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A Procedure for the Assessment of Traffic Impacts During Freeway Reconstruction

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ABSTRACT

This paper reports the results of an effort directed toward developing a consistent methodology to assess the impacts of traffic disruption due to major transportation reconstruction/rehabilitation projects during the period of implementation. In the approach taken by this research, state-of-the-art traffic simulation models are used to estimate the performance of the transportation system during various construction phases. Alternative construction and traffic redirection strategies designed to minimize both the direct and indirect losses associated with the construction/rehabilitation are then evaluated with the development of a systematic, computerized procedure designed to:

1. provide for the creation and comparison of multiple and 'layered' reconstruction/rehabilitation scenarios,
2. minimize the required knowledge of both the detailed interactions with the model as well as the host computer, and
3. produce meaningful, comparative outputs that assist in the selection of reasonable alternatives.

The resulting modeling environment is viewed as a convenient tool to assist both the traffic engineer and the transportation planner in selection of reasonable reconstruction/rehabilitation plans and schedules.

INTRODUCTION

There is general awareness that the infrastructure of many of our public works is in need of urgent repair and upgrading if not complete renewal. Although standard techiques are available to forecast benefits and performance of the transportation network following completion of the projects, little is known about assessing:

1. that performance during the construction phase which, in the case of roadway reconstruction, may result in restrictions in capacity for periods longer than a year, and
2. the "malperformance cost" of the improvement in terms of the disruption due to construction.

In major urban areas, new highway construction and rehabilitation projects will have a profound impact on demands placed on the existing transportation network during progress of the projects.

This paper reports the development and implementation of a tool (CARHOP, Computer Assisted Reconstruction--Highway Operations and Planning) to assist the highway engineer/planner in the analysis of alternative highway reconstruction scenarios. An overview of this new tool is presented in the next section. The following section provides a more detailed description of the menu components of the CARHOP Preprocessor, the interactive, menu-oriented component of the overall CARHOP environment. A sample interactive session with CARHOP is presented in a later section followed by a presentation of an application of the CARHOP modeling environment to a sample network and discusses the results of two demonstration cases.

OVERVIEW OF THE CARHOP ENVIRONMENT

The CARHOP Environment provides a method for testing various TSM alternatives related to the reconstruction of freeways and arterials in an existing transportation network. CARHOP combines the resources of several different computer simulation and optimization models into one interactive package, providing the user access to state-of-the-art, data-intensive computer simulation models in a manner that minimizes data preparation and input. In this way, concentration may focus more on the broader issues of reconstruction, rather than on modification of large data sets and repetitive executions of the simulation. CARHOP allows the engineer to create reconstruction zones, modify their characteristics, and then evaluate the performance of the transportaton network, subject to the altering of the surrounding arterial network characteristics and signal timings. Comparison statistics are compiled from each of the different sub-models invoked on a sub-networkwide basis and along user-specified and computer optimized detour routes around the reconstruction zone. The impacts of different driver behaviors and vehicle occupancies may also be tested within the modeling environment.

The CARHOP Environment is separated into three independent computer packages:

1. CARHOP Preprocessor
2. POSTCARS Executor
3. JOGGER Postprocessor

Each of these packages is compatible with the other and is designed to be run in the order shown above. Although not recommended, it is possible to execute any of the packages without the others.

Description of Major CARHOP Components

The CARHOP Preprocessor provides the user-interface with the rest of the CARHOP Environment. Designed as an interactive, menu-driven program, the preprocessor is responsible for managing all of the input data files and prompting the user for the various pieces of information including the scope of the reconstruction, detour specifications (if any), alternative signal timings and types of outputs to be provided. CARHOP is executed through a series of screen menus, avoiding the memorization of complex commands, and contains extensive error trapping to prevent erroneous data from being passed to subsequent modules. Although current data base information is accessible to the user (e.g., number of lanes, capacities, speeds) for use in designing reconstruction scenarios, modifications to the data base are simply logged during execution of the CARHOP Preprocessor; the actual modifications are performed by subsequent modules, allowing time intensive tasks to be performed in a non-interactive mode, greatly speeding execution. Multiple scenarios may be tested at one time; in a matter of minutes, the user may design several alternative strategies for comparison.

The POSTCARS Executor is responsible for taking the scenarios described by the preprocessor and performing the different operations requested. In the process, several data sets may be created, several different simulations may be performed, and extensive outputs may be generated. POSTCARS coordinates the execution of these simulations and performs the necessary data set conversions. At each stage of POSTCARS execution, information on all operations performed is stored in a log. This provides a hardcopy of the scenario session, together with any special messages or conditions generated by subprograms. POSTCARS is designed to operate in a batch environment, without user intervention.

JOGGER, the CARHOP Postprocessor, compiles statistics and generates comparative outputs based on the statistics generated in the POSTCARS Executor.

Statistics are presented on a link-by-link basis, as well as on a sub-networkwide basis. If detour outputs are requested, statistics are compiled along each detour route and compared with the original routes. Descriptions of each scenario are generated from the preprocessor outputs, providing the user with a hardcopy of the actual scenario descriptions processed by the POSTCARS Executor. As with the POSTCARS Executor, JOGGER is designed to operate in the "batch" computer environment requiring no user interaction.

Rather than being an explicit simulation model, the CARHOP Environment is an organizer and executor. The TRAF Modeling System (Federal Highway Administration, 1985) is used as the base simulation model for the CARHOP Environment. Used like a chalkboard, TRAF is run on the base case scenario; changes are then made to the base case simulating network modifications associated with the reconstruction scenarios. In addition, several support packages are included to facilitate data transfer among these simulation models as well as to create new data sets based on the changes specified by the user. Based on the options requested in a scenario log file created by the CARHOP Preprocessor and the data requirements of each of the submodels, some or all of these programs may be executed. The TRANSYT-7F Simulation Model (Federal Highway Administration, 1984) is included in the CARHOP Environment to provide optimized traffic signal timings along a user-specified detour route. This and other simulation models employed are used to generate modified TRAF data sets, reflecting changes in signal timings, detour routes and network coding. While the TRAF modeling system comprises many different simulation models of varying degrees of statistic resolution, CARHOP supports only three of these models (all in TRAFLO of TRAF): 1) Level 2 (Arterial Package) 2) FREEFLO (Freeway Package) 3) TRAFFIC (Traffic Assignment). FREEFLO is used to gather statistics along the freeway subnetwork. This model is based on a macroscopic representation of traffic flow. For the arterial portion of the transportation system, the TRAFLO Level-2 model is employed. This model is most similar to TRANSYT-7F and, while being macroscopic also, provides a relatively comprehensive set of vehicle and person travel statistics. In addition to the simulation models of TRAF, traffic assignment for the CARHOP Environment is provided by the TRAF implementation of TRAFFIC (Nguyen and James, 1975), which employs an equilibrium-based assignment algorithm.

COMPONENTS OF THE CARHOP PREPROCESSOR

The CARHOP Preprocessor organizes options within CARHOP into ten distinct areas of concentration:

1. Data Base Selection
2. Freeway Incident Specification
3. Reconstruction Zone Specification
4. Detour Route Specification
5. Signal Timing Alteration
6. Physical Network Alteration
7. User Attribute Alteration
8. Transit System Alteration
9. Graphics Specifications
10. Scenario Processing

Figure 1 shows the CARHOP Main Menu. These options provide a wide range of data set manipulation features. Any or all of these options may be used in the specification of a particular TSM strategy scenario. A brief description of each option follows. Associated with each description is a figure representing the visual display of the preprocessor to the user.

1. <u>Data Base Selection</u>

   This module performs the role of "bookkeeper" in the processing of multiple scenarios and is executed before the creation of any CARHOP scenario (Figure 2a).

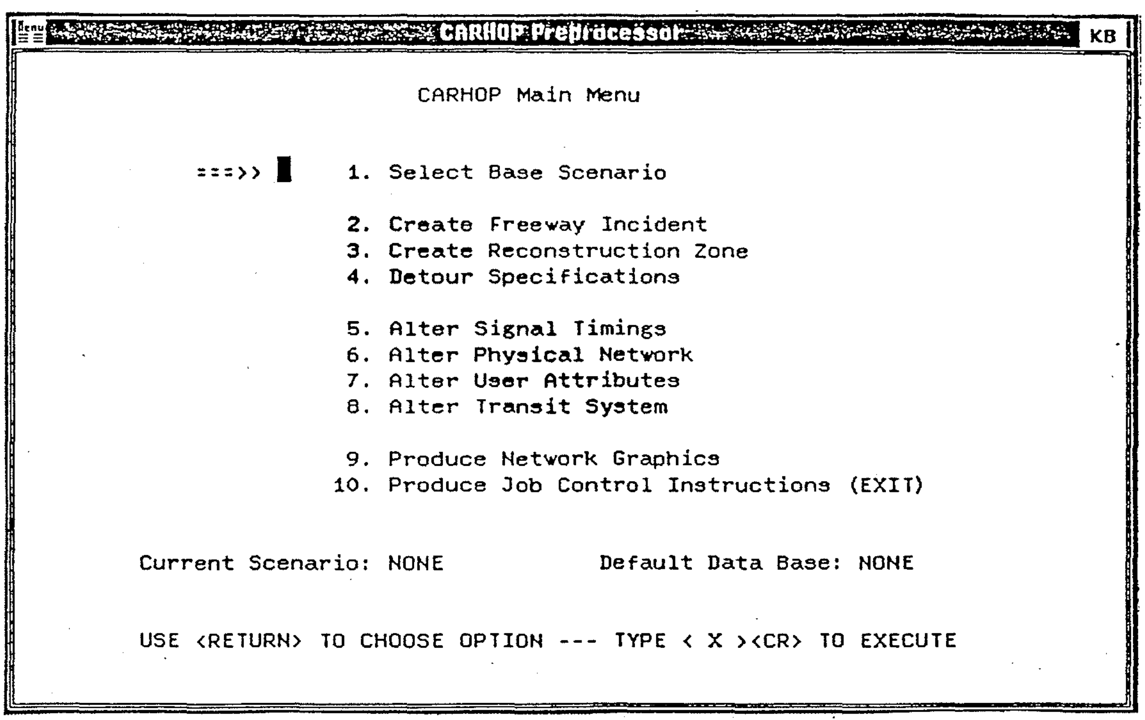


FIGURE 1: CARHOP Main Menu

2. Freeway Incident Specification

Freeway Incident Specification allows the user to create an "incident" on the freeway network. Examples of incidents include stalled vehicle, collisions, bottlenecks, etc. The user need only specify the link on which the incident will occur together with the new estimated capacity (Figure 2b).

