APPENDIX G
Evaluation Procedures for Selected ITS Strategies

This Appendix provides specific procedures for the evaluation of the potential benefits of selected ITS strategies. The purpose of this appendix is to supplement Chapter 6 of the Handbook with steps that analysts can use to derive reasonable estimates of the potential impact of ITS strategies on travel and congestion. The procedures are intended to be applied in the planning stage so that better decisions can he made on the benefits of ITS in comparison with other types of transportation improvements. The procedures do not include a treatment of each ITS market package. However, they address a cross-section of multimodal ITS strategies which may in turn provide ideas for how other ITS market packages might also be analyzed. The emphasis of most of these procedures is on calculating changes in delay or vehicle hours of travel (VHT). However, other measures of performance (e.g., vehicle miles of travel) can also be generated as a byproduct of these procedures. It is important to note that the measures of performance calculated using these procedures are not the only benefits that can be realized for the ITS strategies being discussed. Other quantitative or qualitative benefits may also be realized.

Strategy evaluation can take place in a variety of areas in the planning process: in the formulation of the transportation plan, in corridor or subarea studies, in development of the ITS strategic deployment plan, or in other analyses not connected to a particular type of study.

OVERVIEW

Analytical tools that can adequately examine the benefits of ITS strategies are still in the formative stages. Appendix H provides an extended discussion of the evaluation of ITS strategies using tools that are typically available to the transportation planning and engineering community. The basic approach taken in this appendix is to provide insights into how the most reasonable estimates of ITS benefits can be derived for specific applications using existing, available tools and without an inordinate investment in evaluation. It is recognized that agency budgets for studies and evaluation are limited. It is important to understand that reasonable estimates of benefit can often be obtained without a large, costly undertaking. As more sophisticated tools are introduced, more refined answers can he obtained. But even if more sophisticated tools are available, many agencies will either not have the expertise to use them or their use will not be possible within the time and cost constraints of the agencies conducting the studies.

There are three generic approaches to ITS evaluation that are currently available: sketch planning analysis, travel demand modeling, and traffic simulation. These are related to analysis contexts in Exhibit G-1.

Exibit G-1. Applicable Analysis Tools for Evaluating ITS Strategies

CHOOSING THE ANALYTICAL APPROACH

A variety of factors need to be considered in selecting the analytical approach to ITS. Exhibit G-2 illustrates some of these factors. In some cases, the analysis could also be two-tiered: sketch planning might be used as a screening tool, with more in-depth analysis for selected strategies depending on the outcome. Sketch planning analysis may also be required to generate inputs for some of the more sophisticated tools.

Some of the basic rules in conducting ITS-related analyses include:

- Have key assumptions reviewed by multiple staff, not just a single individual.
- Sensitivity analysis may be warranted for conditions where the validity of key assumptions is highly uncertain. Sensitivity analysis shows how the outcome will change depending on changes in those assumptions.
- Ensure that staff have proper training in the use of travel demand models and simulation models, where used. Changes in model parameters can sometimes have unexpected effects that may not be readily apparent. The basic structure of the models must be understood to avoid problems.
- Maintain good records of assumptions used for each scenario analyzed. Variations may need to be tested later, or assumptions may he questioned. Good records will support the credibility of the process. The specifications for an alternative or strategy tested should be included in the computer-generated output, whether it be spreadsheet, simulation, or travel demand model.

- Expose the underlying assumptions so that decisions can be based on full knowledge.
- Ensure that the study area incorporates the full effects of the strategy being analyzed. Upstream and downstream congestion that may be influenced by a strategy should be included as part of the study area.
- Note any potential secondary effects that may not have been included in the analysis (e.g., diversions that were not accounted for, etc.).
- Make the results understandable to the intended audience. In many cases, the audience will be non-technical.

APPROACHES TO EVALUATING SPECIFIC ITS STRATEGIES

Approaches to the transportation evaluation of selected ITS strategies are discussed below. Only a limited number of ITS strategies are discussed. However, the strategies include a diverse range of multimodal market packages. Each of the three approaches (sketch planning, travel demand modeling, and simulation) are discussed for each of the selected ITS strategies. However, the analyst will either be able to adapt the material here to the evaluation of other strategies or will be able to devise a similar methodology based on the principles described in this appendix.

