Quick Approach To Compare Highway and Bus Transit Alternatives Using the Arterial Analysis Package

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A quick approach to evaluate two types of transportation investments is presented in this paper. The investments are (a) adding lanes to an existing highway, or (b) providing an express bus service (park-and-ride). The procedure focuses on congestion relief, and the only measure of effectiveness considered is delay. The Arterial Analysis Package (AAP) software, developed at the University of Florida, is used to compute delays for the alternatives considered. The quick-response method is not intended to replace the need for a comprehensive investment analysis. It provides a quick indicator of how public investments perform toward reducing traffic delays. The procedure is most effective when dealing with major urban streets operating at a poor level of service caused by limited intersection capacities. Typically, right-of-way costs for additional lanes on similar streets are expensive. Such corridors are the ones considered for some type of transit solution. The express bus is one solution that requires minimum capital cost and offers maximum flexibility.

A quick approach (QA) to evaluate and compare the cost-effectiveness of adding lanes to an existing highway or investing in a park-and-ride express bus system (EBS) is presented in this paper. The EBS system could serve as a transitional step or a final solution to relieve a congested corridor. The QA permits the analysis of traffic operation on managed [high occupancy vehicle (HOV)] or nonmanaged (no preferred treatment) lanes.

The QA is illustrated with a case study of a congested corridor, Dale Mabry Avenue, located within the city of Tampa, Florida. The following alternatives are considered:

- Adding one lane (nonmanaged) in each direction to Dale Mabry Avenue.
- Providing an EBS operating without any preferred treatment. The transit alternative is in turn subdivided into three subalternatives, each corresponding to a specific bus trip frequency.

In comparison to a fixed guideway transit mode, an EBS offers the benefit of minimizing capital cost and providing maximum flexibility. An EBS specifically targets work trips from suburban areas to downtown employment centers during peak-hour periods. It has the advantages of requiring lower overall population density, with relatively localized surburban development centers. An EBS promotes the convenience of transit to a new segment of the population, such as middle class surburban families. Furthermore, an EBS could be easily adapted to function as a feeder network for a future rail system or people mover.

The QA is not intended to replace the need for a comprehensive investment analysis. It focuses on one type of benefit: reduction in delay. The QA provides an appropriate short-term solution to a congested corridor. The Arterial Analysis Package (AAP) with its component programs, Signal Optimization Analysis Package (SOAP), Progression Analysis and Signal System Evaluation Routine (PASSER II), and Transit Network System (TRANSYT), are the software programs recommended to compute the overall delay for each alternative. The algorithms of the individual programs of AAP generate other measures of effectiveness, such as fuel consumption, percentage saturation, maximum queue, and number of stops. However, in order to reflect the public authorities' point of view, delay is the only measure considered. Both passenger-car user costs and farebox revenues are excluded from the evaluation model. In case a quick approach could not provide all the answers, other more comprehensive investment analyses should be performed. The objectives of the proposed method are to provide public authorities measures of how their investment performs with regard to savings in travel time and how alternatives are compared on this basis.

BACKGROUND

Whether to pay for new highways (constructing new roads or adding lanes to existing ones) or to invest in some type of transit system are subjects of a continuous debate taking place in the transportation community. In most cases they are complicated decisions involving a number of factors, all of which could not be assessed objectively. In addition to the direct costs (capital and operational) of each alternative, there are various effectiveness measures that need to be considered in the analysis; for instance, the impact on land development and economic growth, and increase in mobility and accessibility, and other nonmonetary effects of a social, environmental, and esthetic nature.

