY ',
     *'TO DIVERT '/'                    TO OTHER ROUTES. CHECK ALTERNATE ',
     *'ROUTES - DIVERSION MAY TAKE PLACE.')
C     GO TO NEXT PROBLEM, IF ANY
  480 IF (IEND.EQ.1) GOTO 99
      GOTO 5
   99 STOP
      END
C
      SUBROUTINE OPCOST(SP,PTR,CST)
C
C     CALCULATES RUNNING COSTS PER 1000 VEHICLE MILES, GIVEN SPEED AND
C     PERCENTAGE TRUCKS
      SPC=SP
      SPT=SP*0.9
      PT=PTR/100.
C     CAR RUNNING COSTS
      CR=395.6898*EXP(.0157*SPC)*(SPC)**(-.45525)
C     TRUCK RUNNING COSTS
      TK=179.1466*EXP(.02203*SPT)*(SPT)**(-.35902)+(1201.8847*
     *EXP(.0322*SPT)*(SPT)**(-.79202))
      CST=((1.-PT)*CR+PT*TK)
      RETURN
      END
```

Sample Output

```
 PROBLEM   1  SINGLE LANE CLOSURE TEST PROBLEM

MODEL                                 1

COST UPDATE FACTOR                 1.00

PERCENTAGE TRUCKS                    8.

TOTAL NUMBER OF LANES
   INBOUND                            2
   OUTBOUND                           2

LENGTH OF WORKZONE                 1.00 MILES

WORKZONE OPEN LANES
   INBOUND                            1
   OUTBOUND                           2

HOURS OF RESTRICTED CAPACITY
   BEGINNING                          8
   ENDING                            16

HOURS OF WORKZONE ACTIVITY
   BEGINNING                          9
   ENDING                            15

INBOUND CAPACITY
   NORMAL                         4000.  (VPH)
   RESTRICTED                     1800.  (VPH)
   WORKING HOURS                  1332.  (VPH)