Exhibit G-2. Analytical Approaches Favored Based on Selected Factoer and Circumstances

The discussion on simulation is based on three freeway models (FREFLO, FREQ, and FRESIM) and two surface street network (TRANSYT-7F and NETSIM). These represent the most available and used simulation models for most applications in the U.S. However, they are not the only simulation models available. The simulation approaches describe how to use the appropriate models in the analysis of the ITS strategies. Approaches to estimating vehicle emissions impacts are described later this chapter.

Ramp metering is designed to smooth traffic flow, provide priority to higher occupancy vehicles (in some cases), and influence path selection. It improves the speed on a limited access facility by controlling the processing rate of the access points. The increased delays at the access points (ramps) are generally compensated by higher speeds on the facility. If the trip is short, the benefits will not compensate for the delays, and the trip is likely to choose an alternative path.

Sketch Planning Approach

The following presents an analysis based on documented existing conditions. An analysis of future conditions would require additional estimation of speed in the future base (unmetered) condition. The analysis is conducted by individual ramp and segments between ramps.

1. Estimate current freeway speeds for each hour in the peak period by direction, based on non-incident conditions.

2. Estimate the metering rate as a percentage of the on-ramp volume for each hour, depending on how strong the metering plan needs to be to maintain freeway flow. Typically, metering rate will he no less than 80 percent of pre-metering volume. Use 300 vph per lane minimum metering rate and 900 vph maximum.

3. Estimate peak hour ramp delay per vehicle at:

   15 sec. + 5 min. x (demand vol./metering vol. - 1)

   Minimum assumed to be 15 sec., maximum five minutes.

4. Assume diversion to parallel arterials is 50% of the difference between the demand volume and the metering rate. This assumption could be varied by the user. Assume these diverted vehicles travel for two interchanges on the arterial before taking another route. This is consis tent with the logic that primarily short trips will be diverted.

5. For each ramp, calculate vehicle hours of delay under metering as delay per vehicle (step 3) times the new ramp volume with diversion (step 4). Assume no ramp delay for non-metering condition.

6. Estimate freeway speeds with ramp metering at a minimum of 40 miles per hour. This would apply to all non-diverted traffic.

7. Estimate the <u>change in speed</u> on the nearest parallel arterials by calculating the difference in speed (based on v/c ratio for the metered and unmetered conditions) from the BPR formula presented later in this appendix. The free-flow speed (T_o = free flow speed) should he set according to the characteristics of the specific arterial. A typical rule-of-thumb capacity for an urban signalized arterial is 900 vph per lane.

8. Calculate vehicle miles and vehicle hours for freeway and arterial, including ramp delay. The non-metering and metering volumes and speeds should be plotted on a simple sketch to keep all the information in order.

9. Estimate accident reductions. Accident frequency on arterials may need to he increased based on volume increase. Assume same arterial accident rate applied to higher volume.

10. Estimate percentage of days that major incidents will disrupt metering effectiveness. Assume no benefit on these days. A typical value would range between 10 and 30 percent.

11. If estimating benefits on a regional basis, add individual corridor benefits together.

Travel Demand Modeling Approach

Ramp metering can be approximated in the assignment model in one of two basic ways (or in a combination of both). It is important to note that none of the following procedures have been fully tested for these applications. A validation process, or at a minimum, a testing of scenarios for reasonableness, is needed for any individual application. At best, this will provide an order-of-magnitude estimate.

1. At on-ramps: restricting the capacity of the ramps to the maximum metering rate. This would not necessarily limit the assigned volume to the metering rate, but it would put down ward pressure on the assigned ramp volumes. On the mainline: increasing capacity on the limited access facility in the sections metered. Evidence indicates that ramp metering could mainline throughput (represented by capacity) at critical sections by three percent.

2. Modifying the speed-flow relationships on the ramps and limited access facilities to control the delays associated with near-capacity conditions. The objective is to significantly increase the delays on the ramps and slightly reduce the delays on the limited access facility. Speed-flow adjustments can be implemented in several ways. The most logical approach is to modify the speed-flow relationship on the facilities of interest based on traffic engineering principles. If a traditional BPR formula is used, this can be achieved by modifying the exponent value or adjusting the delay factor. be used.