It is generally accepted that urban areas can grow only to certain sizes depending on the type of transportation system available. A relationship between transportation system, land use, and population densities is evident. New York City and Chicago population densities are not possible without heavy

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rail or rapid-transit systems. In other major cities, mobility is dependent on the existence of some form of transit mode. Rights-of-way in cities with high-density population tend to be expensive because of high costs of land, relocation expenses, business damages, and court fees. Consequently, an all-highway solution is rarely cost-effective. Furthermore, building more highway does not always solve the problem. It may simply shift the congestion to other links or nearby roads (traffic redistribution has its limitations). In several fast-growing cities, as in Florida, evaluating the feasibility of a transit system is a necessity to sustain healthy growth. Bus service exists in most large cities in Florida. Miami, Jacksonville, and Tampa have invested in fixed-guideway systems. Commuter rail in southern Florida and a high-speed rail linking major cities are in the final study stages.

Transportation planners are faced with two basic questions:

- At what stage is a transit system warranted?
- What short-term solution or intermediary step could be implemented to gain public support for raising adequate funds?

The first question has no simple answer. It is related to the area population density, growth pattern, trip generation, trip distribution, household average income, existing highway network and its degree of saturation during peak-hour periods, and transit attractiveness to potential users. This part of the study is beyond the proposed QA method. Trip generation and trip distribution analyses should be performed in prior stages as part of a comprehensive transportation planning study. Most of these data are normally available from the metropolitan planning organizations (MPOs). MPOs use mainframe computer programs to extrapolate many of these variables from the census data. However, the QA is independent of this analysis and could be applied regardless of the completion of the prior phase.

The proposed method is specifically designed to provide an answer to the second question. As explained earlier, an EBS (park-and-ride) is by far the most flexible, least expensive, and most appropriate intermediary transit mode. EBS expands transit ridership beyond the traditional user groups, such as transit-dependent, elderly, and low-income households. EBSs typically link suburban residential developments to downtown employment centers. They operate during peak hours on a fixed schedule from parking lots where commuters can safely and conveniently leave their vehicles. EBS users will avoid the frustration of driving on congested roads. Instead, they may comfortably read their newspapers or socialize with fellow passengers. Because an EBS serves work trips from a specific location on a fixed schedule, a first-time rider could well become a regular user. This highlights the importance of the quality of service, punctuality and reliability, parking convenience, and marketing techniques and incentive packages aimed toward employer and apartment managers. It is not uncommon to see developers, businesses, and churches donating land for the parking lots or perhaps sharing part of the construction costs.

OBJECTIVE

The objective of this paper is to outline and illustrate a quick approach for comparing the cost-effectiveness of highway and EBS investments. The sole concern is how each investment performs in relation to savings in travel time. Both alternatives are assumed to serve the same overall number of commuters, although a small percentage of induced demand will be added to the transit alternatives. The procedure is specifically adapted to an EBS because its impact on traffic is similar to that of recreational vehicles or trucks because there are no intermediate stops. Consequently, it is easily simulated using the AAP software. Even though the QA is developed for the EBS, other modes of bus operation could be analyzed if diligent engineering judgment is applied to the modeling process. Because all alternatives serve the same commuter volume with the same trip origin and destination patterns, the economic impacts on growth rate and land use are comparable for all alternatives. Neglecting these impacts in the analysis would not seriously affect the results.

As mentioned earlier, the proposed method is not intended to be a comprehensive investment analysis. Instead, it focuses on an important evaluation criterion: savings in travel time. The weakness of the approach is that it disregards the impacts of parameters other than delay (most of the factors omitted are of a subjective nature). On the other hand, congestion relief is generally the public authorities' primary concern, and delay is the best measure of the degree of congestion. The procedure consists of simulating traffic movement through the corridor for each alternative using AAP software. AAP will compute delays under several geometric, bus-trip frequencies and signal-timing conditions. The use of proven computer software (AAP) confers to the method a degree of conformity, consistency, reliability, and, best of all, a relatively fast and inexpensive execution tool. An additional advantage of the QA is that most of the data needed are already available for the purpose of signal-timing coordination, and the same data base could serve both purposes.