3. Reconstruction Zone Specification

Reconstruction Zone Specification creates the actual reconstruction zone in the data base. It prompts the user for the location of the reconstruction zone and the system alterations resulting from the type of activity that is planned. These alterations include decreasing the lane capacities, lane and ramp closures, and estimated speed reduction zones (Figure 2c).

4. Detour Route Specification

Detour Route Specification allows the user to test various detour strategies associated with the reconstruction zone created in the previous module. There are several levels to this module. First, the user has the option of entering no detours at all. Statistics compiled at this level will provide a measure of the unmitigated impact of the reconstruction. The second level of this module provides the option of a user-specified detour route. Single or multiple routes may be entered. In addition, the user may compare the effectiveness of several different detours (multiple runs). The third level of this module allows the option to create detours based on the reallocation of trips in the traffic assignment model. Used in conjunction with other CARHOP options, the effects of additional lanes, new signal timings, "no truck" restrictions, modified lane stripings and other, innovative strategies for improving traffic flow on the surrounding surface street system may be tested (Figure 2d).

5. Signal Timing Alteration

   Signal Timing Alteration allows the option to test the impact of signal timings on the performance of the reconstruction strategy. Signal timings may be left "as is" or may be optimized. The effects of cycle length and signal progression may also be explored using this module. These modifications may be made to the existing network, to the network containing the reconstruction zone alone, or to the specified detour route. Signal progression and optimum cycle length calculations may be performed on individual intersections, the network immediately surrounding the reconstruction zone or along the specified detour route (Figure 2e).

6. Physical Network Alteration

   Physical Network Alteration provides a method of testing various supply-side Transportation System Management (TSM) strategies. Two-way streets may be converted to one-way streets and vice-versa. The effects of turning restrictions, intersection channelization, parking restrictions, number of lanes and lane widths may be explored. This module may also be implemented with other modules in CARHOP to estimate the impacts of complex reconstruction scenarios (Figure 2f).

7. User Attribute Alteration

   This module provides for the investigation of the effects of different fleet compositions (car to truck ratios, etc.) and vehicle types on system performance. Different driver behaviors (start-delay at intersections, etc.) may also be input (Figure 2g).

8. Transit System Alteration

Transit System Alteration allows for modification to be made to the transit data base. Bus routes may be added and deleted. Average bus occupancies may be modified to test the effects of improved bus ridership on system performance (Figure 2h).

9. Graphics Specifications

This module of CARHOP converts the physical network characteristics into computer plotter instructions for later processing. Detour routes, bus routes and changes in travel patterns between origins and destinations may be represented (Figure 2i).

10. Scenario Processing

Once the single or multiple reconstruction zones, detour routes and other options have been executed (as desired), this option creates a "logfile" containing all of the information in a form to read by the POSTCARS Executor. (No changes to the base case are made during execution of the CARHOP Preprocessor.) A series of sub-options are available giving the user the ability to create more scenarios, delete the scenario just created, or exit CARHOP (Figure 2j).

SAMPLE SESSION

This section provides a "walk-through" sample session in CARHOP in which a reconstruction scenario is created. The scenario created will consist of a single reconstruction zone with one user-specified detour provided as a means of routing a portion of the highway traffic around the reconstruction area.

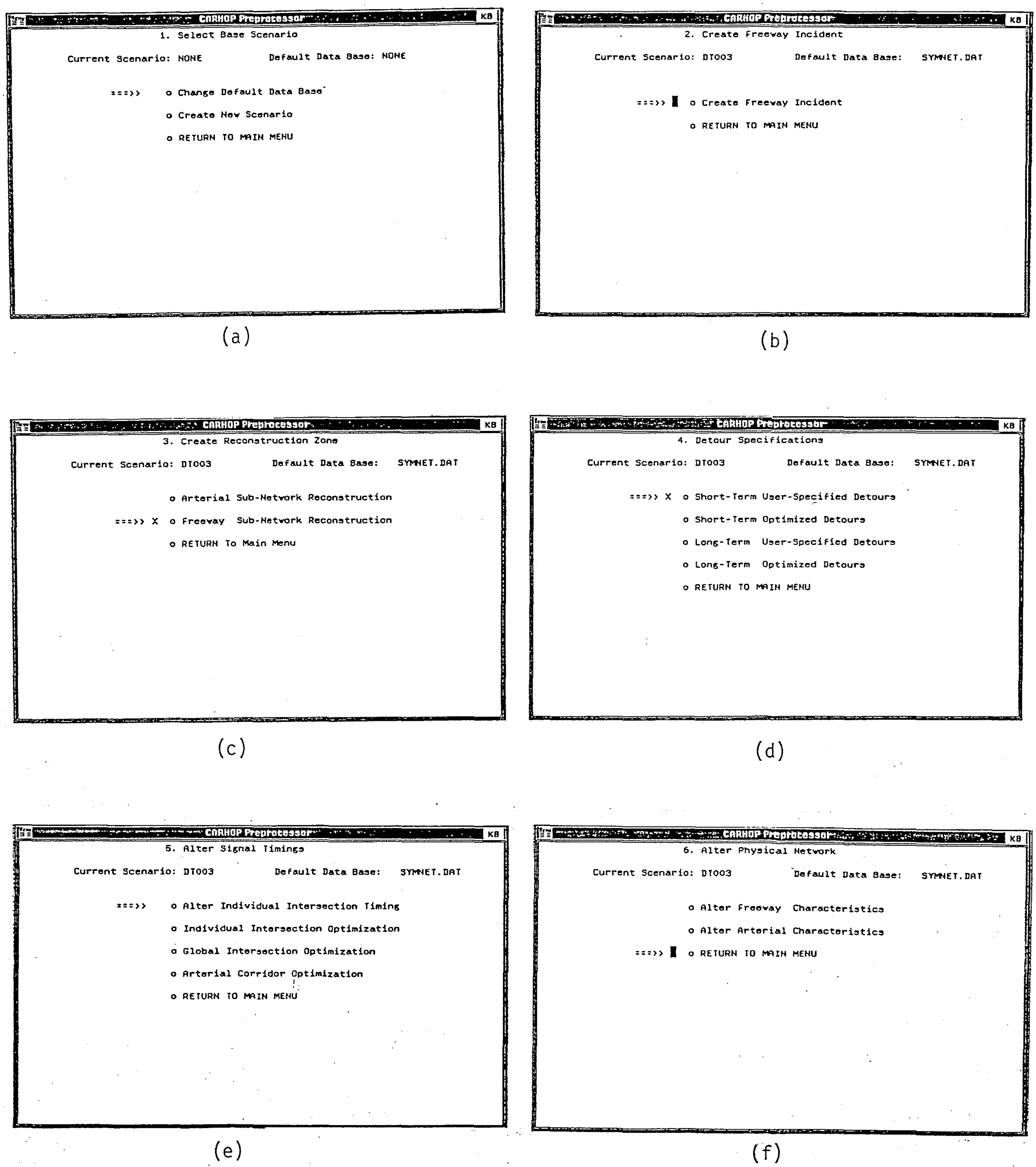
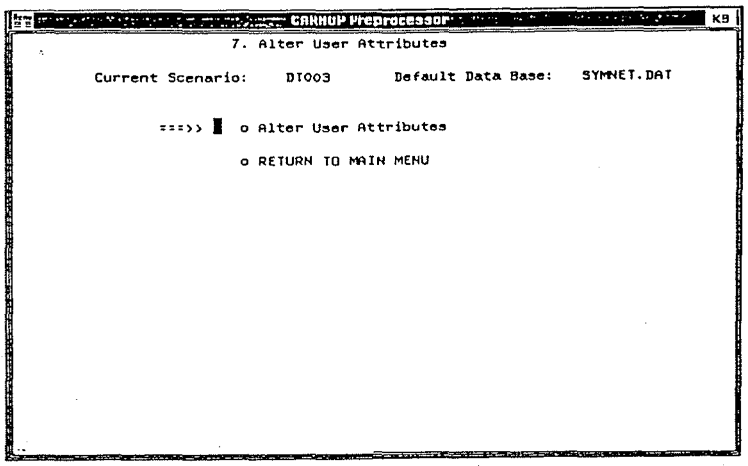
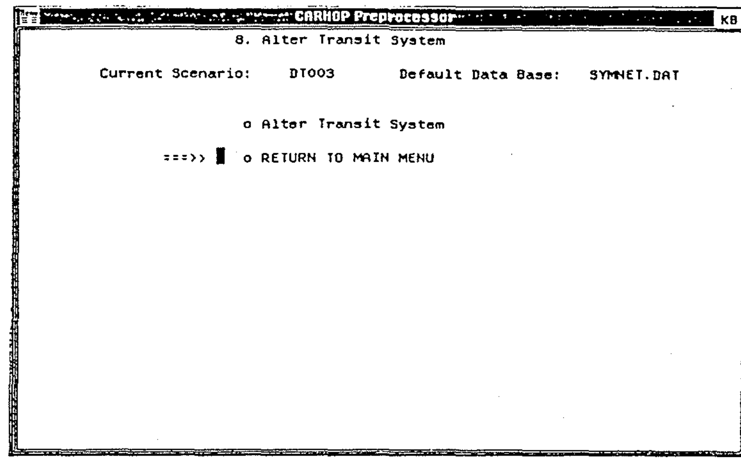