If the available software does not permit the user to specify speed-flow relationships for specific links or facility types, a similar result can be achieved by changing peak hour percentages, free flow speeds or link capacities. Link capacities are discussed above. The best way to implement the delay effects on the ramps is to reduce the free flow speed. This has the effect of giving some delay to all vehicles on the ramp regardless of the level of congestion.

Simulation Approach Using Selected Models

FREFLO: The model has no metering capability. Fixed-time metering can be approximated using ramp capacities equivalent to the metering rate. Ramp capacities may be varied by time slice. No driver response is built into the model. Diversion would have to be calculated using a sketch planning approach. Linkages can be built to arterial simulation models for more advanced applications, but diversion adjustments will need to be made manually.

FREQ: In non-optimized mode, fixed metering rates can be established with options for on-ramp motorists to divert to the arterial based on a user-specified set of decision criteria. Arterial simulation is relatively crude. Also has capability for ramp metering optimization based on a set of user-specified criteria. Considers metering only as aggregate demand reduction on freeway mainline. Does not consider effect of metering on merging operation. In optimized mode, uses linear programming to generate a corridor optimum. User can set maximum and minimum rates as well as decision criteria for drivers to divert from on-ramps to the arterial. Other constraints that can be entered include maximum v/c ratio at bottlenecks, maximum queue lengths at each ramp, and designation of ramps which are not to be controlled. By setting maximum and minimum metering rates for various ramps in various time slices both at the same value, the user can enter their own ramp metering plan.

FRESIM: Several metering types can be selected, including fixed time. Considers both effect of limiting demand and on-ramp merging operations. As an optimization option, generates a local optimum based on mainline demand/capacity relationships or gap acceptance logic.

All of the above models will generate VMT and VHT statistics. For FREQ and FREFLO, the capacity can be adjusted upward by a user-selected value to account for increase in throughput. Experience has shown that an increase in throughput of approximately three percent is possible through ramp metering. Steps 9 through 11 from the sketch planning approach may be applied to take individual corridor daily estimates to annual regional estimates, if desired.

Sketch Planning Approach:

Perform in same manner as without HOV bypass but estimate vehicle occupancy distribution on each ramp, mainline and arterial. Calculate HOV volumes on ramp. Estimate savings in person hours of travel in addition to vehicle hours of travel (should be greater savings due to no delay for HOVs). Assume ramp metering for non-HOVs is more restrictive, keeping total on-ramp vehicle delay the same as for ramp metering without HOV bypass.

Travel Demand Modeling Approach:

If HOV bypass lanes are provided on the metered ramps, the mode choice and assignment models can be affected. The travel time advantage for HOV trips will have a slight impact on the number of HOV trips estimated by the mode choice model. Most mode choice models are not very sensitive to this change. The impact on the assignment of HOV trips can be significant. A possible procedure is as follows:

- Add a parallel ramp with HOV restrictions and increased capacity. Assign non-HOV and HOV trips to the highway network. Skim the HOV and non-HOV paths based on loaded speeds for use in the mode choice model. Rerun the assignment.

Simulation Approach:

FREFLO: Not treated.

FREQ: Incorporates a modal shift algorithm that generates additional HOVs in response to the delay saved by HOV's at the on-ramps. Algorithm calibrated for specific locations in California. Modal shift responsiveness may need to be modified depending on the nature of the urban area and orientation of the freeway. However, the effect of violation rates can be influenced by altering the percentages of HOV and non-HOV vehicles at the entry ramp.

FRESIM: No HOV priority capability.

Incident management programs generally provide benefits in two ways: reducing delay directly through a reduction in incident duration, or reducing delay indirectly through the provision of information, which allows delay savings by individual drivers through alternate routing.

The time of incident duration is reduced by reducing the time for incident detection, verification, response, and clearance.

Sketch planning approach

1. Estimate the number of incidents by severity and duration within the study area for three time periods: A.M., off-peak. and P.M. peak periods. Severity means the number of lanes blocked.

2. Construct a set of incident duration curves by estimating the vehicle hours of travel incurred under existing conditions from each combination of severity (number of lanes blocked), duration. and time period. The analysis will require traffic volume, number of lanes (or capacity), and number of lanes blocked (or capacity reduction). This is the most time-consuming part of the process. To reduce the amount of effort the analyst may need to work with simplifying assumptions, such as using a single-lane incident at one or two representative locations during both a peak and an off-peak period.