GENERAL APPLICATION

The procedure focuses on savings in travel time. Because AAP (TRANSYT/PASSER/SOAP) is the software used to compute delays, only users familiar with these programs and their delay algorithms and who understand the structure and reliability of each program's "measures of effectiveness" should apply the QA.

The method is extremely effective under two conditions: first, when the main intersections dividing the corridor operate during peak hours at a level of service of *D* or worse, resulting in long back-up traffic queues and, second, when the overall delay is mostly the result of inadequate capacity at signalized intersections. This is generally the case because the capacity of an intersection is only a fraction of that of a freeway. The reason for the QA effectiveness under similar conditions is simple and evident: TRANSYT and PASSER are the most relied on software programs for analyzing the operation of coordinated signalized intersections. NETSIM is too complicated and not compatible with a quick approach. Most planners target delay reduction rather than increase in capacity. When the service levels reach *D* or *F*, traffic volumes are at capacity and the flow is critical and unstable. Traffic progression could be stopped at any time. In similar situations, each increment of one vehicle in the traffic volume will have a significant and disproportionate impact on the overall traffic flow. Only computers have the computational capacity to identify the excess in traffic volume and measure its impact on the traffic flow, taking into account all the parameters affecting the operation of signalized intersections.

The effectiveness of the QA is in its ability to identify specifically those excess vehicles responsible for slowing the traffic flow. Furthermore, the QA evaluates the impact on the overall delay if commuters equivalent in number to the occupant of the excess vehicles would switch to a more convenient and efficient express bus mode. Under these circumstances the AAP program has a definite advantage in simulating traffic operation and computing the delay for various bus frequencies. The reason is that AAP takes into consideration the complex intersection operations such as left-turn maneuvers, shared-lane behavior, speed limits, lost time per phase, back-up traffic, oversaturation, progression, clearance, and so on. Furthermore, the perceived and objective improvement of heavily congested arterials is best measured in delay reduction rather than in increase in capacity. Consequently, measuring the effectiveness of each alternative in savings in travel time is reasonably justified.

In summary, the quick approach is very effective when used to analyze heavily congested arterial streets serviced by many signalized intersections. Usually, similar corridors are the ones considered for bus transit solutions. The objective is to reduce the overall number of vehicles during peak hours by increasing the passenger occupancy per vehicle. This is achieved through a complete removal of passenger cars from the corridor by providing a convenient and attractive bus service. A derivative benefit is in the reduction in number of downtown parking spaces needed. If operators of passenger cars simply choose to drive on other roads they might not always reduce traffic congestion but may simply shift the problem to nearby locations. The benefits of traffic redistribution are limited in heavily congested networks. If the EBS is successful in attracting a reasonable number of commuters, this could result in a dramatic improvement in the overall level of service.

Another important advantage of using a computer program to compute delay is the simplicity with which various sensitivity analyses could be performed. Once the data base is established, the bus alternative could be evaluated for various bus-trip frequencies and occupancy ratios to determine the optimal situation.

LIMITATIONS

The QA suffers from the limitations inherent in the AAP individual programs. Situations like nonsignalized intersections, intersections with more than four legs, alignment, ramps, exits, interchanges, oversaturation, pedestrians, right-lane turns, and so on, could adversely affect the validity of AAP simulations. Although AAP is capable of modeling these cases, it is feasible only at a cost of reduced accuracy. Furthermore, AAP Release 2 runs TRANSYT-7F and PASSER 84. It lacks the potential of mapping right turns and accounting for specific left-turn protection modes. These are important factors in optimizing the timings and in computing delays. The most recent release of AAP Version 3 (Fall 1988) is upgraded to include several new applications, such as updates to the component SOAP and TRANSYT programs, and an addition to a right card to allow more correct modeling of all turning movements using TRANSYT-7F Release 5. Finally, the use of the newest version of AAP to generate data and run individual programs does not permit the use of specific features like side friction factors or mid-block entry volumes. If the situation requires, it is best to use the individual programs or perhaps EZ-TRANSYT.