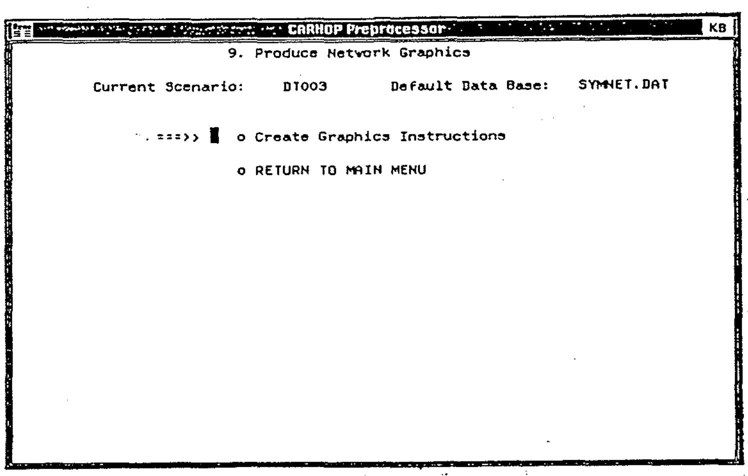
FIGURE 2: Visual Displays of Menu Options



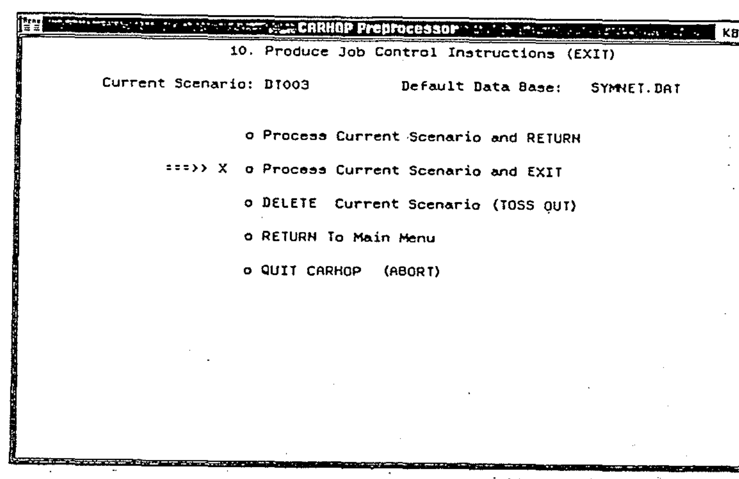
(g)



(h)



(i)



(j)

FIGURE 2 (Cont'd): Visual Displays of Menu Options

CARHOP specification of the reconstruction zone and corresponding detour route consists of the following steps:

1. Specify the Default Data Base, Select Menu Options and Scenario Data Base,
2. Define Reconstruction Zone and Specify Zone Characteristics
3. Specify Detour Route,
4. Process Current Scenario and Exit,

performed in sequential order. Descriptions of each, together with accompanying visual terminal displays, follow.

Specify the Default Data Base, Select Menu Options and Scenario Data Base

The session begins with a display that announces the actuation of the CARHOP environment (Figure 3a). A prompt is then given for the user to provide a name for the default data base, containing the TRAF data base information (Figure 3b). The CARHOP Preprocessor requires a default data base as input. This default data base consists of a standard 'TRAF' input data set containing the network geometrics, signal timings, and origin destination information of the study area. For the demonstration of the CARHOP environment, a hypothetical network was devised. It was chosen to highlight various features of the simulation environment and to demonstrate the behavior of the simulations under varying reconstruction conditions. After receiving the name of the default data base, CARHOP will ask for any other scenario files to be used during the session.

With the names of the default data base(s) entered, the screen is cleared and the main CARHOP Preprocessor menu is displayed. This menu displays the 10 options available as well as a status line showing the current scenario and default data base. Menu options are selected by moving the pointer ('--->') until it is aligned with the option to be performed and then 'marking' that option (Figure 3c).

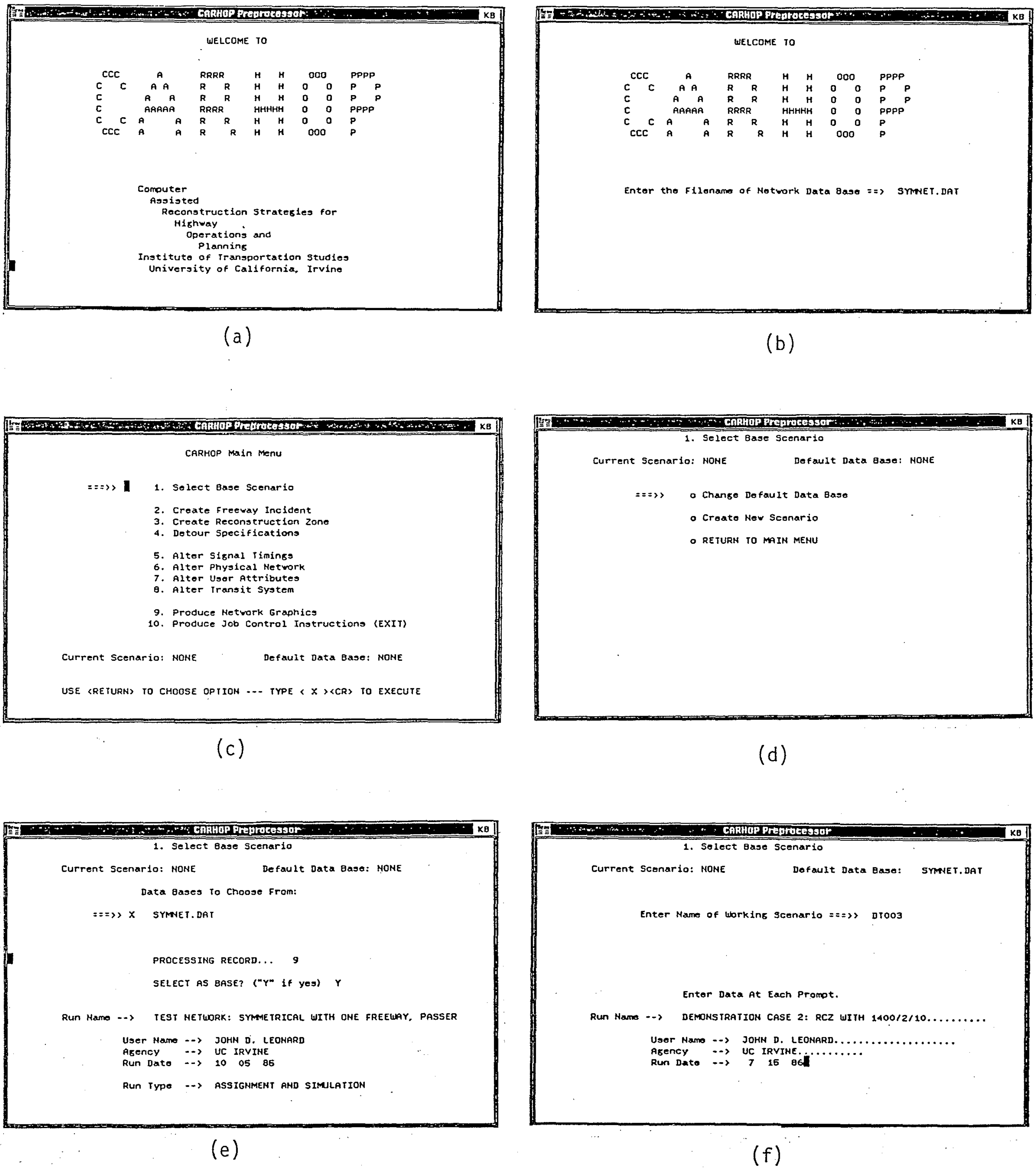


FIGURE 3: Building a Scenario Data Base

The first task in creating a reconstruction scenario file is to specify from which base the scenario file is to be created. This is accomplished by executing MENU OPTION 1. The Option 1 submenu provides the user with three choices: Change Default Data Base, Create New Scenario, and RETURN TO MAIN MENU.

Upon selection of the 'Change Default Data Base' option (Figure 3d), CARHOP will display the choices available. This list will include all of the file names entered by the user when the program was started.

After the data base is selected, an information page will be displayed on the screen, showing important data base information such as run-name, user name, agency, run-data and run-type. (Figure 3e) This information is provided to assist the user in the proper selection of the default data base. The next step is to define a working scenario file. If a default scenario was just selected, CARHOP automatically prompts the user for the name of the working scenario. This option may also be performed without selecting a default data base by marking the appropriate option. Upon selection of a working scenario file, the user enters the appropriate file information (Figure 3f).

Define Reconstruction Zone and Specify Zone Characteristics

To specify a reconstruction zone, the user must select Option 3 of the main menu: 'Create Reconstruction Zone.' CARHOP will then display the associated sub-menu. This sub-menu allows three further choices: Arterial Sub-Network Reconstruction, Freeway Sub-Network Reconstruction and RETURN TO MAIN MENU (Figure 4a). CARHOP next prompts the user for the upstream and downstream mainline nodes encompassing the reconstruction area (Figure 4b). If a reconstruction zone is to encompass several mainline links, each link is entered separately. After typing the downstream node number, CARHOP scans the default data base for the link. If it is not found, an appropriate message is displayed and the user is asked to try again.

If the link is found, an information page will be displayed showing the current characteristics of the input link (Figure 4c). These characteristics are determined from information contained in the default data base and include the number of regular use lanes, the number of special purpose lanes, the nominal lane capacity in vehicles per hour, and the free-flow speed in miles per hour. CARHOP now prompts:

'CREATE RECONSTRUCTION ZONE? (Y/N) --->'

Given a reply of 'Y', CARHOP will create a reconstruction zone. CARHOP will then prompt the user for the number of lanes closed, the new lane capacity and the new free-flow speed (Figure 4d).

Once completed, CARHOP returns the user to the reconstruction sub-menu. Any reconstruction zones that may have been specified are listed as a reminder of the work already completed. The user may specify as many reconstruction zones as desired in any one scenario. When all of the reconstruction zones have been specified, the option 'RETURN TO MAIN MENU' is executed to return the user to the main menu.

