

**STATE-OF-THE-ART REVIEW OF ANALYSIS TOOLS
FOR EVALUATING THE TRAVEL IMPACTS OF
HIGHWAY CONSTRUCTION PROJECTS**

by

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I. INTRODUCTION

Background

Because of its concern about the motorist impacts of roadway construction zones, the Florida Department of Transportation is sponsoring a study entitled "Determination of Motorist Delay in Project-Specific Traffic Control Plans." The objectives of the study are to develop, test, and train Department personnel in the use of a procedure that employs state-of-the-art microcomputer-based analysis tools to determine optimal:

- o Work hours (time of day),
- o Sequencing of work operations,
- o Project-specific traffic control plans,
- o Contractor penalties for excessive project time (incentive/disincentive clauses),
- o Alternative routes during construction, and
- o Other measures to reduce vehicle throughput in the construction zone.

This interim report reviews the state-of-the-art microcomputer-based analysis tools that might be useful in satisfying the above objective. The information presented herein is based upon reviews of highway construction projects throughout the United States and upon evaluations of available microcomputer-based analysis tools. This report summarizes the findings of those reviews and evaluations that are most relevant to the Florida Department of Transportation. More detailed documentation is provided elsewhere (1-2).

Construction Project Travel Impact Evaluation Process

Each highway construction project is different--with a unique set of conditions and constraints that requires individualized analyses and customized solutions. However, many of the factors that should be considered in evaluating the resulting travel impacts are common to most projects. The travel impacts are changes in travel patterns (i.e. the destinations, routes, modes, and departure times of travel), traffic conditions (i.e., travel times or average speeds), accident rates, and road user costs throughout the affected corridor. The affected corridor consists of the highway under construction as well as alternative routes and modes of travel that experience changes in normal traffic conditions.

This section of the report provides an overview of a process for evaluating the travel impacts of highway construction projects. A detailed discussion of this process may be found in companion TTI report 7119-1 prepared for the Florida Department of Transportation (3). A flow chart of the process is presented in Figure 1. The outputs from the process are pertinent measures of effectiveness (MOEs) that would be useful in selecting a traffic-handling strategy for a project. The process identifies the types of

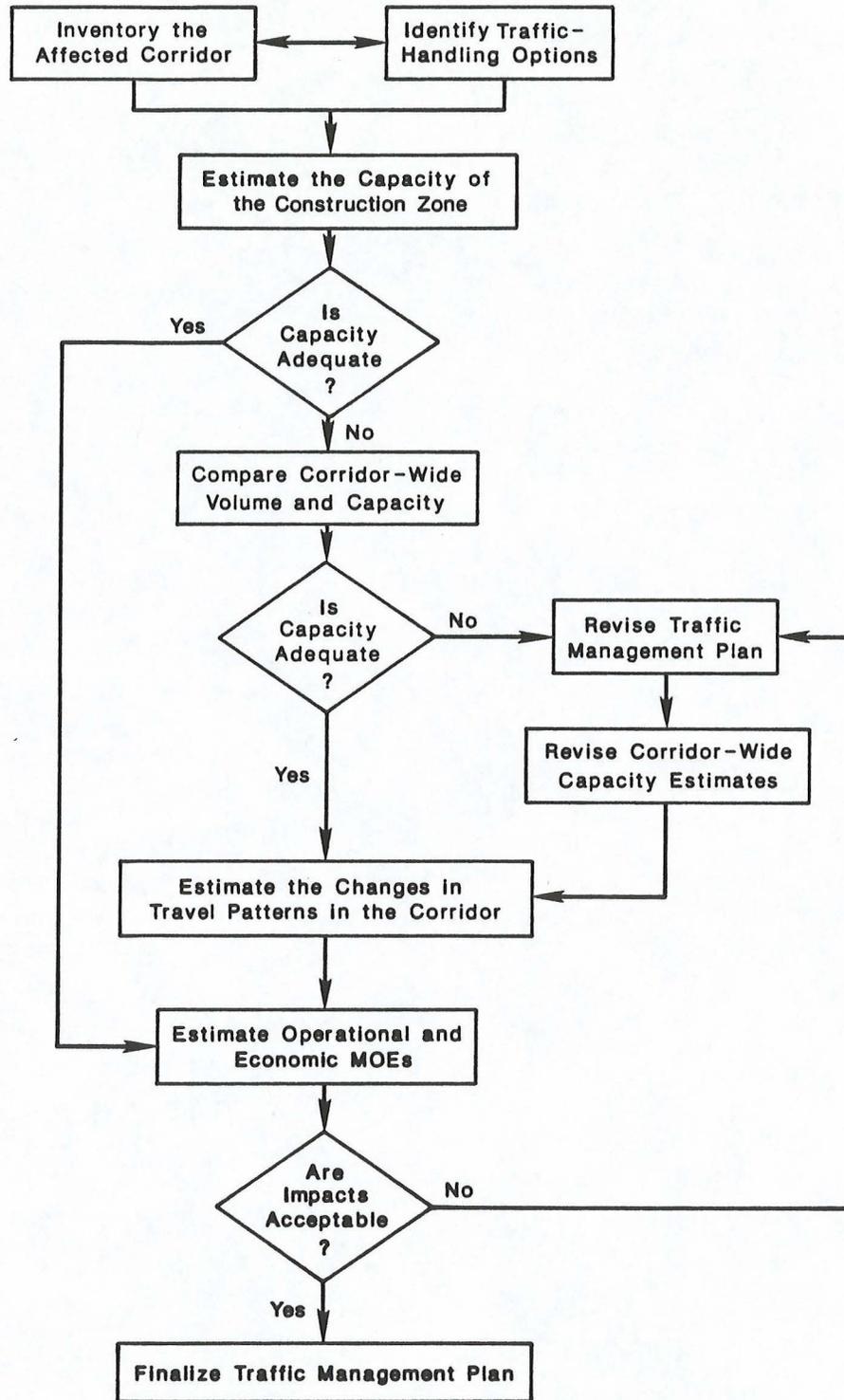


Figure 1. Flow Chart of the Construction Project Travel Impact Evaluation Process

analyses that would be required to evaluate the travel impacts of a construction project and, therefore, serves as a basis of review of analysis tools presented herein.

As Figure 1 illustrates, the highway agency must first inventory the affected corridor and identify the traffic-handling options to be evaluated. These two activities are interrelated. Traffic-handling options range from minor roadway capacity reductions associated with narrowing lane and/or shoulder widths to total roadway closures. Knowledge of conditions in the corridor (particularly current traffic volumes and the availability of alternative routes which can accommodate diverted traffic) influences the selection of traffic-handling options. Conversely, the traffic-handling options selected for consideration influence the scope of the inventory. For example, if significant reductions in capacity for long periods of time are being considered in urban areas, then all routes and modes that are likely to be affected should be inventoried. On the other hand, if adequate construction zone capacity is to be maintained for existing traffic or if no alternative routes are available (as is sometimes the case in rural locations), then the inventory might be restricted to the highway under construction.

Traffic-handling options for multilane highways may be categorized by the magnitude of the traffic capacity reduction through the construction zone. The three basic options are:

1. Minor roadway capacity reductions--the narrowing of lane and/or shoulder widths in order to maintain the same number of lanes on the highway under construction, at least during peak periods.
2. Lane closures--the closure of some, but not all, lanes in one or both directions of the highway under construction.
3. Total roadway closures--the closure of all lanes in one or both directions of the highway under construction.