3. Estimate the reduction in incident duration achievable through various incident management strategies.

4. Estimate the delay savings for the new set of incident durations (compared to the unimproved condition) from the curves generated in step 2. The delay savings is the difference between the delay for the current and new durations attributed to the incident management strategies.

5. Sum the delay savings achieved for each set of strategies and representative sample of incidents.

Travel Demand Modeling Approach

The delay attributed to a specific incident scenario (similar to the sketch planning approach) would be implemented in the assignment model by modifying the time based capacity of the roadway at the incident location. Since most models define capacity as an hourly value, the modeler will need to calculate the weighted average capacity of the roadway over the simulated period, and use this value in the modeling process. For example, if a peak, hour model is used and the incident closes two lanes of a four-lane facility for 30 minutes, the resulting capacity is three fourths of the original value. The incident management strategies will modify the duration of incidents and thereby modify the capacity of the roadway. The following specific steps can be employed:

1. Construct an incident duration curve (or curves), as in the sketch planning approach, for defined sets of conditions using the capacity-reduction technique described above. The only difference is that the travel demand model will be used to estimate delays rather than the QUEUES program. Keep in mind that the travel demand model will assume diversion in the assignment program, which may or may not occur.

2. Follow steps 3 through 5 under the sketch planning procedure.

Simulation Model Approaches

Simulation approaches will follow the same basic steps as in the sketch planning approach above, including construction of the incident duration curve. The primary difference is that the simulation models will be used to estimate delay rather than the QUEUES spreadsheet program. The simulation models (except for FRESIM) can be used to estimate incident delay by modifying their capacity to correspond to the effect of the incident (see Exhibit G-3 for capacity-reducing values) for the prescribed time periods. Temporary capacity modifications in the simulation models can be treated as follows:

FREFLO: Specify the time slices during which the incident is to be active and code in the reduced capacity for those time slices.

FREQ: Specify the reduced capacity in the “reduced capacities” option for all time slices affected by the incident (e.g., a 45-min incident would affect three 15-min ~time slices).

Exhibit G-3. Typical Reductions in Throughput as a Result of Incidents

FRESIM: Indicate the beginning and ending times for the incident and the lane or lanes blocked. In FRESIM, the beginning and ending times of the incident may be indicated to the minute and second and do not need to coincide with time slices, a limitation that exists in FREFLO and FREQ. FRESIM contains its own table of capacity-reducing effects of incidents. FRESIM also allows the simulation of an incident warning sign. This influences drivers to shift out of the incident lane earlier than they would otherwise.

Estimating the impact of traveler information is perhaps the most difficult ITS strategy evaluation task for any of the analysis methods. Most traveler information systems focus on providing warnings about incident. In general, one would expect most of the effect to be on path choice, resulting perhaps in slightly longer trips but shorter in time than compared with no information. Typically, a limited proportion of motorists on an affected route actually change their route (perhaps up to 30 percent in severe, non-closure instances). The travel time savings for these individuals varies widely by the nature and time of the incident and alternate routes available. Typically, though, the origin-to-destination trip time would not reduced by more than 20 percent. These general parameters could be used to assess whether the model is within a reasonable range of the likely impact.

Sketch Planning Approaches

It is assumed that motorist information will normally be in response to an incident and that it will involve diversion from a freeway to another freeway or from a freeway to an arterial. The approach will be to provide representative scenarios. There are two sketch planning approaches, one that is trip-based. and one that is based on the estimation of benefits for individual incidents.

Sketch planning approach (trip-based):

1. Within the region (or a smaller study corridor), estimate average trip distance and trip time for peak and off-peak-periods. An estimate should be obtainable from regional planning data from the MPO.

2. Define the “trip markets” as the number of trips occurring in the region or corridor by time period (longer and shorter periods).

3. Estimate the incident-affected trip travel time for a typical incident situation. This data is typically unavailable, but a sensitivity analysis could be conducted using five-minute, ten-minute, and fifteen-minute increases in trip time.

4. Estimate the time saving potentially achievable through better information. This value will need to account for the availability of altenate routes (limited altenate routes will mean limited time savings) and the lack of congestion on altenate routes (off-peak travel should have greater potential time savings for diversion). A value of 1 minute might be considered for a peak period, peak direction with poor altenate routing and up to 15 minutes for an off-peak or non-peak direction with good altenate routing.

