FINAL REPORT

EXCLUSIVE LANES FOR TRUCKS AND PASSENGER VEHICLES ON INTERSTATE HIGHWAYS IN VIRGINIA: AN ECONOMIC EVALUATION

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16. Abstract

Increases in heavy truck traffic on Virginia's highways in recent years have raised concerns about both safety and capacity, particularly on the interstate system. Transportation agencies have developed a number of strategies for dealing with the impacts on safety and capacity of a truck population that has been increasing in volume and in the percentage of large tractor-trailers. One strategy that has been suggested is separate lanes for trucks and passenger vehicles.

A reliable methodology to determine when separate lanes for trucks and passenger vehicles are economically feasible would enable transportation officials to make informed decisions concerning when this approach should be considered and used. This study evaluated a computer program, Exclusive Vehicles Facilities (EVFS), developed by the Federal Highway Administration for determining the economic feasibility of separating trucks and other vehicles on freeway segments. A 50.7-km (31.5-mi) segment of I-81 in Virginia was selected to demonstrate the application of the program.

A number of factors contribute to the feasibility of exclusive lanes. Although no single factor predominates, traffic volume, vehicle mix percentage, accident rates, and maintenance and construction costs are given more weight than other factors in the program. Among the program's strengths are its ability to analyze a number of alternatives for a variety of different conditions, its ease of use, and the fact that it can be inexpensively applied. Its weaknesses include its inability to differentiate between the lane(s) (i.e., inside, middle, outside) to which restrictions are applied and its unsuitability for analyzing exclusive lane alternatives in which a barrier is used to separate vehicle types.

With respect to I-81, several exclusive lane strategies produced a benefit-cost ratio greater than 1.0 and a net present worth in the millions of dollars. Should I-81 or another high-volume interstate corridor with a large truck percentage be considered for improvement, VDOT should apply EVFS to assist in evaluating the feasibility of exclusive lane alternatives. Since EVFS is designed to perform economic analyses, operational and geometric implications of any exclusive lane strategy should also be considered.

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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ABSTRACT

Increases in heavy truck traffic on Virginia's highways in recent years have raised concerns about both safety and capacity, particularly on the interstate system. Transportation agencies have developed a number of strategies for dealing with the impacts on safety and capacity of a truck population in which the volume and percentage of large tractor-trailers are increasing. One strategy is separate lanes for trucks and passenger vehicles.

A reliable method for determining when separate lanes for trucks and passenger vehicles are economically feasible would enable transportation officials to make informed decisions concerning when this approach should be considered and used. This study evaluated a computer program, Exclusive Vehicles Facilities, developed by the Federal Highway Administration for determining the economic feasibility of separating trucks and other vehicles on freeway segments. A 50.7-km (31.5-mi) segment of Interstate 81 in Virginia was selected to demonstrate the application of the program.

A number of factors contribute to the feasibility of exclusive lanes. Although no single factor predominates, traffic volume, vehicle mix percentage, crash rates, and maintenance and construction costs are given more weight than other factors in the program. Among the program's strengths are its ability to analyze a number of alternatives for a variety of conditions, its ease of use, and the fact that it can be inexpensively applied. Its weaknesses include its inability to differentiate between the lane(s) (i.e., inside, middle, outside) to which restrictions are applied and its unsuitability for analyzing exclusive lane alternatives in which a barrier is used to separate types of vehicles.

With respect to I-81, several exclusive lane strategies produced a benefit-cost ratio greater than 1.0 and a net present worth in the millions of dollars. Should I-81 or another high-volume interstate corridor with a large percentage of trucks be considered for improvement, VDOT should use this computer program to assist them in evaluating the feasibility of exclusive lane alternatives. Since the program is designed to perform economic analyses, the operational and geometric implications of any exclusive lane strategy should also be considered.

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INTRODUCTION

In recent years, increases in heavy truck traffic on Virginia's highways have raised concerns about both highway safety and capacity, particularly on the interstate system. Highly publicized incidents involving conflicts between passenger vehicles and trucks over the past few years have heightened the awareness of transportation officials and the traveling public. Basically, much attention centers on conflicts between passenger vehicle travel and the movement of freight over the same highway.

Differences in the operating characteristics of passenger vehicles and large trucks may increase the likelihood of a crash. When crashes involving passenger vehicles and trucks occur, the difference in mass between the two vehicle types is such that occupants of the lighter vehicles are at greater risk. Also, crashes causing blockages result in travel delays and monetary losses, particularly in congested areas.

The Surface Transportation Assistance Act (STAA) of 1982 specified truck weight limits of 36,320 kg (80,000 lb) overall, with single-vehicle loads of 9,080 kg (20,000 lb) and tandem weights of 15,436 kg (34,000 lb). Further, the act specified that states could no longer prohibit the use of twin-trailer trucks or enact any overall length limit. In addition, the Tandem Truck Safety Act of 1984 required that states allow travel to points of loading for single trailers 6.1 m (20 ft) long and 2.6 m (8 ft, 6 in) wide used in local pickup and delivery. Since these acts were passed, there have been no further changes in size or weight limits. The vehicle dimensions authorized by the STAA, and now common in Virginia, are illustrated in Figure 1.

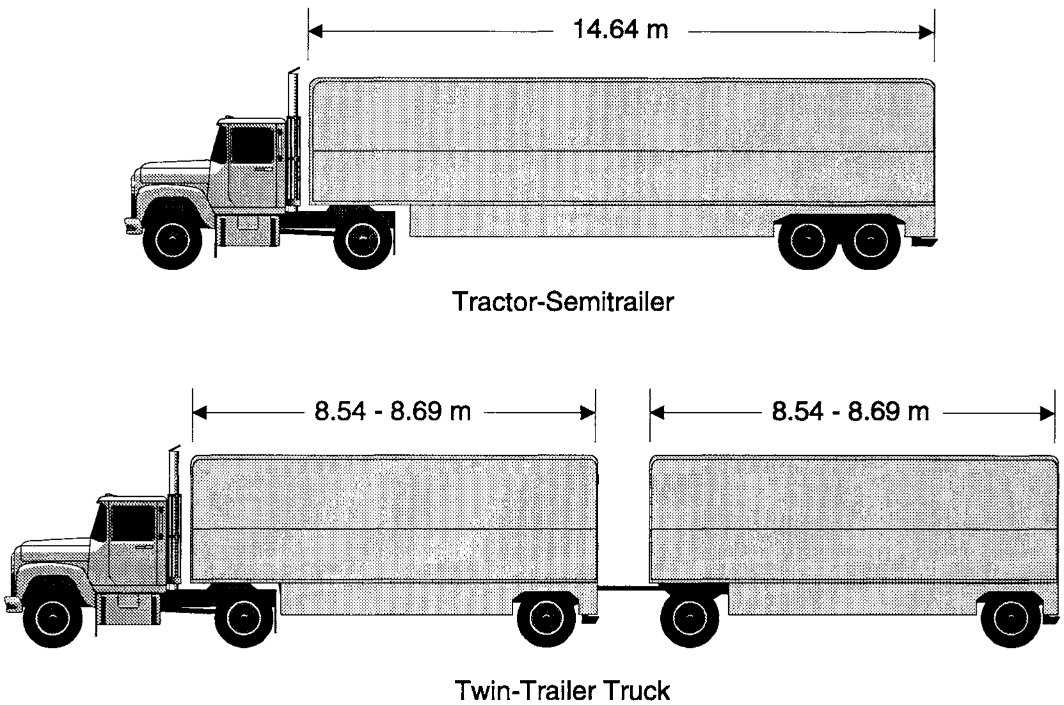

Figure 1. Vehicle dimensions authorized by STAA

PROBLEM STATEMENT

Large truck vehicle miles of travel (VMT) and truck size have increased steadily since trucks were first used for intercity freight transport. Between 1936 and 1983, large truck VMT in the United States increased 13 fold.[1] Over the same period, the percentage of total VMT accounted for by large trucks doubled to approximately 4 percent.[1] An additional 29 percent growth in large truck VMT is expected to occur between 1994 and 2004.[2] Because of a progressive increase in legal size and weight limits over the years, the distribution of larger combination vehicles has increased to the point where five-axle tractor-semitrailers now predominate in the trucking industry.[1]

Since the enactment of the STAA, transportation agencies have attempted to develop broad strategies for dealing with the impacts on safety and highway capacity of a truck population that has been increasing in the volume and percentage of large tractor-semitrailers. Strategies that have been proposed or tried include (1) increasing enforcement of weight violations; (2) imposing a speed limit of 88 km/h (55 mph) for heavy trucks; (3) providing more stringent control of driver licensing, training, and substance abuse; (4) improving truck controllability; (5) upgrading the geometric design of highways; (6) having trucking firms initiate comprehensive safety management systems; (7) restricting use by trucks of certain roads during specified time periods; and (8) providing separate lanes for trucks and passenger vehicles.[3]

In Virginia, the Capital Beltway Safety Team evaluated 53 initiatives that focused on the following priority areas: enforcement, incident management, construction and maintenance work zone safety, traffic management systems, operations and design enhancements, education and public information, and regional initiatives. Focus groups representing regular users of the Beltway suggested five actions to correct the problems associated with Beltway travel. One of the actions was "segregating roadways for trucks and vehicles," a strategy the focus group believed "would be well received by both motorists and truckers."[4] Similar approaches are being considered for other highway corridors in Virginia (particularly I-81 and I-95) and in other states.

Officials of the Virginia Department of Transportation (VDOT) have indicated a strong interest in examining the option of dedicating one or more lanes for the exclusive use of trucks when widening occurs in these corridors. Dedicating lanes is not new, particularly high-occupancy vehicle (HOV) lanes, but Virginia has never dedicated lanes for trucks.

The Federal Highway Administration (FHWA), in cooperation with the states, has sponsored research on issues associated with heavy trucks. In 1990, FHWA developed a methodology and computer program called EVFS (Exclusive Vehicle Facilities).[5] The purpose of this program was to assist in determining the economic feasibility of separating light and heavy vehicles on interstate or other controlled-access highways. EVFS is designed to calculate the net present worth (NPW), benefit-cost ratio (BCR), and other facility performance measures for various lane configurations that designate existing lanes or provide additional lanes exclusively for trucks or passenger vehicles. For exclusive lanes to be provided, three or more lanes in one direction must be available.

PURPOSE AND SCOPE

The purpose of this research was to apply the EVFS analysis format to evaluate the economic feasibility of separating trucks and other vehicles on Virginia's interstate highway system. The research attempted to validate the FHWA procedure and develop guidelines for its use in evaluating candidate freeway sections in Virginia. To test the model for Virginia conditions, a 50.7-km (31.5-mi) segment of I-81 in Virginia, located between Hollins and Christiansburg, was evaluated.

METHODS

The research approach adopted in this study involved the following tasks:

1. Review of the exclusive vehicle facility (EVF) concept. Relevant literature was reviewed to gain insight into concepts and issues related to EVFs and other similar strategies that address heavy vehicle travel factors. Information was obtained through an extensive examination of studies of special lane treatments for large trucks. An extensive search of the published literature addressing exclusive vehicle facilities, truck lane restrictions, and truck operation characteristics was performed through a computerized search using the Transportation Research Information Service (TRIS), the DIALOG data base, and a manual search of the University of Virginia and Virginia Transportation Research Council (VTRC) libraries.

2. *Comprehensive survey of the states.* A survey of current practices in other states was conducted to determine national experience with truck travel restrictions. Data regarding the type of lane/route restriction/designation, its purpose, the manner of implementation, and overall experience were assembled for use in assessing the utility of each strategy.

A telephone survey of state highway and transportation agencies was conducted. A questionnaire (Appendix A) was sent to a representative of each state before the interview to provide the respondent an opportunity to review the questions and assemble necessary information beforehand. Direct conversation by telephone provided an opportunity for clarification of both the questions and responses. In some cases, responses were returned via mail or fax. In these instances, a follow-up telephone call was usually placed to obtain additional information. All 50 states were contacted with a 100 percent response rate.

3. *Sensitivity testing of EVFS.* Sensitivity testing was undertaken to gain a better understanding of the theory and assumptions underlying the EVFS analysis format. Reasonable hypothetical data were entered into the program to test the sensitivity of the program to changes in specific input variables. The purpose behind this effort was to validate the method before performing the analysis on I-81.

4. *EVFS analysis of the I-81 corridor.* An analysis of the I-81 test site using EVFS was performed to demonstrate the application of the model for conditions in Virginia. Cost tables referenced in the program were updated to current (1995) dollar values in this step.

5. *Synthesis of the analysis results.* The major outputs of the analysis were BCR and NPW. The results of the analysis were synthesized into various tables and graphs, and the results were discussed.

6. *Development of conclusions.* Various lane strategies were evaluated based on the results of the analysis. Conclusions with respect to the utility of the model and the feasibility of exclusive lane strategies on I-81 were developed.

7. *Development of recommendations.* Recommendations were suggested concerning future use of the model, ways in which the model could be enhanced, and the development of EVFs in the I-81 corridor.

8. *Identification of areas needing additional research.* Areas in which additional research is needed were identified.

LITERATURE REVIEW

Although a wide range of information is available on various truck lane strategies and their implementation, the effect of these strategies on vehicle operations or safety has not been extensively reported. Few "before and after" studies have been conducted to determine effects on safety, traffic flow, and pavement degradation. Although positive results have been speculated, little quantitative data have been furnished to justify conclusions.

Heavy Vehicle Classifications

The term *truck* usually refers to one or more of the following vehicle classifications: pickups, single units (straight trucks), bobtails (tractor without trailer), and combinations (tractor pulling a semitrailer or multiple trailers). Throughout the literature, the terms *large truck* and *heavy vehicle* are either undefined or used inconsistently. For instance, Garber and Joshua defined a large truck as "any truck that has six or more wheels in contact with the road,"[6] whereas Janson and Rathi considered heavy vehicles to include (1) single-unit trucks weighing more than 4,540 kg (10,000 lb), and (2) combination-unit trucks.[5]

The definition of *truck* for the purpose of traffic enforcement varies among the states. Some states use gross vehicle weight (GVW) to define a truck (e.g., in Illinois, any vehicle weighing more than 7,264 kg [16,000 lb]; in Maryland, any vehicle weighing more than 4,540 kg [10,000 lb]). Several other states define *truck* in terms of physical dimensions (e.g., Kentucky) or the number of wheels in contact with the road (e.g., Georgia). Other definitions include "any vehicle pulling a trailer or capable of carrying a load" or are stated in terms of the number of axles. Some states (e.g., Idaho and Nebraska) have no formal definition yet impose restrictions on this "undefined" vehicle.

In this report, the terms *truck, large truck,* and *heavy vehicle* are used interchangeably to refer to (1) single-unit trucks weighing more than 4,540 kg (10,000 lb), and (2) all combination-unit trucks, unless otherwise noted. This definition was selected to be consistent with the FHWA report by Janson and Rathi.[5]

Adverse Effects of Mixed Vehicle Travel

Passenger vehicle and truck travel are often considered incompatible, especially by motorists who view large trucks with trepidation. Although necessary for the movement of freight, truck traffic affects the safety, operation, and physical condition of the highway system. Large trucks tend to travel at slower speeds, create maneuverability problems, and consume a larger proportion of highway capacity than passenger vehicles.

Since the completion of the interstate highway system, total traffic and large truck volumes have steadily increased. During certain periods on some freeway corridors, large truck volume may approach or exceed that of passenger vehicles. Increases in total traffic and percentage of trucks in the traffic mix increase the probability and severity of adverse impacts related to mixed vehicle travel.

According to Seiff, greater traffic volume, along with a larger percentage of trucks in the vehicle mix, is responsible for an increase in vehicle hours of delay for motorists.[7] Long delays and traffic jams are caused by crashes and cargo spills involving large trucks; even minor crashes involving large trucks can produce major traffic jams in congested areas. Total travel time for passenger vehicles is lengthened on upgrades by slower moving trucks. Media coverage of crashes involving heavy vehicles and corresponding delays is likely responsible for the increased public perception that truck safety is worsening.[7]

Physical characteristics of heavy vehicles are different from those of passenger vehicles. The sheer difference in mass between light and heavy vehicles increases the severity of crash consequences for passenger vehicle occupants when the vehicles collide. Differences in operating characteristics between the two vehicle types such as braking, maneuverability, and travel speed in mixed traffic flow increase the danger for passenger vehicle occupants.[7] A recent study by the Insurance Institute for Highway Safety found that in fatal two-vehicle crashes involving passenger vehicles and large trucks, 98 percent of the fatalities were occupants of the passenger vehicles.[8]

In a study of large truck crashes on interstate and primary highways in Virginia, Garber and Joshua found that when a large truck was involved in a two-vehicle crash, there was a 94 percent chance that the other vehicle was not a large truck.[6] They further concluded that the proportion of large truck/non-large truck crashes was slightly higher than should have been expected. In terms of fatal crashes, their findings indicated that the highest percentage (60.1%) of fatal large truck crashes involved two vehicles. Further, non-large truck/non-large truck and large truck/large truck fatal crashes were underrepresented, and large truck/non-large truck fatal crashes were significantly overrepresented.[6]

Truck crash characteristics are different for rural and urban roadways. In rural crashes, trucks are more often the striking vehicle, whereas in urban areas, trucks are less often the striking vehicle.[9] According to O'Day and Kostyniuk, truck crashes involving head-on collision and opposite-direction sideswipe crashes typically occur in rural areas, whereas angle collision and same-direction sideswipe crashes typically occur in urban settings. The percentage of rural truck crashes resulting in at least one fatality is relatively low (4%); the percentage is considerably higher than that for urban crashes (0.6%).[9]

In summary, the findings of these studies provide evidence that mixed vehicle travel is dangerous, particularly for occupants of lighter vehicles. The incompatibility of passenger vehicle and truck travel appears to be a contributing factor in many crashes. These findings provide a rational basis for investigating the benefits and costs of separating light and heavy vehicle travel.

Objectives of EVFs

Lane restrictions have been provided and evaluated in several states as a means to minimize the interaction between light and heavy vehicles. Although increased safety and improved highway operation are typically cited as the primary motivations for their implementation, these strategies have been used in some cases to achieve other goals, such as reducing pavement deterioration.

Several studies have identified potential benefits of facilities designed exclusively for trucks. Stokes and Albert suggested that separating trucks from passenger vehicles will have the following positive results: (1) improved traffic safety, (2) reduced conflicts, (3) adequate pavement and bridge structures, and (4) reduced maintenance costs.[10] Likewise, Mannering et al. identified improvements in one or more of the following areas achieved by truck lane restrictions: (1) highway operations, (2) safety, (3) pavement wear, and (4) operation and safety through construction zones.[11]

Potential Economic Benefits and Costs of EVFs

The potential benefits, or cost savings, attributable to EVFs must be weighed against the cost of providing and maintaining such facilities. The basic premise underlying the concept of separating light and heavy vehicles is that highway operations will be improved and the number and severity of crashes reduced. As a result, cost savings occur in travel time, vehicle operating cost, lives saved, medical expenses, and property damage. In addition, energy consumption and environmental impacts are reduced. In calculating expenses, only those costs (engineering, construction, right of way, operation, and maintenance) directly attributable to the provision of a particular separation strategy are normally included. Although very difficult to quantify, aesthetic impacts should also be considered. Decisions to provide additional capacity are not usually based on a benefit-cost analysis, and, therefore, one is typically not included. Certain costs may increase or decrease as the result of the particular separation strategy implemented and should be accounted for accordingly.

Factors Influencing the Feasibility of EVFs

No single factor appears to predominate in determining the economic feasibility of separating vehicle types. In identifying candidate highway segments where separation strategies might be appropriate, a number of factors are considered. These include average daily traffic (ADT), expected annual increase in traffic, vehicle mix percentage, and number and frequency of crashes involving passenger vehicles and trucks. Based on test analyses, EVFs appear to be most warranted for congested highways where truck volumes exceed 30 percent of the vehicle mix.[5]

Human factors such as driver expectancy, perspective, and opinion are important as they will dictate compliance with and the effectiveness of separating passenger vehicles and trucks. Cost, constructability, and maintainability are also factors in any decision regarding EVF feasibility. Legal issues concerning lane restrictions must be addressed, and support from the enforcing agency is also necessary.