In congested urban areas, conventional wisdom is to maintain as much capacity as possible through the construction zone. However, recent experiences with freeway construction projects in several large cities (e.g. Pittsburgh, Philadelphia, and Detroit) indicate that it is possible to employ long-term lane closures or total roadway closures without causing intolerable impacts on motorists by taking advantage of alternative routes and modes of travel. In rural areas, traffic volumes are typically lower and so a wider range of options can be considered.

Many factors influence the selection of a traffic-handling strategy, including:

1. The existing cross section and available right-of way,
2. The type of work that must be performed,
3. The time constraints for performing the work,
4. The volume of traffic that normally uses the highway,

5. The availability of unused capacity on alternative routes and modes in the corridor, and
6. The goals and policies of the highway agency with respect to acceptable levels of travel impacts.

A major determinant of the severity of the travel impacts during construction is the magnitude of the reduction in traffic capacity through the construction zone. Therefore, the first step in evaluating a particular traffic-handling option is to estimate the construction zone capacity.

If the construction zone roadway capacity is adequate to accommodate normal traffic volumes (i.e., what the traffic volumes would be without the construction project) at an acceptable level of service or if, as in some rural areas, there are no reasonable alternative routes, then only the construction zone need be evaluated. In this case, the analyst may proceed directly to the estimation of operational and economic MOEs for comparison with other options that are being considered.

If the construction zone roadway capacity is not adequate and motorist diversion to alternative routes and modes must be encouraged, then the scope of the evaluation should be corridor-wide and a corridor-wide traffic management plan should be developed. A corridor traffic management plan has three components:

1. A traffic-handling strategy for the highway under construction--the details of which are specified in the traffic-control plan,
2. Impact mitigation strategies (typically TSM-type improvements) for alternative routes and modes in the affected corridor, and
3. A public information program.

For projects that require a corridor-wide evaluation, the next step in the construction project travel impact evaluation process is to compare the corridor-wide demand volume with the combined roadway capacity of the construction zone plus the available alternative routes. If the corridor-wide capacity is adequate, then the agency may proceed to the next step, the estimation of travel pattern changes in the corridor. If the corridor-wide capacity is not adequate then the traffic management plan must be revised. Revisions may involve a change in traffic-handling option for the construction zone, improvements on alternative routes to increase capacity, or a combination of these. After the plan is revised, the alternative route capacities are again computed and compared to corridor traffic demands to insure that the demand can now be met.

The next step in the construction project travel impact evaluation process is to estimate the changes in travel patterns in the corridor. The experiences from previous urban area freeway construction projects suggest that few trips in the corridor are canceled. The most common changes have been a reallocation of traffic among alternative routes in the corridor. Temporal diversion (traveling on the same highway by the same mode but at a different time), which has the effect of flattening and spreading

out the traffic peaks, has also been observed. Some modal diversion has been observed but the amount has generally been small.

The next step is to estimate the operational and economic MOEs due to (1) the reduced traffic capacity of the construction zone, and (2) the predicted changes in travel patterns in the corridor (if a corridor wide evaluation has been performed). Operational MOEs, including travel times and average speeds, are needed to determine whether the travel impacts for a particular traffic management plan are acceptable as well as to compare alternative traffic management plans. Economic MOEs, particularly road user costs, are needed to compare the costs and benefits of alternative traffic management plans. If the travel impacts associated with a particular plan are deemed unacceptable, then the plan should be either refined or eliminated from further consideration. If the plan is refined, it should be re-evaluated. The process continues until the highway agency has all the information they require to select a final plan.

II. AVAILABLE ANALYSIS TOOLS

Overview

Available analysis tools that were evaluated by TTI to determine whether they might be used to evaluate the travel impacts of highway construction projects are grouped into six categories:

- o Highway capacity analysis procedures,
- o Work zone lane closure models,
- o Freeway simulation models,
- o Corridor and network simulation models,
- o Network-based highway and transit planning models and quick-response estimation techniques, and
- o Traffic optimization models.

Each of the above categories of analysis tools are currently used for certain traffic engineering and planning applications. Except for the work zone lane closure models, none of these tools was developed specifically for highway work zone analysis. Highway capacity analysis procedures translate roadway, traffic, and operational control conditions into estimates of capacity, level of service, and other operational measures of effectiveness (MOEs). Estimates of capacity (for both normal and work zone conditions) are essential for each of the other analysis tools. Work zone lane closure models utilize input-output analysis to estimate the impacts of work zone lane closures upon motorist delays, traffic queues, and additional road user costs.

At the next level of complexity are freeway simulation models which attempt to account for the interactions of ramps and other highway geometric elements in estimating operational and/or economic MOEs. Corridor and network simulation models are the most complex simulation models, for in addition to attempting to account for the effect of roadway geometrics upon traffic operations, these models also attempt to account for traffic signals, pedestrians and other features present in an urban area.

Network-based highway and transit planning models are used to estimate the origins and destinations of motorists, and the redistribution of traffic volumes among the travel routes in a network as a result of added congestion on the primary highway. Quick-response estimation techniques are simplified methods to perform some or all of the same functions as network-based planning models, but using simplified, non-network-based analyses that are less time, labor, and data intensive. Finally, traffic optimization models are used to develop optimal signal phasing and timing plans for isolated signalized intersections, arterial streets, or signal networks.

It should be emphasized that current knowledge on how motorists adjust their travel patterns in response to a major highway construction project is limited. Furthermore, there have been few, if any, construction-related applications of many of the analysis tools reviewed in this report. Therefore, without more detailed field data collection and evaluation, it is difficult to conclude at this time how accurately many of the models would predict the travel impacts of construction projects.

General Considerations in Selecting Appropriate Analysis Tools

The magnitude and duration of the traffic capacity reductions on the highway under construction coupled with the amount of traffic demand determine the appropriate scope and level of effort that a highway agency should expend for the travel impact evaluation. In general, the greater the demand volumes (i.e., in urban areas), the greater the reduction in capacity on the highway under construction and the longer the duration of the reductions, the greater the scope and level of effort justified in the travel impact evaluation.

Generally, the travel impact evaluations for traffic capacity reductions through construction zones in most rural and some suburban areas may be restricted to the highway under construction. With relatively low volumes, it is unlikely that significant travel impacts would extend beyond the highway under construction. In these situations, the simpler work zone lane closure models are all that is likely to be needed (albeit with some enhancements) to estimate the impacts of various traffic control options being considered.

However, for major urban highway construction projects in which significant reductions in capacity (i.e., lane closures or total roadway closures) are being considered and traffic demands are high, travel impacts are likely to extend beyond the highway under construction. Therefore, the impact evaluation should be corridor-wide. A major issue in a corridor-wide evaluation is how traffic will be reallocated among routes in the corridor. For these more complex issues, it may be necessary to use more complex models with larger data requirements that can simulate the characteristics of the urban environment and attempt to estimate changes in travel patterns due to construction.

The most critical decision involves the scope of the evaluation, i.e., whether a corridor-wide evaluation is required or whether the evaluation may be restricted to the highway under construction. The level of effort for a corridor-wide evaluation would obviously be greater than for an evaluation restricted to the highway under construction; therefore, a corridor-wide evaluation should be performed only when justified.

III. APPLICATION OF MODELS TO WORK ZONE CONDITIONS

This chapter presents a discussion of each of the different categories of computer models that may have application in the construction project traffic impact evaluation process. The focus of the discussion is to provide an overview of each model category in terms of its previous applications or potential use to evaluate work zone conditions, the input requirements needed to run the model, and the output provided by the model. A more detailed discussion of some of these models is provided in Appendices A through C (located under separate cover).