5. Estimate the percentage of the trip market that will he able to take advantage of the information. This should account for locations to which the information is being delivered (e.g., if only on the freeway, only the share of trips using the freeways would benefit). The absorption capacity of altenate routes will also limit the trip market that can he affected. Typically, off-peak travel will have a higher percentage of the trip market affected than during the peak. It is expected that these numbers will he no greater than 30 percent of freeway traffic in the off-peak and 10 percent in the peak. Off-peak directions during the peak periods could be between these two values.

6. Estimate the frequency with which the travel information will be useful, based on incident frequency and severity (probably no more than two days per week for each trip).

7. Multiply the time savings potential for each trip market by the percentage of trip market affected and by the percentage of days trips are likely to be affected to generate total time savings.

Sketch planning approach (based on individual freeway incident)

1. Document traffic volumes and speeds for the time period being analyzed.

2. Define the incident condition to be represented (location, duration and severity).

3. Estimate non-incident VHT using average speeds and volumes for the base condition. Estimate additional VHT under incident conditions (no information) using the QUEUES spreadsheet.

4. Estimate diversion of vehicles that would occur with additional information. Experience has indicated that this amount can range from several percent for “weak” messages to 30 percent for strong messages.

5. Recalculate freeway VHT in QUEUES spreadsheet assuming diversion.

6. Calculate increase in arterial VHT using existing speeds and changes in speed estimated from BPR equation or from other preferred capacity/delay calculations. Additional trip length of diverted vehicles must also be accounted for.

7. Sum all component VHTs to provide comparison between the with-information and without-information conditions.

Travel Demand Modeling Approach

Since travel models do not directly consider incidents, only indirect modeling can be performed. This modeling could take the form of a general reduction of nonwork travel during the peak period based on more reliable information about travel conditions (i.e., trips would not be made or would he deferred - these would need to be accounted for elsewhere). Traveler information could also affect the in-route path selection of travelers. Travel demand models were not designed to evaluate any of these effects, and models would need to be “fooled” into providing ballpark estimates, and substantial trial and error would be required. Use of travel demand models for this activity is not recommended.

Simulation approach

In a simulation-based approach, the diversion amount will typically need to be reflected manually in the model input volumes. The diverted amount will need to be reflected in either another freeway or arterial simulation model (as an increased volume), in a network integrated with the primary freeway being analyzed, or reflected in a sketch planning analysis.

FREFLO: Motorist response to variable message signs, highway advisory radio, and other information/diversion strategies would need to be reflected in manual volume adjustments to on-ramps and of-ramps in the simulation model. Little basis exists for estimating diversion percentages other than the general rules described above, and separate estimates would need to be made for the effect on the arterial.

FREQ: Same as for FREFLO.

FRESIM: Same as for FREFLO for route diversion. FRESIM simulates incident warning signs and lane diversion, as discussed above.

TRANSYT-7F: Traffic volume adjustments would need to be made to the input volumes to reflect diversion from the freeway to the arterial. The model can be run with either the same timing plans or be allowed to optimize, if that capability is presumed to exist in real-time on the arterial.

NETSIM: Traffic volume adjustments would need to he made, as with TRANSYT-7F.

Sketch planning approach

Sufficient field evaluation data exist that could be assumed for comparable conditions.

Travel Demand Modeling Approach

The primary modeling impact is in path selection. The generalized benefits of improved speeds will have little impact on the other components of the modeling process. These strategies can be implemented in the assignment model by:

- Modifying the speeds and capacities of the roadways included in the signal system. If this adjustment is to be applied accurately, the increases should be somewhat proportional to the percentage change in speed expected for the level of improvement implemented (changes in free flow speed are the preference). Increases in capacity of 50 to 100 vehicles per hour per lane and in free flow speed of 2 or 3 mph are typical for significant improvements.

- Modifying the speed-flow relationships to reflect higher speeds at near-capacity conditions.

Evaluation of the benefits of signal system improvements indicate that upgrading to computer-controlled signal systems can increase speeds from eight percent (compared to a reasonably well managed pretimed interconnected system) to 25 percent (compared to a non-interconnected system). The results of the travel demand model should be calibrated to or gauged against these general parameters.