States' Experience with EVFs

Truck lane restrictions have been widely used throughout the United States, but dedicating lanes for the exclusive use of heavy vehicles is relatively novel. In several states in which a comprehensive study concerning the effectiveness of truck lane restrictions was conducted (Florida, Nevada, Texas, and Virginia), the change in operation or safety was negligible.[11] However, lane restrictions did receive positive public reaction and high compliance from truck drivers. The potential effect on pavement deterioration rates seemed very positive, and no change in capacity was expected due to truck lane restrictions.

The Four Basic EVF Strategies

Four basic strategies have been used for EVFs: (1) inside lane, light vehicles only (ILLVO), (2) inside lane, heavy vehicles only (ILHVO), (3) outside lane, light vehicles only (OLLVO), and (4) outside lane, heavy vehicles only (OLHVO).

Inside Lane: Light Vehicles Only (ILLVO)

A common vehicle separation strategy is to designate the inside (far left) lane(s) for the exclusive use of light vehicles without using barriers (see Figure 2). Heavy and light vehicles are permitted to use the remaining lanes. The advantages of this arrangement are that large trucks are not precluded from using the middle lane(s) for passing and enough room is typically provided on the outside shoulder to accommodate emergency stops. Additionally, wide loads and slow trucks are better accommodated in the slower outside lanes, which helps minimize the impact on traffic flow, particularly on grades.

Limiting large truck travel to the outside lanes minimizes truck weaving near interchanges with right exits, particularly in urban areas where exits tend to be closely spaced.[12] Should median barriers be required, a comparative cost savings may be realized through the use of standard "Jersey" barriers in lieu of the more substantial barriers needed when heavy vehicles are traveling in the inside lanes.[12]

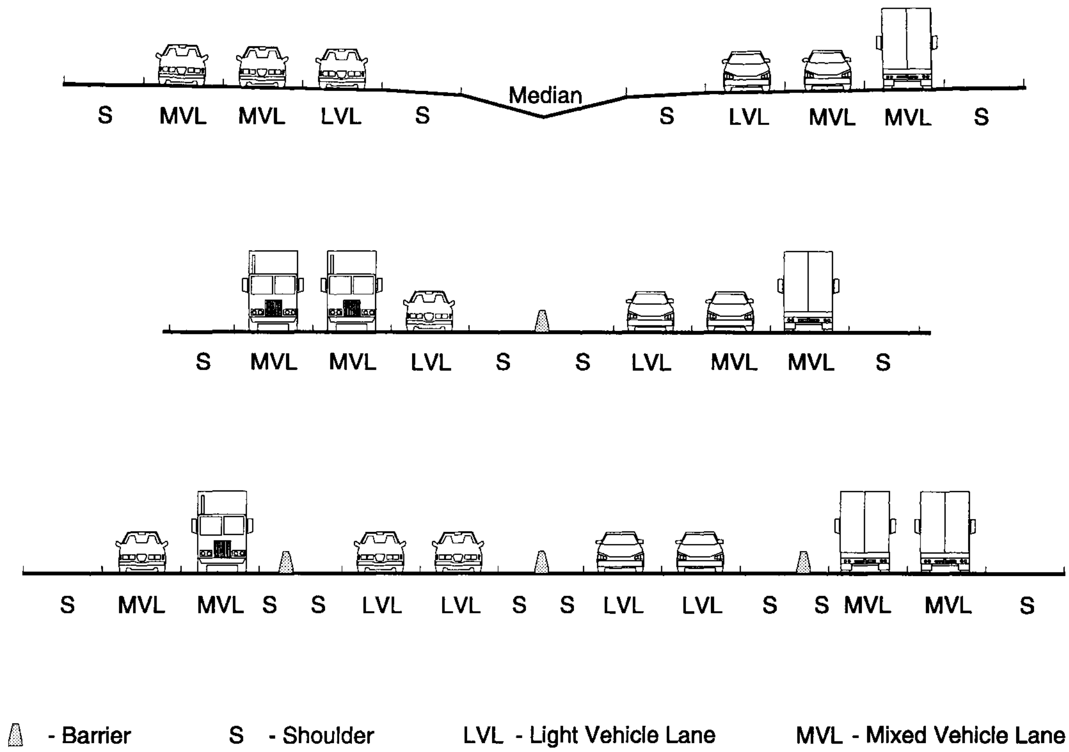

Figure 2. Inside lane: Light vehicles only (nonbarrier and barrier separated)

Dedicating a lane exclusively for passenger vehicles is popular with drivers of light vehicles, as it reduces the large truck intimidation factor and is perceived as a safety improvement. However, several concerns exist with this separation strategy. Restricting trucks from the inside lane(s) will concentrate trucks in the outer lanes. As heavy vehicle volumes increase, gaps between heavy vehicles traveling in the outside lanes will be reduced, in effect forming a moving barrier and making it difficult and unsafe for other vehicles to merge or exit on the right. Given that highway sign placement is typically above or to the right of the outside travel lanes, this lane assignment may cause visual impairment and sign blockage for smaller vehicles traveling in the inside lanes.

The concentration of repetitive heavy loading on the outside lanes will produce accelerated deterioration, particularly if the existing pavement structure is not designed for the total truck traffic.[12] Middleton and Mason contended that this strategy provides a small improvement in highway operations.[13] They pointed out that in addition to operational concerns, enforcement of lane restriction violators is difficult because inside shoulder widths are often too narrow to accommodate large vehicles and requiring stopping on the outside shoulders necessitates multiple lane changes. Enforcement is further complicated near left exits where heavy vehicles may enter the exclusive lane prematurely when preparing to exit.

Inside lanes for the exclusive use of light vehicles have been implemented in many states, often on grades where truck climbing lanes are provided. In most cases, studies were not performed before or after implementation of the exclusive lanes. Therefore, the effect of this strategy on safety and traffic operations is difficult to determine, although the effect of truck climbing lanes on grades is known. The 1994 *Highway Capacity Manual (HCM)* provides additional information related to the effect of trucks on grades.

In 1984, lane restrictions were implemented on the Capital Beltway (I-495) in Maryland and Virginia to improve highway operations and reduce truck crashes. Along sections of the Beltway with a minimum of four lanes in one direction, large trucks were restricted from the inside lane. The restriction was originally applied to 9.48 km (5.89 mi) of the Beltway in Virginia and 50 km (31 mi) in Maryland but has since been extended to include the entire length of the Beltway. Before and after comparative studies conducted by both states indicated a high compliance rate, but the apparent effect this change had on safety was disappointing. The truck crash rate for the restricted section in Virginia increased from 139 crashes per 100 million vehicle miles (MVM) of travel for the 2-year before period to 152 crashes per 100 MVM for the 2-year after period.[14] In Maryland, the truck crash rate increased from 195 to 207 for the same periods.[15] Further, crash severity significantly increased in Maryland (injury rate increased by 21%), but virtually no change in injury rate occurred in Virginia.[14, 15]

Although overall crash rates increased in both states, they were not significant and were most likely attributable to increases in traffic volume and subsequent congestion. Interestingly, sideswipe crashes increased significantly in Maryland from 96 crashes per 100 MVM before the restriction to 119 crashes per 100 MVM after its implementation.[15] This may be explained in part by an increase in large through trucks using the outside lanes, which must also be used by other vehicles for weaving near interchanges.[15]

Inside Lane: Heavy Vehicles Only (ILHVO)

Another method of separating heavy and light vehicles is to designate the inside lane(s) for the exclusive use of heavy vehicles (see Figure 3). Outside lanes are reserved for mixed traffic use. Inside lane exclusive truck facilities may be appropriate in rural areas where exits are widely spaced and their use by through trucks is rare. If highway widening is required to provide additional lanes, this method can best use the existing median right of way. New lanes may then be specifically designed to carry the greater load of trucks rather than having all lanes designed to the same standard.[13]

A disadvantage of this method is that trucks traveling in the exclusive lane must pass on the right when only one exclusive lane for trucks exists. Also, oversized and/or slow moving trucks traveling in this lane will impede the flow of traffic. Therefore, it may be necessary to provide two exclusive heavy vehicle lanes to avoid having these slower vehicles traveling in the

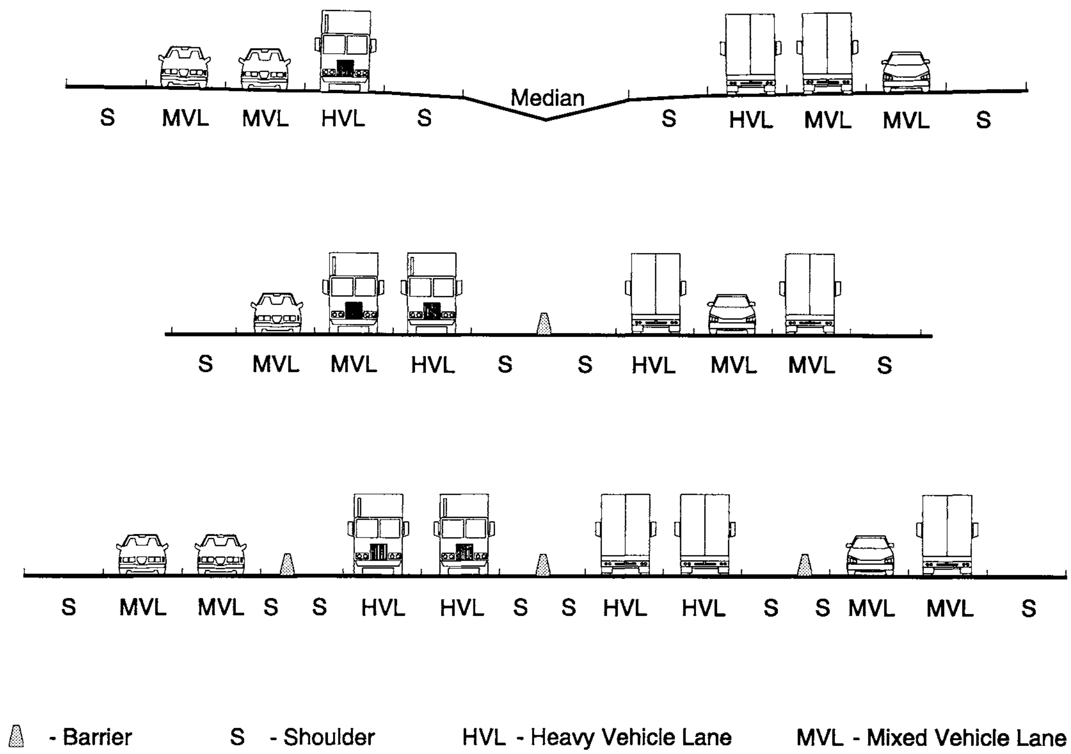

Figure 3. Inside lane: Heavy vehicles only (nonbarrier and barrier separated)

mixed vehicle lanes. Further, assigning heavy vehicles to the passing lane is contrary to normal practice and might be unsettling to some drivers. Last, where interchanges are closely spaced, trucks will be forced to make multiple lane changes, creating a possible safety hazard.[16]

This strategy of designating the inside lane(s) exclusively for trucks has not been tried in the United States. A joint project was proposed by the Florida and Georgia departments of transportation on I-75/I-475 between Tampa and Atlanta to study, in part, the use of the inside lane as an exclusive truck lane through the middle portion of the 715-km (444-mi) project.[17] Apparently, this proposal never advanced because of a lack of funding to pay for this costly initiative.

Outside Lane: Light Vehicles Only (OLLVO)

Another vehicle separation strategy often employed to reduce pavement wear is to exclude trucks from using the outside lane(s), except near interchanges (see Figure 4). On most multilane facilities, heavy vehicles tend to travel in the slower outside lanes, thereby subjecting these lanes to accelerated pavement deterioration from repetitive heavy loading.[11] One method of pavement management is to restrict heavy vehicles from the outside lane(s), causing a shift of

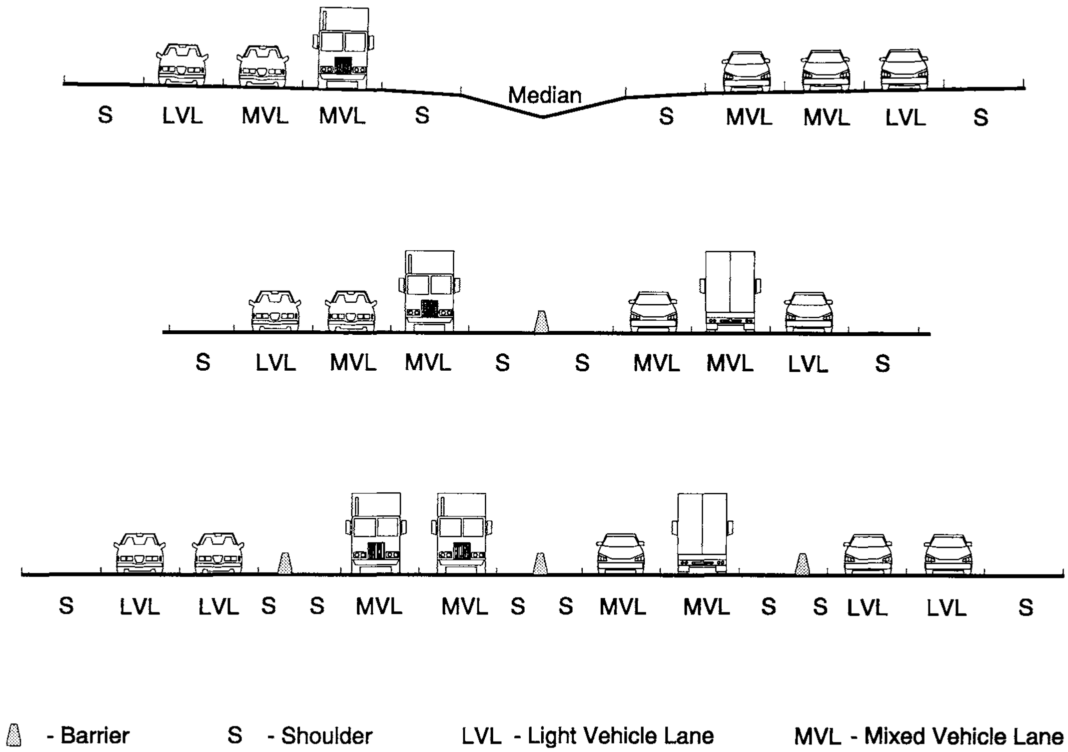

Figure 4. Outside lane: Light vehicles only (nonbarrier and barrier separated)

loading to the less heavily traveled inside lanes, thus evening out pavement wear. Only light vehicles would use the outside lane(s), with mixed traffic in the remaining lane(s). This strategy has similar safety and operational advantages and disadvantages as ILHVO.

This method of decreasing and evening out pavement wear has been implemented in several states but only as a temporary measure until pavement rehabilitation was completed. Idaho, Nevada, North Carolina, and Wisconsin have used it on a voluntary, unenforced basis. Pavement improvements in some areas were postponed for several years as a result of the restrictions.

Outside Lane: Heavy Vehicles Only (OLHVO)

The fourth option for separating passenger vehicles and trucks is to designate the outside lane(s) for the exclusive use of heavy vehicles with the remaining lanes available for mixed vehicle travel (see Figure 5). This strategy is very similar to ILLVO in that it results in a large concentration of heavy vehicles in the outside lane(s). Light vehicles are restricted from traveling in the outside lane(s) except to exit and merge. ILLVO and OLHVO have similar advantages and disadvantages. An additional benefit of OLHVO is that less weaving occurs when trucks are not restricted to the exclusive lane(s) and, accordingly, may travel in inside lanes

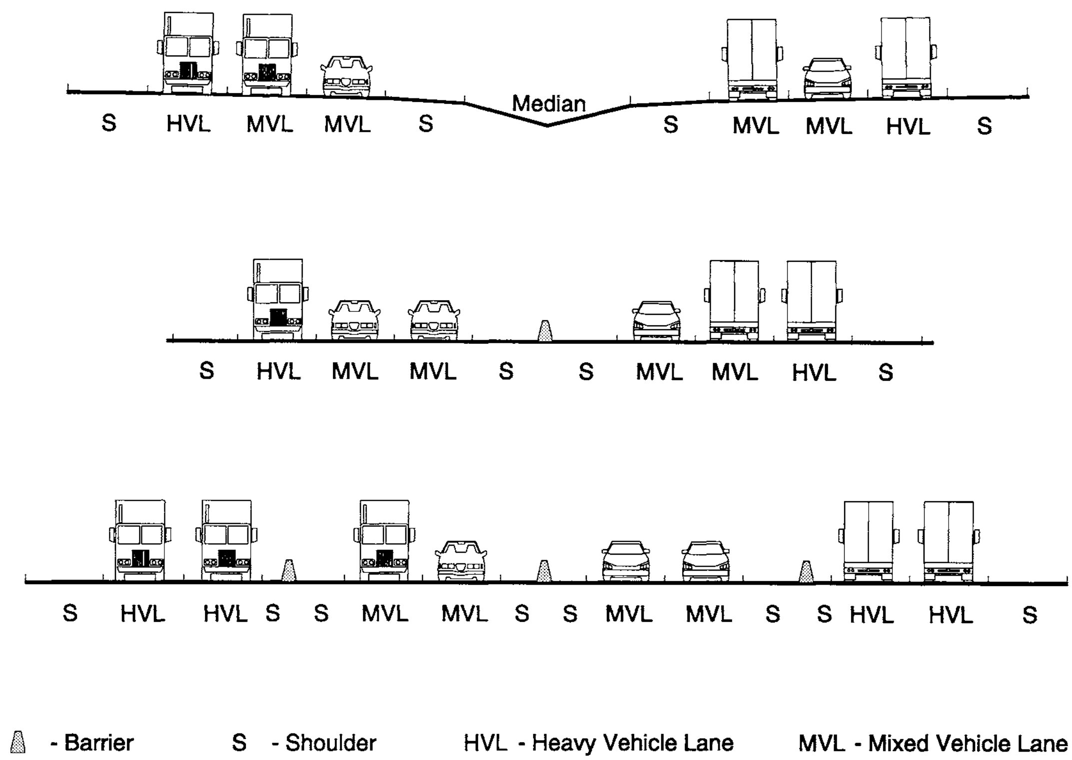

Figure 5. Outside lane: Heavy vehicles only (nonbarrier and barrier separated)

when preparing for an inside exit or when first approaching the lane restriction. However, enforcement of the restrictions for light vehicles in the exclusive lane(s) is difficult near interchanges because passenger vehicles weave to the outside lane for exiting or when attempting to merge.

The use of OLHVO was not referenced in the literature. However, the previously cited Florida/Georgia proposal included several highway sections in which the outside lanes were to be designated exclusively for trucks.

Exclusive Lanes with Barrier Separation

In the previously described traffic separation strategies, highway signage and/or pavement markings are typically used to control the separation of light and heavy vehicles. However, fixed or moveable concrete barriers may be used to provide more positive separation. Barriers are thought to enhance safety, as heavy and light vehicles are physically separated, significantly reducing the probability of a collision between the two. The use of barriers may be especially beneficial in rural areas, where incidents of drivers falling asleep and drifting into another lane are more common.[9] In addition, barrier-separated lanes ensure total control over entering and exiting maneuvers.[13]

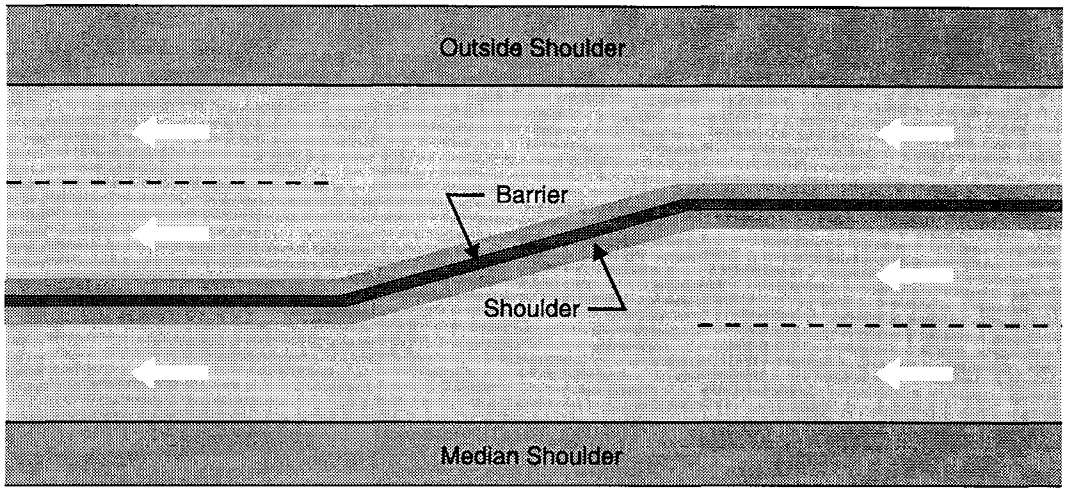

Figure 6. Variable passing lane for barrier-separated facilities

Aside from the additional right-of-way and construction costs, providing barrier-separated travel lanes poses several operational problems. Barrier-separated segments through interchange areas require either (1) special interchange designs to allow all vehicles the opportunity to exit or merge, or (2) gaps in the barrier in the vicinity of interchanges. To maintain proper traffic flow, a minimum of two travel lanes are needed on either side of the barrier to allow the opportunity for passing. To maximize the use of a narrow existing median where four lanes do not exist and right-of-way availability is limited, a variable passing lane may be used (see Figure 6); however, this configuration may contribute to crashes where the left lane ends. In designing a cross section to accommodate the addition of a barrier-separated lane(s), greater lane and shoulder width is typically required compared with providing a nonbarrier-separated lane(s).