Highway Capacity Analysis Procedures

Highway capacity analysis is an essential component of the evaluation of the travel impacts of highway construction projects. Capacity estimates are required for the before-construction condition (to identify alternative traffic management plans) and for during-construction conditions (to evaluate the travel impacts of each alternative). The 1985 Highway Capacity Manual (HCM) (4) is the widely accepted reference for capacity analysis procedures. The Highway Capacity Software which was developed under FHWA sponsorship, is a "faithful replication of the procedures found in the 1985 HCM" (5). The Microcomputers in Transportation Software and Source Book (6) identifies 16 other microcomputer-based capacity analysis procedures, most of which are also based upon the 1985 HCM. This discussion focuses on the HCM procedures and Highway Capacity Software, but other packages could also be used to perform the same analyses.

The Highway Capacity Software is very easy to use. The software is menu driven and incorporates user friendly input procedures. Analysts familiar with the 1985 HCM can use the software without referring to the software's User's Manual (5). Figure 2 summarizes the characteristics of the Highway Capacity Software.

Application to Work Zones

There is insufficient evidence to judge the success of the 1985 HCM procedures and the Highway Capacity Software in estimating capacities through construction zones. The reduction in capacity due to the presence of work activity adjacent to the travel lanes has not been fully quantified. Chapter 6 of the HCM summarizes the data that are available from studies in Texas by Dudek and Richards (7) and in California by Kermode and Myyra (8). Most of the data are for short-term maintenance sites. Capacity data for long-term construction activities with portable concrete barriers are reported for only 10 sites. The 1985 HCM presents the capacity estimation procedures for short-term work zones that were developed by Dudek and Richards; however, those procedures are not included in the Highway Capacity Software.

Input Requirements

The Highway Capacity Software does not allow direct analysis of work zone conditions. Consequently, this analysis must be performed manually. The only input

HIGHWAY CAPACITY SOFTWARE

Application to Work Zone Conditions

- o Work zone capacities not included in computer software. This information can be found, however, in the Highway Capacity Manual

Analysis Capabilities

- o Freeways: (1) Operational Analysis to estimate operational MOEs for basic, ramp, and weaving segments, or (2) Design Analysis to determine the number of lanes required to accommodate a specified flow rate at a desired level of service
- o Signalized Intersections: (1) Operational Analysis to estimate operational MOEs, or (2) Planning Analysis to determine whether existing geometrics have adequate capacity to accommodate projected demand volumes
- o Arterials: Operational Analysis to estimate operational MOEs

Data Requirements -

- o Roadway conditions: type of facility and its development environment, number of lanes, lane and shoulder widths, design speeds, alignments
- o Traffic conditions: volumes and peaking characteristics; distribution of vehicles by type, direction, movement, and lane
- o Control conditions: type of control (STOP, YIELD, and signal); signal phasing, timing, and progression

Outputs

- o Freeways: operational MOEs including capacity, level of service, speed, and density
- o Signalized Intersections: operational MOEs including capacity, level of service, and average stopped delay
- o Arterials: operational MOEs including level of service, total travel time, average delay per vehicle, average speed

Figure 2. Summary of the Highway Capacity Software

necessary is the number of lanes normally available, the number of lanes left open during construction, and the confidence limit that defines the probability that the estimated work zone capacity will be too high. For the Highway Capacity Software to estimate the capacity of a roadway section prior to a work zone condition, data is needed regarding roadway conditions, traffic conditions, and intersection control conditions (if present).

Output Provided

The Highway Capacity Software provides estimates of roadway capacity or basic estimates of traffic conditions (average speeds, level of service) for normal roadway sections. In general, the estimates of roadway capacity would only be useful if utilized in subsequent analysis with one of the models discussed in the following sections.

Work Zone Lane Closure Models

Three existing models can be used to directly evaluate the travel impacts of work zone lane closures: QUEWZ, DELAY, and FREWAY. All three models use input-output analysis to estimate the queuing characteristics.

QUEWZ, which stands for Queue and User Cost Evaluation of Work Zones, was developed for the Texas State Department of Highways and Public Transportation (TSDHPT) by Dudek, Memmott, and Krammes (9-12). The original, mainframe-computer version of the model was developed in 1982. Several enhancements to the mainframe version have already been reported. Additional enhancements are being made as part of an ongoing research effort, and this third version is referred to as QUEWZ3. A microcomputer version QUEWZ-85 has also been developed.

DELAY is a LOTUS 1-2-3 spreadsheet developed under FHWA sponsorship that estimates queuing characteristics--total delay, time to normal flow, maximum number of vehicles in queue, and maximum length of queue in miles--resulting from freeway bottlenecks due to lane closures during either maintenance activities or freeway incidents (13). FREWAY is a microcomputer program developed by Roupail, Spencer, and Rivers (14, 15); it performs routine capacity analyses for basic freeway segments under normal operating conditions (based upon 1965 HCM procedures) and delay calculations for work zone lane closures (based upon input-output analysis). Summaries of these models are shown in Figures 3 through 5. Table 1 presents a summary of the uses of each of the models. As Table 1 indicates, QUEWZ3 has the broadest range of capabilities of the three programs. Therefore, it will be the focus of this review.

Application to Work Zone Conditions

QUEWZ3 was developed as a tool for evaluating highway work zone lane closures. It was developed to computerize commonly used manual techniques for estimating the queue lengths and additional road user costs resulting from lane closures. QUEWZ3 was designed to analyze freeway facilities but can also be applied to multilane highways. QUEWZ3 can analyze work zones with any number of lanes closed in one or both

QUEWZ

Application to Work Zone Conditions

- o Developed specifically for work zone conditions. Used by TSDHPT personnel on several occasions to analyze work zone lane closures

Analysis Capabilities

- o Estimate queue lengths and additional road user costs resulting from freeway work zone lane closures
- o Identify schedules for lane closures such that queuing will not exceed a user-specified queue length in miles or delay in minutes

Data Requirements

- o Configuration of the Work Zone: lane closure strategy (single direction or crossover), length of restricted capacity, total number of lanes and number of open lanes through the work zone in each direction
- o Schedule of Work Activity: beginning and ending hours of restricted capacity, beginning and ending hours of work activity
- o Traffic Volumes: directional hourly traffic volumes
- o Alternative Values for Model Defaults: cost update factor, percentage of trucks, parameters for a speed-volume curve, work zone capacity, maximum acceptable delay to motorists, critical length of queue

Output

- o Summary of Travel Impacts: hourly estimates of diverted traffic, volume through the work zone, section capacity, approach speed, work zone speed, average queue length, additional road user costs
- o Acceptable Lane Closure Schedule

Figure 3. Summary of the QUEWZ Model

DELAY

Application to Work Zone Conditions

- o No known use or validation to work zone conditions

Analysis Capabilities

- o Estimate queueing characteristics resulting from freeway bottlenecks caused by lane closures during maintenance/construction activities or freeway incidents

Data Requirements

- o Capacity flow rates under normal and bottleneck conditions
- o Demand flow rates
- o Incident duration

Output

- o Measures of queueing conditions (total delay in vehicle-hours, time to normal flow, maximum number of vehicles in queue, and maximum length of queue in miles)

Figure 4. Summary of the DELAY Model

FREWAY

Application to Work Zone Conditions

- o Developed specifically for analysis of work zone conditions. Little known use or validation available at this time