CAPACITY ESTIMATE RISK FACTOR,
PROBABILITY THAT ESTIMATED
WORKING HOURS CAPACITY IS
LESS THAN ACTUAL CAPACITY          80.  PERCENT
```

SUMMARY OF USER COSTS - PROBLEM 1

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0						0.	0.
1- 2						0						0.	0
2- 3						0						0.	0
3- 4						0						0	0.
4- 5						0						0.	0.
5- 6						0						0.	0
6- 7						0						0	0
7- 8						0						0	0
8- 9	1750.	1800.	49.	35.	0.0	443						0	443
9-10	1490.	1332.	51.	26.	0.3	1469						0	1469
10-11	1360.	1332.	52.	29.	0.7	2313						0.	2313
11-12	1040.	1332.	54.	34.	0.4	890						0.	890
12-13	1040.	1332.	54.	40.	0.0	149.						0.	149.
13-14	1210.	1332.	52.	38.	0.0	238						0.	238.
14-15	1490.	1332.	51.	26	0.3	1469						0.	1469.
15-16	1670.	1332.	50.	22	1.2	4277						0.	4277
16-17	1790.	1800.	49	30	1.9	5787						0.	5787
17-18	1610.	4000	50.	46	0.9	612						0	612
18-19						0						0.	0
19-20						0						0	0
20-21						0						0.	0.
21-22						0						0.	0
22-23						0						0.	0
23-24						0.						0.	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 17647.

*** WARNING *** QUEUE ESTIMATED TO REACH 1.9 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE.

PROBLEM 2 CROSSOVER TEST PROBLEM

MODEL	2	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	2	
OUTBOUND	2	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	1	
OUTBOUND	1	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	8	
ENDING	16	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	4000	(VPH)
RESTRICTED	1800	(VPH)
WORKING HOURS	1354	(VPH)
OUTBOUND CAPACITY		
NORMAL	4000	(VPH)
RESTRICTED	1800	(VPH)
WORKING HOURS	1354	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	50	PERCENT

SUMMARY OF USER COSTS - PROBLEM 2

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0						0.	0.
1- 2						0.						0.	0.
2- 3						0						0.	0.
3- 4						0						0.	0.
4- 5						0						0.	0.
5- 6						0						0.	0
6- 7						0						0.	0
7- 8						0						0.	0
8- 9	1750.	1800.	49.	35.	0.0	443	1280.	1800.	52.	42	0 0	138	581.
9-10	1490.	1354.	51.	27.	0.3	1344	1240.	1354.	52	38.	0.0	250.	1594.
10-11	1360.	1354.	52.	30.	0.5	1972	1250.	1354.	52.	38.	0.0	259.	2231
11-12	1040.	1354.	54.	36.	0.3	575	1300.	1354.	52	36.	0.0	319.	894.
12-13	1040.	1354.	54	41.	0 0	143	1300	1354.	52	36.	0.0	319.	462
13-14	1210.	1354.	52.	39.	0.0	227.	1330.	1354.	52.	34.	0.0	376.	602
14-15	1490.	1354.	51	27	0.3	1344	1500.	1354.	51	27	0.3	1406.	2750.
15-16	1670.	1354.	50	23	1 1	3918	1860.	1354.	48.	20.	1.5	5276.	9194
16-17	1790.	1800.	49.	30	1 7	5343	2010.	1800.	47	26	2.9	8779.	14121
17-18	1610	4000	50	46	0 8	518	1970	4000	48.	40.	1.6	2164.	2682
18-19						0						0.	0
19-20						0						0.	0
20-21						0						0.	0
21-22						0						0.	0.
22-23						0.						0.	0
23-24						0						0.	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 35112.

*** WARNING *** QUEUE ESTIMATED TO REACH 2.9 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES. CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE.

PROBLEM 3 SINGLE LANE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1 00
PERCENTAGE TRUCKS	8.
TOTAL NUMBER OF LANES	
INBOUND	2
OUTBOUND	2
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	1
OUTBOUND	2
HOURS OF RESTRICTED CAPACITY	
BEGINNING	0
ENDING	23
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
INBOUND CAPACITY	
NORMAL	4000 (VPH)
RESTRICTED	1800. (VPH)
WORKING HOURS	1650 (VPH)

SUMMARY OF USER COSTS - PROBLEM 3

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	1800.	58.	56.	0.0	2						0.	2.
1- 2	160.	1800.	59.	58	0.0	1						0.	1
2- 3	120.	1800.	59.	58	0.0	0						0.	0.
3- 4	100	1800.	59.	59.	0.0	0						0	0
4- 5	130.	1800.	59.	58.	0.0	1						0.	1
5- 6	460.	1800.	57.	54.	0.0	7						0	7
6- 7	1620.	1800.	50	39.	0.0	293						0	293
7- 8	2080.	1800.	47.	25.	0.5	2397						0	2397.
8- 9	1750.	1800.	49	30.	1.0	3315						0	3315
9-10	1490.	1650.	51.	30.	0.6	2124						0	2124
10-11	1360.	1650.	52	38	0.1	358						0.	358.
11-12	1040.	1650.	54	44	0.0	88						0	88
12-13	1040.	1650	54	44	0.0	88						0	88
13-14	1210.	1650	52.	42	0.0	143						0	143
14-15	1490.	1650.	51	39	0.0	278						0.	278
15-16	1670.	1650.	50.	30	0.0	741						0	741
16-17	1790.	1800.	49	30	0.1	827						0.	827
17-18	1610.	1800	50.	38.	0.0	304						0.	304
18-19	1240.	1800.	52.	43.	0.0	124						0.	124
19-20	1000.	1800	54.	46	0.0	63						0.	63
20-21	680.	1800.	56.	51	0.0	21						0.	21.
21-22	630.	1800.	56	51	0.0	17						0	17
22-23	560.	1800	57	52	0.0	12						0.	12
23-24	500	1800	57	53	0.0	9						0	9

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 11214

PROBLEM 4 CROSSOVER TEST PROBLEM

MODEL	2	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	2	
OUTBOUND	2	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	1	
OUTBOUND	1	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	0	
ENDING	23	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	4000	(VPH)
RESTRICTED	1800	(VPH)
WORKING HOURS	1354.	(VPH)
OUTBOUND CAPACITY		
NORMAL	4000.	(VPH)
RESTRICTED	1800	(VPH)
WORKING HOURS	1354.	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	50.	PERCENT

SUMMARY OF USER COSTS - PROBLEM 4

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270	1800.	58.	56	0.0	2	290	1800	58	56.	0.0	2	5
1- 2	160.	1800.	59.	58.	0.0	1.	170	1800.	59.	58.	0.0	1	2.
2- 3	120.	1800.	59.	58.	0.0	0	110.	1800.	59.	58.	0.0	0.	1.
3- 4	100.	1800.	59.	59	0.0	0	80.	1800.	60.	59	0.0	0.	1
4- 5	130.	1800.	59.	58.	0.0	1	110.	1800	59	58.	0.0	0.	1.
5- 6	460.	1800.	57.	54	0.0	7	340	1800	58	55	0.0	4	11
6- 7	1620.	1800.	50.	39.	0.0	293	1110	1800	53.	45.	0 0	87.	380
7- 8	2080.	1800.	47.	25.	0.5	2397	1320.	1800	52	42	0.0	153.	2550
8- 9	1750.	1800.	49.	30.	1.0	3315	1280.	1800	52	42	0.0	138	3453
9-10	1490.	1354.	51	27.	1.1	3737	1240	1354.	52.	38	0.0	250	3987
10-11	1360.	1354.	52	30	1.4	4362	1250	1354	52	38.	0.0	259.	4622
11-12	1040.	1354.	54	30	0.8	2642	1300	1354	52	36.	0.0	319.	2961
12-13	1040.	1354.	54.	39.	0 1	240	1300	1354	52	36.	0.0	319.	559
13-14	1210.	1354.	52.	39.	0.0	227	1330.	1354.	52.	34.	0.0	376.	602
14-15	1490	1354.	51	27	0 3	1344	1500	1354.	51	27	0.3	1406	2750
15-16	1670.	1354.	50	23	1 1	3918	1860	1354.	48	20	1.5	5276.	9194