Specify Detour Route

With a reconstruction zone specified, corresponding detours may also be specified. This is achieved by entering Option 4 from the main menu: DETOUR SPECIFICATIONS. If chosen, the Detour Specification sub-menu is displayed (Figure 5a). There are two sub-options currently implemented: Short-Term User-Specified Detours and Long-Term Optimized Detours. In this example we will specify Short-Term User-Specified Detours.

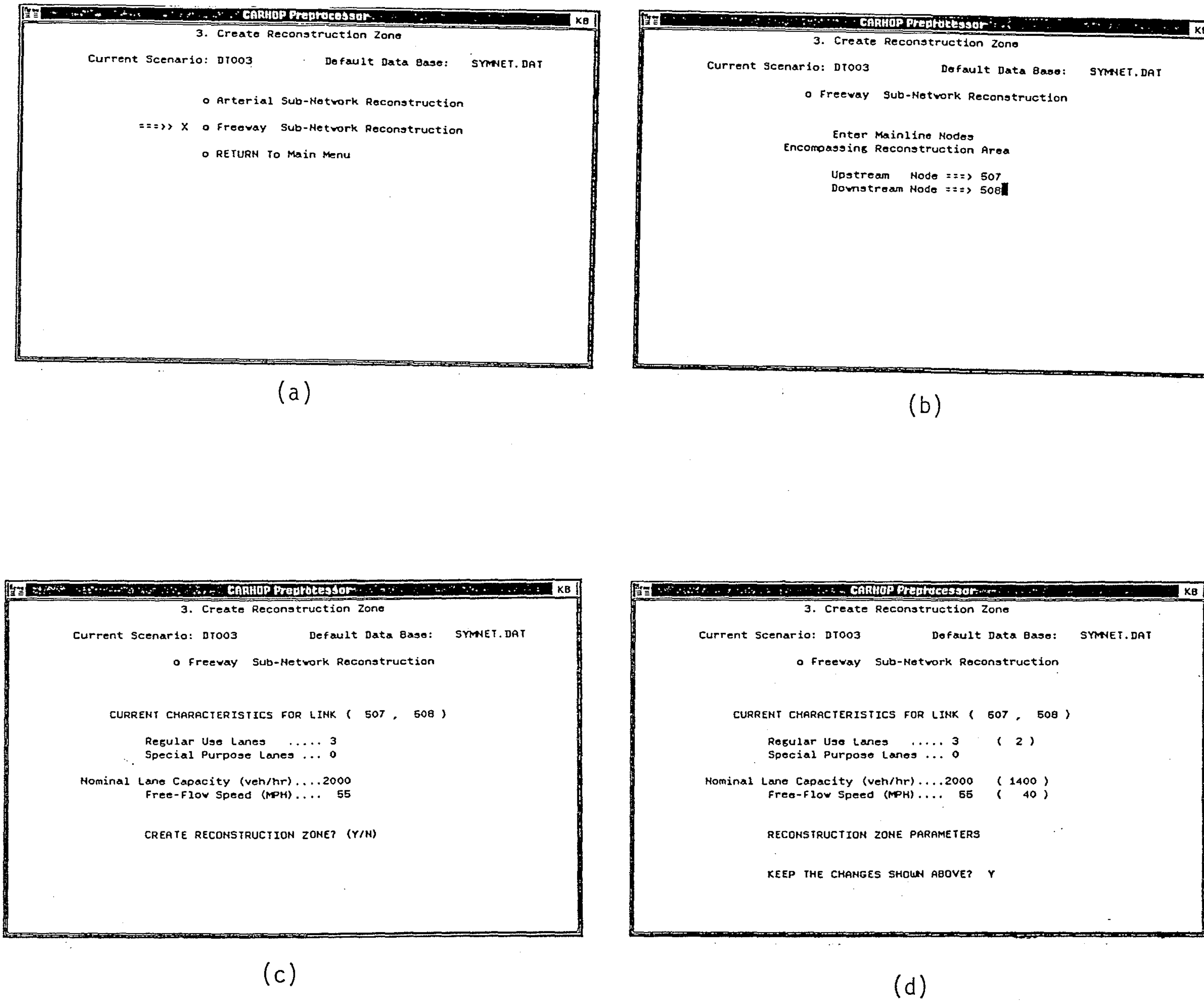
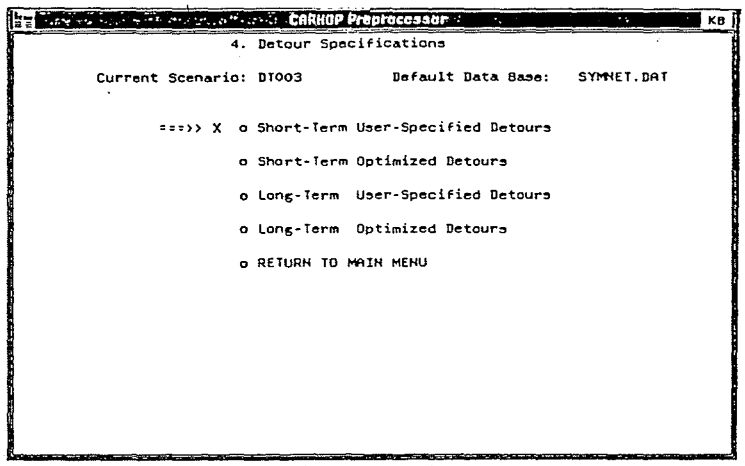
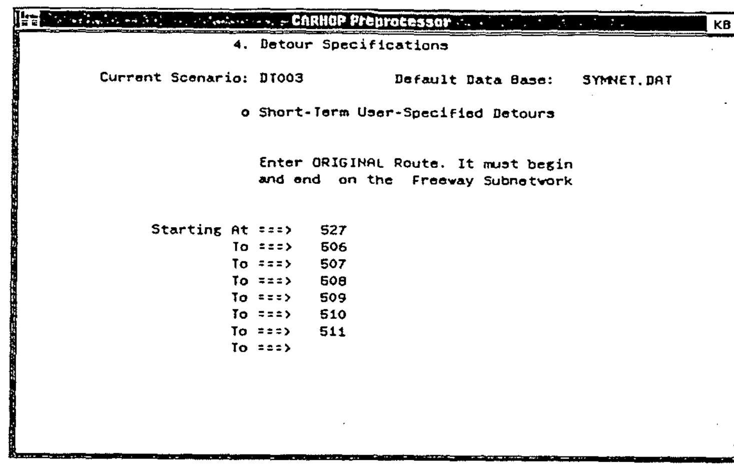


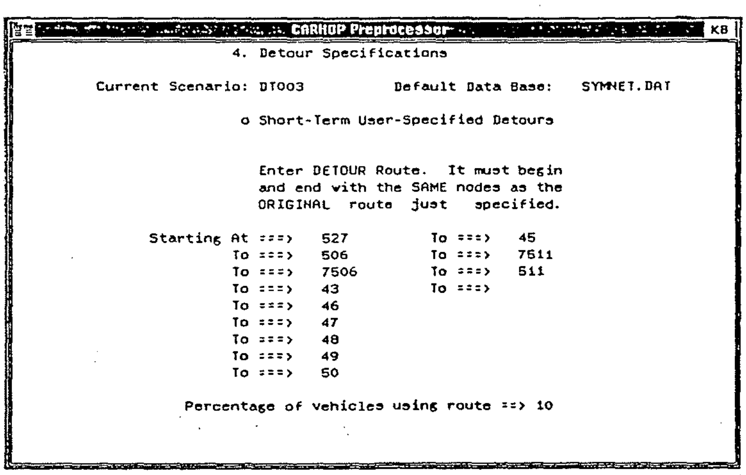
FIGURE 4: Defining a Reconstruction Zone



(a)



(b)



(c)

FIGURE 5: Specifying a Detour Route

CARHOP now prompts the user for the ORIGINAL route (Figure 5b). The route is entered node-by-node. It must begin and end on the freeway sub-network. Next, CARHOP will prompt the user for the DETOUR Route (Figure 5c). This route must begin and end with the same nodes as the original route. The Detour Route may leave the freeway to the arterial sub-network, but must reenter the freeway and end at the same node as the original route. When both routes have been entered, each route is checked for continuity, that is, to determine that each node pair forms a link that exists in the default data base and is connected to the preceding link. If the routes pass this test, the user is prompted for the percentage of vehicles using the detour route. This percentage is used to calculate the volume of trips to be routed from the original route to the detour route.

Process Current Scenario and Exit

The final operation to be performed in this example scenario is to process the information that has just been entered. The processing combines the separate instructions from each different option into a single scenario logfile that can later be used by the POSTCARS Executor and JOGGER Postprocessor. Selecting Option 10 displays the PROCESS CURRENT SCENARIO sub-menu (Figure 6).

