A Procedure for the Assessment of Traffic Impacts During Freeway Reconstruction

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Results are described of an effort directed toward developing a consistent methodology to assess the impacts of traffic disruption due to major transportation reconstruction and rehabilitation projects during the implementation period. In the approach taken, 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 or rehabilitation are then evaluated with the development of a systematic, computerized procedure designed to (a) provide for the creation and comparison of multiple and "layered" reconstruction and rehabilitation scenarios, (b) minimize the required knowledge of both the detailed interactions with the model as well as with the host computer, and (c) 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 and rehabilitation plans and schedules.

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

1. The performance during the construction phase that, 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 or planner in the analysis of alternative highway reconstruction scenarios. An overview of this new tool is presented, followed by 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 a discussion of the results of two demonstration cases.

OVERVIEW OF CARHOP ENVIRONMENT

The CARHOP environment provides a method for testing various transportation system management (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, one may focus more on the broader issues of reconstruction 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 transportation network subject to the alteration of the surrounding arterial network characteristics and signal timings. Comparison statistics are compiled from each of the different submodels invoked on a subnetworkwide 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:

- CARHOP preprocessor
- POSTCARS executor
- JOGGER postprocessor

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

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

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(if any), alternative signal timings, and types of outputs to be provided. CARHOP is executed through a series of screen menus, making unnecessary 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 noninteractive mode, which greatly speeds 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 hard copy 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 subnetwork-wide basis. If detour outputs are requested, statistics are compiled along each detour route and compared with those of the original routes. Descriptions of each scenario are generated from the preprocessor outputs, providing the user with a hard copy 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 (*1*) is used as the base simulation model for the CARHOP environment. Used like a chalkboard, TRAF is run on the base-case scenario; changes simulating network modifications associated with the reconstruction scenarios are then made to the base case. 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. From 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 (*2*) 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. Although the TRAF modeling system comprises many different simulation models of varying degrees of statistical resolution, CARHOP supports only three (all in TRAFLO of TRAF): Level 2 (arterial package), FREEFLO (freeway package), and 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, although also macroscopic, 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 (*3*), which employs an equilibrium-based assignment algorithm.

COMPONENTS OF THE CARHOP PREPROCESSOR

The CARHOP preprocessor organizes options within CARHOP into 10 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, and
10. Scenario processing.

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 the visual display of the preprocessor to the user.

Data-Base Selection

Data-base selection performs the role of "bookkeeper" in the processing of multiple scenarios and is executed before the creation of any CARHOP scenario:

1. Select Base Scenario

Current Scenario: NONE Default Data Base: NONE

- Change Default Data Base
- Create New Scenario
- RETURN TO MAIN MENU

Freeway-Incident Specification

Freeway-incident specification allows the user to create an incident on the freeway network. Examples of incidents include stalled vehicles, collisions, bottlenecks, and so on. The user need only specify the link on which the incident will occur together with the new estimated capacity.

2. Create Freeway Incident

Current Scenario: DT003 Default Data Base: SYMNET.DAT

- Create Freeway Incident
- RETURN TO MAIN MENU

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.

3. Create Reconstruction Zone

Current Scenario: DT003 Default Data Base: SYMNET.DAT

- Arterial Sub-Network Reconstruction
- Freeway Sub-Network Reconstruction
- RETURN TO MAIN MENU

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 creation of detours based on the reallocation of trips in the traffic assignment model. This option, used in conjunction with other CARHOP options, allows the testing of 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.

4. Detour Specifications

Current Scenario: DT003 Default Data Base: SYMNET.DAT

- Short-Term User-Specified Detours
- Short-Term Optimized Detours
- Long-Term User-Specified Detours
- Long-Term Optimized Detours
- RETURN TO MAIN MENU

Signal-Timing Alteration

Signal-timing alteration allows the testing of 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 with 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.

5. Alter Signal Timings

Current Scenario: DT003 Default Data Base: SYMNET.DAT

- Alter Individual Intersection Timing
- Individual Intersection Optimization
- Global Intersection Optimization
- Arterial Corridor Optimization
- RETURN TO MAIN MENU

Physical-Network Alteration

Physical-network alteration provides a method of testing various supply-side 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.