16-17	1790.	1800.	49	30.	1 7	5343	2010.	1800.	47	26	2.9	8779	14121
17-18	1610.	1800.	50	30	1 3	4231	1970.	1800	48	27.	3.6	10720	14951
18-19	1240.	1800	52	37	0.5	838	1680	1800.	50	30.	3 7	10769.	11607
19-20	1000	1800.	54	46	0 0	63	1080	1800.	53	30	2 1	6152.	6215
20-21	680.	1800	56	51	0 0	21	810	1800	55	45	0.4	263.	284
21-22	630	1800.	56	51	0 0	17	740	1800	55	50.	0.0	26	43
22-23	560.	1800.	57	52	0 0	12	650.	1800	56	51.	0.0	18.	31
23-24	500	1800	57	53	0.0	9	470	1800	57	53	0.0	8	17

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 78343.

*** WARNING *** QUEUE ESTIMATED TO REACH 3.7 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE

PROBLEM 5 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1 00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	3	
OUTBOUND	3	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	2	
OUTBOUND	3	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	8	
ENDING	16	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	6000.	(VPH)
RESTRICTED	3600.	(VPH)
WORKING HOURS	2983.	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60	PERCENT

SUMMARY OF USER COSTS - PROBLEM 5

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0.						0	0.
1- 2						0						0.	0
						0.						0.	0.
						0						0	0.
4 5						0						0.	0.
5- 6						0						0.	0
6- 7						0						0.	0
7- 8						0						0.	0.
8- 9	1750.	3600	53.	48.	0.0	73						0.	73
9-10	1490	2983.	54	48	0.0	73						0	73
10-11	1360.	2983	54.	49.	0.0	56						0.	56
11-12	1040.	2983.	56.	51	0 0	26						0.	26
12-13	1040.	2983.	56.	51.	0 0	26						0.	26
13-14	1210.	2983.	55	50.	0.0	40						0.	40
14-15	1490.	2983.	54.	48	0.0	73						0.	73
15-16	1670.	2983.	53.	46	0 0	102						0	102
16-17	1790.	3600.	53.	48	0.0	78						0.	78.
17-18						0						0.	0.
18-19						0.						0.	0
19-20						0						0	0.
20-21						0						0.	0.
21-22						0.						0.	0
22-23						0						0.	0
23-24						0						0.	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 546.

PROBLEM 6 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	3	
OUTBOUND	3	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	1	
OUTBOUND	3	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	8	
ENDING	16	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	6000.	(VPH)
RESTRICTED	1800.	(VPH)
WORKING HOURS	1127	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60.	PERCENT

SUMMARY OF USER COSTS - PROBLEM 6

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0.						0.	0.
1- 2						0						0.	0.
2- 3						0						0.	0.
3- 4						0.						0.	0.
4- 5						0						0.	0.
5- 6						0						0	0.
6- 7						0						0.	0.
7- 8						0.						0.	0
8- 9	1750.	1800.	53.	35.	0.0	464.						0.	464.
9-10	1490.	1127.	54.	20.	0.5	2760						0.	2760.
10-11	1360.	1127.	54.	24.	1 2	5646						0.	5646
11-12	1040.	1127.	56.	30.	1.4	6126						0	6126
12-13	1040.	1127.	56.	30.	1.2	5225						0.	5225.
13-14	1210.	1127.	55.	28.	1.2	5310						0.	5310.
14-15	1490.	1127.	54.	20.	1 7	8004						0.	8004
15-16	1670.	1127.	53.	20.	2.9	12841						0.	12841
16-17	1790.	1800.	53.	30	3.6	15282						0	15282
17-18	1610.	6000	53	46	1 8	2451						0.	2451
18-19						0						0	0
19-20						0						0.	0
20-21						0						0.	0
21-22						0						0.	0
22-23						0						0.	0.
23-24						0						0	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 64108.

*** WARNING *** QUEUE ESTIMATED TO REACH 3.6 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE.

PROBLEM 7 SINGLE LANE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1.00
PERCENTAGE TRUCKS	8.
TOTAL NUMBER OF LANES	
INBOUND	3
OUTBOUND	3
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	2
OUTBOUND	3
HOURS OF RESTRICTED CAPACITY	
BEGINNING	0
ENDING	23
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
INBOUND CAPACITY	
NORMAL	6000. (VPH)
RESTRICTED	3600. (VPH)
WORKING HOURS	2983. (VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60. PERCENT

SUMMARY OF USER COSTS - PROBLEM 7

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	3600.	59.	58.	0.0	1.						0.	1.
1- 2	160.	3600.	59.	59.	0.0	0						0.	0.
2- 3	120.	3600.	60.	59.	0.0	0						0.	0.
3- 4	100.	3600.	60.	59.	0.0	0						0.	0.
4- 5	130.	3600.	59.	59.	0.0	0						0.	0
5- 6	460.	3600.	58.	57.	0.0	2						0.	2.
6- 7	1620.	3600.	53.	49.	0.0	58						0.	58.
7- 8	2080.	3600.	51.	46.	0.0	124.						0.	124
8- 9	1750.	3600.	53.	48.	0.0	73.						0.	73
9-10	1490.	2983.	54.	48.	0.0	73						0	73
10-11	1360.	2983.	54	49.	0.0	56						0.	56
11-12	1040.	2983.	56	51.	0 0	26						0	26.
12-13	1040.	2983.	56.	51.	0.0	26						0	26
13-14	1210.	2983.	55.	50.	0.0	40						0.	40
14-15	1490.	2983.	54.	48	0.0	73						0	73
15-16	1670.	2983	53.	46.	0.0	102						0	102
16-17	1790.	3600.	53	48	0.0	78						0.	78
17-18	1610	3600.	53	49	0.0	57						0	57
18-19	1240	3600.	55.	51	0 0	27						0.	27
19-20	1000.	3600.	56	53.	0 0	15.						0.	15.
20-21	680.	3600.	57.	55.	0.0	6						0.	6
21-22	630.	3600.	57	56	0.0	5.						0.	5.
22-23	560.	3600.	58.	56.	0.0	4.						0.	4.
23-24	500.	3600.	58.	57	0.0	3						0.	3

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 847

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 PROBLEM  8  SINGLE LANE TEST PROBLEM

MODEL                                   1

COST UPDATE FACTOR                   1.00

PERCENTAGE TRUCKS                      8.

TOTAL NUMBER OF LANES
   INBOUND                              3
   OUTBOUND                             3

LENGTH OF WORKZONE                   1.00 MILES

WORKZONE OPEN LANES
   INBOUND                              1
   OUTBOUND                             3

HOURS OF RESTRICTED CAPACITY
   BEGINNING                            0
   ENDING                              23

HOURS OF WORKZONE ACTIVITY
   BEGINNING                            9
   ENDING                              15

INBOUND CAPACITY
   NORMAL                          6000  (VPH)
   RESTRICTED                      1800. (VPH)
   WORKING HOURS                   1127. (VPH)

CAPACITY ESTIMATE RISK FACTOR.
PROBABILITY THAT ESTIMATED
WORKING HOURS CAPACITY IS
LESS THAN ACTUAL CAPACITY            60. PERCENT
```