Analysis Capabilities

- o Estimate the capacity of basic freeway segments under normal operating conditions and during work zone lane closures
- o Estimate queuing characteristics resulting from freeway work zone lane closures

Data Requirements

- o To estimate capacity under normal operating conditions: number of lanes, lane widths, lateral clearances, length and percentage of grades, percentage of trucks and buses
- o To estimate capacity during work zone lane closures: total number of lanes, number of lanes closed, desired percentile value from the distribution of observed capacities

Output

- o Capacity
- o Queuing characteristics: maximum queue length, time to normal flow, queue length at the end of each hour, total vehicle delay, average delay per delayed vehicle, average delay per approach vehicle, percentage of vehicles delayed

Figure 5. Summary of the FREWAY Model

TABLE 1. SOME USES OF WORK ZONE LANE CLOSURE MODELS

	QUEWZ	DELAY	FREWAY
Evaluate Alternative Lane Closure Configurations	Yes	Limited	Limited
Estimate Amount of Traffic Diverting From Freeway	Limited	No	No
Identify Acceptable Lane Closure Schedules	Yes	No	No
Estimate Delays and Queue Lengths	Yes	Yes	Yes
Estimate Additional Road User Costs Due to the Lane Closure	Yes	No	No

directions of the highway facility. However, work zone configurations that maintain the same number of lanes by reducing lane and shoulder widths are not currently accommodated. QUEWZ3 treats the work zone as a simple bottleneck in which all traffic enters at the upstream end and exits at the downstream end. QUEWZ3 has no provisions for analyzing the effects of complex configurations involving ramps, weaving areas, or separate HOV lanes within the work zone. The scope of the model's analysis is limited to the highway on which the lane closure occurs. No attempt has been made at this time to estimate corridor-wide impacts, that is, to consider the impacts that diversion away from a work zone has on traffic conditions on alternative routes in the corridor.

QUEWZ has been used in several Texas cities, including Fort Worth, San Antonio, and Houston and has been tested on the I-495 beltway around Washington, D.C. In Fort Worth, for example, maintenance engineers with the TSDHPT used QUEWZ to estimate queue lengths in order to determine the distance upstream of a lane closure at which supplemental advance warning signs should be placed. In San Antonio, a traffic engineer used the original version of QUEWZ to estimate the effect of a proposed lane closure on a downtown freeway segment. The model predicted unreasonably long queues (because no account was made of diversion or the reductions in traffic volume demands due to an extensive publicity campaign). Although queue lengths of the magnitude predicted were not likely to occur, the results suggested that serious problems could arise and prompted a reassessment of the proposed lane closure. The new diversion algorithm in QUEWZ3 is being validated as part of an ongoing research effort. The tests on the I-495 beltway, a facility where the ramps are relatively far apart, showed very accurate results of QUEWZ to predict the length of queue when lanes were closed due to construction.

Denney and Levine (16) have provided a more formal discussion of the use of the original version of QUEWZ for evaluating active traffic management strategies during work activity on the Southwest Freeway in Houston; they concluded that "the QUEWZ computer model has been shown to provide reasonable evaluations of the effectiveness of these strategies."

QUEWZ3 would be an appropriate model for evaluating the impacts of alternative work zone lane closure configurations and in estimating average speeds, queue lengths, and additional road user costs for the alternative configurations. QUEWZ3 is one of the few computer models that translates estimates of operating conditions into road user costs.

One of the enhancements incorporated into QUEWZ3 has been the addition of a simple diversion algorithm. The algorithm assumes that enough traffic will divert so that delays on the freeway never exceed a maximum acceptable level. QUEWZ3 computes diversion as a function of delays on the freeway itself. It is assumed that unused capacity is available on alternative routes, but no attempt is made to verify that assumption or to assign traffic to specific routes. Currently, a research project is being conducted at the TTI under the sponsorship of the TSDHPT which has as one objective the refinement and validation of a diversion algorithm for QUEWZ3.

Input Requirements

The model was designed to make the input data as simple as possible. The data requirements depend upon the output option that is desired. Some or all of the following information may have to be supplied by the model user: (1) the configuration of the work zone, (2) the schedule of work activity, (3) the traffic volumes approaching the highway segment, and (4) changes to the default values provided for various model constants (optional).

QUEWZ3 is particularly sensitive to the approach volume and work zone capacity estimates that are used. The user may either supply volumes that already account for diversion or supply normal approach volumes and allow QUEWZ3 to estimate diversion. The accuracy of the existing diversion algorithm has not yet been validated. The user also has the option of supplying estimates of work zone capacity or allowing QUEWZ3 to estimate the capacity. QUEWZ3 incorporates the work zone capacity estimation procedure that was developed by Dudek and Richards (7) and included in the 1985 HCM. The model does not allow user-supplied work zone capacities to be greater than 90 percent of the normal capacity.

Output Provided

QUEWZ3 has two output options: the road user cost option and the lane closure schedule option. The road user cost output option analyzes a user-specified work zone configuration and schedule of work activity. The output consists of estimates of traffic volumes (both remaining on the highway and diverting away from the work zone), capacities (with and without the work zone), average speeds (with and without the work zone), queue lengths (with the work zone), and additional road user costs for each hour the lane closure is in place. The lane closure schedule option analyzes all possible lane closure configurations on a highway segment with a specified number of lanes. The output identifies, for each possible number of lanes closed, (1) the hours of the day when that number of lanes could be closed without causing excessive queuing or delays, and (2) the estimated length of queue during each hour of the day. The model user defines the length of queue or minutes of delay that are excessive.

Freeway Simulation Models

The next level of sophistication of computer models with possible application to work zone analysis is the more complex freeway simulation models. Included in this category are such programs as FREQ (17-22), KRONOS (23), and RFLO (24). The latter two models are still in the developmental stage at this time. Hence, this section will focus solely on FREQ.

A series of FREQ models has been developed over the years at the University of California-Berkeley. The original model was developed to aid engineers in the analysis of proposed improvements along 140 miles of freeway in California. The model has been expanded and improved to include the simulation of freeway entry control strategies (20)

and high-occupancy vehicle lanes (21). An important component of FREQ is its ramp metering optimization routine. The most recent version (FREQ10) allows the capacity of freeway links to be varied over time, which is particularly useful in evaluating short-term construction zone lane closures (22). The model is deterministic and macroscopic, and has received widespread validation and use in analyzing proposed geometric improvements and various traffic control strategies across the country (17, 25, 26). Figure 6 summarizes the characteristics of FREQ.

Application to Work Zones

The latest version of FREQ (FREQ10) has been modified to allow temporary changes in capacity (such as an off-peak lane closure) to be analyzed. At the present time, TTI is experimenting with the model for the Florida Department of Transportation to determine its appropriateness for use in evaluating the impacts of freeway construction projects. The major advantage of FREQ over the freeway work zone lane closure models is that it provides the capabilities to consider the effects of ramp locations, configurations (whether they are exit or entrance ramps), and volumes upon traffic approaching and passing through the work zone.

The model is relatively easy to use, although it is somewhat more complicated than the freeway work zone lane closure models previously discussed. Table 2 illustrates some of the possible uses of FREQ for highway construction project evaluation.