Barrier-separated facilities create an enforcement problem since they essentially require that patrols be doubled in segments in which lanes are physically separated to maintain the same level of enforcement that existed prior to separation. Providing a means for adequate access to all lanes in the case of an emergency is also a legitimate concern.

Separate Roadways for Light and Heavy Vehicles

Separate roadways for light and heavy vehicles is a variation of the concept of separating specific vehicle types on the same highway section. Separate roadways may be either parallel or isolated. As with barrier-separated travel lanes, separate roadways are intended to eliminate conflicts between vehicle types, with the result being improved operations and safety.

Separate facilities avoid some of the operational problems associated with barrier-separated lanes but require more right of way, separate sign structures, and special design treatments to allow interchanges to be shared and thus tend to be significantly more costly. At times, parallel separate facilities may need to be shared by all vehicles, such as when a crash closes one roadway and all traffic must be diverted to the other. Therefore, it is prudent that all lanes be designed to withstand heavy vehicle loads, therefore eliminating possible savings because of thinner pavement designs for the lanes designated for light vehicles. However, pavement may be specially designed for the heavy vehicle segment to withstand heavier loading, thereby reducing the frequency of resurfacing in those lanes.

The separate roadway concept is in effect for 53 km (33 mi) of the New Jersey Turnpike. The majority of the section has six lanes in each direction, with the interior three-lane section designated for light vehicles and the exterior three-lane section designated for local traffic, buses, and heavy vehicles. Of the section, 14.5 km (9 mi) has two lanes on the exterior section with three lanes on the interior.[18] Directional flow is separated by a concrete median barrier, with metal beam guardrail and shoulders between the interior and exterior sections.

The distribution of light vehicle traffic across the facility is 40 percent in the exterior lanes and 60 percent in the interior lanes, and the truck compliance rate is high.[18] The purpose of providing separate roadways was to improve traffic management through automated traffic control and increased flexibility when parts of the Turnpike had to be closed because of crashes and maintenance. However, this design is also believed to enhance safety; the truck crash rates for this section and other portions of the Turnpike are significantly lower.[18]

Separate truck facilities exist on I-5 in Los Angeles, California, and Portland, Oregon. Both facilities require trucks to leave the main roadway yet permit passenger vehicles to travel on the main roadway or the separate facility for trucks. The facility in Los Angeles was constructed to reduce weaving-related conflicts involving heavy vehicles. The facility in Portland was built to reduce weaving and minimize delays created by slower moving trucks on significant grades.[18]

Designated Truck Routes

Designated truck routes are implemented mainly in urban areas. "Through truck routes" and highway "business" or "bypass" routes exist in several states. In some locations, they are imposed to circumvent heavy vehicle traffic around congested city roadways or prevent trucks from traveling on routes with inadequate geometric design. Other route restrictions ban vehicles carrying hazardous materials and reroute them through low-population areas. To reduce the adverse impacts of heavy vehicles in the traffic mix, through trucks approaching Atlanta, Georgia, are restricted from freeways within the I-285 loop and must remain on I-285. Similar designations have been imposed on a voluntary basis in Minneapolis/St. Paul and on I-710 in Los Angeles. Both jurisdictions report nominal effects as a result of these voluntary bans.[18]

Time-of-Day Restrictions

The specific implications of time-of-day restrictions are not well known. The results of a 1975 Urban Mass Transit Administration study suggested that a complete ban of truck traffic on urban freeways during daylight hours could increase average network speeds by about 16 km/h (10 mph) during peak hours.[16] This estimate assumes that additional capacity created through the removal of trucks would not be consumed by latent travel demand. Safety benefits of time-of-day restrictions are also questionable. For example, fewer and less frequent delays attributable to truck crashes and less impedance of traffic attributable to slow trucks have been speculated.[11] However, truck crashes (like truck travel) tend to peak during off-peak hours. The fact that operating speeds are much higher during off-peak periods suggests that operating speed and not time of day could be the problem.[16]

Another concern with restricting trucks from using certain routes or lanes during specified time periods is that some trucks may be forced to travel on parallel auxiliary routes, insufficiently designed for the increased truck volume, resulting in subsequent crashes and/or delay. Also, time-of-day restrictions raise legal issues, may be difficult to enforce, and may be opposed by the public if they adversely affect delivery schedules.

Although there are potential benefits associated with imposing traffic regulations during specified hours, this is not usually done for legal loads. Time-of-day restrictions usually apply to oversized or overweight trucks; they are restricted during nighttime hours from traveling on specific roadways to increase safety or during peak periods to prevent traffic flow impediment attributable to slower travel speeds.[11]

In 1988, Florida conducted a 6-month experiment that involved the restriction of trucks from the leftmost lane of I-95 in Broward County between 7 A.M. and 7 P.M. For this study, a truck was defined as any vehicle having three or more axles. A high level of truck driver compliance (98%) was achieved. Although crashes for all vehicles decreased 2.5 percent for a 24-hour period, the crash rate during the prohibition period rose 6.3 percent.[18] However, the proportion of crashes involving trucks decreased 3.3 percent during the hours of the restriction.[18] Despite an overall increase in the crash rate during the prohibition period, drivers reportedly felt safer with the truck lane restriction.

Reduced Pavement Wear Strategies

The primary objective of truck lane restrictions is to improve highway safety and operations. Truck lane restrictions have also been found to be an effective means of extending the life of highway pavements. The greatest proportion of trucks traveling on interstate and primary highways travel in the outside lane. Given that trucks do the greatest damage to highway pavements, pavement performance can be improved by redistributing trucks more evenly across the highway cross section, thus reducing the frequency of pavement rehabilitation.

Some jurisdictions with a high percentage of truck traffic design pavement to withstand higher loads and thereby increase time between resurfacing. Improved pavement mixes and thicker pavement sections may contribute to decreased pavement wear, and roads may be initially designed dependent on expected truck volumes per lane. In this manner, a new lane(s) designed for the exclusive use of trucks can help extend the life of the entire roadway section.

Advantages and Disadvantages of EVFs

The four basic vehicle separation strategies (ILLVO, ILHVO, OLLVO, and OLHVO) are thought to improve traffic operations and safety by minimizing the interaction between heavy and light vehicles. Concrete barriers provide more positive separation. However, each strategy has advantages and disadvantages that should be considered, as summarized in Table 1.

Table 1. Advantages and disadvantages of exclusive vehicle facility strategies

Option	Advantages	Disadvantages
Nonbarrier Separated		
ILLVO	Trucks better accommodated in outside lanes Trucks can pass Less truck weaving near interchanges Reduced truck intimidation factor	Truck concentration creates moving barrier Accelerated pavement wear in outside lanes Signs blocked by large trucks
ILHVO	Through trucks better accommodated Reduced pavement wear in outside lanes	More truck weaving near interchanges
OLLVO	Reduced truck intimidation factor Reduced pavement wear in outside lanes	More truck weaving near interchanges
OLHVO	Trucks better accommodated in outside lanes Trucks can pass Less truck weaving near interchanges	Truck concentration creates moving barrier Accelerated pavement wear in outside lanes Signs blocked by large trucks
Barrier Separated		
ILLVO/OLHVO	More positive separation Reduced truck intimidation factor	Need minimum of 4 lanes in one direction Requires special treatment near interchanges Doubles enforcement requirements
ILHVO/OLLVO	More positive separation Reduced truck intimidation factor Reduced pavement wear in outside lanes	Need minimum of 4 four lanes in one direction Requires special treatment near interchanges Doubles enforcement requirements

SURVEY OF STATE TRANSPORTATION AGENCIES

Truck Travel Strategies

Truck travel strategies designed to improve traffic operations and safety can be subdivided into four categories: (1) lane restrictions, (2) route designations, (3) route restrictions, and (4) time-of-day restrictions. The survey found that 29 of 50 states (58%) have implemented one or more of these strategies. Table 2 summarizes the practices used in each state.

Truck Lane Restrictions

Lane restrictions for trucks have been implemented on freeways in many states to address the problems of safety, traffic delays, and pavement deterioration. Two general types of lane restrictions exist. Trucks are restricted to the outside lane(s) usually to improve traffic operations and/or increase the level of safety. Restrictions of this sort are typically mandatory, but the level of enforcement varies from state to state. Trucks are restricted to the inside lane(s), usually on a temporary, voluntary basis, to decrease the rate of pavement deterioration on the more heavily traveled outer lanes. Most lane restrictions are implemented on a site-specific basis, but some statewide policies exist (e.g., California and Georgia). Half of the states impose lane restrictions on trucks on at least some of their highways. Table 3 summarizes the truck travel practices used in each state.

Designated Truck Routes and Lanes

Nine states (18%) designate specific routes or lanes for use by trucks. Though most truck routes may be used by other traffic, only California designates routes to be used exclusively by trucks. Oregon is the only state that designates a lane for the exclusive use of heavy vehicles. Truck routes are usually designated to prevent through traffic from entering urban areas and are typically selected based on their ability to carry heavier loads. Table 4 provides a summary description of designated truck routes and lanes throughout the United States. This list may be incomplete as a result of respondents failing to consider freeway bypasses as truck routes.

Restricted Truck Routes

Only nine states (18%) prohibit truck travel on certain freeway sections. Route restrictions are typically imposed in urban areas to reduce congestion, although route restrictions have also been imposed for safety enhancement on routes with steep downgrades or inadequate structures. States imposing truck route restrictions are summarized in Table 5.

Table 2. Summary of U.S. truck travel strategies

State	Lane Restriction	Truck Route Designation	Route Restriction	Time-of-Day Restriction
Alabama				
Alaska				
Arizona			X	
Arkansas				
California	X	X		
Colorado	X			
Connecticut	X			
Delaware				
Florida			X	X
Georgia	X		X	
Hawaii				X
Idaho	X			
Illinois	X			
Indiana	X	X		
Iowa				
Kansas				
Kentucky	X		X	
Louisiana				
Maine				
Maryland	X	X	X	
Massachusetts				
Michigan	X			
Minnesota				
Mississippi				
Missouri				
Montana				
Nebraska	X			
Nevada	X			
New Hampshire				
New Jersey	X	X		
New Mexico				
New York	X	X		
North Carolina	X			
North Dakota				
Ohio				
Oklahoma				

State	Lane Restriction	Truck Route Designation	Route Restriction	Time-of-Day Restriction
Oregon	X	X		
Pennsylvania	X	X	X	
Rhode Island	X		X	
South Carolina				
South Dakota				
Tennessee	X			
Texas	X	X		
Utah	X			
Vermont			X	
Virginia	X		X	
Washington	X			
West Virginia				
Wisconsin	X	X		
Wyoming	X			
Total	25	9	9	2

Table 3. Summary of U.S. truck travel practices

State	Restricted Vehicles	Restriction Type	Location of Restriction	Purpose of Restriction	Mandatory or Voluntary	Compliance & Enforcement	Notes
Calif.	Vehicles towing trailer	Restricted to rightmost lane except for passing	Statewide	Improve traffic operations (move slower vehicles into right lane)	Mandatory	Medium compliance and enforcement	Right lanes designed for heavier loads
Colo.	Trucks[1]	Restricted from rightmost lane	Site specific: very short interstate segments	Reduce concrete pavement deterioration	Voluntary	High compliance	In effect on short-term basis until rehabilitation completed (no change noticed in pavement condition)
Conn.	Commercial vehicles	Restricted from leftmost lane	Site specific: I-91 (approx. 24 km); I-95	Increase safety; reduce heavy vehicle intimidation; maintain high travel speeds in left lane	Mandatory	High compliance	
Ga.	Vehicles with 6 or more tires	2 directional lanes, restricted from left lane except to pass; 3 lanes, restricted to 2 right lanes	Statewide		Mandatory	Low compliance	
Idaho	Trucks,[1] buses	Restricted to leftmost lane	Site specific	Reduce pavement deterioration (postpone resurfacing)	Voluntary	Medium compliance	In effect less than 2 years

State	Restricted Vehicles	Restriction Type	Location of Restriction	Purpose of Restriction	Mandatory or Voluntary	Compliance & Enforcement	Notes
Ill.	Vehicles over 7,264 kg	Restricted to 2 rightmost lanes	Site specific: near Chicago	Improve traffic operations; increase safety	Mandatory except near left exits	High compliance; low enforcement	Restriction reduced delays especially during peak hours; improved traffic operations by reducing gaps caused by slower trucks; apparent increase in safety by reduced weaving (not proven)
		Restricted to leftmost lane	Site specific: south of Springfield	Reduce pavement deterioration	Voluntary	Medium compliance	In effect approximately 1 year
Ind.	Trucks,[1] truck tractors, semi-trailers, truck tractor-semitrailers	Restricted from leftmost lane	Statewide: where 3 or more lanes in one direction	Improve traffic operations; increase safety	Mandatory		
Ky.	Trucks[1]	Restricted to rightmost lane	Site specific: I-75 S. out of Cincinnati	Improve traffic operations; increase safety on steep grades	Mandatory	High compliance and enforcement	
Md.	Vehicles over 4,540 kg GVW	Restricted to 2 rightmost lanes	Site specific: Baltimore Beltway and Capitol Beltway	Improve traffic operations; increase safety	Mandatory	High compliance and enforcement	
Mich.	Vehicles over 4,540 kg GVW	Restricted to 2 rightmost lanes	Statewide when 3 or more directional lanes	Improve traffic operations; increase safety	Mandatory except reasonable distance from left exit	High compliance	Implemented circa 1986

State	Restricted Vehicles	Restriction Type	Location of Restriction	Purpose of Restriction	Mandatory or Voluntary	Compliance & Enforcement	Notes
Neb.	Trucks[1]	Restricted from rightmost lane	Site specific: no current restrictions imposed	Reduce pavement deterioration	Voluntary	High compliance	13-16 km lane restriction in effect in east-central Nebraska for 18 mo (asphalt rutting was main concern)
Nev.	Trucks[1]	Restricted from rightmost lane	Site specific: 19-32 km segments of interstate with asphalt rutting	Reduce pavement deterioration	Voluntary	High compliance	Duration of restriction dependent on time required to restore pavement
N.J.	Vehicles over 4,540 kg GVW (buses excluded)	Restricted from leftmost lane	Statewide: any divided highway with 3 or more directional lanes	Improve traffic operations; increase safety	Mandatory	High compliance	In effect for very long time
N.Y.	Vehicles 8,172 kg GVW or greater	Restricted from leftmost lane	Site specific: New York Thruway, I-90/I-87 interchange	Increase safety; keep through trucks away from major interchanges	Mandatory		In effect several miles before I-90/I-87 interchange to improve exiting maneuver of passenger vehicles
N.C.	Trucks[1]	Restricted to rightmost lane	Site specific: I-40 WB from US 276 to Tenn. state line	Improve traffic operations; increase safety	Mandatory		
Ohio							Voluntary climbing lanes provided on some grades

State	Restricted Vehicles	Restriction Type	Location of Restriction	Purpose of Restriction	Mandatory or Voluntary	Compliance & Enforcement	Notes
Ore.	Motor trucks greater than 3,632 kg GVW that can carry a load	Restricted to rightmost lane	Site specific: I-5 where steep upgrades exist; other routes	Increase safety	Mandatory	High compliance	Due to heavy truck travel in right lane, section of highway changed to concrete and widened from 3.66 to 4.27 m
Pa.	Trucks[1]	Restricted to rightmost lane	Site specific: long, steep uphill grades	Improve traffic operations	Mandatory	High compliance and enforcement	Turnpike signed: "Slower Trucks Right Lane" or "No Trucks Left Lane"
R.I.	Buses (10 or more passengers), campers, trailers, vehicles with camper or trailer, commercial vehicles	Restricted to 2 rightmost lanes (except 1.61 km before left exit)	I-95, I-195, I-295	Improve traffic operations; increase safety	Mandatory	Medium compliance	Citations issued where restrictions posted (fines do not exceed $25); policy revised 6 times in past 65 years
Tenn.	Commercial vehicles	Restricted to 2 rightmost lanes	Site specific: I-24 in mountainous areas; I-75 on downgrades	Increase safety	Mandatory	High compliance; low enforcement	I-24 has stopping lane (trucks must stop before descending); runaway truck ramps provided adjacent to inside lanes (runaway trucks must weave to inside)
Tex.	Trucks[1]	Restricted to rightmost lane	Site specific: I-10 east of Katy	Increase safety	Mandatory	Medium compliance	

State	Restricted Vehicles	Restriction Type	Location of Restriction	Purpose of Restriction	Mandatory or Voluntary	Compliance & Enforcement	Notes
Utah	Trucks[1]	Restricted to rightmost lane	Site specific: 8 km section of I-80 near Salt Lake City	Improve traffic operations	Mandatory	Low enforcement	Restriction had positive effect in one location (too early to draw conclusion of overall effectiveness)
Va.	Vehicles 3,405 kg GVW or greater	Restricted from leftmost lane	Site specific: I-81, I-495	Improve traffic operations and safety	Mandatory	Low compliance	
Wash.	Vehicles over 4,540 kg GVW	Restricted to rightmost or leftmost lane (usually rightmost)	Site specific: I-5, I-90, I-405	Improve traffic operations	Mandatory	High compliance	Pavement markings used to denote restriction
Wis.	Vehicles over 2,724 kg GVW	Restricted to leftmost lane	Site specific: marshy areas	Reduce pavement deterioration	Voluntary	High compliance	Site was rehabilitated
Wyo.	Trucks,[1] recreational vehicles	Restricted to 2 rightmost lanes	Site specific: I-80 near Rock Springs and Evanston (3.22 km)	Improve traffic operations	Mandatory	Medium compliance and enforcement	

[1]These states do not provide a definition of *truck* for the purpose of imposing lane restrictions.