There are five choices available from this sub-menu. To create more scenarios, the 'Process Current Scenario and RETURN' option would be selected. Had any errors or undesirable selections been made, Option 3 'Delete Current Scenario (TOSS OUT)' would be selected. If option 10 had inadvertently been chosen, 'RETURN TO MAIN MENU' would allow the user to return to the main menu to select other options. 'QUIT CARHOP' option is provided as a means to stop execution of the current carhop session without saving the current scenario. The option 'PROCESS CURRENT SCENARIO AND EXIT' produces comparisons of the reconstruction

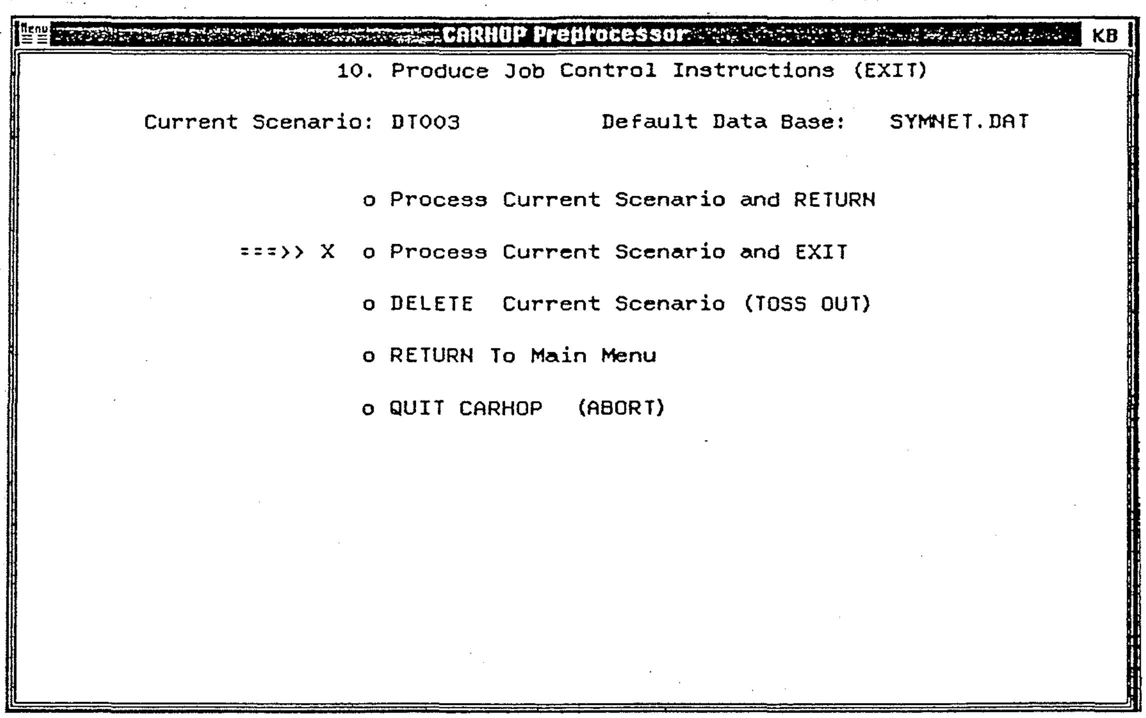


FIGURE 6: Processing a Reconstruction Scenario

scenario to the base case when the POSTCARS Executor and JOGGER Postprocessor are executed.

DEMONSTRATION OF THE CARHOP RECONSTRUCTION METHODOLOGY

To demonstrate use of the CARHOP Environment in the study of freeway reconstruction and its impacts on the surrounding arterial sub-network, two case studies are presented:

1) A range of freeway reconstruction scenarios with Implementation of the Long-Term Detour Specification of CARHOP.

2) Fixed Freeway Reconstruction (2 open mainline lanes) with a ranged percentage of traffic along the detour route.

The demonstration network illustrated in Figure 7 includes a typical freeway section over-laid on a grid-pattern arterial network. The network was designed to be symmetrical about the major and minor axes to simplify interpretation of the operation of the underlying TRAF Simulation Modeling System. The Freeway sub-network consists of a single section of freeway, with three through lanes in each direction, bisecting an arterial grid sub-network. The arterial subnetwork comprises four east-west corridors and five north-south corridors and connects to the freeway subnetwork at three alternating interchanges, each of symmetrical diamond shape. Streets on the arterial subnetwork are spaced at one-half mile intervals. In terms of the TRAF data base designations, the arterial portion of the study area is coded as a Level 2 subnetwork and consists of 31 links, 26 regular nodes, 18 entry/exit nodes and 12 interface nodes. The freeway portion is coded as a FREEFLO subnetwork and consists of 30 links, 16 regular nodes, 2 entry/exit nodes and 12 interface nodes.

Prior to running the test cases, the signal timings were optimized using the PASSER II-80 simulation model along all north-south corridors of travel. Each of

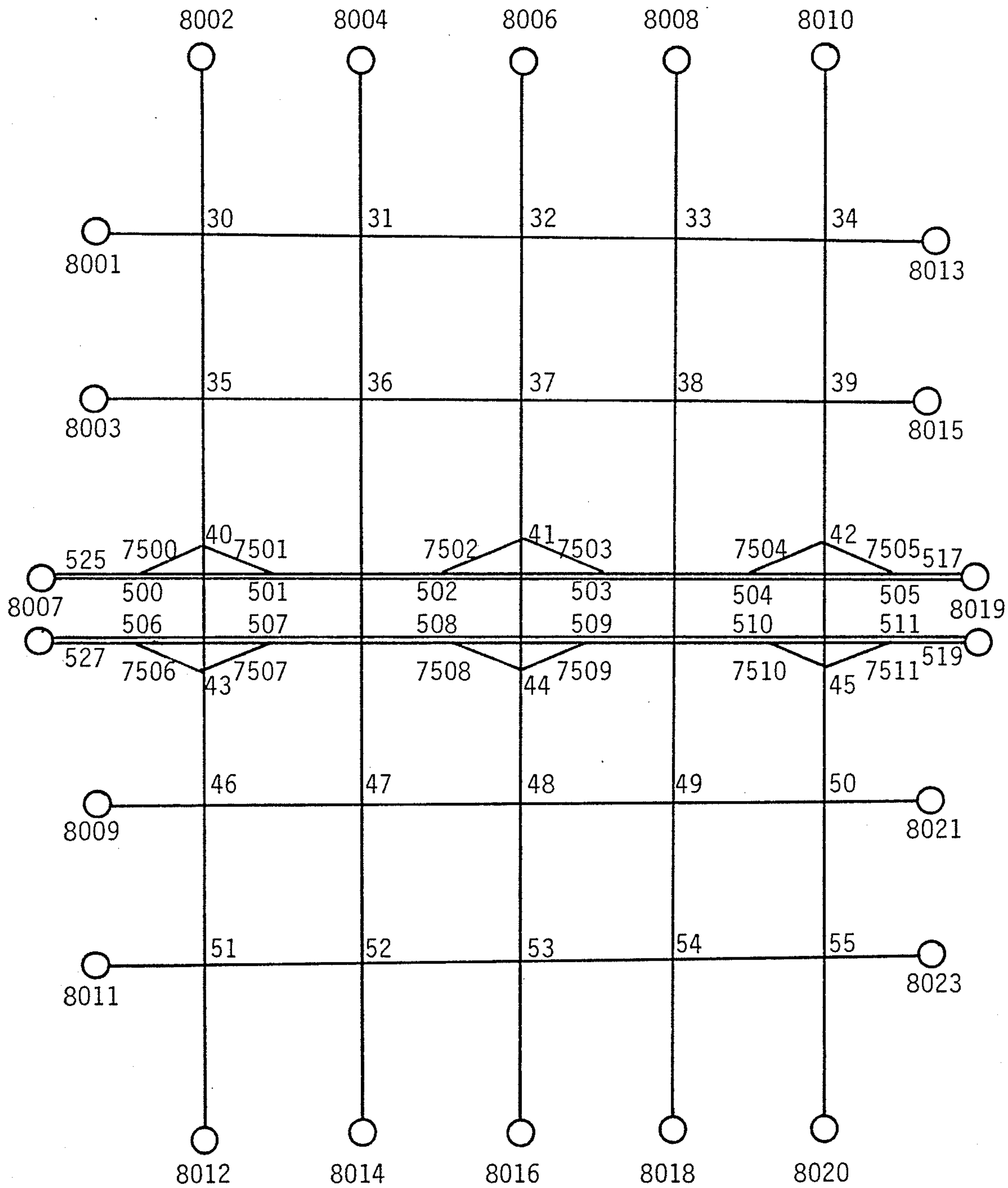


FIGURE 7: Demonstration Network

the test cases was chosen to demonstrate a particular facet of the CARHOP Environment and the performance of the TRAF Simulation Modeling System under a range of inputs.

Test Case 1

Test Case 1 examines the use of CARHOP to assess the effects of freeway reconstruction with the 'Long-Term' detour route option specified. In each of the scenarios of Test Case 1, the freeway mainline traffic flow is constrained and the traffic is allowed to reroute around the bottle-neck.

Test Case 1 consists of five separate CARHOP scenarios. A reconstruction zone of three successive links is established along both directions of the freeway. The number and severity of constraints in each scenario is sequentially increased from minor speed and capacity constraints to full closure of the freeway mainline:

Scenario Number	Scenario Name	Link Capacity	Free Flow Speed	Open Lanes
BASE	SYMNET	2000	55	3
1	MT001	1800	45	3
2	MT002	1400	40	3
3	MT003	1400	40	2
4	MT004	1400	40	1
5	MT005	1400	40	0

The link constraints shown above apply to all links in the reconstruction zone; a total of six freeway links are directly impacted by the constraints. Estimated link capacities are taken from the ITE Highway Capacity Manual's work zone estimates (Transportation Research Board, 1985).

Figure 8 displays a sample of the scenario summary output for scenario MT003 of Test Case 1. The tables in Figure 8 compare the characteristics of the link in the scenario with that in the base case.

For example, link 507-508 has two lanes in scenario MT003 while in the base case it has three lanes. The freeflow capacity of the link was reduced from 2000

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

INFORMATION SUMMARY FOR SCENARIO:MT003

```
SCENARIO       ----> MT003
DESCRIPTION    ----> CONSTRAINED RCZ, 1 LANE CLOSED: 1400/40/2
DATA CREATED   ---->  7 15 86
USER NAME      ----> JOHN D. LEONARD
AGENCY         ----> UC IRVINE
```

CREATED FROM BASE NETWORK: SYMNET

LENGTH OF SIMULATION (IN SECONDS) = 3600

RECONSTRUCTION ZONE SPECIFIED AT LINK (507, 508)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	5.4
TRIPS THROUGH ZONE	=	4496.0	2799.0
VOLUME/CAPACITY	=	0.7493	0.9996
MINUTES PER TRIP	=	0.8886	5.5256

RECONSTRUCTION ZONE SPECIFIED AT LINK (508, 509)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	13.6
TRIPS THROUGH ZONE	=	4270.0	2398.0
VOLUME/CAPACITY	=	0.7117	0.8564
MINUTES PER TRIP	=	0.8906	2.2060

RECONSTRUCTION ZONE SPECIFIED AT LINK (509, 510)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	19.8
TRIPS THROUGH ZONE	=	4463.0	2619.0
VOLUME/CAPACITY	=	0.7438	0.9354
MINUTES PER TRIP	=	0.8672	1.5136