Input Requirements

Figure 6 summarizes the basic input requirements for FREQ. The length of freeway to be analyzed is first broken into a series of smaller sections (called "links") that have constant geometric and traffic demand characteristics. Each link is described in terms of the number of lanes, roadway capacity, ramp locations, percentage of trucks using the link, and vertical grade. Traffic demands are specified using a table that indicates the amount of traffic getting on the freeway at each entrance ramp with destinations at each exit ramp. A separate table is needed for each hour (or time period) being simulated. As a final note, there are other default model inputs that can be changed by the user, if desired.

The effects of a work zone must be input directly into the model through adjustments in the link characteristics (such as reducing the number of lanes available at the beginning of the time period when the lane is closed) and the traffic demand table (if, for example, a ramp is closed upstream or within the work zone).

Output Provided

Output provided by FREQ consists of estimates of mainlane and ramp delays, average speeds, exiting volumes, queue lengths, fuel consumption, and vehicle emissions. These are provided for each link for each time period and also for the entire simulation. Estimates of additional road user costs are not provided. However, the output could be used to manually compute additional road user costs due to the work zone.

FREQ

Application to Work Zone Conditions

- o Testing currently underway to use FREQ to evaluate work zone conditions

Analysis Capabilities

- o Estimate operating conditions (speeds, flows, densities, queues, delays), fuel consumption, and vehicle emissions on a section of a directional freeway over a specified period of time
- o Estimate impacts of various freeway traffic management strategies (lane closures, ramp closures, ramp metering, priority entry, and priority lane control) on freeway operating conditions
- o Optimize ramp metering rates

Data Requirements

- o Roadway Characteristics: link lengths, number of lanes, capacities, ramp locations and capacities, design speeds, grades, and truck percentages for the freeway and alternative route
- o Traffic Demand: Ramp origin-destination matrix and existing traffic on alternative route for each time slice (exit and entrance ramp volumes can be used to estimate the ramp origin-destination matrix using the SYNPD2 module in FREQ)
- o Optional inputs to adjust program parameters (vehicle occupancy, speed-flow curves, vehicle emission data, etc.) as desired by the user

Output

- o Performance summaries of MOEs on freeway and alternative route by link and by time slice (cumulative summary of MOEs also provided)
- o Optional outputs include contour diagrams of speeds, densities, queue lengths, fuel consumption, emissions, and noise

Figure 6. Summary of the FREQ Model

TABLE 2. SOME USES OF FREQ

Evaluate the Impacts of:	FREQ
Permanent Lane Closures, Ramp Closures, or Lane Drops	Yes
Reduced Lane/Shoulder Widths	Limited
Minor Changes in Geometrics	Limited
Ramp Metering	Yes
HOV (Priority) Lanes	Yes
Temporary Lane Closures, Ramp Closures, or Incidents	Yes
Surveillance and Control	Yes
Diversion (Traffic Reassignment)	Limited
Consideration of Changes on Alternative Routes	Limited

In summary, the FREQ model provides the ability to consider ramps and basic roadway geometrics in more detail than the freeway lane closure models. However, FREQ cannot fully estimate the effect of traffic diversion to alternative routes if excessive congestion develops. FREQ does have the ability to model diversion of delayed entrance ramp traffic to a downstream entrance ramp location. However, traffic on the freeway cannot be diverted to the alternative route (unless done so manually by adjusting the ramp volume table). In addition, it is not known whether this diversion algorithm is appropriate for modeling driver behavior under work zone conditions.

Corridor and Network Simulation Models

The most complex and extensive simulation models that exist are those developed to model traffic operations within a freeway corridor or an entire urban area. This section focuses on three such models; TRAFLO, INTRAS, and NETSIM. TRAFLO (27) is a portion of the integrated traffic simulation package TRAF, which is being developed under the supervision of FHWA (28). TRAFLO is designed to allow simulation of region-wide traffic operations through an entire urban area. Hence, its data requirements and level of complexity are fairly high. INTRAS (29-32) is an extremely detailed model of freeway operations based upon a complex analysis of individual vehicles. NETSIM (33) is a very popular model developed for FHWA for extremely detailed analysis of traffic operations on an urban arterial street network. Like INTRAS, NETSIM is based upon a complex analysis of individual vehicles as they pass through the roadway network.

It should be noted that models such as INTRAS and NETSIM that attempt to account for individual vehicles typically require an extensive amount of time to learn, data to get the model running, and computer time to process the simulation run. While TRAFLO does not account for individual vehicles, it is developed to allow an analysis of an entire urban area, and so also has similar characteristics regarding level of effort to use and data requirements.

Application to Work Zones

Neither INTRAS nor NETSIM has been applied to a work zone situation. Indeed, given the current lack of data regarding detailed driver behavior and individual vehicle operations within work zones, the use of these two models to evaluate work zone conditions would not seem to be appropriate for most situations. However, it may be possible, for example, to evaluate a complex weaving section created by a construction zone on a freeway using INTRAS or estimate the effect of a midblock lane closure on an arterial using the NETSIM model. Tables 3 and 4 present examples of some of the possible uses of these models in the highway construction project travel impact evaluation process. TRAFLO has the capability to model both freeway corridors and urban arterial networks and so is included in both tables.

An attempt was made to use a portion of the TRAFLO model as a basis of an analysis tool for major construction projects. A computer program named CARHOP (for

TABLE 3. SOME USES OF CORRIDOR SIMULATION MODELS

Evaluate the Impacts of:	TRAFLO	INTRAS
Permanent Lane Closures, Ramp Closures, or Lane Drops	Yes	Yes
Reduced Lane/Shoulder Widths	Limited	Yes
Minor Changes in Geometrics	Limited	Yes
Ramp Metering	Yes	Yes
HOV (Priority) Lanes	Yes	No
Temporary Lane Closures, Ramp Closures, or Incidents	Yes	Yes
Surveillance and Control	Yes	Yes
Diversion (Traffic Reassignment)	Yes	Limited
Consideration of Changes on Alternative Routes	Yes	Limited

TABLE 4. SOME USES OF NETWORK SIMULATION MODELS

Evaluate the Impacts of:	TRAFLO		NETSIM
	I	II	
Installing Signal Control at an Intersection	Yes	Limited	Yes
Signal Timing Changes: - Pretimed Signals - Traffic-Actuated Signals	Yes Limited	Yes No	Yes Yes
Left-Turn Restrictions	Yes	Yes	Yes
Minor Roadway Widening	Limited	Limited	Yes
New or Expanded Bus Service	Yes	Yes	Yes
Removal of Parking	Limited	Limited	Yes
Reversible Lanes	Yes	Yes	Yes

Computer Assisted Reconstruction strategies for Highway Operations and Planning) (34-36) was developed for the California Department of Transportation (CALTRANS) to allow the user to evaluate the impact of alternative construction scenarios and impact mitigation strategies. A series of menus were designed to guide the user through selections of the types of scenarios and strategies to evaluate. Once a particular strategy or scenario is selected, CARHOP adjusts the input database, simulates the scenario as needed, and provides output statistics summarizing the results of the simulation. The developers of CARHOP were able to demonstrate the use of the model on a demonstration project. The creation of the initial database and the calibration of the model required extensive effort. The results of the demonstration study were not compared to actual work zone conditions, so it is not known how accurate or reliable the model may be. At the present time, no further development or implementation of the model is planned by CALTRANS.