METHODOLOGY

The QA combines the advantages of simplicity, conformity, and objectivity. AAP simulation for each alternative is achieved by following the same general optimization process. The procedure consists of the steps described in the following subsections.

Step 1

Step 1: The use of AAP (PASSER and TRANSYT) to optimize the traffic operation and compute delay under existing conditions.

The optimization procedure should not be any different from the steps used to optimize signal timing using AAP. It consists of first applying TRANSYT to model the traffic operation with the existing timings. PASSER is then used to maximize the bandwidth by selective phasing optimization as indicated by the time-space diagram. Afterward, the best phasings are selected and PASSER is once again applied to optimize the cycle length and the timings. It is then necessary to input PASSER's phasings and timings into TRANSYT and check for any improvement over the initial run. Finally, TRANSYT will be used to optimize the cycle length and timings.

The results should always be checked by examining the primary and secondary bandwidths on the time-space diagram and the traffic progression on the progression plots. In some cases it is beneficial to start by using SOAP on critical intersections. Analysts should respect the local stated policies for minimum green, clearance, all red for pedestrian, and so on. If additional restrictions or requirements are applicable, they should be taken into consideration.

Step 2

Step 2: Use of AAP to simulate delay after geometric improvement (adding one or more lanes).

The second step consists of simulating the traffic flow in the corridor after the geometric improvement (adding one or more lanes to the main street). If adding some left-turn lanes is part of the improvement, they should be accounted for. AAP optimization will be achieved following the same procedure outlined in Step 1.

Step 2 could consist of multiple optimizations, depending on the number of geometric alternatives considered. Simulating a managed (restricted lane) geometric alternative is feasible if the right data are available (estimates of HOV lane volumes and average occupancy per vehicle).

Step 3

Step 3: Use of AAP to simulate delay under various express bus transit frequencies (optimize the number of buses needed).

The third step simulates the overall delay for the bus transit cases. At this stage several assumptions must be made. First, the peak-hour volume is assumed to serve primarily work-trip purposes (a reasonable assumption in heavily congested streets). Second, the work-trip volume is considered to be a finite number with limited elasticity. The third assumption is related to the validity of the models used to forecast trip generation, relative bus occupancy, traffic growth projection, induced demand estimation, and other forecasting parameters. Understanding these assumptions is important because the model transfers a number of commuters from passenger cars to the EBS, based on a realistic bus-car occupancy ratio. In summary, all the assumptions are reduced in the model to establish a realistic bus occupancy ratio for the EBS as a function of bus-trip frequency. The average occupancy of a car is a measure normally available at the city planning offices. In any case, it is generally accepted that ridership for new transit systems builds up over a period of time.

Once a reasonable bus-car occupancy ratio is determined from field studies or from referring to comparable systems, a number of cars will be taken off the highway and replaced by a number of buses determined by the occupancy ratio equation. In Step 3, several bus-trip frequencies should be considered to determine the optimal effectiveness of the system (most delay reduction per unit investment). However, it is logical that the real occupancy of each bus should decrease when the trip frequency increases, although widely dispersed parking lots could be served. For each case, AAP will simulate the traffic movement under the new condition and generate various measures of effectiveness. Although the total number of vehicles using the network will change at each modal split considered, the overall number of commuters will remain constant, except for a small percentage of induced travel (new vehicles diverted from other routes and attracted by the improvement in the level of service).

Step 4

Step four: Cost-benefit analysis.

Cost-benefit analysis is achieved by computing the ratio of the benefit to the cost. As explained earlier, the benefit for all alternatives is measured in savings in travel time. The alternative of Step 1 is the base condition. It has zero cost and zero benefit. The costs of the alternatives in Step 2 (geometric improvement) are subdivided into costs of construction; rights-of-way, including land cost, relocation expenses, business damages, and court fees; law enforcement; and maintenance. The costs associated with the bus transit alternatives of Step 3 are separated into capital and operational expenses. Capital cost includes the cost of the buses needed; of parking lots (average cost per space by number of spaces); and of the infrastructure for management, storage, and maintenance. Operational costs include management, maintenance, fuel, and overhead.