6. Alter Physical Network

Current Scenario: DT003 Default Data Base: SYMNET.DAT

- Alter Freeway Characteristics
- Alter Arterial Characteristics
- RETURN TO MAIN MENU

User-Attribute Alteration

User-attribute alteration 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.

7. Alter User Attributes

Current Scenario: DT003 — Default Data Base: SYMNET.DAT

- Alter User Attributes
- RETURN TO MAIN MENU

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.

8. Alter Transit System

Current Scenario: DT003 — Default Data Base: SYMNET.DAT

- Alter Transit System
- RETURN TO MAIN MENU

Graphics Specifications

The graphics 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.

9. Produce Network Graphics

Current Scenario: DT003 — Default Data Base: SYMNET.DAT

- Create Graphics Instructions
- RETURN TO MAIN MENU

Scenario Processing

Once the single or multiple reconstruction zones, detour routes, and other options have been executed (as desired), the scenario-processing option creates a "logfile" containing all the information in a form to be 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.

10. Produce Job Control Instructions (EXIT)

Current Scenario: DT003 — Default Data Base: SYMNET.DAT

- Process Current Scenario and RETURN
- Process Current Scenario and EXIT
- DELETE Current Scenario (TOSS OUT)
- RETURN To Main Menu
- QUIT CARHOP (ABORT)

SAMPLE SESSION

In this section a sample session in CARHOP is provided 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.

CARHOP specification of the reconstruction zone and corresponding detour route consists of the following steps, performed in sequential order. Descriptions of each, together with some accompanying visual terminal displays, follow.

1. Specify the default data base and select menu options and scenario data base,
2. Define reconstruction zone and specify zone characteristics,
3. Specify detour route, and
4. Process current scenario and exit.

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

The session begins with a display that announces the actuation of the CARHOP environment (Figure 1). A prompt is then given for the user to provide a name for the default data base containing the TRAF data base information. 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 (O-D) 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 or bases 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.

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, CARHOP will display the choices available. This list will include all the file names entered by the user when the program was started.

After the data base has been selected, an information page will be displayed on the screen (Figure 2) showing important data-base information such as run name, user name, agency, run date, and run type. 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.

Define Reconstruction Zone and Specify Zone Characteristics

To specify a reconstruction zone, the user must select Option 3 of the main menu. CARHOP will then display the associated submenu, which allows three further choices: Arterial Subnetwork Reconstruction, Freeway Subnetwork Reconstruction, and Return to Main Menu (see Reconstruction-Zone Specification in previous section). CARHOP next prompts the user for the upstream and downstream mainline nodes encompassing the reconstruction area. If a reconstruction zone is to encompass several mainline links, each link is entered separately. After the downstream node number has been typed, CARHOP scans the default data

```
                    WELCOME TO

  CCC      A      RRRR     H   H    OOO     PPPP
 C   C    A A     R   R    H   H   O   O    P   P
 C       A   A    R   R    H   H   O   O    P   P
 C       AAAAA    RRRR     HHHHH   O   O    PPPP
 C   C  A     A   R   R    H   H   O   O    P
  CCC   A     A   R    R   H   H    OOO     P


            Computer
              Assisted
                Reconstruction Strategies for
                  Highway
                    Operations and
                      Planning
            Institute of Transportation Studies
              University of California, Irvine
```

FIGURE 1 Display announcing actuation of CARHOP environment.

```
              1. Select Base Scenario

Current Scenario: NONE            Default Data Base: NONE

            Data Bases To Choose From:

     ===>> X    SYMNET.DAT


              PROCESSING RECORD...    9

              SELECT AS BASE? ("Y" if yes)   Y

Run Name -->    TEST NETWORK: SYMMETRICAL WITH ONE FREEWAY, PASSER

          User Name -->   JOHN D. LEONARD
          Agency    -->   UC IRVINE
          Run Date  -->   10  05  85

          Run Type  -->   ASSIGNMENT AND SIMULATION
```

FIGURE 2 Information page display, Option 1.

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 3). 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.

Once this has been completed, CARHOP returns the user to the reconstruction submenu. 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.

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 this is chosen, the detour specification submenu is displayed (see Detour-Route Specification in previous section). There are two suboptions currently implemented: Short-Term User-Specified Detours and Long-Term Optimized Detours. In this example the first suboption will be described.