SUMMARY OF USER COSTS - PROBLEM 8

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	1800.	59.	56.	0.0	2						0.	2.
1- 2	160	1800.	59	58.	0 0	1						0.	1.
2- 3	120	1800.	60	58.	0 0	0						0.	0.
3- 4	100.	1800.	60.	59.	0.0	0						0	0.
4- 5	130.	1800.	59.	58.	0.0	1						0.	1.
5- 6	460.	1800.	58.	54.	0.0	9						0.	9
6- 7	1620.	1800.	53.	39.	0.0	314						0.	314.
7- 8	2080.	1800.	51.	25	0.4	2407						0.	2407
8- 9	1750.	1800.	53.	30.	0.6	3316						0	3316.
9-10	1490.	1127.	54.	20.	1 0	5148						0.	5148
10-11	1360.	1127.	54.	24.	1 8	8031						0.	8031
11-12	1040.	1127.	56	30.	2 0	8509.						0.	8509.
12-13	1040.	1127.	56.	30.	1.8	7608						0.	7608
13-14	1210.	1127.	55.	28.	1.8	7694						0.	7694
14-15	1490.	1127.	54.	20	2.3	10393						0.	10393
15-16	1670.	1127.	53	20	3 5	15231						0	15231
16-17	1790.	1800.	53	30	4 1	17670						0	17670
17-18	1610	1800	53	30	3 9	16554						0	16554
18-19	1240.	1800.	55	30	2 9	12512						0.	12512
19-20	1000.	1800	56	30.	1.2	5370						0.	5370
20-21	680.	1800.	57	49	0 1	64						0	64.
21-22	630	1800.	57.	51.	0 0	19						0.	19
22-23	560.	1800	58	52	0.0	14						0.	14
23-24	500	1800	58	53	0 0	11						0	11

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 120878

*** WARNING *** QUEUE ESTIMATED TO REACH 4 1 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE.

```
 PROBLEM  9  SINGLE LANE TEST PROBLEM
MODEL                                 1

COST UPDATE FACTOR                 1.00

PERCENTAGE TRUCKS                    8.

TOTAL NUMBER OF LANES
   INBOUND                            4
   OUTBOUND                           4

LENGTH OF WORKZONE                 1.00 MILES

WORKZONE OPEN LANES
   INBOUND                            4
   OUTBOUND                           3

HOURS OF RESTRICTED CAPACITY
   BEGINNING                          0
   ENDING                            23

HOURS OF WORKZONE ACTIVITY
   BEGINNING                          9
   ENDING                            15

OUTBOUND CAPACITY
   NORMAL                        8000  (VPH)
   RESTRICTED                    5400  (VPH)
   WORKING HOURS                 4577. (VPH)

CAPACITY ESTIMATE RISK FACTOR,
PROBABILITY THAT ESTIMATED
WORKING HOURS CAPACITY IS
LESS THAN ACTUAL CAPACITY          60. PERCENT
```

SUMMARY OF USER COSTS - PROBLEM 9

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0	290	5400.	59	59.	0.0	1	1.
1- 2						0	170	5400.	59	59	0.0	0	0.
2- 3						0	110	5400.	60.	59	0.0	0.	0.
3- 4						0	80	5400.	60.	60	0.0	0.	0.
4- 5						0	110	5400.	60	59	0.0	0.	0.
5- 6						0	340.	5400	59.	58	0.0	1.	1
6- 7						0	1110	5400	57	55	0.0	9.	9.
7- 8						0	1320.	5400.	56	54	0.0	15.	15.
8- 9						0	1280.	5400.	56	54.	0.0	13.	13.
9-10						0	1240	4577.	56	53.	0.0	19.	19.
10-11						0	1250	4577	56	53.	0.0	19	19
11-12						0	1300.	4577.	56.	53.	0.0	21.	21
12-13						0	1300	4577.	56	53.	0.0	21	21
13-14						0	1330	4577.	56.	53	0.0	23	23
14-15						0	1500	4577.	55	52	0 0	31	31
15-16						0	1860	4577	54	50	0.0	56	56
16-17						0	2010	5400	54	51	0.0	45	45
17-18						0.	1970	5400.	54	51	0 0	43	43
18-19						0	1680	5400	55	52.	0.0	28.	28
19-20						0	1080	5400	57	55	0.0	9	9
20-21						0	810	5400	57	56	0.0	4	4
21-22						0	740	5400.	58	57.	0.0	4	4.
22-23						0	650.	5400	58	57.	0.0	3.	3
23-24						0	470	5400.	59.	58.	0.0	2.	2.

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 368.