Input Requirements

Figures 7, 8, and 9 present a summary of the characteristics of TRAFLO, INTRAS, and NETSIM. As can be seen in the summaries, input requirements for each model are quite extensive. This is to be expected, since the models attempt to simulate traffic conditions within an urban area at a high level of detail. Generally speaking, the roadway network to be analyzed must be defined using the link approach previously described. In addition, traffic signal settings must be defined for all the traffic signals. INTRAS and NETSIM also require input regarding individual vehicle and driver characteristics, although default values can sometimes be used to satisfy certain requirements. Of course, traffic demand volumes must be provided hour-by-hour (or for whatever time periods are being simulated).

Output Provided

Similar types of output are provided by each of the models. Summaries of travel times, delays, queue lengths, speeds, fuel consumptions, vehicle emissions are generally provided for each roadway link and for the entire roadway system. TRAFLO and NETSIM also provide MOEs for signalized intersections (such as the percent of time that not all vehicles waiting can get through on the green phase).

Although these models provide the most complex and detailed simulation analysis possible, the models are still not capable of predicting traffic diversion to alternative routes. An equilibrium traffic assignment program is available with TRAFLO, but it is not known how reasonable its results may be for work zone situations. One test of equilibrium traffic assignment has been performed for a long-term major freeway construction project (37). The traffic assignment was found to be within 28% of actual traffic volumes, on the average. However, there were some roadway sections for which the assigned volumes were much higher or lower than actual volumes during construction. Additional research and experience will be needed to determine if this assignment approach is valid for major construction projects.

TRAFLO

Application to Work Zone Conditions

- o Some use in work zone conditions has been performed. No known validation of model to actual work zone conditions, however

Analysis Capabilities

- o Estimate operating conditions (speeds, flows, densities, queues, delays), fuel consumption, and vehicle emissions over a section of a freeway corridor (freeways and surrounding arterial street system) or urbanized region over a specified period of time
- o Estimate impacts of various freeway traffic management strategies (lane closures, ramp closures, ramp metering, priority entry, and priority lane control) and/or TSM techniques on surrounding arterial street system

Data Requirements

- o Roadway Characteristics: link lengths, number of lanes, capacities, ramp locations and capacities, free-flow speeds, and truck percentages for the freeway(s); similar data along with intersection control characteristics for the arterial street system
- o Traffic Demand: Zonal origin-destination matrix or turning percentage and entry volumes for each entry link in the model for each time slice
- o Optional inputs to adjust program parameters (vehicle occupancy, speed-flow curves, queue discharge characteristics, vehicle emission data)

Output

- o Performance summaries of MOEs on freeway(s) and arterial street system by link and by time slice (cumulative summary of MOEs also provided)

Figure 7. Summary of the TRAFLO Model

INTRAS

Application to Work Zone Conditions

- o No known use or validation to work zone conditions at this time

Analysis Capabilities

- o Microscopic analysis of operating conditions over a section of a freeway corridor (freeways and surrounding arterial street system) over a specified period of time.
- o Estimate impacts of expected traffic pattern changes and proposed traffic management strategies for reconstruction

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, grade, superelevation, radius of curvature, ramp locations, free-flow speeds, and truck percentages for the freeway(s); similar data along with intersection control characteristics (type of control, signal timing settings) for the arterial street system
- o Traffic Demand: Entry volumes (by vehicle type and lane distribution) for each entry link, and turning percentages for each time slice
- o Optional inputs to adjust program parameters (following distance and lane change time, queue discharge characteristics, vehicle emission data)

Output

- o Traffic Performance Summary Tables: delays, densities, speeds, travel miles, volumes, fuel consumption and vehicle emissions for freeway links; similar output with cycle failures and degree of saturation for the arterial street system (provided by link and overall for each time slice and for the entire simulation period)
- o Optional Outputs: digital plots of vehicle time-space trajectories, contour maps of speeds, volumes, densities, delays, headways, and travel times; direct comparisons and statistical tests of MOE values from separate simulation runs

Figure 8. Summary of the INTRAS Model

NETSIM

Application to Work Zone Conditions

- o No known use or validation to work zone conditions

Analysis Capabilities

- o Microscopic analysis of traffic operations over time throughout an urban arterial network
- o Estimate the impacts of traffic volume changes during reconstruction or the impact of major and minor TSM improvements (parking and turning controls, changes in intersection control, real-time surveillance and control systems, etc.) upon traffic operations

Data Requirements

- o Roadway (Link) Data: link length, number of lanes and lane types, grades, channelization, capacities, speeds, queue discharge rates, lost times, pedestrian volumes, traffic volumes, truck percentages, turning percentages, bus characteristics, and traffic surveillance characteristics; changes can be made to these data within the simulation to represent temporary conditions
- o Intersection (Node) Data: type of intersection control, signal control characteristics (cycle lengths, phase sequences and durations)

Output

- o Traffic Performance Summary Tables: travel, delay, stops, speeds, queues, link occupancies, degree of saturation, cycle failures, fuel consumption, and vehicle emissions for each link and for entire network, at several points in time and for the entire simulation period

Figure 9. Summary of the NETSIM Model

Network-Based Highway and Transit Planning Models and Quick Response Estimation Techniques

For construction projects in high-volume urban areas that require a corridor-wide evaluation of travel impacts, an attempt must be made to estimate the changes in travel patterns that may occur as a result of the construction project. A long-term lane closure on a major freeway, for example, may cause a substantial number of motorists who normally use the freeway to take alternative routes or even change their choice of travel mode.

Network-based highway and transit planning models and quick-response estimation techniques are tools which may have potential application in the construction project travel impact evaluation process. Both tools may be useful in estimating (1) the origins and destinations of motorists using the facility (which may then provide insight as to possible alternative routes), and (2) the redistribution of traffic among the routes in the corridor once the construction zone is in place and/or TSM improvements have been made to increase the capacity of alternative routes.

Application to Work Zones

Network-based planning models have been used in developing traffic management plans for projects in several major urban areas (e.g. Detroit, Miami). No documentation exists as to how the model results compared to actual travel patterns throughout the corridor during the construction project. Quick-response techniques were utilized during the planning for the reconstruction of the Parkway East in Pittsburgh. Again, no comparison of the model results to actual conditions was made.

It is possible that both types of tools may have application to the travel impact evaluation process. However, little quantitative data exists as to how drivers change their travel patterns during highway construction projects. Research is underway at TTI to gather this type of data for Texas. Until a better understanding of this phenomenon is obtained, it will not be possible to say whether these models provide realistic information for the evaluation process.

Input Requirements

A summary of the characteristics of network-based planning models and quick-response estimation techniques are provided in Figures 10 and 11. Generally speaking, network-based planning models require extensive data, including a detailed description of the roadway network, a description of geographic zones throughout the area that identify where vehicles begin and end their trips, and a table that describes how many trips go from one geographic zone to the other. Once this data is obtained and a model developed, it must first be calibrated to existing conditions before it can be used, a process that is also time-consuming and labor-intensive. If an existing model is available (from a previous long-range regional planning analysis) and has been calibrated, the use of the model for construction project traffic impact evaluation is dramatically easier.