CARHOP now prompts the user for the original route, which is entered node by node. It must begin and end on the freeway subnetwork. Next CARHOP will prompt the user for the detour route (Figure 4), which must begin and end with the same nodes as the original route. The detour route may leave the freeway and go to the arterial subnetwork but must reenter the freeway and end at the same node as the

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                    3. Create Reconstruction Zone

Current Scenario: DT003          Default Data Base:    SYMNET.DAT

                    o Freeway  Sub-Network Reconstruction


     CURRENT CHARACTERISTICS FOR LINK (  507 ,   508 )

          Regular Use Lanes    ..... 3
          Special Purpose Lanes ... 0

 Nominal Lane Capacity (veh/hr)....2000
          Free-Flow Speed (MPH)....  55
```

FIGURE 3 Current characteristics of input link.

```
                    4. Detour Specifications

Current Scenario: DT003          Default Data Base:    SYMNET.DAT

                    o Short-Term User-Specified Detours

                    Enter DETOUR Route.  It must begin
                    and end with the SAME nodes as the
                    ORIGINAL  route  just   specified.

     Starting At ===>   527             To ===>   45
              To ===>   506             To ===>   7511
              To ===>   7506            To ===>   511
              To ===>   43              To ===>
              To ===>   46
              To ===>   47
              To ===>   48
              To ===>   49
              To ===>   50