Table 4. Designated U.S. truck routes and lanes

State	Policy	Purpose	Location of Restriction	Exclusive for Trucks?	Notes
Calif.	Truck routes designated in urban areas	Reduce weaving near interchanges	North of Los Angeles Downtown Los Angeles	Trucks only, mandatory Recommended for trucks	Mandatory truck routes enforced; pavement designed for heavier loads
Ind.	Roads classified as "heavy duty" or "extra heavy duty"	Truck routes recommended based on highway geometrics	Northwest industrial corridor	Not exclusive	
Md.	Truck routes designated		Route 40 near Aberdeen and other routes	Not exclusive	
N.J.	Separate facility provided	Improve traffic operations	N.J. Turnpike (separate facility parallel to main route)	Not exclusive, mandatory	Approx. 40% of cars use separate facility
N.Y.	Short bypasses around urban areas designated	Reduce traffic congestion	Urban areas	Not exclusive, mandatory	
Ore.	Truck lane provided	Reduce delays on steep upgrades	I-5 on steep upgrades	Trucks only, mandatory	Truck lane separated from other traffic by pavement markings
Pa.	Truck routes designated		Site specific		Pavement not specially designed for heavier loading
Tex.	Truck routes designated	Reduce congestion	Urban areas	Not exclusive	Truck routes designated by local jurisdiction
Wis.	Truck routes recommended	Reduce congestion	Urban areas	Not exclusive, mandatory in larger cities	

Table 5. Summary of U.S. truck route restrictions

State	Policy	Purpose	Location	Notes
Ariz.	Trucks restricted from specific interstate routes	Prevent heavy loadings on inadequate structures	Site specific	
Fla.	Trucks restricted from specific interstate routes	Prevent heavy loadings on inadequate structures	Site specific	
Ga.	Trucks restricted except for pickup/delivery	Improve traffic operations	I-285 in Atlanta	Tickets written for violations
Ky.	Trucks restricted from interstates based on size and weight	Improve traffic operations, increase safety, reduce pavement deterioration	Statewide	Route restrictions imposed based on road geometrics, structures, etc.
Md.	Trucks restricted from specific freeway routes	Improve traffic operations, increase safety	Baltimore-Washington Expressway	
Pa.	Trucks restricted from sections of specific routes	Improve traffic operations, increase safety	Site specific: long, steep downgrades	
R.I.	Twin 16.2-m trailers restricted from specific freeways	Increase safety		
Va.	Trucks restricted from sections of specific interstate routes	Improve traffic operations	Site specific: I-66, I-264	
Vt.	Trucks restricted from specific section of freeway	Prevent truck traffic through main street of town	Route 105 through St. Johnsburg	

Truck Time-of-Day Restrictions

Two states (4%) reported the use of time-of-day restrictions to regulate heavy vehicle operation. Florida uses them during peak traffic hours in urban areas with high ADTs. Hawaii requested and has received the voluntary compliance of trucking companies to refrain from using specified highways during the morning peak travel hours. Additional time-of-day restrictions may exist, especially in urban areas, as respondents to the survey representing state agencies may be unaware of local practices.

Summary

Among the truck travel strategies addressed in this survey, restricting trucks from using specified lanes is the most widely used, with more than half of the states imposing some type of lane restriction. When truck lane restrictions are imposed, trucks are usually directed to travel in the outside lane(s). Two states, California and Oregon, provide exclusive truck facilities. California designates a mandatory truck-only route to improve safety. Oregon designates a mandatory truck-only lane to reduce delays for other motorist on steep grades. Strategies being used in other states include designated truck routes, route restrictions, and time-of-day restrictions.

EVFS ANALYSIS OF VIRGINIA'S INTERSTATE 81

An analysis of I-81 using the EVFS format was conducted. The major steps involved (1) sensitivity testing, (2) site selection, (3) data collection, (4) program updating, and (5) application of the program to I-81.

Exclusive Vehicle Facilities (EVFS) Program

EVFS is an analysis format for determining the economic feasibility of separating passenger vehicles and trucks on limited-access facilities either by designating existing lanes and/or constructing additional ones.[5] The program, written in Basic, offers the user the choice of two analysis formats called *Level 1* and *Level 2*. A complete listing of Level 1 and Level 2 data input parameters is presented in Appendix B.

Level 1 is a quick analysis format that requires few user inputs and is used to obtain a sketch evaluation of many alternatives. Level 1 outputs provide guidance as to which alternatives may warrant further examination in Level 2.[5]

Level 2 is a detailed approach requiring 57 data inputs. Default values are provided for 41 of the 57 input variables, but users may substitute their own values for any of the inputs. Default cost are in 1985 dollars, as are the vehicle operating cost tables referenced by the program. Input variables are subdivided into five categories: (1) General Site Information, (2) Traffic Characteristics, (3) Other Factors, (4) Facility Construction and 4R Work Cost, and (5) Value-of-Time and Accident Costs.

EVFS calculates the NPW and BCR for each alternative being considered. Potential benefits or cost savings accounted for in the program include[5]:

- travel time savings due to faster traffic flow

- vehicle operating cost savings due to improved traffic flow
- injury and property damage savings due to fewer severe accidents
- travel delay savings due to fewer blockages causing accidents.

The analysis format also accounts for the following project costs:

- engineering and construction
- right-of-way acquisition and demolition
- periodic pavement resurfacing (which may be less frequent for light vehicle lanes).

Several lane assignment configurations for light, heavy, and mixed vehicle travel are considered in the analysis format. Light vehicle lanes can be used by motorcycles, automobiles, pickup trucks, light vans, buses, and trucks weighing less than 4,540 kg (10,000 lb) GVW. Only single-unit trucks weighing more than 4,540 kg (10,000 lb) GVW and all combination-unit trucks can travel in heavy vehicle lanes. Mixed vehicle lanes can be used by both light and heavy vehicles. The analysis format is designed to evaluate the following scenarios:

- *Case 0:* two or more existing lanes, no restrictions
- *Case 1:* three or more existing lanes, restrict one or more lanes to light and/or heavy vehicles
- *Case 2:* two existing lanes, add one or more lanes (no lane restrictions)
- *Case 3:* two existing lanes, add one or more lanes (impose nonbarrier-separated lane restrictions)
- *Case 4:* two existing lanes, add one or more lanes (impose barrier-separated lane restrictions).

The purpose of the base case (Case 0) is to establish existing conditions for comparison with other scenarios. Case 1 is appropriate for evaluating highway segments with three or more existing lanes in one direction. For two lanes in each direction, Cases 2, 3, and 4 are appropriate. Case 2 examines the option of allowing use of all lanes by both light and heavy vehicles after one or more additional lanes have been provided. Cases 3 and 4 involve the addition of either nonbarrier- or barrier-separated lanes, of which lane restrictions (for either light or heavy vehicles) are imposed. The analysis format is described in the decision tree diagram shown in Figure 7.

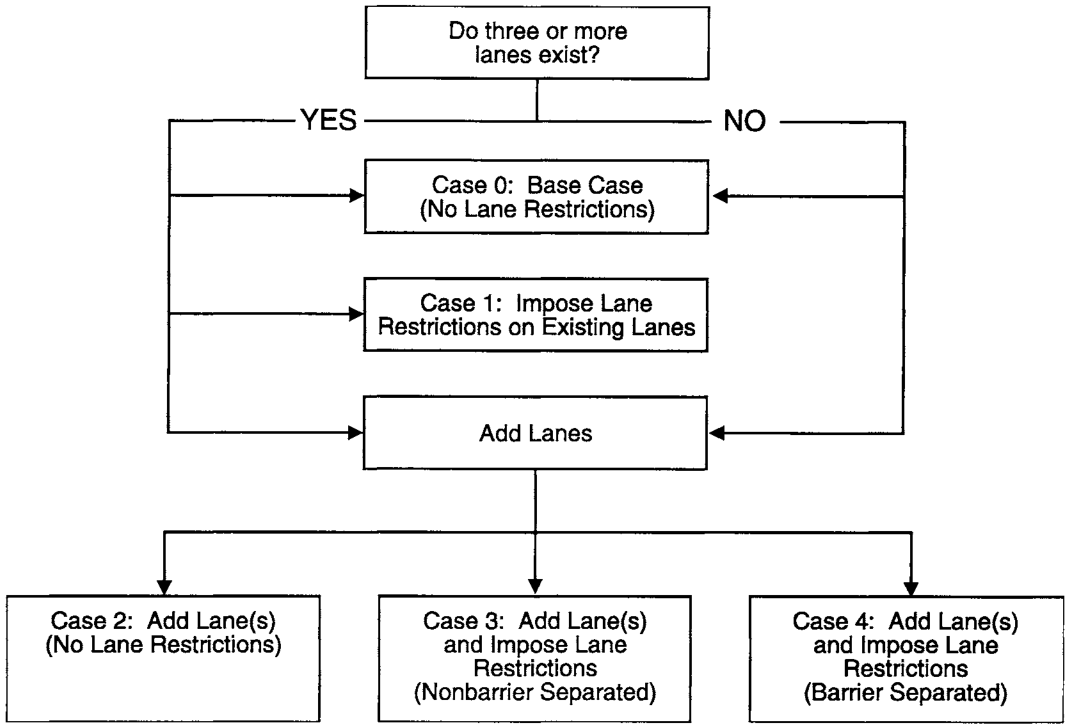

Figure 7. EVFS alternatives decision tree

The EVFS program has several limitations. It cannot be used to evaluate the cost-effectiveness of HOV lanes or toll facilities. Also, EVFS is not designed to evaluate the need for hill climbing lanes. Further, EVFS does not include demand forecasting in its calculations though future demand is considered in the analysis. On the other hand, EVFS can be used to evaluate reversible lanes options.

Sensitivity Analysis

BCR and NPW for alternative lane strategies are calculated in Level 2 based on the values provided for the 57 user inputs. Different input values yield different results. For instance, a discount rate of 4 percent produces higher BCRs than does a discount rate of 10 percent, assuming all other inputs are held constant, since lower interest rates reflect lower construction and maintenance costs. Figure 8 shows how BCR varies with discount rate for three hypothetical scenarios (Scenarios A, B, and C). The results are consistent with the known effects of discount rates. A description of each scenario is provided in Appendix C.

An attempt was made to determine if other general relationships exist. Data for Scenarios A, B, and C were input into the program to produce initial results. Next, one or several inputs

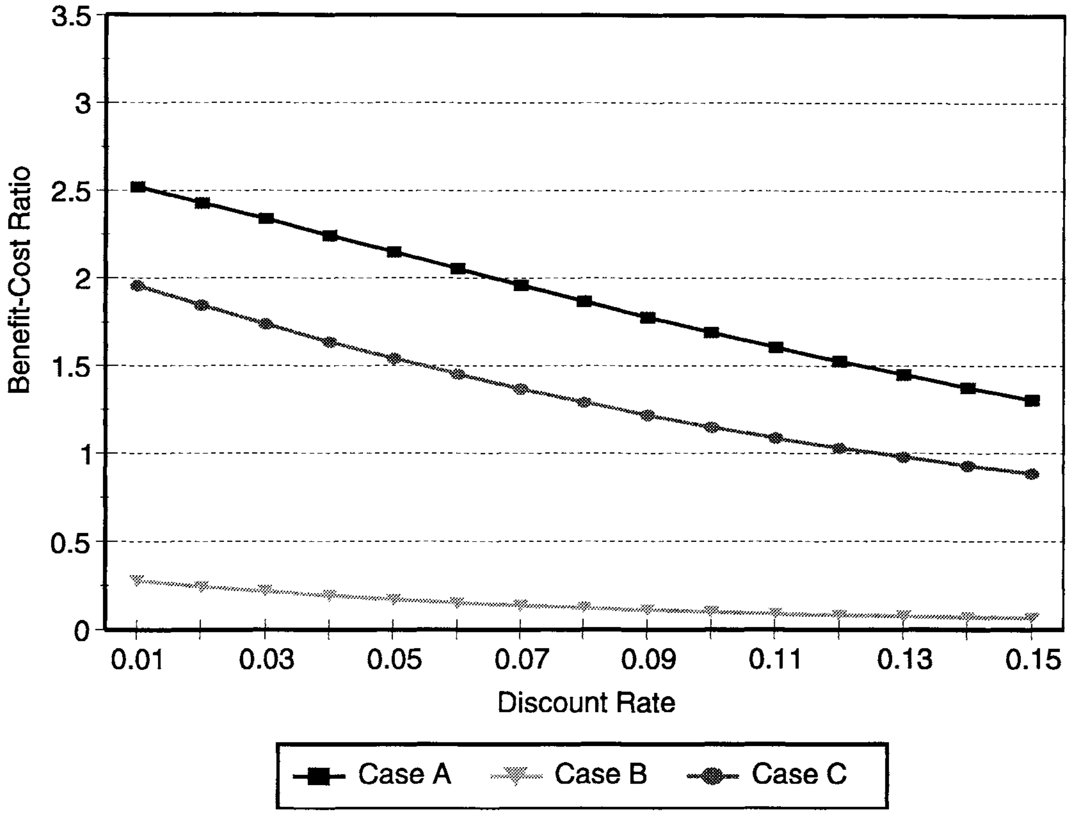

Figure 8. BCR vs. discount rate

were then examined to reveal relationships between changes in inputs and the results. For like changes in inputs, the three scenarios were compared to determine if the outputs were consistent relative to each other.

Although it was impractical to consider all possible data combinations, a number of input combinations were evaluated for each scenario. In nearly all cases, the model produced results that were interpreted to be reasonable. In rare instances, the results could not be easily understood. For example, in testing the sensitivity of the results to changes in vehicle mix percentage, questionable outputs were produced for Scenario B when a vehicle mix of 30 percent light vehicles (LV), 7 percent single-unit vehicles (SU), and 63 percent combination vehicles (CV) was designated. Likewise, no output was generated when a vehicle mix of 30 percent LV, 35 percent SU, and 35 percent CV was assigned (see Figure 9). These results might be explained by the fact that these mix percentages are not reasonable and fall outside the scope of the program's capability to produce legitimate results.

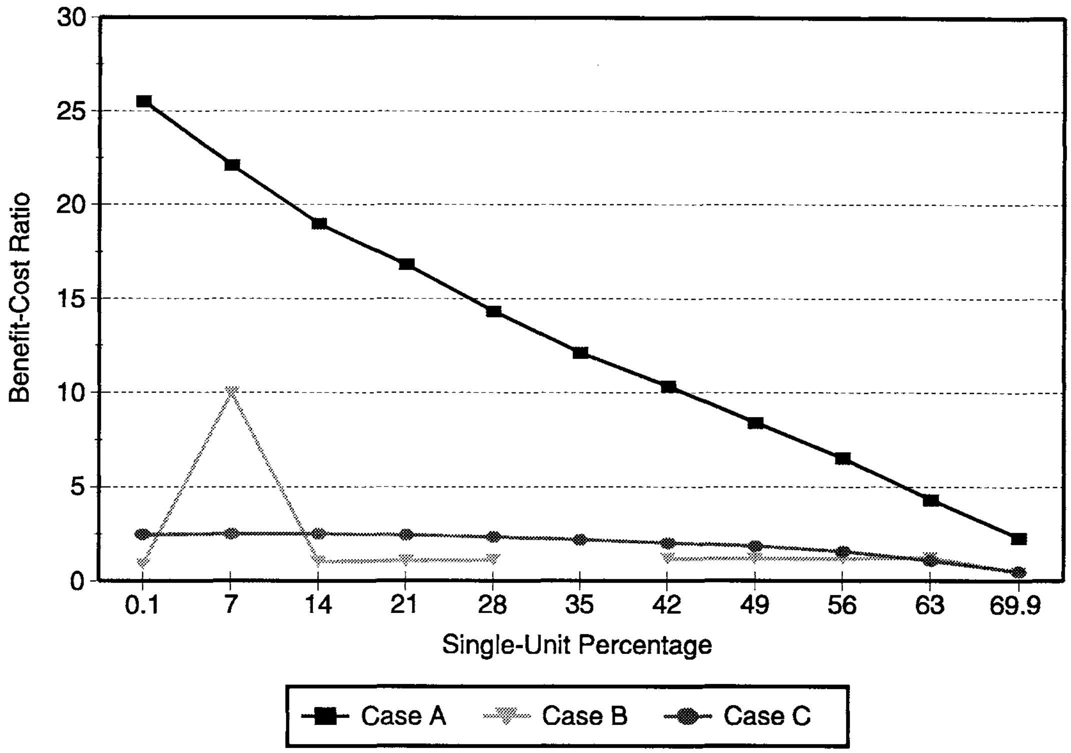

Figure 9. BCR vs. 30% light vehicle and variable single-unit vehicle and combination vehicle percentages

Site Selection Process

To demonstrate the application of the program, a test section was selected. Using the selection criteria described, the 50.7-km (31.5-mi) segment of I-81 in Virginia, located between U.S. Routes 460 and 220, was used.

Selection Criteria

The selection of a test site was based on eight selection criteria: (1) facility access control; (2) ADT; (3) percentage of large trucks in the vehicle mix; (4) number of collisions involving light and heavy vehicles; (5) inclusion in VDOT's Six-Year Improvement Program; (6) number of lanes; (7) topography; and (8) practical considerations (e.g., availability of data, distance from VTRC).

The first criterion was used to identify controlled-access sites (an EVFS program requirement). The next three criteria were used to locate sites with a relatively high traffic volume, percentage of large trucks, and number of crashes involving passenger vehicles and trucks, as facilities with these characteristics are more likely to benefit from exclusive lane treatments. Inclusion in VDOT's Six-Year Improvement Program was used as a criterion because it lists high-priority locations in the corridor. Variable number of lanes and topographical diversity were used as criteria because of the opportunity to evaluate alternatives under various geometric operating conditions. Last, factors such as availability of data and proximity to VTRC were used as criteria for practical reasons.

The search for candidate sites was limited to I-81 because of the large percentage of trucks that use this facility relative to other controlled-access facilities in Virginia. On I-81, five candidate sites were identified. Table 6 lists the sites and provides descriptive information concerning each segment.

Table 6. I-81 candidate analysis test sites

Site	Location	Length (km)	1993 ADT	% Large Trucks	Total LV/HV Collisions	6-Yr Plan	Other
1	Fr: U.S. Rte. 460 To: U.S. Rte. 220	50.7	39,500	24	52	Yes	4- and 6-lane sections Extensive accurate data
2	Fr: U.S. Rte. 220 To: I-64 West	66.8	28,000	31	36	No	
3	Fr: I-64 West To: I-64 East	48.3	31,300	31	29	Yes	Near Charlottesville
4	Fr: Va. Rte. 211 To: U.S. Rte. 11	54.7	25,000	35	26	No	
5	Fr: U.S. Rte. 11 To: W.Va. State Line	41.9	31,100	29	33	Yes	

LV/HV = light vehicle/heavy vehicle.

Site Selection

Although EVFS could have been easily applied to any of the five sites, Site 1 was chosen because in addition to having the highest ADT and number of LV/HV collisions and an acceptable percentage of large trucks in the vehicle mix, it is included in VDOT's Six-Year Plan, was diverse in terms of topography, had sections with both two and three lanes in one direction, and much of the needed data were readily available. In addition, Site 1 is a moderate driving distance from VTRC; contains several sections with an exclusive light vehicle lane; has a left exit, a truck weigh facility, and a rest area facility; and intersects the proposed "Smart Road" and I-73. The Smart Road is a proposed 9.2-km (5.7-mi) automated highway that would provide a direct link between Blacksburg and I-81.

Site Description

Interstate 81 is a major north-south interstate corridor that links Canada in the north to the southeastern United States in the south through the states of New York, Pennsylvania, Maryland, Virginia, and Tennessee. In Virginia, I-81 is classified as a rural freeway, with four lanes throughout. The portion of I-81 that incorporates the study site traverses the rugged terrain of southwestern Virginia. This section was constructed in the early to mid-1960s and was designed to carry 6 percent large trucks. Today, of the 40,000 vehicles that travel this section daily, approximately 25 percent are large trucks.

Figure 10 depicts I-81 through Botetourt, Roanoke, and Montgomery counties. The analysis site is bounded by U.S. Route 460 (south end) and U.S. Route 220 (north end). On two short stretches near Christiansburg, a climbing lane is provided to compensate for steep grades (+4%). Southbound, heavy trucks are also restricted from traveling in the inside lane on these sections.