RECONSTRUCTION ZONE SPECIFIED AT LINK (504, 503)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	5.4
TRIPS THROUGH ZONE	=	4491.0	2799.0
VOLUME/CAPACITY	=	0.7485	0.9996
MINUTES PER TRIP	=	0.8874	5.5256

RECONSTRUCTION ZONE SPECIFIED AT LINK (503, 502)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	13.6
TRIPS THROUGH ZONE	=	4265.0	2398.0
VOLUME/CAPACITY	=	0.7108	0.8564
MINUTES PER TRIP	=	0.8905	2.2060

RECONSTRUCTION ZONE SPECIFIED AT LINK (502, 501)

		SYMNET	MT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	19.3
TRIPS THROUGH ZONE	=	4458.0	2618.0
VOLUME/CAPACITY	=	0.7430	0.9350
MINUTES PER TRIP	=	0.8671	1.5118

DETOUR OPTION SELECTED ----> LONG-TERM CARHOP-OPTIMIZED

NUMBER OF DETOUR ROUTES ----> 64

```
ORIGINAL ROUTE:
8001  30  35  40  43  7507  507  508  509  510  511  519  8019
DETOUR   ROUTE:
8001  30  31  36  37  38  39  42  45  7511  511  519  8019
ORIGINAL ROUTE:
8001  30  35  40  43  7507  507  508  509  510  7510  45  50  55  8020
DETOUR   ROUTE:
8001  30  31  36  37  38  39  42  45  50  55  8020
ORIGINAL ROUTE:
8001  30  35  40  43  7507  507  508  509  510  7510  45  50  8021
DETOUR   ROUTE:
8001  30  31  36  37  38  49  50  8021
ORIGINAL ROUTE:
8001  30  35  40  43  7507  507  508  509  510  7510  45  50  55  8023
DETOUR   ROUTE:
8001  30  31  36  37  38  49  54  55  8023
ORIGINAL ROUTE:
8002  30  35  40  43  7507  507  508  509  510  511  519  8019
DETOUR   ROUTE:
8002  30  31  36  37  38  39  42  45  7511  511  519  8019
ORIGINAL ROUTE:
8002  30  35  40  43  7507  507  508  509  510  7510  45  50  55  8020
DETOUR   ROUTE:
8002  30  31  36  37  38  39  42  45  50  55  8020
```

FIGURE 8: Scenario Summary Output

vehicles per hour per lane (vphpl) to 1400 vphpl. The results of the simulation indicate that the reconstruction link in the base case has a simulated speed of 33.8 MPH; during reconstruction the simulation produces a speed of 5.4 MPH. Other statistics shown in the reconstruction zone summary include the number of trips through the zone, the volume/capacity ratio and minutes per trip required to pass through the zone.

The final section of the scenario summary report contains the detour summary. The detour summary includes: the type of detour option selected, the number of detour routes and a list of the original and suggested detour routes for all O-D pairs impacted by the construction.

Figure 9 gives a tabular comparison of four cumulative sub-networkwide statistics, as well as global totals for the entire transportation system. Histogram comparisons for each performance measure by sub-network type and global network are also provided by CARHOP. Samples of these are displayed in Figures 10 to 17.

Test Case 2

The second test case demonstrates an application of CARHOP to evaluate the effectiveness of a particular "Short-Term User-Specified" detour during freeway reconstruction. It consists of five CARHOP scenarios. Reconstruction zones comprising three successive links are established along the south section of freeway. Test Case 2 examines a fixed reconstruction zone strategy: two lanes open along the freeway with a freeflow speed of 40 MPH and a capacity of 1400 vphpl with the percentage of freeway trips routed from the freeway to the arterials gradually increased.

The scenarios of Test Case 2 consist of:

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

CUMULATIVE SUBNETWORK WIDE COMPARISON

ARTERIAL SUBNETWORK

	SYMNET	MT001	MT002	MT003	MT004	MT005
AVERAGE SPEED	15.9	13.5	10.8	9.2	3.5	1.8
VEHICLE TRIPS	19747.	18135.	17527.	17107.	14293.	10664.
VEHICLE HOURS	2042.9	2472.8	2947.6	3425.6	6723.3	9392.1
VEHICLE MILES	32531.7	33472.6	31954.7	31516.5	23391.0	16845.4

FREEWAY SUBNETWORK

	SYMNET	MT001	MT002	MT003	MT004	MT005
AVERAGE SPEED	34.3	33.4	31.1	10.2	2.7	0.8
VEHICLE TRIPS	7689.	7637.	7573.	6326.	3549.	1710.
VEHICLE HOURS	876.6	835.8	860.2	2149.5	5524.3	7710.9
VEHICLE MILES	30103.4	27931.5	26717.8	21880.4	14743.7	5797.8

CUMULATIVE GLOBAL COMPARISONS

	SYMNET	MT001	MT002	MT003	MT004	MT005
AVERAGE SPEED	21.5	18.6	15.4	9.6	3.1	1.3
VEHICLE TRIPS	27436.	25772.	25100.	23433.	17842.	12374.
VEHICLE HOURS	2919.5	3308.6	3807.8	5575.1	12247.7	17103.0
VEHICLE MILES	62635.1	61404.1	58672.5	53396.8	38134.7	22643.2

FIGURE 9: Comparison of Cumulative Network Statistics for Various Strategies in Test Case 1