PROBLEM 10 SINGLE LANE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1.00
PERCENTAGE TRUCKS	8
TOTAL NUMBER OF LANES	
INBOUND	4
OUTBOUND	4
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	4
OUTBOUND	2
HOURS OF RESTRICTED CAPACITY	
BEGINNING	0
ENDING	23
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
OUTBOUND CAPACITY	
NORMAL	8000. (VPH)
RESTRICTED	3600 (VPH)
WORKING HOURS	2968. (VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60 PERCENT

SUMMARY OF USER COSTS - PROBLEM 10

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0	290	3600	59	58	0.0	1.	1.
1- 2						0	170.	3600.	59.	59.	0.0	1.	1.
2- 3						0.	110	3600.	60	59.	0.0	0.	0.
3- 4						0.	80	3600.	60	59	0.0	0.	0.
4- 5						0	110	3600	60	59	0.0	0	0
5- 6						0	340	3600	59	58	0.0	2.	2
6- 7						0	1110	3600	57	52.	0.0	24.	24.
7- 8						0	1320.	3600.	56.	51.	0.0	38.	38
8- 9						0	1280	3600.	56	51.	0.0	35.	35
9-10						0	1240	2968.	56	50	0.0	49.	49.
10-11						0	1250	2968.	56	49	0.0	50.	50
11-12						0	1300.	2968	56	49	0.0	55.	55.
12-13						0	1300	2968.	56	49.	0.0	55.	55.
13-14						0	1330	2968	56	49	0.0	59.	59.
14-15						0	1500	2968.	55.	47	0.0	83.	83.
15-16						0	1860.	2968	54.	44.	0.0	159.	159.
16-17						0	2010.	3600.	54.	46.	0.0	128.	128
17-18						0	1970	3600	54	46.	0.0	120.	120.
18-19						0	1680	3600.	55.	48.	0.0	75	75
19-20						0	1080.	3600.	57.	53.	0.0	22	22
20-21						0	810	3600.	57	54.	0.0	11.	11.
21-22						0	740	3600.	58	55.	0.0	9.	9
22-23						0	650	3600.	58.	55.	0.0	6.	6
23-24						0	470.	3600.	59.	57.	0.0	3	3

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 986

PROBLEM 11 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	4	
OUTBOUND	4	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	4	
OUTBOUND	1	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	0	
ENDING	23	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
OUTBOUND CAPACITY		
NORMAL	8000.	(VPH)
RESTRICTED	1800.	(VPH)
WORKING HOURS	1200	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60.	PERCENT

SUMMARY OF USER COSTS - PROBLEM 11

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0.	290.	1800.	59	56	0.0	3.	3.
1- 2						0.	170.	1800.	59	58.	0.0	1.	1.
2- 3						0.	110.	1800	60.	58.	0.0	0.	0.
3- 4						0	80	1800.	60	59.	0.0	0.	0.
4- 5						0	110	1800	60	58.	0.0	0.	0
5- 6						0	340.	1800.	59	55	0.0	5.	5
6- 7						0	1110.	1800.	57.	45.	0.0	101.	101.
7- 8						0.	1320.	1800.	56	42.	0.0	173.	173.
8- 9						0	1280.	1800	56	42.	0.0	157	157.
9-10						0.	1240.	1200.	56	29.	0.0	704	704
10-11						0	1250.	1200	56.	29.	0 1	1179.	1179.
11-12						0	1300	1200	56.	28	0.3	2002	2002
12-13						0	1300	1200.	56	28.	0.5	3038.	3038.
13-14						0	1330	1200.	56	27.	0 7	4260.	4260
14-15						0	1500.	1200.	55.	23	1 1	6701	6701
15-16						0	1860.	1200	54.	20.	2.0	12015.	12015
16-17						0	2010.	1800	54	26	2.8	16286.	16286
17-18						0	1970	1800	54	27.	3 2	18214	18214
18-19						0	1680	1800	55	30	3 2	18269	18269
19-20						0	1080	1800.	57	30	2.4	13676	13676
20-21						0	810	1800	57	31.	0 9	4638	4638.
21-22						0	740	1800	58	50	0.0	32	32
22-23						0	650	1800.	58.	51.	0.0	22.	22
23-24						0	470.	1800	59.	53	0.0	10	10

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 101485.

*** WARNING *** QUEUE ESTIMATED TO REACH 3.2 MILES LONG. QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE

```
 PROBLEM 12  SINGLE LANE TEST PROBLEM

MODEL                                   1

COST UPDATE FACTOR                   1.00

PERCENTAGE TRUCKS                      8.

TOTAL NUMBER OF LANES
   INBOUND                              5
   OUTBOUND                             5

LENGTH OF WORKZONE                   1.00 MILES

WORKZONE OPEN LANES
   INBOUND                              4
   OUTBOUND                             5

HOURS OF RESTRICTED CAPACITY
   BEGINNING                            0
   ENDING                              23

HOURS OF WORKZONE ACTIVITY
   BEGINNING                            9
   ENDING                              15

INBOUND CAPACITY
   NORMAL                          10000.  (VPH)
   RESTRICTED                       7200.  (VPH)
   WORKING HOURS                    6200   (VPH)

CAPACITY ESTIMATE RISK FACTOR,
PROBABILITY THAT ESTIMATED
WORKING HOURS CAPACITY IS
LESS THAN ACTUAL CAPACITY         60   PERCENT
```