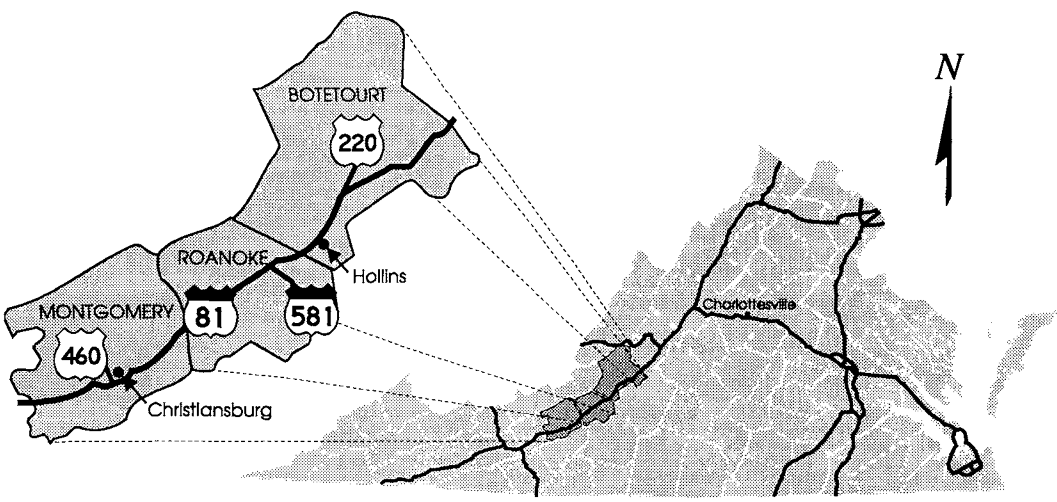

Figure 10. Location of study site

Data Requirements and Categories

Requirements

EVFS was designed to evaluate highway sections by direction. Analysis sections are generally not greater than 8 km (5 mi) long. Longer sections are permitted if characteristics are similar throughout. To meet these conditions, the I-81 test site was subdivided into 15 sections: 8 southbound and 7 northbound. A description of each section is provided in Appendix D. To evaluate the 50.7-km (31.5-mi) corridor, a weighted average BCR and a total NPW, based on the length of each subsection, were determined from the results.

Five general categories and 57 input parameters are used to conduct Level 2 analyses. The majority of the data required was made available by various divisions in VDOT or, if not attainable, were developed from other sources. A compilation of the data collected for each of the 15 sections is presented in Appendix E. Values are based on 1995 costs and conditions.

Categories

Five categories of data were collected to perform Level 2 analyses:

1. general site information

2. traffic characteristics

3. other factors

4. facility construction and 4R work cost

5. value-of-time and accident costs.

General Site Information (Items 1-11)

Items 1 and 2 are related to classification and the number of lanes that allow both passenger vehicles and trucks. Items 3-7 are used to specify future conditions with regard to light and heavy vehicle restrictions. Items 8-11 describe geometric characteristics (length, number of interchanges, grade, and curvature). The average road gradient and average curvature were determined by calculating the weighted average of the horizontal and vertical curvature of the road as shown on VDOT highway construction plan and profile sheets.

Traffic Characteristics (Items 12-25)

Items 12-17 are related to present and future traffic conditions. The ADT for 1995 and average annual increase in ADT were estimated through trend analysis. These values assume an even split between northbound and southbound traffic and that the Smart Road and I-73 will not be open to through traffic within the next 10 years. Current peak and off-peak volumes were estimated by applying average peak and off-peak ratios from 24-hour counts taken south of the study site in July and August 1995. This ratio was assumed unchanged in estimating future peak and off-peak volumes. Items 18-19 list the speed limit for light and heavy vehicles. Items 20-25 concern the percentage of vehicles by classification, current and in the future. The percentage of LV, SU, and CV was obtained from *VDOT's 1990 Average Daily Traffic Volumes on Interstate, Arterial, and Primary Routes,* which was the last edition in which classification counts were recorded. Between 1980 and 1990, the data reflect insignificant fluctuations in the mix percentages, which is the rationale for holding the projected mix percentages constant.

Other Factors (Items 26-28)

Items 26-27 are required for an economic analysis. Item 26 is the number of years of the analysis period. Twenty years was used because it is a reasonable period to evaluate the performance of significant highway improvements. Construction time period (Item 27) was estimated based on the length of the section and number of structures that would need to be widened. The program requires that a minimum period of 1 year be used. The period of construction may be shortened or lengthened depending on seasonal variations and incentive/ disincentive clauses in the contract. Item 28 is the discount rate.

Facility Construction and 4R Work Cost (Items 29-42)

Items 29-35 concern construction cost. In this analysis, base cases of three and four lanes in one direction were assumed since the desire was to evaluate exclusive lane alternatives with respect to three and four travel lanes with no restrictions. Therefore, it was not appropriate to include construction and right-of-way costs related to lane widening since they have theoretically been committed. Typically, the decision to widen a facility is based on highway capacity and level of service, not benefit-cost analyses. Only costs directly related to the implementation of specific exclusive lane alternatives need to be included (e.g., barrier separation, additional pavement markings and signing, special interchange designs). In some instances, one might want a benefit-cost analysis relative to existing conditions (in this case, two lanes in one direction), in which case construction and right-of-way costs for lane widening should be included.

Items 36-42 concern pavement design factors. Pavement serviceability index (PSI) parameters *delta* and *beta*, and minimum allowable PSI, influence the shape of PSI deterioration curves used to predict the frequency of pavement resurfacing. The program default values for these variables were used in the analysis. Although VDOT does not use PSI to determine when resurfacing should occur, a PSI of 2.5 was estimated to correspond with the threshold condition at which pavement resurfacing is typically desired. Equivalent single-axle loading (ESAL) values for SU and CV were taken from a study by Sadek, Freeman, and Demetsky.[19] The program default value for ESALs was used for LV.

Value-of-Time and Accident Costs (Items 43-57)

Items 43-57 relate to values required in an economic analysis: value-of-time (Items 43-45), accident rates (Items 46-48), accident costs (Items 49-51), and accident delay (Items 52-57). Values for LV, SU, and CV value-of-time were obtained by updating the default values to 1995 dollars using the Consumer Price Index (CPI). CPI indices for 1970 through 1995 are presented in Appendix F.

Crash rates for the three vehicle classification types were calculated from VDOT crash summary statistics for 1992 through 1994. Fatal, injury, and property damage only (PDO) crash costs were obtained from VDOT's 1995 study *Justifying a Safety Service Patrol in the Fredericksburg District* that provided these estimates for I-95.[20] The fatal crash cost of $2,450,000 used in the analysis is lower than the 1994 comprehensive cost estimate of $2,890,000 recommended by the National Safety Council for use in benefit-cost analyses.[21]

The percentage of crashes blocking none, one, and two lanes and the average minutes to clear truck and nontruck involvements were obtained from VDOT's 1995 study *Justifying a Safety Service Patrol in the Salem District.*[22] Last, maximum queue length before diversion (Item 57) is the maximum distance between an incident and the nearest upstream interchange or opportunity to divert traffic to other routes.

Program Updating

The Level 1 and 2 analysis formats reference six tables that provide vehicle operating costs in 1985 dollars and also apply the 1985 *HCM* method in computing results. Therefore, before the analysis could be conducted, the program had to be updated. Using the CPI index (Appendix F), the vehicle operating cost tables were converted to 1995 dollars and revised in the program through the system's DOS editor.

Impedance is a function of a highway section's free-flow travel, as well as its capacity, and is one of the factors used by the program to calculate travel times. Lane capacities are calculated in the program according to the 1985 *HCM.* The formula for capacity is:

$$c = 2{,}000(W)(T_{SU})(T_{CV})$$

where

c = lane capacity (in vehicles per lane-hour)

W = lane width and clearance adjustment factor

T_{SU} = truck adjustment factor for single-unit vehicles

T_{CV} = truck adjustment factor for combination vehicles.

In 1994, the *HCM* was revised. One of the revisions was to increase the equivalent lane capacity from 2,000 passenger vehicles per hour per lane (pcphpl) to 2,200 pcphpl for four-lane freeways and 2,300 pcphpl for six-lane freeways. This change theoretically increases the capacity on any given freeway segment. With respect to EVFS, the effect of this change would be to lower the values for NPW and BCR. It is not known if this effect would be statistically significant. A revision of EVFS was contemplated but was not pursued because the objectives of this research could be accomplished without expending the significant effort needed to incorporate the 1994 *HCM* method.

Analysis and Results

EVFS Analysis Outputs

Using EVFS to analyze a given section of highway is relatively simple, once all required data are compiled. Data are input through a Lotus 123 spreadsheet user interface. A short series of commands execute the program and generate an output. The program produces two reports: *Benefit/Cost Summary* and *Statistics Summary.* Samples of each are shown in Appendix G.

The Benefit/Cost Summary provides the estimated BCR and NPW (both with and without vehicle operating cost) for the lane strategy being analyzed. In addition, computed costs and benefits are summarized under the headings *Cost Summary* and *Benefit Summary.* Under Cost Summary, net estimated resurfacing, vehicle operation, construction, and right-of-way costs are listed. Under Benefit Summary, net estimated travel time, accident, and accident delay costs are shown. The sums of the costs and benefits are then used by the program to determine BCR and NPW.

The Statistics Summary provides the net difference in total VMT, total accidents, average accident cost, average delay cost, and average travel speed between the base case and the alternative case being investigated. General site information, including the exclusive lane strategy being analyzed, is also listed in this report.

Summary of Results

The EVFS analysis format can be used to analyze many exclusive lane configurations. For I-81, 10 were considered: 4 for three-lane sections and 6 for four-lane sections.

Three-lane sections:

1. 2 unrestricted lanes (UL), 1 light vehicle lane (LVL)

2. 1 UL, 2 LVL

3. 2 LVL, 1 heavy vehicle lane (HVL)

4. 2 LVL, 1 HVL (barrier separated [Bar.]).

Four-lane sections:

1. 3 UL, 1 LVL

2. 2 UL, 2 LVL

3. 1 UL, 3 LVL

4. 3 LVL, 1 HVL

5. 2 LVL, 2 HVL

6. 2 LVL, 2 HVL (Bar.).

Other lane combinations exist, such as 1 LVL, 2 HVL (Bar.) and 1 LVL, 3 HVL but were not analyzed because they were considered unlikely to produce favorable results. Strategies that designate any combination of unrestricted and heavy vehicle lanes are not considered valid options in EVFS and, therefore, could not be analyzed.

The EVFS model is not designed to analyze highway sections in which lane restrictions are in effect. On Sections 6 and 8 of the study site, trucks are restricted from traveling in the inside lane of these three-lane sections. To analyze alternative strategies for each section, it was assumed that three unrestricted lanes were available.

BCR Results

The objective in applying EVFS is to determine which lane strategy is the most cost-effective. One economic measure computed in the model is BCR. BCR for a particular alternative is the proportion of the total estimated savings divided by the total estimated costs relative to existing conditions. A BCR equal to 1.0 indicates that the net incremental benefits are equal to the net incremental costs at a stated rate-of-return. A value of 1.0 is break-even. Accordingly, for values less than 1.0, net costs outweigh net benefits, and for values greater than 1.0, net benefits outweigh net costs. Table 7 presents the corresponding BCRs for the 10 alternatives considered in this study. The BCRs are given with respect to the base cases, which for the purpose of this study were assumed to be three- and four-lane sections in which no lane restrictions are imposed.

Table 7. BCR for alternative exclusive lane strategies by section

		3-Lane Sections				4-Lane Sections					
Dir.	Sect.	2 UL, 1 LVL	1 UL, 2 LVL	2 LVL, 1 HVL	2 LVL, 1 HVL (Bar. Separated)	3 UL, 1 LVL	2 UL, 2 LVL	1 UL, 3 LVL	3 LVL, 1 HVL	2 LVL, 2 HVL	2 LVL, 2 HVL (Bar. Separated)
SOUTHBOUND	1	0.514	0.640	1.421	1.242	0.517	0.524	0.682	0.930	2.413	0.638
	2	0.489	0.443	1.189	1.033	0.286	0.410	0.478	0.760	2.367	0.522
	3	1.396	0.977	1.680	1.362	0.873	1.201	1.119	1.118	4.436	0.712
	4	0.998	1.483	2.319	1.878	1.150	1.076	- -1	1.518	3.593	0.957
	5	1.658	1.221	1.947	1.663	0.948	1.371	- -1	1.275	4.680	0.892
	6	3.847	2.782	3.105	3.679	1.321	2.444	2.350	1.887	5.902	1.825
	7	3.098	2.213	2.515	2.784	1.065	1.961	1.820	1.524	4.781	2.212
	8	7.474	5.441	6.089	5.544	2.566	4.753	4.345	3.703	11.580	2.755
NORTHBOUND	9	3.242	2.473	2.909	3.232	1.112	2.074	0.546	1.768	5.529	1.604
	10	1.943	1.421	1.636	1.939	0.667	1.235	0.853	0.994	3.109	0.961
	11	3.112	2.234	3.359	2.851	1.782	2.558	- -1	2.200	8.081	1.531
	12	1.112	1.630	2.497	2.022	1.282	1.195	- -1	1.634	3.870	1.032
	13	3.002	2.060	3.375	2.905	1.883	2.577	2.248	2.245	8.939	1.537
	14	1.562	1.371	3.199	2.424	0.914	1.298	1.411	2.036	6.423	1.236
	15	1.260	1.560	3.302	2.893	1.270	1.284	1.637	2.160	5.633	1.495

UL = unrestricted lane; LVL = light vehicle lane; HVL = heavy vehicle lane.

[1] No values could be produced for these sections through the EVFS analysis format because of an apparent glitch in the program.

BCRs for Three-Lane Sections. In the southbound direction, for alternatives that use three lanes, BCRs greater than 1.0 were determined for many strategies. For Sections 1-5, the strategy 2 LVL, 1 HVL produced the best BCRs. For Sections 6-8, the strategy 2 UL, 1 LVL produced the best BCRs. BCRs for the northbound sections were slightly more favorable than those for the southbound sections. Every northbound alternative analyzed had a BCR greater than 1.0. For Sections 9 and 10, the strategy 2 UL, 1 LVL had the best BCRs among northbound alternatives. For Sections 11-15, the strategy 2 LVL, 1 HVL had the best BCRs.

BCRs for Four-Lane Sections. These results were more variable. In both the northbound and southbound directions, the strategy 2 LVL, 2 HVL had significantly higher BCRs than other alternatives. For the strategy 1 UL, 3 LVL, no results could be calculated for Sections 4, 5, 11, and 12. When attempting this analysis, the program displayed the message "Overflow in module LEVEL2 at address 18A3:1CDE." The reason for this message and its meaning are unknown, but when new values for vehicle mix percentage were substituted for the actual values, outputs were generated. Substituting for other input variables had no effect.

Overall, for each of the 10 strategies analyzed (with the exception of 2 LVL, 2 HVL [Bar.]), BCRs were best for Sections 6 and 8, probably because of their steep grades.

Variability in BCRs. Another way to consider these results would be to examine the profile formed by plotting the BCR for each strategy over the length of the study site. Figures 11 through 14 show how BCR varies by milepost for alternatives that use three and four lanes.

In the southbound direction, as demonstrated in Figures 11 and 12, the BCRs for each alternative trend upward from milepost 150 to milepost 118. This might be explained in part by an increase in the horizontal and vertical curvature in this direction. Also, the results for the various alternatives tend to mirror one another. For adjacent sections, an increase or decrease in BCR for one alternative is usually reflected by a similar change in another alternative. In some instances, for reasons that are not apparent, the change is opposite that for other alternatives. For example, in Figure 11, the BCR for the strategy 2 UL, 1 LVL is less than for adjacent sections, whereas other alternatives have higher BCRs relative to adjacent sections.

In Figures 13 and 14, BCRs are seen to increase and decrease alternatively over the length of the study site. With the exception of a few alternatives, changes in one alternative over the 50.7-km (31.5-mi) segment are usually reflected by similar changes in other alternatives.

When exclusive lane strategies are being considered for a highway corridor, it is generally recommended that only a single strategy be used, rather than a combination of strategies, for several reasons. First, it may be difficult if not impossible to connect or transition different lane strategies safely. Second, the use of several lane strategies within a corridor would be confusing to most drivers. Therefore, to determine which single strategy will generate the greatest rate of return, one could take a weighted average of the BCRs over the entire length of the corridor

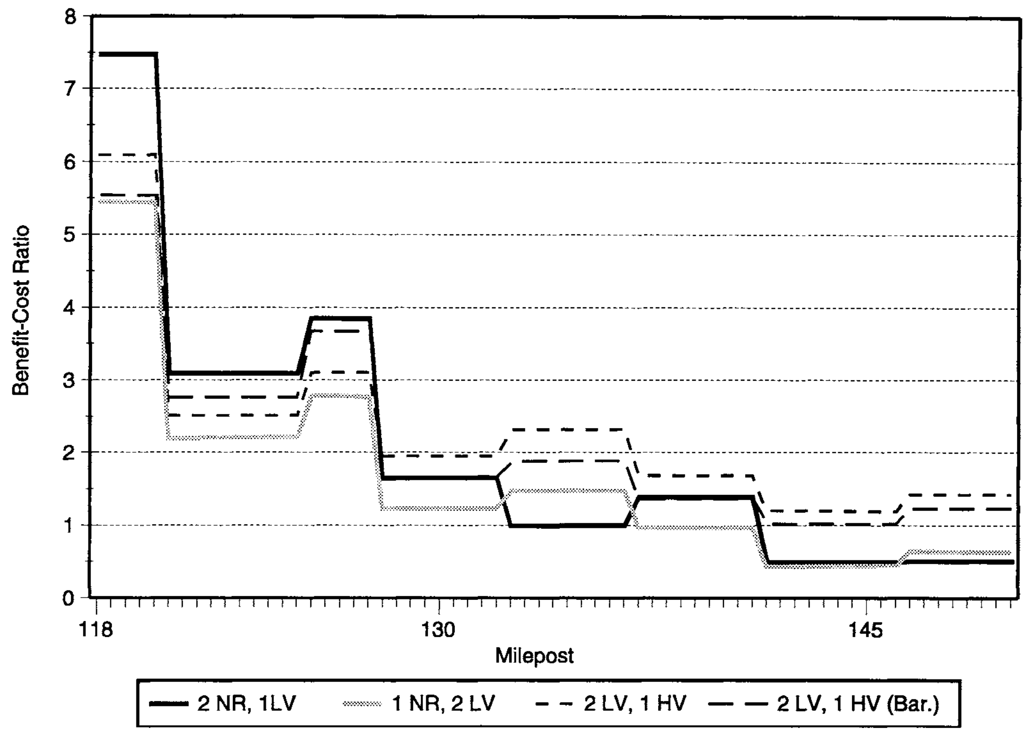

Figure 11. BCR by milepost for three-lane sections (southbound)

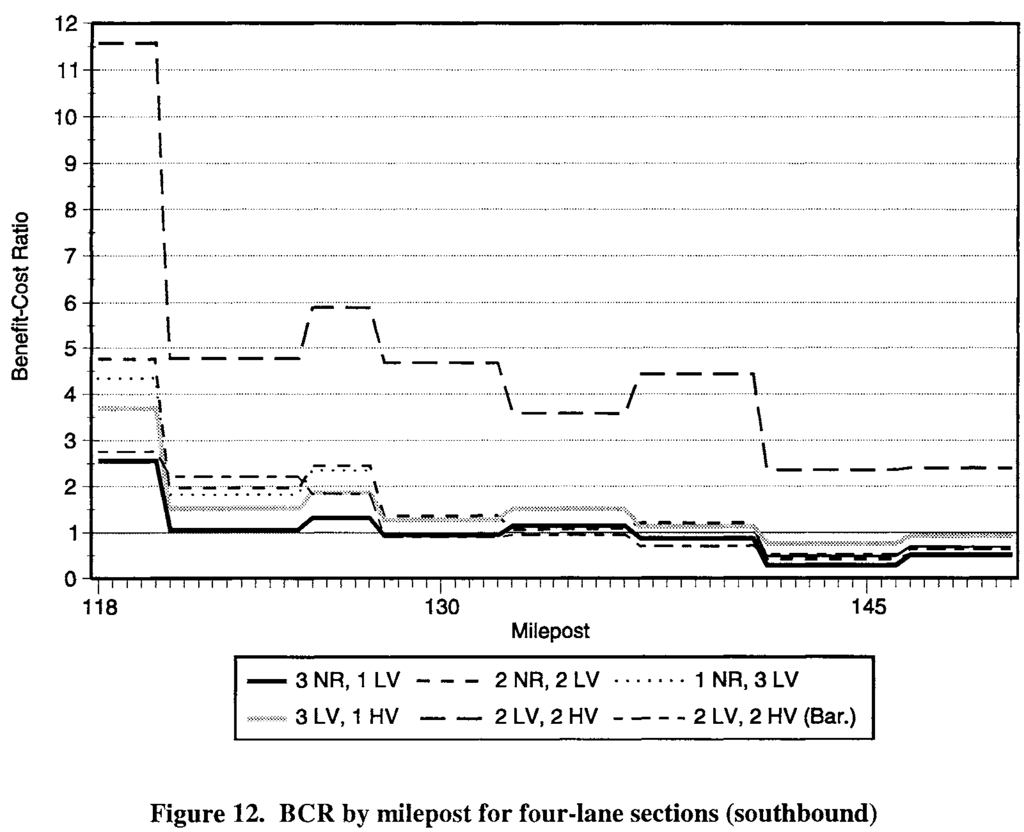

Figure 12. BCR by milepost for four-lane sections (southbound)