Simulation approach

- The benefits would need to be represented by signal timing changes within TRANSYT-7F, NETSIM, or comparable network/arterial simulation model. The ability to accomplish this depends on the ability of the analyst to replicate signal timing patterns and algorithms. Each case needs to he handled individually, using the guidelines for model operation provided for each model.

The analysis of ITS electronic toll collection technologies deals with the efficiency improvement of electronic toll collection, not the imposition of tolls itself. Conversion to electronic technologies yields substantial cost savings over manned toll booths, in addition to the delay-reduction potential. The analysis procedures below deal with estimating delay reduction.

Sketch planning approach

- Document traffic volumes through toll plaza by hour and the distribution by type of toll payment (exact change lanes, other lanes, and existing passes, if any).

- Document average service time per vehicle for each type of toll payment, including electronic toll payment (may he slightly reduced speed at toll plaza).

- Estimate capture rate for electronic toll collection from each payment type.

- Estimate processing time saved for the diversion from each payment type.

- Multiply the processing time saved for each payment type by the number of vehicles for the corresponding payment types.

- If existing queuing delays at the toll plaza are long, an additional assessment can be made of total vehicle delay saved brought about by higher toll facility capacity. The QUEUES model can be used, inputting a weighted average processing for the total toil facility (by direction) for conditions with and without electronic toll collection. The volume inputs will need to be demand volume, not processed volume. Demand volume is typically more peaked than processed volume.

Travel Demand Modeling Approach

Travel demand modeling approaches assume that a toll facility is included in the modeling process. Electronic toll collection mainly affects the processing rate. The strategy can be implemented in the assignment model by:

- Modifying the capacity and free flow speed of the toll plaza area(s). If the toll plaza includes a mix of electronic and manual toll collection, a weighted average processing rate and speed should be used.

- If the user wished to simulate an exclusive electronic toll lane, a separate network would need to be established for the toll lane (similar to the coding of an HOV lane). If it were assumed that an ample percentage of drivers had AVI tags, the assignment of trips to the toll lanes would be an outcome of the assignment model balancing, the impedance added by the toll versus the impedance attributed to congestion. During non-congested periods, few drivers would likely use the toll lanes.

- If the user wished to simulate a shared HOV and electronic toll lane or lanes, two separate networks would need to be established, one for the electronic toll lane and one for the HOV lane. Because of the sharing, a proportion of capacity would need to be allocated to each (e.g., one third of the capacity to HOVs and two thirds to tolls, based on the expected propor tion of traffic for each).

Simulation approaches

FREFLO: Toll plazas could be specified as a block of capacity on the mainline based on the maximum toll processing rate for all the booths. The effect of changes in toll operations (e.g., increasing toll processing rate through electronic toll collection) could be estimated by changing the capacity in vehicles per hour based on the type of weighted average calculation used under the sketch planning approach.

FREQ: Same as FREFLO.

FRESIM: FRESIM could simulate toll operations through its mainline metering capability. However, there may be limitations to this capability, depending on toll plaza configuration. A weighted average processing rate would need to be used, similar to the sketch planning example.

The capability for bus pre-emption of traffic signals has existed for many years. However, it is not widely practiced due to practical problems associated with operations. Under the right conditions, bus pre-emption can provide noticeable time savings. The analytical approaches below assume that no crossing bus routes are pre-empted.

Sketch planning approach

- Identify the routes and signals to be preempted.

- Estimate average delay per vehicle (for peak hour, or for additional hours, if desired) for the pre-empted approaches, through the Highway Capacity Manual procedures or other tech nique. A simplified approach to estimating delay/vehicle would be to take the difference between free flow speed and average operating speed, divide this into section length, and divide the resulting value by the number of signals.

- Assuming random bus arrivals (unless otherwise known), estimate the proportion of buses undelayed is equal to the proportion green time on the approach. The delay per bus without pre-emption for the remaining buses would be equal to the average delay per vehicle for the delayed vehicles. This would be calculated as the average delay per vehicle, divided by the proportion of vehicles delayed (assumed as the proportion of red time to total cycle time, if there is no signal coordination; if there is coordination, the proportion will be lower, but the operating speed should also be higher than the uncoordinated condition.