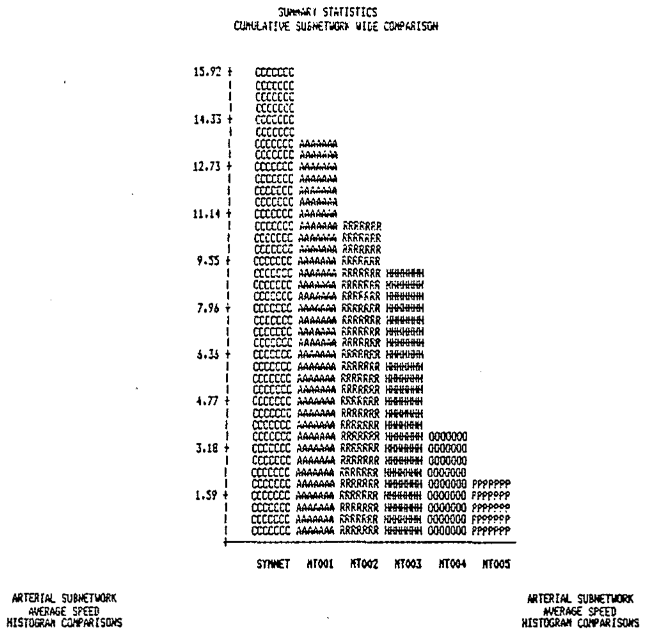


FIGURE 10: Average Speed - Arterial Subnetwork

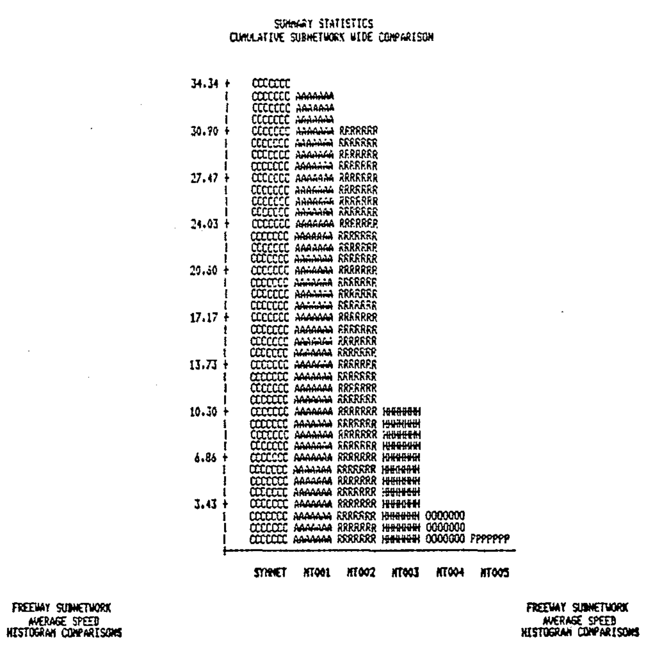


FIGURE 11: Average Speed - Freeway Subnetwork

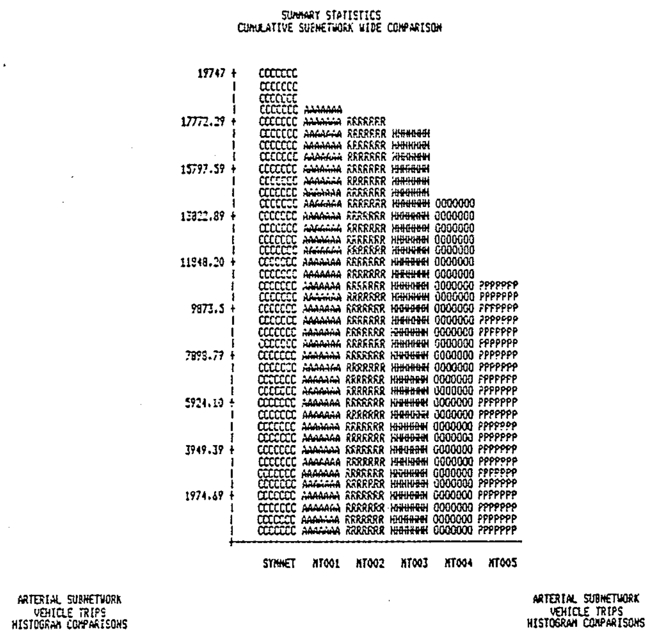


FIGURE 12: Vehicle Trips - Arterial Subnetwork

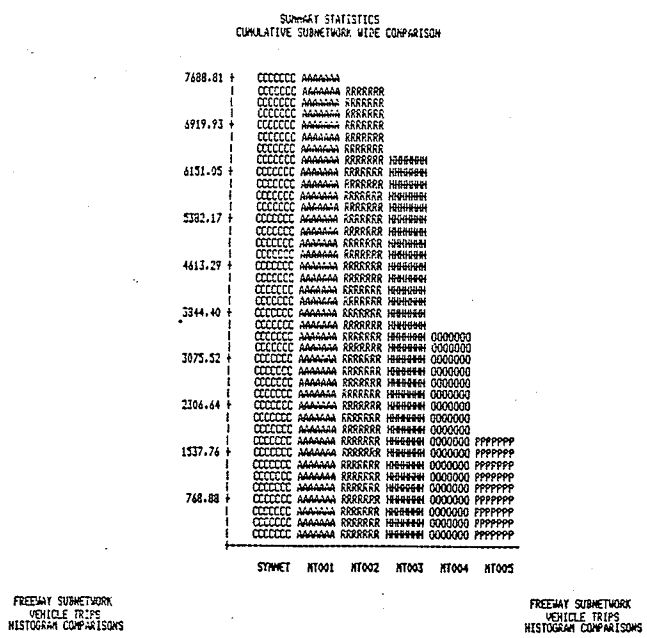


FIGURE 13: Vehicle Trips - Freeway Subnetwork

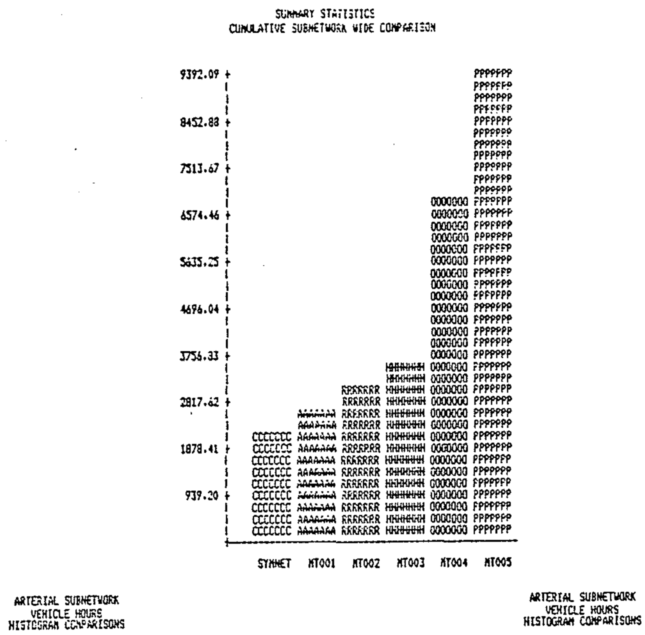


FIGURE 14: Vehicle Hours - Arterial Subnetwork

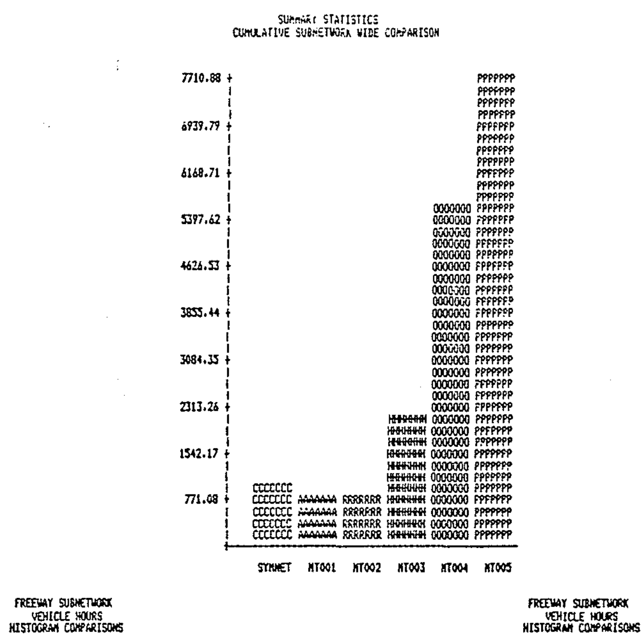


FIGURE 15: Vehicle Hours - Freeway Subnetwork

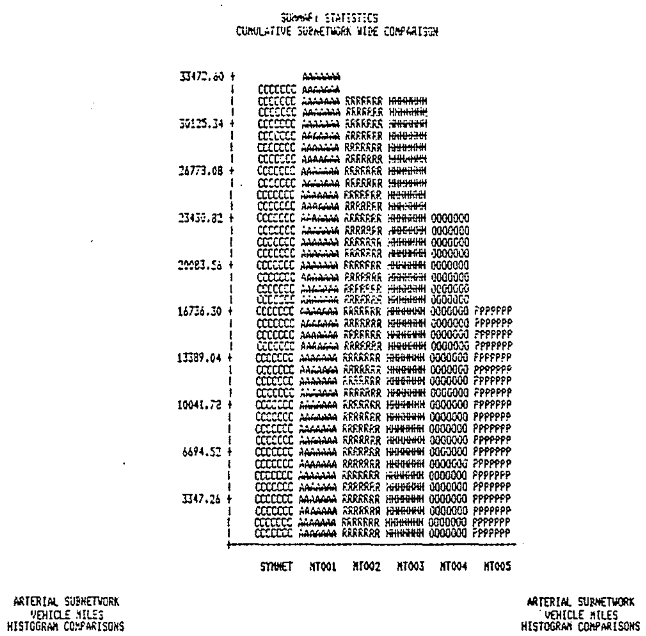


FIGURE 16: Vehicle Miles - Arterial Subnetwork

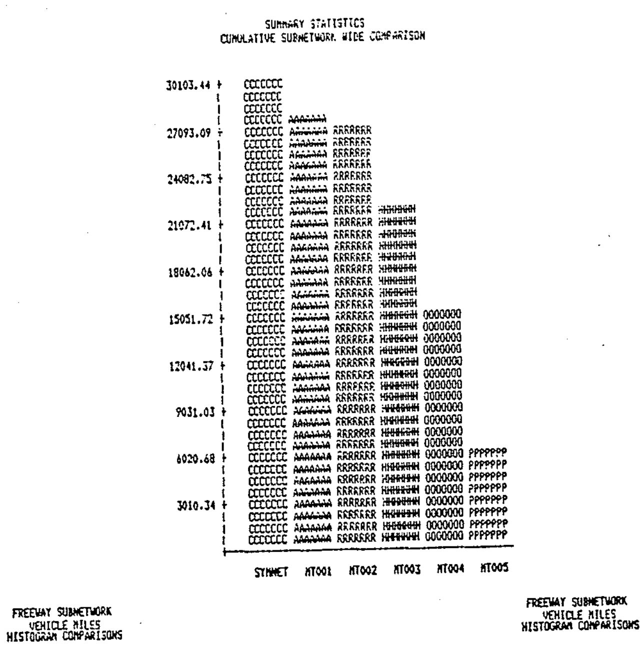


FIGURE 17: Vehicle Miles - Freeway Subnetwork

Scenario Number	Scenario Name	Link Capacity	Free Flow Speed	Open Lanes	Percent Detour
BASE	SYMNET	2000	55	3	N/A
1	DT001	1400	40	2	0
2	DT002	1400	40	2	5
3	DT003	1400	40	2	10
4	DT004	1400	40	2	15
5	DT005	1400	40	2	20

Figure 18 shows that the summary output freeway performance improves as the percentage of trips routed along the detour increases. The associated freeway speeds increase, from 11.5 MPH with 0% detoured to 13.1 MPH with 20% detoured. The number of vehicle hours is also decreased, from 2200.6 with 0% detoured to 1867.0 with 20% detoured.

When no traffic is routed from the freeway to the arterials in the short-term, the speeds along the arterial are relatively unaffected. As the percentage of trips routed along the detour is increased, the arterial subnetwork average speed begins to decrease, ranging from 14.4 MPH with a 5% detour to 10.1 MPH with a 20% detour. The number of vehicle trips in the arterial subnetwork decreases slightly.

The individual scenario report shown in Figure 19 contains a table of the travel time along routes, comparing the time, in minutes per trip, required for a vehicle to travel along the original and detour routes. This statistic demonstrates the trade-off occurring during the routing of freeway trips along the detour route. During the base case, a vehicle requires 4.8 minutes to traverse the original route through the reconstruction zone. When the reconstruction constraints are imposed and no traffic is allowed to detour, the time required increases to 31.8 minutes. By comparison, travel time along the detour route is 9.8 minutes in the base case. As the percentage of trips routed along the detour route is increased, conditions along that route become congested, resulting in an increase in travel time along the route. With 5% of the freeway traffic being routed along the detour, the travel

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

CUMULATIVE SUBNETWORK WIDE COMPARISON

ARTERIAL SUBNETWORK

	SYMNET	DT001	DT002	DT003	DT004	DT005
AVERAGE SPEED	15.9	15.7	14.4	12.1	10.6	10.1
VEHICLE TRIPS	19747.	19221.	19310.	19008.	18496.	18153.
VEHICLE HOURS	2042.9	2021.6	2211.6	2573.9	2834.9	2899.4
VEHICLE MILES	32531.7	31828.9	31909.4	31212.5	29978.3	29345.0

FREEWAY SUBNETWORK

	SYMNET	DT001	DT002	DT003	DT004	DT005
AVERAGE SPEED	34.3	11.5	12.5	12.7	13.0	13.1
VEHICLE TRIPS	7689.	6153.	6263.	6327.	6352.	6350.
VEHICLE HOURS	876.6	2200.6	2012.8	1972.7	1889.0	1867.0
VEHICLE MILES	30103.4	25226.1	25249.3	25054.4	24500.6	24378.6

CUMULATIVE GLOBAL COMPARISONS

	SYMNET	DT001	DT002	DT003	DT004	DT005
AVERAGE SPEED	21.5	13.5	13.5	12.4	11.5	11.3
VEHICLE TRIPS	27436.	25374.	25573.	25335.	24848.	24503.
VEHICLE HOURS	2919.5	4222.2	4224.5	4546.5	4723.9	4766.4
VEHICLE MILES	62635.1	57055.0	57158.7	56266.9	54478.9	53723.6

FIGURE 18: Summary Statistics for Test Case 2

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

INFORMATION SUMMARY FOR SCENARIO:DT002

SCENARIO	--->	DT002
DESCRIPTION	--->	RECON ZONE (1400/40/2): 5% DETOUR
DATA CREATED	--->	7 15 86
USER NAME	--->	JOHN D. LEONARD
AGENCY	--->	UC IRVINE