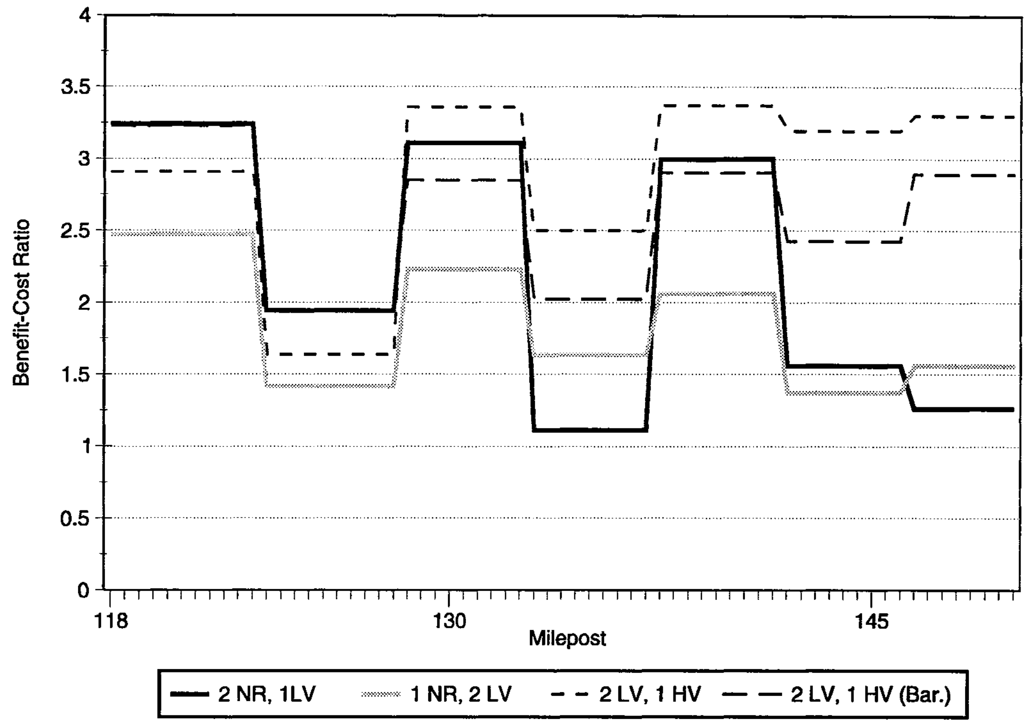

Figure 13. BCR by milepost for three-lane sections (northbound)

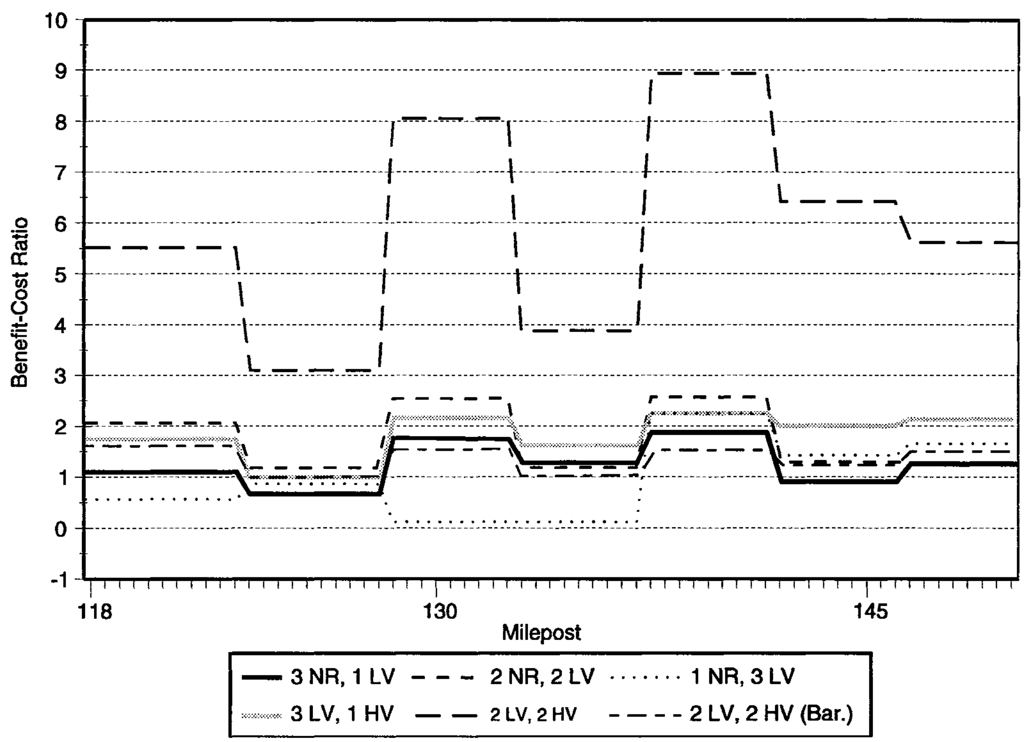

Figure 14. BCR by milepost for four-lane sections (northbound)

Table 8. Weighted average of BCRs by direction

Strategy	Southbound (Sections 1-8)	Northbound (Sections 9-15)
2 UL, 1 LVL	2.069	2.186
1 UL, 2 LVL	1.605	1.817
2 LVL, 1 HVL	2.252	2.868
2 LVL, 1 HVL (Bar.)	2.112	2.590
3 UL, 1 LVL	0.974	1.261
2 UL, 2 LVL	1.468	1.744
1 UL, 3 LVL	1.512	1.326
3 LVL, 1 HVL	1.424	1.842
2 LVL, 2 HVL	4.463	5.903
2 LVL, 2 HVL (Bar.)	1.181	1.331

UL = unrestricted lane; LVL = light vehicle lane; HVL = heavy vehicle lane.

being investigated. Table 8 provides the weighted average BCR by direction for each strategy in the study corridor.

With the exception of the strategy 3 UL, 1 LVL in the southbound direction, the weighted average BCR is greater than 1.0 for all strategies. For three-lane sections, the strategy 2 LVL, 1 HVL produced the highest average BCR in both the southbound and northbound direction. Likewise, for four-lane sections, the strategy 2 LVL, 2 HVL resulted in significantly higher average BCRs in both directions compared with other alternatives.

NPW Results

BCR represents an estimate of the rate of return of an alternative with respect to existing conditions. A more useful economic performance indicator is NPW, which permits economic comparisons between alternatives. NPW provides an estimate of the present worth of the net incremental benefits (or costs) expected to accrue over the life of the project, which for the purpose of this study is 20 years. NPW is found by taking the difference between the present worth of the net incremental benefits and net incremental costs. In cases where costs exceed benefits, a negative value for NPW will be determined. In applying NPW as an evaluation criterion, the project with the greatest NPW is considered the best. However, in evaluating alternative projects, the project with the highest NPW will not necessarily have the highest BCR. Table 9 presents the NPW for the corresponding alternatives investigated for the study site.

Table 9. NPW for various lane strategies by section (in thousands of dollars)

		3-Lane Sections				4-Lane Sections					
Dir.	Sect.	2 UL, 1 LVL	1 UL, 2 LVL	2 LVL, 1 HVL	2 LVL, 1 HVL (Bar. Separated)	3 UL, 1 LVL	2 UL, 2 LVL	1 UL, 3 LVL	3 LVL, 1 HVL	2 LVL, 2 HVL	2 LVL, 2 HVL (Bar. Separated)
SOUTHBOUND	1	-521	-1,311	1,530	1,007	-340	-1,015	-1,767	-388	3,002	-2,912
	2	-405	-2,175	733	146	-639	-1,151	-3,185	-1,467	2,624	-4,162
	3	293	-110	3,178	2,097	-99	355	839	826	6,038	-3,160
	4	-3	2,010	5,492	4,514	121	204	- -1	3,292	6,953	-429
	5	461	928	3,971	3,254	-42	645	- -1	1,762	6,405	-984
	6	1,490	5,774	6,819	7,324	323	2,460	7,188	4,725	8,348	4,542
	7	1,487	5,326	6,651	7,075	88	2,218	5,913	3,816	8,722	6,043
	8	2,405	10,209	11,700	11,473	1,117	4,537	12,641	10,214	12,785	8,913
NORTHBOUND	9	1,704	6,928	8,975	9,444	163	2,656	-3,511	5,937	11,195	5,144
	10	796	2,201	3,325	4,139	-540	644	-1,266	-50	5,791	-348
	11	1,444	5,058	9,667	8,936	618	2,652	- -1	7,507	12,044	4,768
	12	158	2,622	6,234	5,253	228	524	- -1	4,035	7,695	323
	13	1,548	5,183	11,588	10,788	719	2,910	9,154	9,132	14,575	5,731
	14	427	1,389	8,175	6,970	-73	557	2,406	6,065	9,989	2,256
	15	279	2,040	8,372	7,844	190	606	3,542	6,454	9,844	3,965

UL = unrestricted lane; LVL = light vehicle lane; HVL = heavy vehicle lane.

[1]No values could be produced for these sections through the EVFS analysis format because of an apparent glitch in the program.

NPWs for Three-Lane Sections. In the southbound direction, for alternatives that use three lanes, most of the alternatives produced positive NPWs. For Sections 1-5 and 8, the strategy 2 LVL, 1 HVL had the greatest NPW. For Sections 6 and 7, the strategy 2 LVL, 1 HVL (Bar.) resulted in the largest NPW. In the northbound direction, for Sections 9 and 10, the strategy 2 LVL, 1 HVL (Bar.) produced the best results. For Sections 11-13, the strategy 2 LVL, 1 HVL had the largest NPW.

NPWs for Four-Lane Sections. For these alternatives, the strategy 2 LVL, 2 HVL resulted in the greatest NPW for all sections (Sections 1-15). For the strategy 1UL, 3LVL, no results could be calculated for Sections 4, 5, 11, and 12.

Variations in NPW. NPW results can be displayed by plotting the NPW for each strategy over the entire length of the study site. Figures 15 through 18 show the variation in NPW by milepost for three- and four-lane sections. The NPW profiles are similar to those displayed in Figures 11 through 14 for BCRs. The BCR and NPW results appear to be correlated. Although most alternatives produced positive NPWs, in the southbound direction between mileposts 135 and 150, more than half resulted in negative NPWs.

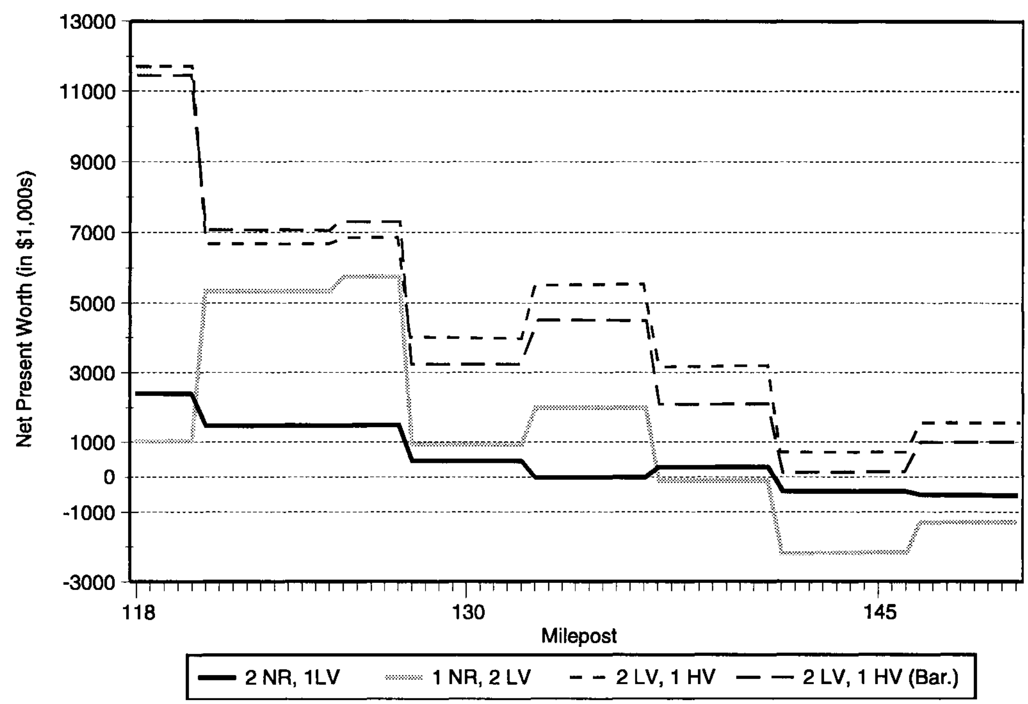

Figure 15. NPW by milepost for three-lane sections (southbound)

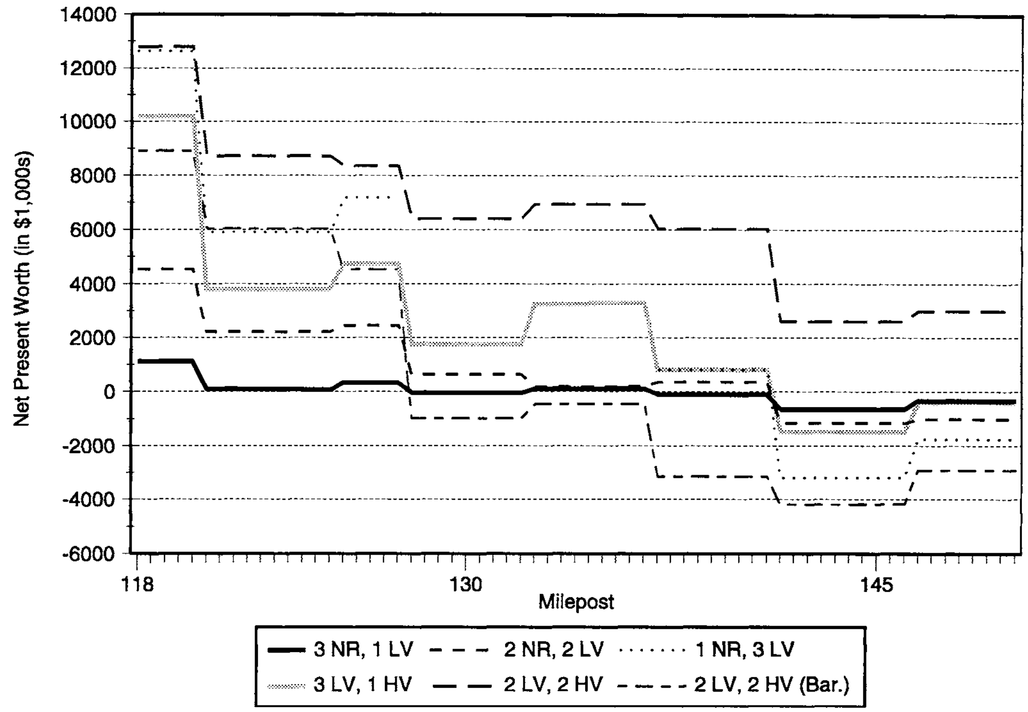

Figure 16. NPW by milepost for four-lane sections (southbound)

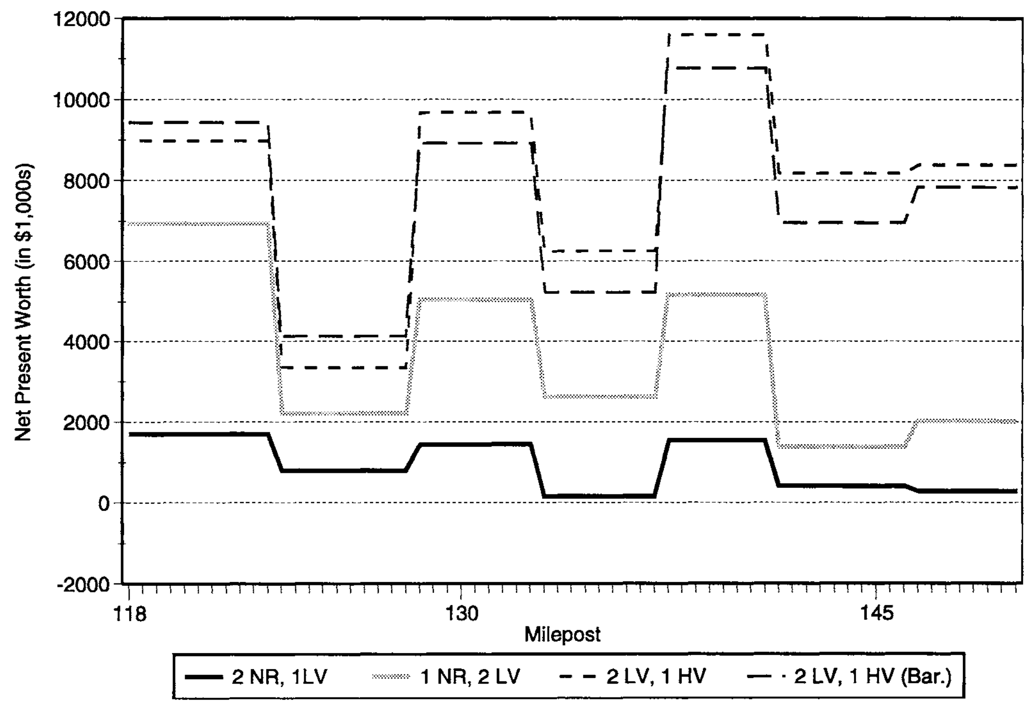

Figure 17. NPW by milepost for three-lane sections (northbound)

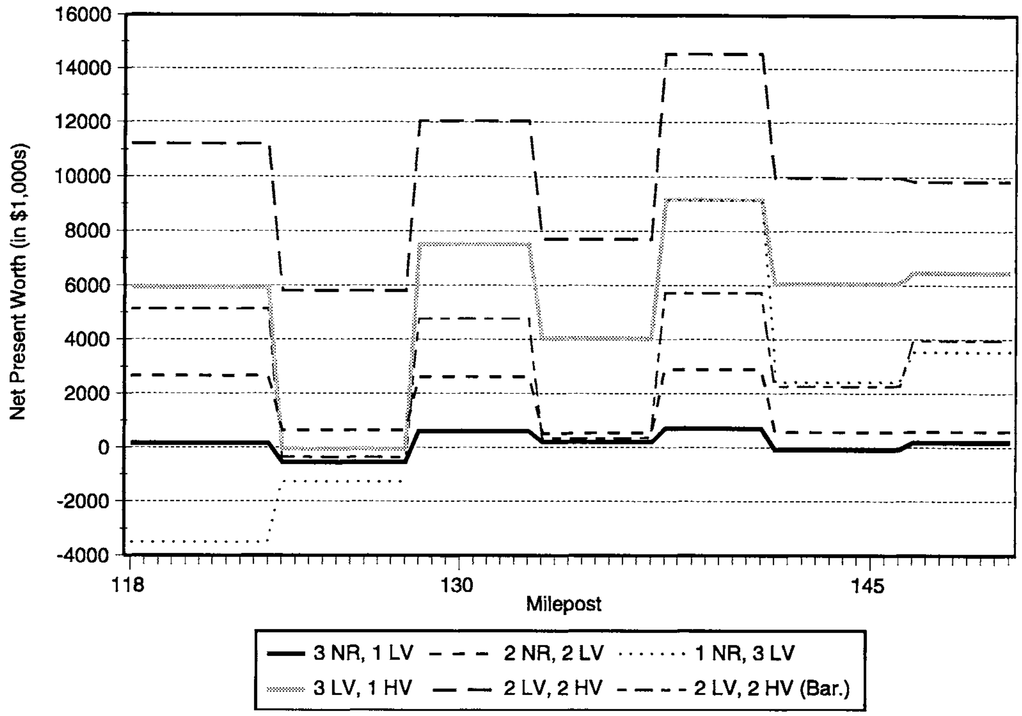

Figure 18. NPW by milepost for four-lane sections (northbound)

Another way to evaluate alternative strategies is to consider the total NPW for each alternative in the southbound and northbound direction. Table 10 shows the total NPW for each alternative. The strategy that is estimated to produce the greatest cost savings is 2 LVL, 2 HVL. Total savings are estimated in excess of $125 million.