- Calculate the amount of peak hour (or additional hours) bus delay that can be saved through pre-emption. Assume 50 percent of the average delay per delayed bus can be saved through pre-emption. Limitations in how quickly signals can change and the presence of queued traffic in front of the bus will not allow full elimination of signal delay. Multiply the average delay per delayed bus by the number of delayed buses expected during the peak hour (or additional hours). Assume 50 percent reduced delay to one signal cycle worth of other traffic on the bus approach for each pre-empting bus (not all buses need pre-emption). Conduct the analysis for both directions of travel.

- Calculate the delay increase on the side street approaches. Assume increased delay of 50 percent times the average green time for the nnpre-empted approaches for cross street traffic times the number of signal cycles likely to be preempted.

- Calculate person delays for each component of the signal cycle assuming appropriate vehicle occupancies. Tabulate total person delay and vehicle delay.

- If it is desired to estimate the potential effect of faster transit travel times on transit ridership, an elasticity value could be applied. As speed increases, transit ridership could be expected to increase. However, the amount of speed increase will not typically have a significant effect on ridership.

Travel Demand Modeling Approach

The effect of a bus pre-emption system can be estimated using a travel demand system, but all except the last two steps of the sketch panning approach need to be undertaken to derive an estimate of change in transit speeds. The approach assumes the availability of a mode choice model. Once an estimate of the change in transit speeds is provided, the following steps can he undertaken:

- Increase transit speeds on transit network for those paths affected.

- Increase hourly capacity on pre-empted route proportional to the ratio of green time with pre-emption vs. without pre-emption. Decrease hourly capacity on the side streets, also based on the ratio of pre-empted vs. nonpre-empted green time.

- The mode choice model will account for any mode shifts. But any shifts in mode in the equipped corridor are likely to be very small.

Simulation approach

NETSIM: Can simulate buses explicitly in the model, but no provision is made for bus pre-emption. An approximation could be made by reducing average bus dwell times (a model input for each bus stop) in proportion to the amount of delay per bus estimated to be saved through pre-emption as per sketch planning guidelines above. An alternative approach is to modify the signal timings to favor person trips (additional green time would be assigned to approaches servicing pre-empting buses).

The change in green time would be increased by 25 percent of the existing green time (average time assumed saved by a passing bus) multiplied by the percentage of cycles that encounter a bus. Thus, 10 percent of the cycles with buses would mean a 2.5 percent increase in green time on that approach.

TRANSYT-7F: Take weighted average of additional green time provided to pre-empted approach and assign it to the bus route approach (same method as above). Calculate person delay savings by multiplying (post-model) the vehicle delays by the appropriate transit and auto vehicle occupancies.

Aside from the management and administrative benefits, electronic fare collection may provide time savings to the traveler through reduced bus dwell times. The benefits can be estimated as follows:

Sketch planning approach

- Estimate the number of fares being paid (by route or by system) through passes, transfers, cash or other, method.
- Estimate the transaction time for each.
- Estimate the capture rate of electronic fare cards from each current payment method.
- Estimate time savings for a transaction for conversion of each payment type to electronic means.
- Multiply estimated time savings for each combination of fare conversion by the capture rate for each fare conversion type.
- Estimate the change in average dwell times brought about by the fare conversion, based on the number of boardings per bus stop. Estimate the impact on change in average bus speed.
- If estimating benefits for individual bus stops, estimate the number of passengers by fare type and the proportion being converted to electronic payment. Perform same operation as above.

Travel Demand Modeling Approach

The effect of an automated fare collection system can be estimated using a travel demand modeling system, but the sketch planning approach needs to be applied to generate the inputs to the mode choice model. Once an estimate of the change in transit speeds is provided, those speed improvements can be coded into the transit network. Shifts in mode will be evaluated within the mode choice modeling step.

Simulation Approach

NETSIM: Average dwell times can be modified in the model based on the change in weighted average transition time. This will account for benefits to bus operations as well as benefits to traffic (which are not accounted for in the sketch planning procedure).

TRANSYT-7F: No practical way to simulate.

Bus automatic vehicle location and passenger information systems will allow passengers to time their trip to the bus stop more exactly and reduce the inconveniences of waiting in inclement weather or uncertainty concerning bus arrival time. There is no procedure for travel demand modeling or simulation.

Sketch Planning Approach

The sketch planning approach calculates the reduction in the amount of time reduced in waiting for the bus.