          Percentage of vehicles using route ==> 10
```

FIGURE 4 Specification of detour route.

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 submenu. There are five choices available from this submenu. 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, the user would return to the main menu to select other options. The 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 scenario to the base case when the POSTCARS executor and JOGGER postprocessor are executed.

DEMONSTRATION OF CARHOP RECONSTRUCTION METHODOLOGY

To demonstrate use of the CARHOP environment in the study of freeway reconstruction and its impact on the surrounding arterial subnetwork, two case studies are presented:

1. A range of freeway reconstruction scenarios with implementation of the long-term detour specification of CARHOP and
2. Fixed freeway reconstruction (two open mainline lanes) with a ranged percentage of traffic along the detour route.

The demonstration network shown in Figure 5 includes a typical freeway section overlaid 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 subnetwork consists of a single section of freeway with three through lanes in each direction bisecting an arterial grid subnetwork. 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 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.

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

In Test Case 1 CARHOP is used 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 bottleneck.

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 are sequentially increased from minor speed and capacity [in vehicles per hour per lane (vphpl)] constraints to full closure of the freeway mainline (Table 1). The link constraints shown in Table 1 apply to all links in the reconstruction zone; six freeway links are directly affected by the constraints. Estimated link

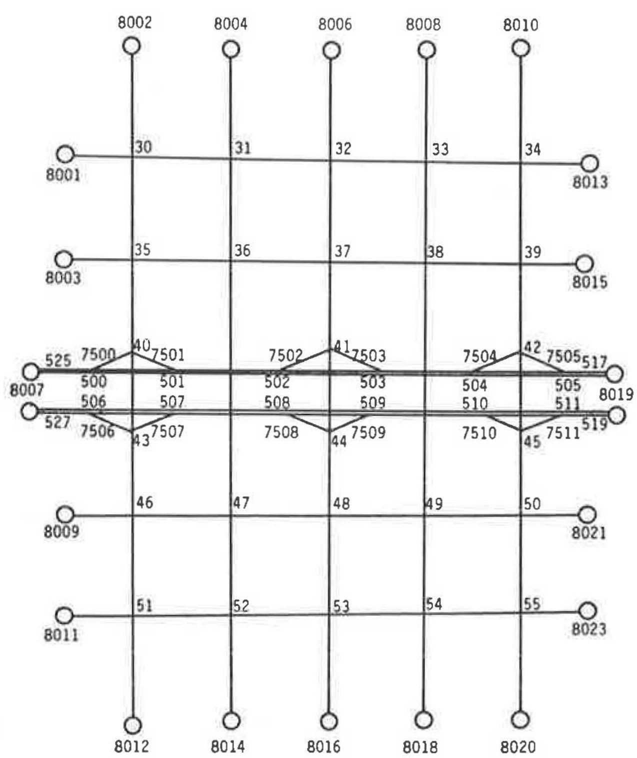

FIGURE 5 Demonstration network.

TABLE 1 SCENARIOS FOR TEST CASE 1

Scenario No.	Scenario Name	Link Capacity (vphpl)	Free-Flow Speed (mph)	Open Lanes
Base	SYMNET	2,000	55	3
1	MT001	1,000	45	3
2	MTOO2	1,400	40	3
3	MT003	1,400	40	2
4	MT004	1,400	40	1
5	MT005	1,400	40	0

capacities are taken from the *Highway Capacity Manual* work-zone estimates (*4*).

Figure 6 shows 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 those in the base case.

For example, Link 507, 508 has two lanes in Scenario MT003, whereas in the base case it has three. The free-flow capacity of the link was reduced from 2,000 vphpl to 1,400 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, which 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 affected by the construction.

Figure 7 gives a tabular comparison of four cumulative subnetworkwide statistics, as well as global totals for the entire transportation system. Histogram comparisons for each performance measure by subnetwork type and global network are also provided by CARHOP (Figures 8 and 9).

Test Case 2

In the second test case CARHOP is applied to evaluate the effectiveness of a particular short-term user-specified detour during freeway reconstruction. Test Case 2 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 are open along the freeway with a free-flow speed of 40 mph and a capacity of 1,400 vphpl; the percentage of freeway trips routed from the freeway to the arterials is gradually increased. The scenarios for Test Case 2 are shown in Table 2.

Figure 10 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 no trips detoured to 13.1 mph with 20 percent detoured. The number of vehicle hours also decreases, from 2,200.6 with no trips detoured to 1,867.0 with 20 percent 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 5 percent detours to 10.1 mph with 20 percent detours. The number of vehicle trips in the arterial subnetwork decreases slightly.

The individual scenario reports, one of which is shown in Figure 11, contain 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. For the base case, a vehicle requires 4.8 min 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 min. By comparison, travel time along the detour route is 9.8 min 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 percent of the freeway traffic routed along the detour, the travel time increases to 27.7 min per trip, whereas the travel time along the original route decreases to 29.9 min. With 10 percent of the freeway trips routed along the detour, the fastest route again becomes the freeway, with a trip taking 29.8 min along the original route and 67.1 min along the detour route. The travel times when 15 and 20 percent of the freeway trips are routed along the detour are 125.9 and 202.5 min, respectively. The equilibrium that can be expected to be realized under these conditions thus is approximately 5 percent of the freeway traffic selecting the detour route.

TABLE 2 SCENARIOS FOR TEST CASE 2

Scenario No.	Scenario Name	Link Capacity (vphpl)	Free-Flow Speed (mph)	Open Lanes	Percentage of Trips Detoured
Base	SYMNET	2,000	55	3	N/A
1	DT001	1,400	40	2	0
2	DT002	1,400	40	2	5
3	Dt003	1,400	40	2	10
4	DT004	1,400	40	2	15
5	DT005	1,400	40	2	20

INFORMATION SUMMARY FOR SCENARIO:MT003

SCENARIO ----> MT003
DESCRIPTION ----> RECON BOTH DIRECTIONS:
LANES REDUCED TO 2
DATA CREATED ----> 10 05 85
USER NAME ----> JOHN D. LEONARD
AGENCY ----> UC IRVINE -- ITS

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	19.8
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

FIGURE 6 Scenario summary output.

	SYMNET	MT001	MT002	MT003	MT004	MT005
ARTERIAL SUBNETWORK						
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.P	2947.6	3425.6	6723.3	9392.1
VEHICLE MILES	32531.7	33472.6	31954.7	31516.5	23391.0	16845.4
FREEWAY SUBNETWORK						
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						
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 7 Summary statistics for Test Case 1.

```
15.92 + CCCCCCC
      I CCCCCCC
      I CCCCCCC
      I CCCCCCC
14.33 + CCCCCCC
      I CCCCCCC
      I CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
12.73 + CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
11.14 + CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
 9.55 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
 7.96 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
 6.36 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
 4.77 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
 3.18 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
 1.59 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
      +------------------------------------------------

         SYMNET  MT001   MT002   MT003   MT004   MT005
```

FIGURE 8 Average speed—arterial subnetwork.