Right-of-way costs might be obtained from the appropriate department of the city government. Construction costs for lanes and parking lots are normally updated by the city public works department. Finally, capital and operational costs for the EBS could be obtained from the local transit agency if any exists. If some of the data are still missing, county or state agencies might provide this information. Finally, FHWA and UMTA, of the U.S. Department of Transportation (DOT), and the American Public Transit Association (APTA) publish annual statistics on a wide range of data. They are good references for providing average or state figures if nothing else exists.

The benefit of each alternative is determined by multiplying the simulated time savings, determined by AAP, for each improvement with an accepted dollar value of an hour saved. Most public and private references use a value between minimum wage and $8/hr saved. The unit value must be updated using the consumer price index. However, if the purpose of applying the QA is simply to rank the alternatives, the result is unaffected by the dollar value associated with a unit time saved. Savings of travel time for each alternative are computed by comparing the overall delay to that simulated for alternative zero or base case.

The cost-benefit ratio for each alternative is found by dividing the dollar value of the time saved per year (2 peak hours per day, 300 days per year) by the total annualized cost for capital and operational expenditures. The service lives used to annualize capital costs are 12 years for buses, 20 years for parking and roads, and 100 years for rights-of-way. A discount rate acceptable to public planners should be used. It is preferable to perform the analyses for low-, average-, and high-discount-rate values.

STUDY CASE

Dale Mabry Avenue is selected to illustrate the application of the QA. It is one of the most congested arterials in Tampa, Florida. Data on the intersections' geometry and traffic volumes at peak hours were provided by the city traffic engineers.

First, PASSER was used to determine the optimal phasings. Then TRANSYT was used to evaluate PASSER results and perform the final optimizations. The delay values used to compute the benefits for each alternative are the ones simulated using TRANSYT cycle and timing optimizations. T-0 corresponds to TRANSYT optimization for the existing condition or alternative zero. T-1 represents TRANSYT optimization results for the geometric improvement case, which consists of adding one through lane on each direction of the avenue. T-2 corresponds to TRANSYT optimization for the first bus alternative, which consists of providing 20 bus trips per peak hour with a bus-car occupancy ratio of 28 to 1.15 passengers. T-3 corresponds to TRANSYT optimization of the second bus alternative, which consists of adding 30 bus trips per peak hour with a bus-car occupancy ratio of 25 to 1.15 passengers. Finally, T-4 corresponds to the optimization of the third bus alternative, which consists of providing 40 bus trips per peak hour, with an occupancy ratio of 22 to 1.15 passengers. The average passenger car occupancy ratio measured in Tampa is 1.15 passengers per car.

Each bus costs about $140,000. It has a seating capacity of 48 passengers (plus 25 standees). The bus service life is 12 years with a zero salvage value. Parking costs are computed using a unit cost of $3,000 per space. Bus operation costs are calculated considering a unit cost of $2.50 per revenue-mile. These values were provided by the Hillsborough Area Regional Transit (HART) servicing the Tampa area. The road section considered for improvement is 6 mi. long. The right-of-way cost is about \$15/sq ft. Construction costs are, on average, \$900,000/lane-mi. Law enforcement is around \$6,000/lane-mi, and the maintenance cost is approximately \$5,500/lane-mi. These figures were supplied by various city departments in Tampa.