SUMMARY OF USER COSTS - PROBLEM 12

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	7200.	59.	59.	0.0	1						0.	1.
1- 2	160.	7200.	60.	59.	0.0	0.						0.	0.
2- 3	120.	7200.	60.	60.	0.0	0						0.	0.
3- 4	100.	7200.	60.	60.	0.0	0.						0	0.
4- 5	130.	7200.	60.	60.	0.0	0						0	0.
5- 6	460.	7200.	59.	58.	0.0	1						0	1.
6- 7	1620.	7200.	56.	54.	0.0	14						0	14
7- 8	2080.	7200.	55.	53.	0.0	28						0	28.
8- 9	1750.	7200.	56.	54.	0.0	18.						0.	18
9-10	1490.	6200.	56.	54.	0.0	17						0.	17
10-11	1360.	6200.	57.	55	0.0	14						0.	14
11-12	1040.	6200.	57.	56.	0.0	7						0.	7
12-13	1040.	6200.	57	56	0.0	7						0.	7
13-14	1210.	6200.	57.	55.	0.0	10						0	10
14-15	1490.	6200.	56	54.	0.0	17						0.	17
15-16	1670.	6200.	56.	53.	0.0	23.						0.	23
16-17	1790	7200.	56.	54.	0.0	19						0.	19
17-18	1810	7200.	56	54	0.0	14						0.	14.
18-19	1240	7200.	57	56	0 0	7						0.	7
19-20.	1000.	7200.	58	57.	0 0	5						0.	5
20-21	680.	7200.	58	58	0 0	2						0.	2
21-22	630.	7200.	58.	58	0 0	2						0.	2
22-23	560.	7200.	59	58.	0.0	2.						0.	2
23-24	500	7200.	59	58	0.0	2						0.	2

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 214.

PROBLEM 13 SINGLE LANE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1.00
PERCENTAGE TRUCKS	8.
TOTAL NUMBER OF LANES	
INBOUND	5
OUTBOUND	5
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	3
OUTBOUND	5
HOURS OF RESTRICTED CAPACITY	
BEGINNING	0
ENDING	23
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
INBOUND CAPACITY	
NORMAL	10000. (VPH)
RESTRICTED	5400 (VPH)
WORKING HOURS	4500 (VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60. PERCENT

SUMMARY OF USER COSTS - PROBLEM 13

HOUR	+++ INBOUND DIRECTION +++ VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	+++ OUTBOUND DIRECTION +++ VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	5400.	59.	59.	0.0	1						0.	1.
1- 2	160.	5400.	60.	59	0.0	0						0.	0.
2- 3	120.	5400.	60.	59.	0.0	0						0.	0
3- 4	100.	5400.	60.	60	0.0	0						0.	0.
4- 5	130.	5400.	60.	59.	0.0	0.						0.	0
5- 6	460.	5400.	59.	58.	0.0	2						0.	2
6- 7	1620.	5400.	56.	52.	0.0	30						0.	30.
7- 8	2080.	5400.	55.	50.	0.0	59						0.	59
8- 9	1750.	5400.	56.	52.	0.0	37						0.	37.
9-10	1490.	4500.	56.	52.	0.0	36						0.	36.
10-11	1360.	4500.	57.	52.	0.0	29						0.	29.
11-12	1040.	4500.	57.	54	0.0	14						0.	14
12-13	1040.	4500.	57.	54.	0 0	14						0.	14
13-14	1210.	4500.	57.	53.	0 0	21						0.	21
14-15	1490.	4500.	56	52.	0 0	36						0.	36.
15-16	1670	4500	56	51	0.0	49						0.	49
16-17	1790	5400.	56	52	0 0	39						0	39
17-18	1610.	5400	56	53	0 0	30						0.	30
18-19	1240.	5400	57	54	0 0	15						0.	15
19-20	1000.	5400	58	55	0.0	9						0	9
20-21	680.	5400.	58	57	0.0	4						0	4
21-22	630	5400	58	57	0 0	3						0.	3
22-23	560.	5400.	59	57	0.0	3						0.	3
23-24	500.	5400	59	58	0.0	2						0	2.

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 436

PROBLEM 14 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	5	
OUTBOUND	5	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	2	
OUTBOUND	5	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	0	
ENDING	23	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	10000.	(VPH)
RESTRICTED	3600.	(VPH)
WORKING HOURS	2745.	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60.	PERCENT

SUMMARY OF USER COSTS - PROBLEM 14

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUMF (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	3600.	59.	58	0.0	1						0.	1
1- 2	160.	3600.	60.	59.	0.0	1.						0.	1
2- 3	120.	3600.	60.	59	0.0	0						0.	0.
3- 4	100.	3600.	60.	59.	0.0	0						0	0
4- 5	130.	3600.	60.	59.	0.0	0						0.	0
5- 6	460.	3600.	59.	57.	0.0	3						0	3
6- 7	1620.	3600.	56.	49	0.0	73						0	73
7- 8	2080.	3600.	55.	46.	0.0	152						0.	152.
8- 9	1750.	3600.	56.	48.	0.0	91						0.	91
9-10	1490.	2745.	56.	46.	0.0	102						0.	102
10-11	1360.	2745.	57.	48.	0.0	78.						0.	78
11-12	1040.	2745.	57.	51.	0.0	37						0.	37
12-13	1040.	2745.	57.	51.	0 0	37						0.	37.
13-14	1210.	2745.	57.	49.	0 0	56						0	56
14-15	1490.	2745.	56.	46	0.0	102						0	102
15-16	1670.	2745.	56	45.	0 0	143						0.	143.
16-17	1790.	3600.	56	48	0.0	97						0.	97
17-18	1610.	3600	56.	49.	0.0	72						0.	72
18-19	1240.	3600.	57.	51	0.0	35						0.	35
19-20	1000.	3600.	58.	53	0.0	20						0.	20
20-21	680.	3600.	58	55	0.0	8						0.	8
21-22	630.	3600.	58	56	0.0	7						0.	7.
22-23	560.	3600	59	56	0.0	5						0.	5
23-24	500.	3600	59.	57	0 0	4						0	4