NETWORK-BASED HIGHWAY AND TRANSIT PLANNING MODELS

Application to Work Zone Conditions

- o Some use for planning of traffic management for major urban freeway construction projects in Detroit and Miami
- o An analysis of the results of equilibrium assignment for freeway construction in Pittsburgh found predicted versus actual link volumes to be within 28% of each other (on the average)

Analysis Capabilities

- o Perform traffic assignment analyses to evaluate changes in the allocation of trips among routes in the corridor resulting from a reconstruction project using various traffic assignment techniques (i.e., iterative or incremental capacity restraint assignment or equilibrium assignment)
- o Perform the select link analyses such as subarea analysis, ramp analysis, and freeway weaving analysis
- o Perform trip distribution (Gravity Model) analyses to obtain trip tables

Data Requirements

- o Network link data: link length, connections, speed, and capacity; and optionally, observed ground count volumes or peak-hour capacities
- o Zonal productions and attractions and trip length frequency
- o Prohibited turn data and node coordinate data (optional)
- o Description of reconstruction area in terms of the characteristics of the affected links (i.e., link location and capacity)

Output

- o Report of the travel patterns in terms of updated-assigned volumes, travel impedances, and link speeds
- o Vehicle-Miles Traveled/Vehicle-Hours Traveled

Figure 10. Summary of Network-Based Highway and Transit Planning Models

QUICK RESPONSE ESTIMATION TECHNIQUES: NCHRP 187 Manual Methods

Application to Work Zone Conditions

- o Some uses of NCHRP techniques in Pittsburgh for major urban freeway reconstruction. No known validation of techniques to actual conditions during construction

Analysis Capabilities

- o Perform simplified travel demand forecasting analyses to obtain trip tables; identify users of reconstruction segment; compare corridor-wide and individual link volumes for the different traffic-handling options
- o Estimates changes in mode split and vehicle trips resulting from improvements in HOV services

Data Requirements

- o Land use and socioeconomic characteristics; zonal network with centroids; zonal productions and attractions
- o Transit fares, auto operating costs, attraction-end parking costs
- o Urban area population
- o Knowledge of the highway network

Output

- o Number of trips for a given land use (Trip Generation); origin-destination trip table (Trip Distribution); corridor-wide and individual-link volumes (Traffic Assignment Procedures)
- o Revised mode shares (Mode-Choice Analysis); number of vehicle trips on a given facility (Automobile-Occupancy Characteristics)

Figure 11. Summary of Quick Response Estimation Techniques
(NCHRP 187 Manual Methods)

Quick-response estimation techniques require the same type of information as network-based planning models, but in less detail or in a form that is easier to use. These techniques were developed so that users could make rough estimates of the impacts of major land use and roadway changes by applying generalized values (selected from tables or from charts) to a simplified analysis methodology. These generalized values reduce the amount of data that is necessary to make travel pattern estimates. However, since the data represents only general conditions, it may not be applicable for a specific location. In addition, the impact of highway construction upon the values or even the applicability of the methodology itself for work zone conditions is not known at this time.

For both tools, the impact of a construction project must be manually incorporated into the model by adjusting roadway capacities and other model inputs as necessary.

Output Provided

In general, the types of output provided by both tools include distribution of trips among the geographic zones in the area, overall traffic volumes, and estimates of changes in transit or ridesharing usage (if analyzed). Network-based planning models provide a little more detail in the output, estimating the total miles and hours of travel. In general, little or no traffic operations data is provided.

Traffic Optimization Models

Along most urban arterials, signalized intersections are the primary restrictions to the flow of traffic. Because of the major impact that signalization has upon the overall efficiency of traffic movement, considerable effort has been devoted to the development of procedures to optimize traffic signal operations so as to best utilize the capacity of these intersections. A number of programs are available to aid the traffic engineer in the development of optimized signal phasing and timing plans.

Among the programs for single intersection optimization, SOAP (Signal Operations Analysis Program) (38) is one of the most well-known and documented tools available. The program can be used for developing optimum signal timing plans and optimal cycle lengths for both fixed-time and traffic-actuated signals. At the next level of sophistication are programs for minimizing delay and stops throughout a network of intersections. TRANSYT-7F (39) and SIGOP III (40) are both well-accepted traffic engineering tools for this purpose. These programs are significantly more complicated than the single intersection programs, since they must consider the interaction of signal timing (green splits), cycle length, and timing offsets between signals, searching for the combination that minimizes delays and stops throughout the network. Bandwidth maximization programs also search for the optimum signal timing and offset combinations for signals along an arterial or limited network, but with emphasis on providing the best traffic progression from signal to signal. The principal programs of this type are PASSER II (41) and MAXBAND 86 (42). Summaries of each of these models are provided in Figures 12 through 16.

SOAP

Application to Work Zone Conditions

- o No known use or validation to work zone conditions

Analysis Capabilities

- o Optimize cycle length, phase sequence, and phase durations for an isolated, fixed-time (or approximated traffic-actuated) signalized intersection (up to 8-phases) in steady-state traffic conditions
- o Estimate the impacts of changes in approach volumes (due to reconstruction) or the mitigating effect of signal timing changes upon traffic operations at the intersection

Data Requirements

- o Approach Data: traffic volumes, turning movements, truck percentages, and approach capacities or number of lanes
- o Intersection (Node) Data: existing signal timing characteristics (if to be evaluated), minimum green durations

Output

- o Traffic MOEs: delay, saturation ratio, queue length, stops, fuel consumption, left-turn conflicts
- o Optimized Signal Timing Settings: phasing sequences and durations, cycle length
- o Comparison Reports (Optional): direct tabular comparisons of delay and fuel consumption for alternative runs

Figure 12. Summary of the SOAP Model

TRANSYT-7F

Application to Work Zone Conditions

- o Used to analyze an arterial work zone in Seattle

Analysis Capabilities

- o Optimize fixed-time traffic signals for an urban arterial network, based on the minimization of delays and stops at intersections for steady-state traffic conditions
- o Estimate impacts of major TSM improvements at intersections and along arterials upon operating conditions (delays, stops, speeds, fuel consumption) throughout the arterial network

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, capacities, traffic volumes, fraction of volume coming from each upstream feeding link
- o Intersection (Node) Data: signal control characteristics (cycle length, number of phases, phase sequences, phase durations)
- o Calibration Data (Optional): flow/speed multipliers, platoon dispersion factors

Output

- o Traffic Performance Summary Tables: degree of saturation, travel time, delays, stops, queue lengths, and fuel consumption by link and for the entire network
- o Signal Timing Tables: phase intervals and offsets
- o Optional Outputs: flow profile plots, time-space diagrams

Figure 13. Summary of the TRANSYT-7F Model

SIGOP III

Application to Work Zone Conditions

- o No known use or validation for work zone conditions

Analysis Capabilities

- o Optimize fixed-time traffic signals for an urban arterial network, based on the minimization of delays, stops, and queues at intersections for steady-state traffic conditions
- o Estimate impacts of traffic volume changes due to reconstruction or the effectiveness of major TSM improvements upon operating conditions (delays, stops, speeds, etc.) throughout the arterial network

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, turning bays, truck percentages, speeds, headways, lost time, traffic volumes and turning percentages
- o Intersection (Node) Data: signal control characteristics (cycle lengths, phase sequences, phase timings, and offsets)

Output

- o Traffic Performance Summary Table: Speeds, delays, stops, queues, fuel consumption, vehicle emissions, and degree of saturation for each link and for the total network
- o Optimized Signal Timings: cycle length, phase durations, and offsets

Figure 14. Summary of the SIGOP III Model

PASSER II-87

Application to Work Zone Conditions

- o No known use or validation to work zone conditions

Analysis Capabilities

- o Coordinated analysis to maximize progression bandwidth and minimize vehicular delay for fixed-time traffic signals along an urban arterial in steady-state traffic conditions
- o Estimate impacts of signal timing changes on travel times, speeds, and delays along an arterial
- o Simulation of existing signal timing plans along an arterial