```
34.34 + CCCCCCC
      I CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
      I CCCCCCC AAAAAAA
30.90 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
27.47 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
24.03 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
20.60 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
17.17 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
13.73 + CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
      I CCCCCCC AAAAAAA RRRRRRR
10.30 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
 6.86 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH
 3.43 + CCCCCCC AAAAAAA RRRRRRR HHHHHHH
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO
      I CCCCCCC AAAAAAA RRRRRRR HHHHHHH OOOOOOO PPPPPPP
      +------------------------------------------------

         SYMNET  MT001   MT002   MT003   MT004   MT005
```

FIGURE 9 Average speed—freeway subnetwork.

	SYMNET	DT001	DT002	DT003	DT004	DT005	DT006
ARTERIAL SUBNETWORK							
AVERAGE SPEED	15.9	15.8	15.7	14.4	12.1	10.6	10.1
VEHICLE TRIPS	19747.	19686.	19221.	19310.	19008.	18496.	18153.
VEHICLE HOURS	2042.9	2048.4	2021.6	2211.6	2573.9	2834.9	2899.4
VEHICLE MILES	32531.7	32458.0	31828.9	31909.4	31212.5	29978.3	29345.0
FREEWAY SUBNETWORK							
AVERAGE SPEED	34.3	34.5	11.5	12.5	12.7	13.0	13.1
VEHICLE TRIPS	7689.	7418.	6153.	6263.	6327.	6352.	6350.
VEHICLE HOURS	876.6	855.0	2200.6	2012.8	1972.7	1889.0	1867.0
VEHICLE MILES	30103.4	29506.5	25226.1	25249.3	25054.4	24500.6	24378.6
CUMULATIVE GLOBAL COMPARISONS							
AVERAGE SPEED	21.5	21.3	13.5	13.5	12.4	11.5	11.3
VEHICLE TRIPS	27436.	27104.	25374.	25573.	25335.	24848.	24503.
VEHICLE HOURS	2919.5	2903.5	4222.2	4224.5	4546.5	4723.9	4766.4
VEHICLE MILES	62635.1	61964.5	57055.0	57158.7	56266.9	54478.9	53723.6

FIGURE 10 Summary statistics for Test Case 2.

```
INFORMATION SUMMARY FOR SCENARIO:DT002

        SCENARIO        ---->  DT002
        DESCRIPTION     ---->  SHORT TERM RECON, ONE DIRECTION:
                                                   LANE REDUCTIONS
        DATA CREATED    ---->  10  05  85
        USER NAME       ---->  JOHN D. LEONARD
        AGENCY          ---->  UC IRVINE -- ITS

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        1.7
TRIPS THROUGH ZONE    =     4496.0     2808.0
VOLUME/CAPACITY       =     0.7493     1.0029
MINUTES PER TRIP      =     0.8886    17.8684

RECONSTRUCTION ZONE SPECIFIED AT LINK (  508, 509 )

                              SYMNET     DT002

NUMBER OF LANES       =          3          2
FREE FLOW  CAPACITY   =       2000       1400
SPEED THROUGH ZONE    =       33.7        8.1
TRIPS THROUGH ZONE    =     4270.0     2596.0
VOLUME/CAPACITY       =     0.7117     0.9271
MINUTES PER TRIP      =     0.8906     3.6945

RECONSTRUCTION ZONE SPECIFIED AT LINK (  509, 510 )

                              SYMNET     DT002

NUMBER OF LANES       =          3          2
FREE FLOW  CAPACITY   =       2000       1400
SPEED THROUGH ZONE    =       34.6       16.9
TRIPS THROUGH ZONE    =     4463.0     2745.0
VOLUME/CAPACITY       =     0.7438     0.9804
MINUTES PER TRIP      =     0.8672     1.7786

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

NUMBER OF DETOUR ROUTES  ---->    1
PERCENTAGE OF VEHICLES USING ROUTE  =    0

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      31.8
                  DETOUR ROUTE  =   9.8      11.4
```

FIGURE 11 **Travel-time comparisons along 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. With CARHOP, assorted MOEs may be generated and used to evaluate 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, and the changes are stored 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 compiled on a link-by-link basis and 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 that provide visual comparisons of various performance measures on each subnetwork and on the global network. These comparisons are intended to assist in the selection of reasonable freeway reconstruction and 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 along 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.

ACKNOWLEDGMENT

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