For the bus alternatives, an induced traffic demand equivalent to 15 percent of bus ridership is assumed to be diverted from other routes because of the improvement in the level of service. Furthermore, not all the EBS users are presumed to be diverted from the passenger car mode; 15 percent of them will be considered as new commuters attracted by the system. Consequently, transit alternatives are expected to carry a total number of commuters equivalent to the geometric alternatives plus 30 percent of the EBS ridership. The remaining assumptions used in the study case are that an hour delay costs \$3.35 (minimum wage) and the farebox revenues are about 30 percent of the operational costs (HART figure). The revenues from the bus fares are subtracted from the transit costs because they reduce the public subsidy.

The cost-benefit ratios are computed a second time for the alternatives considering the loss in potential revenues from the gas tax as an additional cost for the bus alternatives. These ratios are computed separately because, although a clear loss in income from the gas tax will occur, the monetary benefit may be more than offset by adverse environmental impacts like pollution. Whether to account for the gas-tax-revenue losses or not is left to the judgment and discretion of the QA user.

The cost-benefit analysis and the results of the computer optimizations are included in the tables. Table 1 summarizes the AAP simulations for delay. The costs for the geometric improvement are given in Table 2, and the costs for the transit alternatives are given in Table 3. The cost-benefit analysis presented in Table 4 shows the bus alternative with a trip frequency of 20 round trips per day to have the highest cost-benefit ratio. It provides the highest revenue by unit investment. However, if the cost-benefit ratio rather than the relative ranking of alternatives is the goal of the planner, an incremental cost-benefit analysis should be performed.

CONCLUSION

The proposed quick-response method is a simple and effective procedure to compare the effectiveness of widening a major arterial street operating at a poor level of service or to provide an express bus service (park-and-ride). Highway and transit are costly investments; the QA provides a quick and inexpensive tool to perform a preliminary evaluation. Furthermore, most of the data required are normally available and constantly updated for the purpose of signal-timing coordination. Most of the cost figures needed should be available at the local public offices. As a last resort, the user may refer to publications of a number of private, state, and federal agencies, such as FHWA, UMTA, and APTA. Finally, because computer modeling is needed to simulate traffic delays and not to optimize the signal timings, approximate input data are more tolerable.

It is important to understand the way traffic delays are

TABLE 1 SUMMARY OF AAP RESULTS

RUN # (AAP)	DESCRIPTION OF ALTERNAT.	TOTAL DELAY (VEH X HR)	Ave. DELAY (SEC /VEH)	STOPS TOTAL	STOPS %	FUEL CONS. (GALLONS)	CYCLE (SEC)
T-0	120 SEC CYCLE	1641	113.0	30435	58	1971	120
T-1	+ 2-Lane OPT	907	62.4	28791	55	1416	120
T-2	+ 20B/H OPT	958	79.3	27351	63	1332	120
T-3	+ 30B/H OPT	801	71.3	25623	63	1332	120
T-4	+ 40B/H OPT	722	68.1	22856	60	1049	120

Alt 0: do nothing

Alt 1: add 2 lanes, one in each direction

Alt 2: provide 20 buses (28 pass. per bus, 15% induced demand)

Alt 3: provide 30 buses (25 pass. per bus, 15% induced demand)

Alt 4: provide 40 buses (22 pass. per bus, 15% induced demand)

OPT: computer optimization (TRANSYT)

B/H: bus trip per hour

TABLE 2   COSTS FOR GEOMETRIC IMPROVEMENT

ALT. #	ITEM	CAPITAL COST	SERVICE LIFE	ANNUAL COSTS
ALT 1	R-O-W	$14,256,000	100 Yrs	($1,425,000)
	Const.	$10,800,000	20 Yrs	($1,269,000)
	Maintenance			($66,000)
	Law Enforcement			($72,000)
TOTAL ANNUALIZED COST =				($2,832,000)