CREATED FROM BASE NETWORK: SYMNET

LENGTH OF SIMULATION (IN SECONDS) = 3600

RECONSTRUCTION ZONE SPECIFIED AT LINK (507, 508)

		SYMNET	DT002
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	1.8
TRIPS THROUGH ZONE	=	4496.0	2810.0
VOLUME/CAPACITY	=	0.7493	1.0036
MINUTES PER TRIP	=	0.8886	17.0432

RECONSTRUCTION ZONE SPECIFIED AT LINK (508, 509)

		SYMNET	DT002
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	8.3
TRIPS THROUGH ZONE	=	4270.0	2597.0
VOLUME/CAPACITY	=	0.7117	0.9275
MINUTES PER TRIP	=	0.8906	3.6127

RECONSTRUCTION ZONE SPECIFIED AT LINK (509, 510)

		SYMNET	DT002
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	17.4
TRIPS THROUGH ZONE	=	4463.0	2743.0
VOLUME/CAPACITY	=	0.7438	0.9796
MINUTES PER TRIP	=	0.8672	1.7197

DETOUR OPTION SELECTED ---> SHORT-TERM USER-SPECIFIED

NUMBER OF DETOUR ROUTES ---> 1
PERCENTAGE OF VEHICLES USING ROUTE = 5

ORIGINAL ROUTE:
527 506 507 508 509 510 511

DETOUR ROUTE:
527 506 7506 43 46 47 48 49 50 45 7511 511

TRAVEL TIME COMPARISON ALONG ROUTES

		SYMNET	DT002
ORIGINAL ROUTE	=	4.8	29.9
DETOUR ROUTE	=	9.8	27.7

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

INFORMATION SUMMARY FOR SCENARIO:DT003

SCENARIO	--->	DT003
DESCRIPTION	--->	RECON ZONE (1400/40/2): 10% DETOUR
DATA CREATED	--->	7 15 86
USER NAME	--->	JOHN D. LEONARD
AGENCY	--->	UC IRVINE

CREATED FROM BASE NETWORK: SYMNET

LENGTH OF SIMULATION (IN SECONDS) = 3600

RECONSTRUCTION ZONE SPECIFIED AT LINK (507, 508)

		SYMNET	DT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	1.8
TRIPS THROUGH ZONE	=	4496.0	2803.0
VOLUME/CAPACITY	=	0.7493	1.0011
MINUTES PER TRIP	=	0.8886	17.0103

RECONSTRUCTION ZONE SPECIFIED AT LINK (508, 509)

		SYMNET	DT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	8.2
TRIPS THROUGH ZONE	=	4270.0	2597.0
VOLUME/CAPACITY	=	0.7117	0.9275
MINUTES PER TRIP	=	0.8906	3.6485

RECONSTRUCTION ZONE SPECIFIED AT LINK (509, 510)

		SYMNET	DT003
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	17.4
TRIPS THROUGH ZONE	=	4463.0	2741.0
VOLUME/CAPACITY	=	0.7438	0.9789
MINUTES PER TRIP	=	0.8672	1.7201

DETOUR OPTION SELECTED ---> SHORT-TERM USER-SPECIFIED

NUMBER OF DETOUR ROUTES ---> 1
PERCENTAGE OF VEHICLES USING ROUTE = 10

ORIGINAL ROUTE:
527 506 507 508 509 510 511

DETOUR ROUTE:
527 506 7506 43 46 47 48 49 50 45 7511 511

TRAVEL TIME COMPARISON ALONG ROUTES

		SYMNET	DT003
ORIGINAL ROUTE	=	4.8	29.8
DETOUR ROUTE	=	9.8	67.1

FIGURE 19: Travel Time Comparisons Along Detour Route

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

INFORMATION SUMMARY FOR SCENARIO:DT004

SCENARIO ----> DT004
DESCRIPTION ----> RECON ZONE (1400/40/2): 15% DETOUR
DATA CREATED ----> 7 15 86
USER NAME ----> JOHN D. LEONARD
AGENCY ----> UC IRVINE

CREATED FROM BASE NETWORK: SYMNET

LENGTH OF SIMULATION (IN SECONDS) = 3600

RECONSTRUCTION ZONE SPECIFIED AT LINK (507, 508)

		SYMNET	DT004
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	3.7
TRIPS THROUGH ZONE	=	4496.0	2788.0
VOLUME/CAPACITY	=	0.7493	0.9957
MINUTES PER TRIP	=	0.8886	8.1717

RECONSTRUCTION ZONE SPECIFIED AT LINK (508, 509)

		SYMNET	DT004
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	9.0
TRIPS THROUGH ZONE	=	4270.0	2584.0
VOLUME/CAPACITY	=	0.7117	0.9229
MINUTES PER TRIP	=	0.8906	3.3489

RECONSTRUCTION ZONE SPECIFIED AT LINK (509, 510)

		SYMNET	DT004
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	18.1
TRIPS THROUGH ZONE	=	4463.0	2733.0
VOLUME/CAPACITY	=	0.7438	0.9761
MINUTES PER TRIP	=	0.8672	1.6530

DETOUR OPTION SELECTED ----> SHORT-TERM USER-SPECIFIED

NUMBER OF DETOUR ROUTES ----> 1
PERCENTAGE OF VEHICLES USING ROUTE = 15

ORIGINAL ROUTE:
527 506 507 508 509 510 511

DETOUR ROUTE:
527 506 7506 43 46 47 48 49 50 45 7511 511

TRAVEL TIME COMPARISON ALONG ROUTES

		SYMNET	DT004
ORIGINAL ROUTE	=	4.8	22.7
DETOUR ROUTE	=	9.8	125.9

CARHOP OUTPUT PROCESSOR
SUMMARY STATISTICS

INFORMATION SUMMARY FOR SCENARIO:DT005

SCENARIO ----> DT005
DESCRIPTION ----> RECON ZONE (1400/40/2): 20% DETOUR
DATA CREATED ----> 7 15 86
USER NAME ----> JOHN D. LEONARD
AGENCY ----> UC IRVINE

CREATED FROM BASE NETWORK: SYMNET

LENGTH OF SIMULATION (IN SECONDS) = 3600

RECONSTRUCTION ZONE SPECIFIED AT LINK (507, 508)

		SYMNET	DT005
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.8	6.1
TRIPS THROUGH ZONE	=	4496.0	2734.0
VOLUME/CAPACITY	=	0.7493	0.9764
MINUTES PER TRIP	=	0.8886	4.9578

RECONSTRUCTION ZONE SPECIFIED AT LINK (508, 509)

		SYMNET	DT005
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	33.7	11.4
TRIPS THROUGH ZONE	=	4270.0	2540.0
VOLUME/CAPACITY	=	0.7117	0.9071
MINUTES PER TRIP	=	0.8906	2.6207

RECONSTRUCTION ZONE SPECIFIED AT LINK (509, 510)

		SYMNET	DT005
NUMBER OF LANES	=	3	2
FREE FLOW CAPACITY	=	2000	1400
SPEED THROUGH ZONE	=	34.6	19.5
TRIPS THROUGH ZONE	=	4463.0	2690.0
VOLUME/CAPACITY	=	0.7438	0.9607
MINUTES PER TRIP	=	0.8672	1.5369

DETOUR OPTION SELECTED ----> SHORT-TERM USER-SPECIFIED

NUMBER OF DETOUR ROUTES ----> 1
PERCENTAGE OF VEHICLES USING ROUTE = 20

ORIGINAL ROUTE:
527 506 507 508 509 510 511

DETOUR ROUTE:
527 506 7506 43 46 47 48 49 50 45 7511 511

TRAVEL TIME COMPARISON ALONG ROUTES

		SYMNET	DT005
ORIGINAL ROUTE	=	4.8	18.1
DETOUR ROUTE	=	9.8	202.5

FIGURE 19 (Cont'd): Travel Time Comparisons Along Detour Route

time increases to 27.7 minutes per trip while the travel time along the original route decreases to 29.9 minutes. With 10% of the freeway trips being routed along the detour, the fastest route again becomes the freeway, with a trip taking 29.8 minutes along the original route and 67.1 minutes along the detour route. The travel times with 15% and 20% of the freeway trips routed along the detour are 125.9 and 202.5 minutes, respectively. The equilibrium that can be expected to be realized under these conditions thus is approximately 5% of the freeway traffic selecting the detour route.

CONCLUSIONS

The CARHOP Environment can provide the transportation planner and engineer with an effective method of measuring system performance during the reconstruction process. Using CARHOP, assorted measures of effectiveness may be generated and used to evalute alternative reconstruction strategies and possible mitigation procedures.

CARHOP provides an interactive, user-friendly, menu-driven, screen-oriented environment for the generation of reconstruction scenarios consisting of any combination of reconstruction zones (freeway lane constrictions) and detour strategies. CARHOP allows several scenarios to be created in a single interactive session, storing the changes for subsequent processing by the other modules of the CARHOP Environment. Statistics output by CARHOP include vehicle speed, vehicle miles, vehicle trips and vehicle minutes. They are complied on a link-by-link basis, aggregated for the freeway and arterial subnetworks, as well as for the network as a whole.

These outputs provide individual scenario reports on conditions in the immediate reconstruction zone. Histograms are generated, providing visual comparisons of various performance measures on each subnetwork and the global network. These comparisons are intended to assist in the selection of reasonable freeway reconstruction/rehabilitation schedules.

To test and demonstrate the capabilities of CARHOP, a section of the Interstate 5 freeway in Orange County, California was analyzed relative to various reconstruction strategies. The section analyzed, which begins at the interchange with State Route 55 and extends north to immediately south of the interchange with State Route 91, is scheduled for major reconstruction by the California Department of Transportation.

In the analysis, a number of reconstruction strategies, encompassing various diversion strategies involving detours to the surface street network, were evaluated. The results were useful in identifying courses of action that were optimal in the sense of traffic management, and offered encouragement relative to the potential usefulness of this tool.

ACKNOWLEDGEMENT

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