- Estimate existing average wait time per passenger
- Estimate wait time with passenger information system to be three minutes.
- Wait time savings is the difference between the two amounts. Multiply this amount by the number of boarding passengers. Transferring passengers should not be counted, as they have no control over wait time.

SAFETY EVALUATION

There are no models or sketch planning procedures readily available to assess the impacts of most ITS strategies on accidents. Some estimates can be derived based on documented evidence of accident reductions. These should be used, where possible. There is the potential for estimating the effect of diversion strategies on accidents by multiplying accident rates by volume. The shifting of volume from facility to facility would be accounted for in the calculation of total accidents. However, this does not account for the safety benefits of certain ITS strategies, such as advance warning systems.

ITS-RELATED AIR QUALITY ANALYSES

Emissions inventory analysis refers to the estimation of the total amount of emissions (in this case by mobile sources) within a corridor, subarea or region. This can also be referred to as emissions burden analysis. The results are expressed in grams, pounds, or tons of emissions. Concentrations of pollutants can he estimated through emissions dispersion models such as CAL3QHC or CALINE4. Concentrations are normally expressed in parts per million (ppm).

The 1990 Clean Air Act Amendments require that projects and programs not increase the number or severity of violations of the air quality standards for carbon monoxide. This is one of the tests for “project-level conformity.” The other test is that the project be contained in a conforming metropolitan area TIP and the state TIP. Projects using Federal funds cannot be built if they fail either of these two tests.

A corridor-level evaluation is the appropriate level in which to examine project-level conformity for carbon monoxide. The examination includes the evaluation of CO "hot spots" to determine whether the project will increase the number or severity of violations. The evaluation of ITS in this respect would incorporate the following steps:

- Identification of sensitive receptor sites that could incur a CO violation or increase the severity of existing CO violations. Sensitive receptors normally refer to areas that would be occupied on an extended basis, such as back yards of homes, playgrounds, parks, or building struc tures. For example, the CO impact of ramp metering signals would most likely impact the back yards of homes or perhaps commercial property.

- Collection of data to support the dispersion model analysis. This would include items such as traffic volume, idling time in queue, etc. (See manuals for dispersion models.)

- Run the dispersion model with and without the change in ITS strategy, using emissions factors consistent with the year of opening. Future years will also normally be required.

- Identify whether additional violations will occur. If so, mitigation measures will need to be identified for non-exempt projects. It should also be noted that violations could be displaced by the removal of other violations.

Those analyzing CO hot spots should refer to procedural documents associated with the dispersion models. It should be noted that there are acknowledged weaknesses in the emission factors used for these models with respect to how ITS strategies affect emissions. Additional research on improvements to the methods of estimating emissions is ongoing.

The calculation of emissions and fuel consumption are included in the simulation models FREQ and FRESIM. However, caution should be exercised as the emission factors may not represent the latest available data. The evaluation of ITS strategies requires the consideration of "modal emissions." Modal emissions refers to emissions produced at various points in the speed change cycle: acceleration, deceleration, idling, and a constant travel speed. Emissions models such as MOBIL5A use average speeds from a set of federally established driving cycles. Use of these averages does not adequately reflect the nature of the changes brought about by ITS. The use of modal emissions factors within simulation models will typically produce better estimates of change in emission. and fuel consumption. For analyses conducted using travel demand models, the MOBIL5A factors (or the latest version of EMFAC in California) will need to be used, recognizing their limitations.

Recent research has indicated the dramatic differences in emissions rates at low speeds or non-steady-state speeds versus those at mid-range steady state speeds (i.e., little acceleration or deceleration. A spreadsheet is the most practical analysis tool. A possible procedure includes the following steps:

- Use the average volumes and speeds by link from the results of the transportation analysis. Calculate ramp average speed including the time spent in queue at the ramp meter.

- Identify the emissions factor (gram per vehicle mile) from MOBILE5A (or comparable emission factor set) at 40 mph.
- Multiply the emissions factor at 40 mph by the relative factor in Exhibit H-8 for the average speed on the link.
- Multiply the result of the previous step by the link length to obtain total emissions per vehicle over that length. Then multiply by volume to obtain total link emissions. This is equivalent to multiplying the result of the previous step by VMT on the link.
- Sum the results for all the links.
- For signalized operations, a more exact representation would involve splitting links into approaches (with high emissions) and mid-block sections (with low emissions). Forthcoming research should make this approach more feasible.

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