RIGHT OF WAY: $15/sq.ft.x(2x15ft)x6milesx5280ft/mi= $14,256k

CONSTRUCTION: 6 miles x 2 lanes x $900k/lane-mile = $10,800k

LAW ENFORCEMENT: $6,000 per lane-mile

MAINTENANCE: $5,500 per lane-mile

DISCOUNT RATE: 10% per year

TABLE 3   COSTS FOR TRANSIT IMPROVEMENTS

ALT #	ITEM	CAPITAL COST	SERVICE LIFE	ANNUAL COSTS
ALT 2	BUS:	$1,400,000	12 Yrs	($205,000)
	PARKING:	$1,680,000	20 Yrs	($197,000)
	OPERATION:			($126,000)
	TOTAL ANNUAL COSTS =			($528,000)
ALT 3	BUS:	$2,100,000	12 Yrs	($308,000)
	PARKING:	$2,250,000	20 Yrs	($264,000)
	OPERATION:			($189,000)
	TOTAL ANNUAL COSTS =			($761,000)
ALT 4	BUS:	$2,800,000	12 Yrs	($411,000)
	PARKING:	$2,640,000	20 Yrs	($310,000)
	OPERATION:			($252,000)
	TOTAL ANNUAL COSTS =			($973,000)

BUS COST = $140,000 x # Trips/PH / 2   (2 Trips per Peak Hour)

BUS OPERATION = 2*#Bus/PH x $2.5/rev-mile x 6miles x 300dayx70%

BUS OCCUPANCY (45 SEATS CAPACITY):
Alt.2: 20 buses/peak-hour: 28 passengers/bus (62%occupancy)
Alt.3: 30 buses/peak-hour: 25 passengers/bus (55%occupancy)
Alt.4: 40 buses/peak-hour: 22 passengers/bus (49%occupancy)
85% Would Have Used Dale Mabry Avenue

PARKING COST: $3,000 per space

DISCOUNT RATE: 10% per year

TABLE 4 COST-BENEFIT ANALYSIS

ALT #	TIME SAVING (TS) (VEH X Hr)		BENEFIT / Yr (TSx$3.35x300x2)	COST / Yr ($)	BEN./COST. ($)
ALT 0	0		0	0	0
ALT 1	734	45%	1,475kx2= 2,951k	2,832k	1.04
ALT 2	683	42%	1,373k	528k	2.60
ALT 3	840	51%	1,688k	761k	2.22
ALT 4	919	56%	1,847k	973k	1.90

**** BEST = ALT 2 (20 Bus-Trip / P.H.) ****

For Alt.# 1 (adding 2 lanes) traffic delay will be reduced beyond the peak hour periods. Assuming peak hour traffic accounts for 50% of the daily delay, the benefits for this alternative is multiplied by a factor of 2.

If the loss in potential gas-tax revenues are to be considered as an additional cost for the bus alternatives, the respective benefit cost ratio would be as following:
Alt 1 : 1.04 Alt 2 : 1.210 Alt 3 : 1.08 Alt 4 : 1.04
(Alt# 2 is still the case with the highest benefit to cost ratio)

To optimize the benefits, an incremental cost benefit analysis should be performed.

generated, the impact of oversaturation, and the validity and reliability of computer solutions under specific conditions. It is always advisable to check the results of the existing case in the field (measure peak-hour delays). If the delays measured in the field are compatible with the computer output for the initial case, the delay simulations for the alternative cases will be valid also because the traffic operation after improvement is less critical. Computer modeling is, in general, more accurate for less critical traffic flows.

To summarize, the quick-response method is not intended to replace the need for a comprehensive investment analysis. It is just one indicator of how public investments perform toward reducing traffic delay. In many cases, congestion relief is the main objective of transportation planners.

The procedure is, therefore, most effective when dealing with major urban arterial streets operating at a poor level of service as a result of inadequate intersection capacities. Typically, rights-of-way on similar streets for additional lanes are quite expensive, which makes transit systems more attractive. The EBS is a transit mode requiring minimum capital cost and providing maximum flexibility. Furthermore, an EBS is most convenient for a new type of transit users—suburban middle class families.

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