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 1126

PROBLEM 15 SINGLE LANE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1.00
PERCENTAGE TRUCKS	8
TOTAL NUMBER OF LANES	
INBOUND	5
OUTBOUND	5
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	1
OUTBOUND	5
HOURS OF RESTRICTED CAPACITY	
BEGINNING	0
ENDING	23
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
INBOUND CAPACITY	
NORMAL	10000. (VPH)
RESTRICTED	1800. (VPH)
WORKING HOURS	1200. (VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60. PERCENT

SUMMARY OF USER COSTS - PROBLEM 15

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1	270.	1800.	59.	56	0.0	3.						0.	3
1- 2	160	1800.	60.	58	0.0	1						0.	1.
2- 3	120.	1800.	60.	58.	0.0	1						0	1
3- 4	100.	1800.	60.	59.	0.0	0						0.	0
4- 5	130.	1800.	60.	58.	0.0	1						0.	1.
5- 6	460.	1800.	59.	54.	0.0	10						0.	10
6- 7	1620.	1800.	56.	39.	0.0	328.						0.	328.
7- 8	2080.	1800.	55.	25.	0.2	2414						0.	2414
8- 9	1750.	1800.	56.	30.	0.4	3318						0.	3318
9-10	1490.	1200.	56.	23.	0.6	4664						0.	4664
10-11	1360.	1200.	57	26.	0.9	6829						0.	6829.
11-12	1040.	1200.	57.	30.	0.9	6617						0.	6617
12-13	1040.	1200.	57.	30.	0 7	4960						0.	4960
13-14	1210.	1200.	57	30.	0.6	4254						0.	4254
14-15	1490.	1200.	56.	23.	0.8	6115						0.	6115.
15-16	1670.	1200.	56	20	1.4	10284.						0.	10284
16-17	1790.	1800.	56	30.	1 7	12348						0.	12348.
17-18	1610.	1800.	56.	30	1 6	11241						0.	11241
18-19	1240.	1800.	57	30	1 0	7213.						0.	7213
19-20	1000.	1800.	58	39	0.3	1061						0.	1061.
20-21	680.	1800.	58.	51	0 0	26						0.	26
21-22	630.	1800.	58	51	0.0	21						0	21
22-23	560	1800	59.	52	0.0	16						0	16.
23-24	500.	1800	59	53	0 0	12						0.	12

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 81736

*** WARNING *** QUEUE ESTIMATED TO REACH 1 7 MILES LONG QUEUE DOES NOT CONSIDER DRIVERS LEAVING THE FREEWAY TO DIVERT TO OTHER ROUTES CHECK ALTERNATE ROUTES - DIVERSION MAY TAKE PLACE.

PROBLEM 16 SINGLE LANE CLOSURE TEST PROBLEM

MODEL	1
COST UPDATE FACTOR	1.00
PERCENTAGE TRUCKS	8
TOTAL NUMBER OF LANES	
INBOUND	6
OUTBOUND	6
LENGTH OF WORKZONE	1.00 MILES
WORKZONE OPEN LANES	
INBOUND	5
OUTBOUND	6
HOURS OF RESTRICTED CAPACITY	
BEGINNING	9
ENDING	15
HOURS OF WORKZONE ACTIVITY	
BEGINNING	9
ENDING	15
INBOUND CAPACITY	
NORMAL	12000. (VPH)
RESTRICTED	9000. (VPH)
WORKING HOURS	8250. (VPH)

SUMMARY OF USER COSTS - PROBLEM 16

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0.						0.	0.
1- 2						0						0.	0.
2- 3						0						0.	0.
3- 4						0.						0.	0.
4- 5						0						0.	0.
5- 6						0						0.	0.
6- 7						0						0.	0
7- 8						0						0.	0
8- 9						0						0.	0.
9-10	1490.	8250	57	55.	0.0	10						0.	10
10-11	1360.	8250	57	56	0 0	8						0	8
11-12	1040	8250.	58.	57.	0.0	5						0.	5.
12-13	1040	8250.	58	57	0.0	5						0	5
13-14	1210.	8250	57.	56.	0.0	6						0	6
14-15	1490.	8250.	57	55.	0.0	10.						0.	10.
15-16	1670.	8250.	57	55.	0.0	13						0.	13
16-17						0						0.	0
17-18						0						0.	0.
18-19						0						0.	0.
19-20						0						0.	0
20-21						0						0.	0
21-22						0						0	0
22-23						0.						0.	0
23-24						0						0.	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 58.

PROBLEM 17 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	6	
OUTBOUND	6	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	4	
OUTBOUND	6	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	9	
ENDING	15	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	12000.	(VPH)
RESTRICTED	7200.	(VPH)
WORKING HOURS	7400.	(VPH)

WORK ZONE CAPACITY GREATER THAN RESTRICTED CAPACITY - PROBLEM 17 SKIPPED

POSSIBLE SOURCE OF ERROR: USER-SUPPLIED CAPACITY ESTIMATE GREATER THAN 90% OF NORMAL CAPACITY

PROBLEM 18 SINGLE LANE TEST PROBLEM

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MODEL                                      1

COST UPDATE FACTOR                      1.00

PERCENTAGE TRUCKS                         8.