Data Requirements

- o Approach Data: speeds, traffic volumes, capacities, turning movements
- o Intersection (Node) Data: acceptable cycle lengths and phase sequences, minimum allowable green times, distances between intersections

Output

- o Optimum (within constraints) cycle length, phase sequences, phase durations
- o Progression bandwidths, bandwidth efficiency and attainability, average progression speed
- o Intersection level of service, saturation ratio, stops, delay, fuel consumption, and time-space diagrams

Figure 15. Summary of the PASSER II-87 Model

MAXBAND-86

Application to Work Zone Conditions

- o No known use or validation to work zone conditions

Analysis Capabilities

- o Optimization of fixed-time traffic signals in urban arterial or grid networks using an integer programming procedure to maximize bandwidth
- o Estimate impacts of signal timing changes on travel times and speeds along an arterial or network

Data Requirements

- o Roadway (Link) Data: lengths, speeds, traffic volumes, capacities, turning movements (optionally, one may input green times for each signal phase in lieu of traffic data)
- o Intersection (Node) Data: acceptable cycle lengths, phase sequences (including left-turn patterns), and durations; basic spatial relationships between intersections

Output

- o Inbound and outbound bandwidths, optimum cycle length, phase lengths and sequences, offsets, progression travel times and speeds on links

Figure 16. Summary of the MAXBAND-86 Model

Application to Work Zones

There has been little documented experience with using these models as part of the highway construction project travel impact evaluation process. TRANSYT-7F was used to evaluate alternative construction lane closure scenarios and aid in the development of traffic control plans as part of the Downtown Seattle Transit Project (43). The authors concluded that the model (used as an urban arterial simulation model) provided assistance in the preliminary and final design phases. However, no data was collected to determine how well the conditions predicted by the model compared to actual traffic conditions during construction.

These models do have the potential to aid in the highway construction project travel impact evaluation process. When a corridor-wide evaluation is necessary, major highway construction will often cause a significant change in travel patterns on the surrounding arterial street system. It may be necessary to adjust traffic signal timings at some locations in order to accommodate the travel pattern changes and provide the best operations possible during construction. Another potential use of these models would be to encourage traffic to divert from the highway under construction by changing the signal timings to deliberately give preference to travel movement along the alternative routes.

Input Requirements

Data for most signal optimization programs consists of three main types: (1) traffic volumes, (2) signal controller information, and (3) basic geometrics, including the relative location of intersections and descriptions of the arterial segments. Generally speaking, bandwidth maximization programs, such as PASSER II and MAXBAND 86, require slightly less information than the delay minimization programs like TRANSYT-7F and SIGOP III. In fact, PASSER II and MAXBAND 86 may be run without any traffic data if the user can supply the green times necessary for each phase. Delay minimization programs consider the time-dependent nature of traffic movement from intersection to intersection in slightly more detail and model certain types of traffic behavior, such as platoon dispersion, explicitly. In addition, TRANSYT-7F and SIGOP III also have explicit simulation capabilities, which require more information.

Output Provided

Signal optimization programs typically provide optimized signal settings for intersections, estimates of traffic performance characteristics along the arterial, and time-space diagrams to aid the user in visualizing travel flow along the arterials. MAXBAND 86 and PASSER II provide more information relative to bandwidth maximization (such as progression efficiency and attainability), while TRANSYT-7F and SIGOP III provide more details about traffic conditions on both the intersections and the individual links in the network (average speeds, total travel, delays, headways).

IV. SUMMARY AND RECOMMENDATIONS

This report has presented an overview of a basic process for evaluating the travel impacts of highway construction activities, and provided an assessment of computer models in six major categories which might be useful in the evaluation process. The categories vary in terms of the types of issues they can address, their complexity and data requirements, and the output that they provide. In general, the work zone lane closure model QUEWZ is the simplest and most directly applicable to evaluating traffic conditions through a freeway or multilane highway work zone. However, QUEWZ does have limitations in terms of its sensitivity to basic roadway geometrics such as the presence of exit and entrance ramps. The freeway simulation model FREQ can provide an assessment of ramp effects and other geometric characteristics, but requires more data to operate and time to learn. Corridor and network simulation models are more complex, since they must address conditions that exist within an urban area. They are complicated to use and require large amounts of data, but provide the most detailed level of simulation analysis.

Highway capacity analysis, by itself, is not likely to be adequate to fully evaluate the traffic impacts of construction. However, the output provided is necessary as input for nearly all of the other computer models, and so is an important component of the evaluation process.

Network-based planning models and quick-response estimation techniques have the potential for predicting how major highway construction projects might affect travel patterns. They are likely to be applicable only in urban areas where a corridor-wide analysis is necessary. The types of information provided by the models that would be useful in the evaluation process would be an assessment of the origins and destinations of drivers using a facility, and an estimate of how traffic might redistribute itself among the various routes in a corridor or entire urban area as a result of construction. At the present time, there is not enough evidence to judge whether the basic assumptions used in these models are applicable to highway construction conditions.

Traffic optimization models can provide optimized traffic signal timings on an urban arterials based on estimates of travel pattern changes, and so would be useful in the highway construction traffic impact evaluation process. These models can also be used to estimate how well possible changes in traffic volumes on an arterial (as a result of roadway construction) could be accommodated through changes in traffic signal timings. The scope of these models is limited, and would serve as supplemental sources of information for a travel impact evaluation.

It should be apparent from the reviews and evaluations presented herein (1) that there are a number of analysis tools that could be used as part of the process of evaluating the travel impacts of highway construction projects, but (2) that there is not an individual analysis tool that could satisfy all of the objectives stated by the Florida Department of Transportation or that would be appropriate for the gamut of construction projects. The analyses performed for a given project should be no more data-intensive or time-consuming than necessary to provide sufficient information to make proper

decisions. The appropriate scope and level of analysis varies among projects and should be carefully selected. The most critical decision is whether the analysis may be restricted to the highway under construction or whether it should be corridor-wide. The computer programs that can be used to perform an evaluation restricted to the highway under construction are less data intensive and time-consuming than the computer programs required for a corridor-wide evaluation. However, if the impacts of a project are likely to extend beyond the highway under construction, then the additional effort required to perform a corridor-wide evaluation should be taken.

It is recommended that the procedure used by the Florida Department of Transportation have at least two levels of analysis tools. The first level would consist of analysis tools that could be used when the travel impact evaluation can be restricted to the highway under construction. This level would be used for (1) rural and some suburban areas where ramps are spaced widely and where traffic volumes are relatively low, and (2) in certain urban areas when lanes and/or shoulders are narrowed to maintain the normal number of lanes or when lanes are closed for only part of the day. Analysis tools that should be considered for this level are QUEWZ3 and FREQ10. Both models can simulate freeway lane closures. Neither has strong capabilities for estimating diversion, although QUEWZ3 has a simple diversion algorithm that estimates the amount of traffic that would have to divert from the construction zone in order to keep delays within acceptable ranges. QUEWZ3 requires less data and is easier to use than FREQ10. FREQ10, however, has the additional capabilities of simulating ramp operations and optimizing ramp metering. For most construction projects either QUEWZ3 or FREQ10 should provide sufficient analysis capabilities for an appropriate travel impact evaluation.

A few major projects in urban areas warrant a corridor-wide evaluation which requires a second level of analysis tools with traffic assignment capabilities. The three options are network-based highway and transit planning models, network-based freeway corridor simulation models, and non-network-based quick-response estimation techniques. Additional research and experience with these models will be needed, however, before their appropriateness for highway construction project travel impact evaluation can be determined.

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