TOTAL NUMBER OF LANES
   INBOUND                                 6
   OUTBOUND                                6

LENGTH OF WORKZONE                      1.00 MILES

WORKZONE OPEN LANES
   INBOUND                                 3
   OUTBOUND                                6

HOURS OF RESTRICTED CAPACITY
   BEGINNING                               9
   ENDING                                 15

HOURS OF WORKZONE ACTIVITY
   BEGINNING                               9
   ENDING                                 15

INBOUND CAPACITY
   NORMAL                             12000  (VPH)
   RESTRICTED                          5400. (VPH)
   WORKING HOURS                       4500  (VPH)

CAPACITY ESTIMATE RISK FACTOR,
PROBABILITY THAT ESTIMATED
WORKING HOURS CAPACITY IS
LESS THAN ACTUAL CAPACITY               60  PERCENT
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SUMMARY OF USER COSTS - PROBLEM 18

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0						0	0
1- 2						0.						0.	0.
2- 3						0						0.	0.
3- 4						0						0	0.
4- 5						0						0	0.
5- 6						0						0	0.
6- 7						0						0.	0.
7- 8						0						0	0.
8- 9						0						0.	0.
9-10	1490.	4500.	57.	52.	0.0	39						0.	39
10-11	1360.	4500.	57.	52.	0.0	31						0.	31.
11-12	1040.	4500.	58.	54.	0.0	16						0	16
12-13	1040.	4500.	58	54.	0.0	16						0.	16
13-14	1210	4500.	57	53	0.0	23						0	23
14-15	1490.	4500.	57.	52	0.0	39						0.	39.
15-16	1670.	4500.	57.	51.	0.0	53						0.	53.
16-17						0.						0.	0
17-18						0						0.	0.
18-19						0						0.	0
19-20						0						0	0
20-21						0						0.	0
21-22						0						0.	0
22-23						0.						0.	0
23-24						0.						0.	0

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 217.

PROBLEM 19 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8	
TOTAL NUMBER OF LANES		
INBOUND	6	
OUTBOUND	6	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	2	
OUTBOUND	6	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	9	
ENDING	15	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	12000.	(VPH)
RESTRICTED	3600.	(VPH)
WORKING HOURS	2800	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60	PERCENT

SUMMARY OF USER COSTS - PROBLEM 19

HOUR	*** INBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	*** OUTBOUND DIRECTION *** VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0						0.	0.
1- 2						0						0.	0.
2- 3						0						0.	0.
3- 4						0						0.	0.
4- 5						0						0.	0.
5- 6						0						0.	0.
6- 7						0						0.	0
7- 8						0.						0.	0.
8- 9						0						0.	0.
9-10	1490.	2800.	57.	47.	0.0	101.						0	101
10-11	1360.	2800.	57.	48.	0.0	78						0.	78
11-12	1040.	2800.	58.	51.	0.0	37						0.	37
12-13	1040.	2800	58.	51	0.0	37.						0.	37
13-14	1210.	2800.	57.	49.	0.0	56						0.	56.
14-15	1490.	2800.	57.	47.	0 0	101						0.	101
15-16	1670.	2800.	57.	45.	0.0	141						0.	141.
16-17						0						0.	0.
17-18						0						0.	0
18-19						0.						0.	0.
19-20						0.						0.	0.
20-21						0						0.	0
21-22						0.						0.	0.
22-23						0						0.	0.
23-24						0						0.	0.

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 551

PROBLEM 20 SINGLE LANE TEST PROBLEM

MODEL	1	
COST UPDATE FACTOR	1.00	
PERCENTAGE TRUCKS	8.	
TOTAL NUMBER OF LANES		
INBOUND	6	
OUTBOUND	6	
LENGTH OF WORKZONE	1.00	MILES
WORKZONE OPEN LANES		
INBOUND	1	
OUTBOUND	6	
HOURS OF RESTRICTED CAPACITY		
BEGINNING	9	
ENDING	15	
HOURS OF WORKZONE ACTIVITY		
BEGINNING	9	
ENDING	15	
INBOUND CAPACITY		
NORMAL	12000.	(VPH)
RESTRICTED	1800.	(VPH)
WORKING HOURS	1200.	(VPH)
CAPACITY ESTIMATE RISK FACTOR, PROBABILITY THAT ESTIMATED WORKING HOURS CAPACITY IS LESS THAN ACTUAL CAPACITY	60	PERCENT

SUMMARY OF USER COSTS - PROBLEM 20

HOUR	INBOUND DIRECTION VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	OUTBOUND DIRECTION VOLUME (VPH)	CAPACITY (VPH)	APRCH SPEED (MPH)	WORK ZONE SPEED (MPH)	LENGTH OF QUEUE (MILES)	ADDITIONAL HOURLY USER COSTS ($)	TOTAL ADD. HOURLY USER COSTS DUE TO LANE CLOSURE ($)
0- 1						0.						0.	0.
1- 2						0						0.	0.
2- 3						0						0.	0.
3- 4						0						0	0.
4- 5						0						0.	0.
5- 6						0						0.	0.
6- 7						0.						0.	0.
7- 8						0						0.	0
8- 9						0						0.	0
9-10	1490.	1200.	57.	23.	0.2	2282						0.	2282
10-11	1360.	1200	57.	26.	0.5	4448.						0.	4448.
11-12	1040.	1200.	58.	30.	0.5	4236						0.	4236.
12-13	1040.	1200.	58	30	0.3	2579						0	2579
13-14	1210.	1200.	57	30.	0 2	1872						0.	1872.
14-15	1490.	1200.	57.	23	0 4	3732.						0.	3732
15-16	1670.	1200.	57.	20	0.8	7898						0	7898.
16-17	1790.	12000.	56	54	0.6	449						0	449
17-18						0						0.	0
18-19						0.						0.	0
19-20						0.						0.	0.
20-21						0.						0.	0
21-22						0						0.	0
22-23						0						0.	0.
23-24						0.						0	0.

TOTAL ADDITIONAL DAILY USER COSTS DUE TO LANE CLOSURE = 27495

CORE USAGE OBJECT CODE= 17064 BYTES,ARRAY AREA= 3260 BYTES,TOTAL AREA AVAILABLE= 173056 BYTES