CONCLUSIONS

- *BCR and NPW are two of the four basic methods commonly employed in economic evaluations of transportation improvements, the other two being equivalent uniform annual worth and internal rate of return.*[23] *Each method will produce similar results, and the reason for selecting one over the other is typically a matter of convenience or preference concerning how the results will be presented.* The most difficult part in performing an economic evaluation of a transportation system improvement is accounting for all costs and savings that will accrue over the life span of the improvement. Assuming all costs and savings can be known with a satisfactory degree of confidence, calculating the BCR or NPW is a relatively straightforward procedure. The EVFS analysis format facilitates the calculation of these two economic performance measures through the application of prediction models. The reliability of the results is a function of the accuracy of the model and the quality of the data supplied to the program.

Table 10. Total NPW for each strategy by direction (in thousands of dollars)

Strategy	Southbound (Sections 1-8)	Northbound (Sections 9-15)
2 UL, 1 LVL	5,207	6,356
1 UL, 2 LVL	20,651	25,421
2 LVL, 1 HVL	40,074	56,336
2 LVL, 1 HVL (Bar.)	36,890	53,374
3 UL, 1 LVL	529	1,305
2 UL, 2 LVL	8,253	10,549
1 UL, 3 LVL	21,629	10,325
3 LVL, 1 HVL	22,780	39,080
2 LVL, 2 HVL	54,877	71,133
2 LVL, 2 HVL (Bar.)	7,851	21,839

UL = unrestricted lane; LVL = light vehicle lane; HVL = heavy vehicle lane.

- *The EVFS model is a useful analytical tool.* Given the shrinking pool of resources and the demand for greater financial accountability from the public, the importance of using cost analysis in project decision making should not be underestimated. It should also be understood that no economic analysis is perfect, since it is dependent on estimated costs and predictions of future conditions. Nevertheless, cost analysis is a valuable tool when used properly. Despite its shortcomings, EVFS is a valuable analytical tool.

- *The EVFS model does have shortcomings.*

  — One of the main weaknesses in the analysis format concerns the assignment of lane restrictions. The program does not require the analyst to indicate to which lane(s) (i.e., inside, middle, outside) a restriction is to be imposed. Based on the literature, there is strong evidence that the particular lane(s) to which vehicle types are assigned will affect safety, traffic flow, and pavement performance. For example, when truck lane restrictions are imposed, there are distinct advantages and disadvantages relative to whether or not trucks are relegated to travel in the inside or outside lanes. Apparently, the program assumes the best case scenario, although this is not clear.

  — Determination of BCR and NPW for alternatives in which the only physical improvement was the addition of a barrier required some hand calculations because the program was not designed to consider this condition. Another weakness includes the many assumptions that are needed to simplify the many site-specific complexities of a freeway system. Also, the analyst has the ability to influence the results greatly depending on the input values supplied to the program. Therefore, estimates of costs and benefits should be viewed with caution. Relatively small differences between alternative cases may not be statistically significant. Rather than consider results in absolute terms, the model may be better used simply to rank alternatives.

— The analysis format could be improved in several ways. The Level 1 analysis format, which provides a quick sketch evaluation of a number of alternatives, relies heavily on default values imbedded in the program for computing results. A comparison of the default values with actual input values for I-81 revealed much disparity, thus calling into question the value of the Level 1 format. The program could be improved by providing default values more representative of actual conditions. In addition, models for freeway simulation, route assignment, and elastic demand could be embedded within its framework. This expansion of the analysis format would enable an improved modeling of route diversion alternatives during incidents and of traffic attracted from alternate routes because of additional capacity. Unfortunately, this change would also increase the data collection demands placed upon the user.

- *In the I-81 study site, several alternatives appear to warrant further investigation.* For strategies that use three lanes, the strategies 2 LVL, 1 HVL and 2 LVL, 1 HVL (Bar.) had the greatest NPWs; however the latter strategy should be eliminated from consideration because of operational problems created by a single barrier-separated lane. For strategies that use four lanes, the strategy 2 LVL, 2 HVL clearly produced the most favorable results in terms of NPW.

RECOMMENDATIONS

The EVFS analysis format is primarily intended for use by transportation planners to provide additional information to decision makers concerning the overall feasibility of various exclusive lane strategies. This research has shown EVFS to be a useful analytical tool in this respect. With this in mind, the following general recommendations and guidelines are offered:

General Recommendations

- *For interstate facilities being considered for widening and/or for which problems related to heavy vehicle travel exist, investigate the economic feasibility of exclusive lane alternatives by incorporating the EVFS methodology into the planning process.*

- *On I-81, construct exclusive lanes for passenger vehicles and trucks as part of a pilot study.* If three lanes are available, 2 LVL, 1 HVL should be tested. For four available lanes, 2 LVL, 2 HVL should be tested. Data should be collected before and after implementation to assess the effects of the strategy on safety, traffic operations, and pavement performance. If possible, actual benefits and costs should be compared with the results generated by the model to assess its reliability.

- *Develop a user's manual to assist analysts in applying the model.*
- *Improve data collection efforts,* particularly with respect to volumes and vehicle mix percentages and delays caused by incidents, among other data needed to apply the EVFS model.

Recommended Guidelines

- Use EVFS only for analyzing controlled-access facilities.
- Ensure that a minimum of three lanes are available to implement exclusive lane alternatives.
- Use EVFS to perform an analysis in only one direction.
- Use EVFS only for site-specific analysis. Analysis sections should not normally exceed ? km (5 mi), though longer sections can be evaluated by combining the results from shorter sections.
- Ensure that the most accurate data available are being used, as the reliability of the results is a direct function of the accuracy of the data used.
- Do not use EVFS to determine the need to add a lane(s).
- Since EVFS is designed to estimate the economic performance of various exclusive lane strategies, in deciding whether to implement a particular exclusive lane alternative, consider other factors such as the operational and geometric implications of a particular strategy.
- Consider a variety of alternatives in any EVFS feasibility analysis.

FUTURE RESEARCH NEEDS

EVFs are presumed to improve safety, traffic operations, and pavement performance, particularly on heavily traveled truck corridors. However, there is little actual experience to support many of the apparent benefits of this strategy. Given the potential benefits, additional research is needed and justified.

Further research is needed in the following areas:

- the effects of assigning large trucks to the inside or outside lanes on level of service and the requirements for the use of barriers

- the effects on safety of concentrating large volumes of trucks traveling at high speeds in restricted lanes or roadways

- the differential design of pavements on six-lane highways.

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APPENDIX A

QUESTIONNAIRE:
EXCLUSIVE FREEWAY LANES FOR HEAVY VEHICLES

Questionnaire
Exclusive Freeway Lanes for Heavy Vehicles
August 1995

The Virginia Transportation Research Council and the University of Virginia are conducting a study of the potential benefits of exclusive highway facilities for cars and trucks. In order to better understand the feasibility of this approach we are attempting to determine practical experiences of other states. We would appreciate it if you could answer the following questions concerning your state's experiences.

Shortly after you receive this survey we will be calling you to answer any questions you may have and to obtain responses to these questions. This survey is provided to give you an opportunity to consider the issues raised. Thank you again for your help.

1. How does your state define a "heavy vehicle" for purposes of truck lane restrictions?

___

___

2. Does your state currently restrict heavy vehicles from using specific lane(s) on interstate highways (i.e., Do you have exclusive passenger vehicle lanes)?

___ Yes ___ No

If yes, are these restrictions mandatory or voluntary? ___

What is the compliance experience?

___ High ___ Medium ___ Low ___ Don't know

What is the primary purpose of these restrictions?

___ Improve traffic operations ___ Increase Safety
___ Reduce pavement deterioration ___ Other

3. If the answer to question 2 is yes, please answer the following:

Are the restrictions: ___ Statewide ___ Site specific

If site-specific, please provide the location(s) and approximate length(s):

___

___

Are lane restrictions in the : ___ Left lane(s) ___ Right lanes(s)

4. Does your state currently restrict heavy vehicles **from** using specific interstate (freeway) routes?

___ Yes ___ No

If yes, which route(s)?

____

____

Why are these restrictions imposed? ___ Improve traffic operations

___ Increase safety ___ Reduce pavement deterioration ___ Other

5. Does your state designate specific freeway truck routes?

___ Yes ___ No

If yes, please specify which route(s)?

____

____

Are they exclusively for trucks? ___ Yes ___ No

6. Does your state provide exclusive lanes for trucks?

___ Yes ___ No

If yes, which lane(s)? ___ Left lanes(s) ___ Right lane(s)

Please specify freeway name and location:

____

____

Why were these exclusive lanes provided? ___ Improve traffic operations
___ Increase safety ___ Reduce pavement deterioration ___ Other

7. Does your state impose time of day restrictions for trucks on any freeway lanes?

___ Yes ___ No

If yes, for each facility please describe what restrictions are in place:

____

____

8. Does your state have separate speed limits for passenger vehicles and trucks?

___ Yes __ No

If yes, where are these applied?

____

____

What is the speed limit for cars? ______

What is the speed limit for trucks? ______

Why were different limits established?

___ Increase safety ___ Improve highway operations ___ Other

Are any changes in legislation expected?

____

9. Do you have any data or experience regarding the success of truck or passenger vehicle restrictions in your state?

____

____

____

10. Do you have any additional comments concerning your state's experience with strategies for dealing with heavy and light vehicles?

____

____

____

____

____

Thank you very much for your time and assistance in completing this survey. If we can be of assistance, please contact Joe Vidunas or Heather Wishart at:

Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903
Phone: (804) 293-1903
Fax: (804) 293-1990

Would you like a copy of the final report? ___ Yes ___ No

APPENDIX B

LEVEL 1 AND LEVEL 2 DATA INPUT PARAMETERS

Level 1 Sketch Analysis Inputs

General Site Characteristics:

1. Is this a rural, suburban, or urban highway section?	R/S/U
2. What is the approximate length of this section in miles?	
3. How many interchanges are located along this section?	
4. How many lanes are there currently in each direction?	(1-4)
5. How many lanes are to be added in each direction?	(1-4)
6. Number of new lanes of right-of-way to acquire?	(0-4)
7. Current average daily traffic (ADT) (one direction)?	
8. Average annual increase in ADT (one direction)?	
9. Current heavy vehicle percentage of total ADT in 10 years?	
10. Heavy vehicle percentage of total ADT in 10 years?	
11. Length of the analysis period (number of years)?	
12. Present value discount rate?	

Level 2 Detailed Analysis Inputs

General Site Information:

1. Is this a rural, suburban, or urban highway section R/S/U?
2. Current mixed-vehicle lanes in each direction (0-6)?
3. Future mixed-vehicle lanes in each direction (0-6)?
4. Future light-vehicle lanes in each direction (0-6)?
5. Future heavy-vehicle lanes in each direction (0-4)?
6. Number of new lanes of right-of-way to acquire (0-4)?
7. Will exclusive vehicle lanes be barrier separated (Y/N)?
8. Length of section in miles (including decimal places)?
9. Number of interchanges along this section?
10. Average road gradient along section (typical value = 0%)?
11. Average curvature along section (typical value = 2 deg.)?

Traffic Characteristics:	**Defaults:**
12. Current average daily traffic (ADT) (one direction)?	
13. Average annual increase in ADT (one direction)?	
14. Current peak-period volume/hr (3 hours/day)?	(calculated)
15. Future peak-period volume/hr in 10 years?	(calculated)
16. Current off-peak volume/hr (15 hours/day)?	(calculated)
17. Future off-peak volume/hr in 10 years?	(calculated)
18. Speed limit for LV along this section (mph)?	65
19. Speed limit for SU and CV along this section (mph)?	55
20. Current LV percentage of total ADT?	(calculated)
21. Future LV percentage of ADT in 10 years?	(calculated)
22. Current SU percentage of total ADT?	(calculated)
23. Future SU percentage of total ADT in 10 years?	(calculated)
24. Current CV percentage of total ADT?	(calculated)
25. Future CV percentage of ADT in 10 years?	(calculated)

ADT - Average Daily Traffic
LV - Light Vehicle
SU - Single-Unit Vehicle
CV - Combination Vehicle

Other Factors:

26. Length of the analysis period (number of years)?
27. How many years of this period are construction?
28. Present value discount rate?

Facility Construction and 4R Work Cost (in 10^3 dollars):	**Defaults:**
29. Construction cost per lane mile (unseparated)?	$ 1,900
30. Construction cost per interchange (unseparated)?	$ 500
31. Right-of-way acquisition cost/mile (unseparated)?	$ 810
32. Construction cost per lane mile (w/barriers)?	$ 2,660
33. Construction cost per interchange (w/barriers)?	$ 700
34. Right-of-way acquisition cost/mile (w/barriers)?	$ 1,134
35. Average cost per lane mile for major resurfacing?	$ 108
36. PSI parameter (delta) (in million 18-kip ESALs)?	2.0
37. PSI parameter (beta) used as the power exponent?	1.2
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5
39. PSI at which resurfacing is desired (0-5 scale)?	2.5
40. Average ESALs per light vehicle?	0.0003
41. Average ESALs per single-unit vehicle?	0.06
42. Average ESALs per combination vehicle?	1.5

PSI - Pavement Serviceabilty Index
ESAL - Equivalent Single Axle Loads

Value-of-Time and Accident Costs (in dollars):	**Defaults:**
43. Light vehicle value-of-time per hour?	$ 5.00
44. Single-unit vehicle value-of-time per hour?	$ 10.00
45. Combination vehicle value-of-time per hour?	$ 15.00
46. Light vehicle accident rate per LV MVM?	0.986
47. Single-unit vehicle accident rate per SU MVM?	1.697
48. Combination vehicle accident rate per CV MVM?	1.555
49. Accident costs per fatality accident?	$226,800
50. Accident costs per injury accident?	$ 9,288
51. Accident costs per PDO accident?	$ 1,242
52. Percent of total accidents blocking no lanes?	59%
53. Percent of total accidents blocking one lane?	28%
54. Percent of total accidents blocking two lanes?	13%
55. Average minutes to clear non-truck involvements?	39
56. Average minutes to clear truck involvements?	63
57. Maximum queue length before diversion (miles)?	3.0

MVM - Million Vehicle Miles
PDO - Property Damage Only

APPENDIX C

DATA INPUTS FOR HYPOTHETICAL SCENARIOS A, B, & C

LOCATION: SCENARIO A

DETAILED ANALYSIS INPUTS - LEVEL 2

General Site Information:

1. Is this a rural, suburban, or urban highway section?	R/S/U	R
2. Current mixed-vehicle lanes in each direction?	(1-6)	3
3. Future mixed-vehicle lanes in each direction?	(0-6)	0
4. Future light-vehicle lanes in each direction?	(0-4)	2
5. Future heavy-vehicle lanes in each direction?	(0-4)	2
6. Number of new lanes of right-of-way to acquire?	(0-4)	1
7. Will exclusive vehicle lanes be barrier-separated?	(Y/N)	Y
8. Section length in miles (including decimal places)?		30.0
9. Number of interchanges along this section?		7
10. Average road gradient along section (typical value = 0%)?		0%
11. Average curvature along section (typical value = 2 deg.)?		2

DETAILED ANALYSIS INPUTS - LEVEL 2

Traffic Characteristics:

	Defaults	
12. Current average daily traffic (ADT) (one direction)?		80000
13. Average annual increase in ADT (one direction)?		3000
14. Current peak-period volume/hr (3 hours/day)?	6667	0
15. Future peak-period volume/hr in 10 years?	9167	0
16. Current off-peak volume/hr (15 hours/day)?	4000	0
17. Future off-peak volume/hr in 10 years?	5500	0
18. Speed limit for LV along this section (mph)?	65	65
19. Speed limit for SU and CV along this section (mph)?	55	65
20. Current LV percent of total ADT?	64.2%	70.0%
21. Future LV percentage of total ADT in 10 years?	56.3%	65.0%
22. Current SU percent of total ADT?	28.6%	8.0%
23. Future SU percentage of ADT in 10 years?	35.8%	9.0%
24. Current CV percent of total ADT?	7.2%	22.0%
25. Future CV percentage of ADT in 10 years?	7.9%	26.0%

ADT - Average Daily Traffic   SU - Single-Unit Vehicle
LV - Light Vehicle   CV - Combination Vehicle   Press Enter

DETAILED ANALYSIS INPUTS - LEVEL 2

Other Factors:

26. Length of the analysis period (number of years)?	20

27. How many years of this period are construction?	3
28. Present value discount rate?	10.0%

DETAILED ANALYSIS INPUTS - LEVEL 2

Facility Construction and 4R Work Cost (in 1000 dollars):

	Defaults	
29. Construction cost per lane mile (unseparated)?	$1,500	$1,500
30. Construction cost per interchange (unseparated)?	$400	$450
31. Right-of-way acquisition cost/mile (unseparated)?	$390	$400
32. Construction cost per lane mile (w/barriers)?	$2,100	$2,050
33. Construction cost per interchange (w/barriers)?	$560	$560
34. Right-of-way acquisition cost/mile (w/barriers)?	$546	$600
35. Average cost per lane mile for major resurfacing?	$108	$110
36. PSI parameter (delta) (in million 18-kip ESALs)?	2.0	0
37. PSI parameter (beta) used as the power exponent?	1.2	0
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	0
39. PSI at which resurfacing is desired (0-5 scale)?	2.5	0
40. Average ESALs per light vehicle?	0.0003	0
41. Average ESALs per single-unit vehicle?	0.06	0
42. Average ESALs per combination vehicle?	1.5	0

DETAILED ANALYSIS INPUTS - LEVEL 2

Value of Time and Accident Costs (in dollars):

	Defaults	
43. Light vehicle value-of-time per hour?	$5.00	$0.00
44. Single-unit vehicle value-of-time per hour?	$10.00	$0.00
45. Combination vehicle value-of-time per hour?	$15.00	$0.00
46. Light vehicle accident rate per LV MVM?	0.728	0.950
47. Single-Unit vehicle accident rate per SU MVM?	1.253	1.550
48. Combination vehicle accident rate per CV MVM?	1.148	1.650
49. Accident cost per fatality accident?	$226,800	$225,000
50. Accident cost per injury accident?	$9,288	$10,000
51. Accident cost per PDO accident?	$1,242	$3,500
52. Percent of total accidents blocking no lanes?	59%	60%
53. Percent of total accidents blocking one lane?	28%	25%
54. Percent of total accidents blocking two lanes?	13%	15%
55. Average minutes to clear non-truck involvements?	39	45
56. Average minutes to clear truck involvements?	63	70
57. Maximum queue length before diversion (miles)?	2.1	3.0

LOCATION: SCENARIO B

DETAILED ANALYSIS INPUTS - LEVEL 2

General Site Information:

1. Is this a rural, suburban, or urban highway section?	R/S/U	U
2. Current mixed-vehicle lanes in each direction?	(1-6)	2
3. Future mixed-vehicle lanes in each direction?	(0-6)	2
4. Future light-vehicle lanes in each direction?	(0-4)	1
5. Future heavy-vehicle lanes in each direction?	(0-4)	0
6. Number of new lanes of right-of-way to acquire?	(0-4)	1
7. Will exclusive vehicle lanes be barrier-separated?	(Y/N)	N
8. Section length in miles (including decimal places)?		17.0
9. Number of interchanges along this section?		4
10. Average road gradient along section (typical value = 0%)?	0%	
11. Average curvature along section (typical value = 2 deg.)?	3	

DETAILED ANALYSIS INPUTS - LEVEL 2

Traffic Characteristics:

	Defaults	
12. Current average daily traffic (ADT) (one direction)?		26000
13. Average annual increase in ADT (one direction)?		750
14. Current peak-period volume/hr (3 hours/day)?	2167	0
15. Future peak-period volume/hr in 10 years?	2792	0
16. Current off-peak volume/hr (15 hours/day)?	1300	0
17. Future off-peak volume/hr in 10 years?	1675	0
18. Speed limit for LV along this section (mph)?	65	65
19. Speed limit for SU and CV along this section (mph)?	55	65
20. Current LV percent of total ADT?	75.0%	81.0%
21. Future LV percentage of total ADT in 10 years?	69.7%	77.5%
22. Current SU percent of total ADT?	19.0%	6.0%
23. Future SU percentage of ADT in 10 years?	23.8%	7.5%
24. Current CV percent of total ADT?	6.0%	13.0%
25. Future CV percentage of ADT in 10 years?	6.6%	15.0%

ADT - Average Daily Traffic   SU - Single-Unit Vehicle
LV - Light Vehicle   CV - Combination Vehicle   Press Enter

DETAILED ANALYSIS INPUTS - LEVEL 2

Other Factors:

26. Length of the analysis period (number of years)? 25

27. How many years of this period are construction?	2
28. Present value discount rate?	4.0%

DETAILED ANALYSIS INPUTS - LEVEL 2

Facility Construction and 4R Work Cost (in 1000 dollars):

	Defaults	
29. Construction cost per lane mile (unseparated)?	$2,300	$2,100
30. Construction cost per interchange (unseparated)?	$600	$650
31. Right-of-way acquisition cost/mile (unseparated)?	$420	$800
32. Construction cost per lane mile (w/barriers)?	$3,220	$2,050
33. Construction cost per interchange (w/barriers)?	$840	$700
34. Right-of-way acquisition cost/mile (w/barriers)?	$588	$1,100
35. Average cost per lane mile for major resurfacing?	$108	$95
36. PSI parameter (delta) (in million 18-kip ESALs)?	2.0	0
37. PSI parameter (beta) used as the power exponent?	1.2	0
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	0
39. PSI at which resurfacing is desired (0-5 scale)?	2.5	2.2
40. Average ESALs per light vehicle?	0.0003	0.0004
41. Average ESALs per single-unit vehicle?	0.06	0.05
42. Average ESALs per combination vehicle?	1.5	1.7

DETAILED ANALYSIS INPUTS - LEVEL 2

Value of Time and Accident Costs (in dollars):

	Defaults	
43. Light vehicle value-of-time per hour?	$5.00	$0.00
44. Single-unit vehicle value-of-time per hour?	$10.00	$0.00
45. Combination vehicle value-of-time per hour?	$15.00	$0.00
46. Light vehicle accident rate per LV MVM?	1.318	0.620
47. Single-Unit vehicle accident rate per SU MVM?	2.268	1.100
48. Combination vehicle accident rate per CV MVM?	2.078	1.590
49. Accident cost per fatality accident?	$226,800	$225,000
50. Accident cost per injury accident?	$9,288	$10,000
51. Accident cost per PDO accident?	$1,242	$3,500
52. Percent of total accidents blocking no lanes?	59%	64%
53. Percent of total accidents blocking one lane?	28%	32%
54. Percent of total accidents blocking two lanes?	13%	4%
55. Average minutes to clear non-truck involvements?	39	31
56. Average minutes to clear truck involvements?	63	57
57. Maximum queue length before diversion (miles)?	2.1	1.6

LOCATION: SCENARIO C

DETAILED ANALYSIS INPUTS - LEVEL 2

General Site Information:

1. Is this a rural, suburban, or urban highway section?	R/S/U	S
2. Current mixed-vehicle lanes in each direction?	(1-6)	3
3. Future mixed-vehicle lanes in each direction?	(0-6)	0
4. Future light-vehicle lanes in each direction?	(0-4)	2
5. Future heavy-vehicle lanes in each direction?	(0-4)	2
6. Number of new lanes of right-of-way to acquire?	(0-4)	1
7. Will exclusive vehicle lanes be barrier-separated?	(Y/N)	Y
8. Section length in miles (including decimal places)?		24.2
9. Number of interchanges along this section?		3
10. Average road gradient along section (typical value = 0%)?	1%	
11. Average curvature along section (typical value = 2 deg.)?	1	

DETAILED ANALYSIS INPUTS - LEVEL 2

Traffic Characteristics:

	Defaults	
12. Current average daily traffic (ADT) (one direction)?		47000
13. Average annual increase in ADT (one direction)?		1350
14. Current peak-period volume/hr (3 hours/day)?	3917	0
15. Future peak-period volume/hr in 10 years?	5042	0
16. Current off-peak volume/hr (15 hours/day)?	2350	0
17. Future off-peak volume/hr in 10 years?	3025	0
18. Speed limit for LV along this section (mph)?	65	65
19. Speed limit for SU and CV along this section (mph)?	55	55
20. Current LV percent of total ADT?	69.6%	67.0%
21. Future LV percentage of total ADT in 10 years?	63.0%	63.0%
22. Current SU percent of total ADT?	23.8%	9.0%
23. Future SU percentage of ADT in 10 years?	29.8%	10.0%
24. Current CV percent of total ADT?	6.6%	24.0%
25. Future CV percentage of ADT in 10 years?	7.3%	27.0%

ADT - Average Daily Traffic   SU - Single-Unit Vehicle
LV - Light Vehicle   CV - Combination Vehicle   Press Enter

DETAILED ANALYSIS INPUTS - LEVEL 2

Other Factors:

26. Length of the analysis period (number of years)? 20

27. How many years of this period are construction?		3
28. Present value discount rate?		7.5%

DETAILED ANALYSIS INPUTS - LEVEL 2

Facility Construction and 4R Work Cost (in 1000 dollars):

	Defaults	
29. Construction cost per lane mile (unseparated)?	$1,900	$1,850
30. Construction cost per interchange (unseparated)?	$500	$600
31. Right-of-way acquisition cost/mile (unseparated)?	$405	$550
32. Construction cost per lane mile (w/barriers)?	$2,660	$2,300
33. Construction cost per interchange (w/barriers)?	$700	$750
34. Right-of-way acquisition cost/mile (w/barriers)?	$567	$750
35. Average cost per lane mile for major resurfacing?	$108	$90
36. PSI parameter (delta) (in million 18-kip ESALs)?	2.0	2.2
37. PSI parameter (beta) used as the power exponent?	1.2	1.1
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	1.8
39. PSI at which resurfacing is desired (0-5 scale)?	2.5	2.7
40. Average ESALs per light vehicle?	0.0003	0.0008
41. Average ESALs per single-unit vehicle?	0.06	0.09
42. Average ESALs per combination vehicle?	1.5	1.9

DETAILED ANALYSIS INPUTS - LEVEL 2

Value of Time and Accident Costs (in dollars):

	Defaults	
43. Light vehicle value-of-time per hour?	$5.00	$6.50
44. Single-unit vehicle value-of-time per hour?	$10.00	$12.00
45. Combination vehicle value-of-time per hour?	$15.00	$19.50
46. Light vehicle accident rate per LV MVM?	0.986	1.742
47. Single-Unit vehicle accident rate per SU MVM?	1.697	1.221
48. Combination vehicle accident rate per CV MVM?	1.555	1.259
49. Accident cost per fatality accident?	$226,800	$195,000
50. Accident cost per injury accident?	$9,288	$17,900
51. Accident cost per PDO accident?	$1,242	$3,800
52. Percent of total accidents blocking no lanes?	59%	63%
53. Percent of total accidents blocking one lane?	28%	26%
54. Percent of total accidents blocking two lanes?	13%	11%
55. Average minutes to clear non-truck involvements?	39	29
56. Average minutes to clear truck involvements?	63	67
57. Maximum queue length before diversion (miles)?	4.0	2.2

APPENDIX D

INTERSTATE 81 SECTION DESCRIPTIONS

Southbound I-81				
Section	**Description**	**Exit**	**Milepost**	**Length**
1	Fr: End of Ramp from U.S. Rte. 220 To: End of Ramp from Rte. 815	150 146	150.02 146.35	5.91 km (3.67 mi)
2	Fr: End of Ramp from Rte. 815 To: Beginning of Ramp to Rte. 419	146 141	146.35 141.45	7.89 km (4.90 mi)
3	Fr: Beginning of Ramp to Rte. 419 To: End of Ramp from Rte. 112	141 137	141.45 136.94	7.26 km (4.51 mi)
4	Fr: End Ramp from Rte. 112 To: Beginning of Ramp to Rte. 647	137 132	136.94 132.40	7.31 km (4.54 mi)
5	Fr: Beginning of Ramp to Rte. 647 To: End of Ramp from Rte. 603	132 128	132.40 127.99	7.10 km (4.41 mi)
6	Fr: End of Ramp from Rte. 603 To: Rte. 636 Underpass	128 No Exit	127.99 124.93	4.93 km (3.06 mi)
7	Fr: Rte. 636 Underpass To: Rte. 641 Overpass	No Exit No Exit	124.93 120.74	6.75 km (4.19 mi)
8	Fr: Rte. 641 Overpass To: Beginning of Ramp to U.S. Rte. 11/460	No Exit 118	120.74 118.52	3.57 km (2.22 mi)
Northbound I-81				
9	Fr: End of Ramp from U.S. Rte. 11/460 To: 0.6 Mile North of Rte. 636 Underpass	118 No Exit	118.64 123.17	7.29 km (4.53 mi)
10	Fr: 0.6 Mile North of Rte. 636 Underpass To: Beginning of Ramp to Rte. 603	No Exit 128	123.17 128.17	8.05 km (5.00 mi)
11	Fr: Beginning of Ramp to Rte. 603 To: End of Ramp from Rte. 647	128 132	128.17 132.43	6.86 km (4.26 mi)
12	Fr: End of Ramp from Rte. 647 To: Beginning of Ramp to Rte. 112	132 137	132.43 136.99	7.34 km (4.56 mi)
13	Fr: Beginning of Ramp to Rte. 112 To: End of Ramp from Rte. 419	137 141	136.99 141.67	7.53 km (4.68 mi)
14	Fr: End of Ramp from Rte. 419 To: Beginning of Ramp to Rte. 115	141 146	141.67 146.38	7.58 km (4.71 mi)
15	Fr: Beginning of Ramp to Rte. 115 To: Beginning of Ramp to U.S. Rte. 220	146 150	146.38 150.14	5.91 km (3.76 mi)

APPENDIX E

LEVEL 2 ANALYSIS INPUT DATA

LEVEL 2 ANALYSIS INPUT DATA - I-81 (3-Lane Sections)								
General Site Information	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Rural, suburban, or urban highway R/S/U?	R	R	R	R	R	R	R	R
2.Current mixed-vehicle lanes in each direction (0-6)?	3	3	3	3	3	3	3	3
3. Future mixed-vehicle lanes in each direction (0-6)?								
4. Future light-vehicle lanes in each direction (0-6)?								
5. Future heavy-vehicle lanes in each direction (0-4)?								
6. Number of new lanes of right-of-way to acquire (0-4)?	0	0	0	0	0	0	0	0
7. Will exclusive vehicle lanes be barrier separated? (Y/N)? (y/N)?								
8. Length of section in miles (including decimal places)?	3.67	4.90	4.51	4.54	4.41	3.06	4.19	2.22
9. Number of interchanges along this section?	1	1	3	0	2	0	0	0
10. Ave. road gradient along section (typ. value = 0 %)?	-0.11	-0.01	-0.11	0.62	-0.45	3.40	0.19	2.93
11. Ave. curvature along section (typ. value = 2 deg.)?	0.46	0.37	0.38	0.36	0.88	1.24	0.90	0.65
Traffic Characteristics	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
12. Current ave. daily traffic (ADT) (one direction)?	21,546	24,273	22,970	21,240	20,045	20,000	20,000	20,000
13. Ave. annual increase in ADT (one direction)?	795	663	778	482	545	500	500	500
14. Current peak-period volume/hr. (3 hours/day)?	1,430	1,611	1,524	1,410	1,331	1,328	1,328	1,328
15. Future peak-period volume/hr. in 10 years?	1,959	2,051	2,041	1,746	1,693	1,660	1,660	1,660
16. Current off-peak volume/hr. (15 hours/day)?	1,150	1,296	1,227	1,134	1,070	1,068	1,068	1,068
17. Future off-peak volume/hr. in 10 years?	1,575	1,650	1,642	1,404	1,361	1,335	1,335	1,335
18. Speed limit for LV along this section (mph)?	65	65	65	65	65	65	65	65
19. Speed limit for SU and CV along this section (mph)?	65	65	65	65	65	65	65	65
20. Current LV percentage of total ADT?	78	79.5	75	74	74	69	69	69
21. Future LV percentage of ADT in 10 years?	78	79.5	75	74	74	69	69	69
22. Current SU percentage of total ADT?	2	3.5	4	4	4	5	5	5
23. Future SU percentage of ADT in 10 years?	2	3.5	4	4	4	5	5	5
24. Current CV percentage of total ADT?	20	17	21	22	22	26	26	26
25. Future CV percentage of ADT in 10 years?	20	17	21	22	22	26	26	26
Other Factors	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
26. Length of analysis period (number of years)?	20	20	20	20	20	20	20	20
27. How many years of this period are construction? direction)?	1	1	1	1	1	1	1	1
28. Present value discount rate?	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Facility Construction and 4R Work Cost (in 1000's dollars)	Southbound Sections							
	1	2	3	4	5	6	7	8
29. Construction cost per lane mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0	$0
30. Construction cost per interchange (unseparated)? increase in	$0	$0	$0	$0	$0	$0	$0	$0
31. Right-of-way acquisition cost/mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0	$0
32. Construction cost per lane mile (w/barriers)?	$1,053	$892	$1,285	$1,075	$1,046	$855	$921	$1,137
33. Construction cost per interchange (w/barriers)?	$0	$0	$0	$0	$0	$0	$0	$0
34. Right-of-way acquisition cost/mile (w/barriers)?	$0	$0	$0	$0	$0	$0	$0	$0
35. Ave. cost per lane mile for major resurfacing?	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9
36. PSI parameter (delta) (in million 18-kip ESAL's)?	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
37. PSI parameter (beta) used as the power exponent?	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
39. PSI at which resurfacing is desired (0-5) scale?	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
40. Ave. ESAL's per light vehicle?	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
41. Ave. ESAL's per single-unit vehicle?	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
42. Ave. ESAL's per combination vehicle?	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28

Value-of-Time and Accident Costs (in dollars)	Southbound Sections							
	1	2	3	4	5	6	7	8
43. Light vehicle value-of-time per hour?	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70
44. Single-unit vehicle value-of-time per hour?	14.66	14.66	14.66	14.66	14.66	14.66	14.66	14.66
45. Combination vehicle value-of-time per hour?	20.94	20.94	20.94	20.94	20.94	20.94	20.94	20.94
46. Light vehicle accident rate per LV MVM?	0.525	0.561	0.763	0.404	0.698	0.681	0.715	0.720
47. Single-unit vehicle accident rate per SU MVM?	1.799	1.023	0.762	0.765	0.829	0.306	0.224	0.844
48. Combination vehicle accident rate per CV MVM?	0.191	0.111	0.238	0.365	0.309	0.565	0.455	1.108
49. Accident costs per fatality accident?	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0
50. Accident costs per injury accident?	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862
51. Accident costs per PDO accident?	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427
52. Percent of total accidents blocking no lanes?	90%	90%	90%	90%	90%	90%	90%	90%
53. Percent of total accidents blocking one lane?	5%	5%	5%	5%	5%	5%	5%	5%
54. Percent of total accidents blocking two lanes?	5%	5%	5%	5%	5%	5%	5%	5%
55. Ave. minutes to clear non-truck involvements?	89	81	68	39	112	108	54	102
56. Ave. minutes to clear truck involvements?	75	35	99	78	55	78	194	31
57. Maximum queue length before diversion (miles)?	3.37	2.80	3.01	4.54	4.07	3.40	7.59	9.81

NOTE: Values for the shaded blocks varied consistent with the four exclusive lane alternatives analyzed.

LEVEL 2 ANALYSIS INPUT DATA - I-81 (3-Lane Sections)							
General Site Information	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
1. Rural, suburban, or urban highway R/S/U?	R	R	R	R	R	R	R
2.Current mixed-vehicle lanes in each direction (0-6)?	3	3	3	3	3	3	3
3. Future mixed-vehicle lanes in each direction (0-6)?							
4. Future light-vehicle lanes in each direction (0-6)?							
5. Future heavy-vehicle lanes in each direction (0-4)?							
6. Number of new lanes of right-of-way to acquire (0-4)?	0	0	0	0	0	0	0
7. Will exclusive vehicle lanes be barrier separated? (Y/N)? (y/N)?							
8. Length of section in miles (including decimal places)?	4.53	5.00	4.26	4.54	4.68	4.71	3.67
9. Number of interchanges along this section?	0	0	2	0	3	1	1
10. Ave. road gradient along section (typ. value = 0 %)?	-1.92	-1.80	0.37	-0.89	-0.20	-0.15	0.40
11. Ave. curvature along section (typ. value = 2 deg.)?	0.68	1.39	0.75	0.32	0.40	0.44	0.48
Traffic Characteristics	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
12. Current ave. daily traffic (ADT) (one direction)?	20,000	20,000	20,045	21,2404	22,970	24,273	21,546
13. Ave. annual increase in ADT (one direction)?	500	500	545	482	778	663	795
14. Current peak-period volume/hr. (3 hours/day)?	1,328	1,328	1,331	1,410	1,524	1,611	1,430
15. Future peak-period volume/hr. in 10 years?	1,660	1,660	1,693	1,746	2,041	2,051	1,959
16. Current off-peak volume/hr. (15 hours/day)?	1,068	1,068	1,070	1,134	1,229	1,296	1,150
17. Future off-peak volume/hr. in 10 years?	1,335	1,335	1,361	1,404	1,642	1,650	1,575
18. Speed limit for LV along this section (mph)?	65	65	65	65	65	65	65
19. Speed limit for SU and CV along this section (mph)?	65	65	65	65	65	65	65
20. Current LV percentage of total ADT?	69	69	74	74	75	79.5	78
21. Future LV percentage of ADT in 10 years?	69	69	74	74	75	79.5	78
22. Current SU percentage of total ADT?	5	5	4	4	4	3.5	2
23. Future SU percentage of ADT in 10 years?	5	5	4	4	4	3.5	2
24. Current CV percentage of total ADT?	26	26	22	22	21	17	20
25. Future CV percentage of ADT in 10 years?	26	26	22	22	21	17	20
Other Factors	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
26. Length of analysis period (number of years)?	20	20	20	20	20	20	20
27. How many years of this period are construction?	1	1	1	1	1	1	1
28. Present value discount rate?	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Facility Construction and 4R Work Cost (in 1000's dollars)	Northbound Sections						
	9	10	11	12	13	14	15
29. Construction cost per lane mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0
30. Construction cost per interchange (unseparated)? increase in	$0	$0	$0	$0	$0	$0	$0
31. Right-of-way acquisition cost/mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0
32. Construction cost per lane mile (w/barriers)?	$917	$855	$1,053	$1,074	$1,199	$1,030	$1,048
33. Construction cost per interchange (w/barriers)?	$0	$0	$0	$0	$0	$0	$0
34. Right-of-way acquisition cost/mile (w/barriers)?	$0	$0	$0	$0	$0	$0	$0
35. Ave. cost per lane mile for major resurfacing?	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9
36. PSI parameter (delta) (in million 18-kip ESAL's)?	2.0	2.0	2.0	2.0	2.0	2.0	2.0
37. PSI parameter (beta) used as the power exponent?	1.2	1.2	1.2	1.2	1.2	1.2	1.2
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	1.5	1.5	1.5	1.5	1.5	1.5
39. PSI at which resurfacing is desired (0-5) scale?	2.5	2.5	2.5	2.5	2.5	2.5	2.5
40. Ave. ESAL's per light vehicle?	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
41. Ave. ESAL's per single-unit vehicle?	0.37	0.37	0.37	0.37	0.37	0.37	0.37
42. Ave. ESAL's per combination vehicle?	1.28	1.28	1.28	1.28	1.28	1.28	1.28

Value-of-Time and Accident Costs (in dollars)	Northbound Sections						
	9	10	11	12	13	14	15
43. Light vehicle value-of-time per hour?	6.70	6.70	6.70	6.70	6.70	6.70	6.70
44. Single-unit vehicle value-of-time per hour?	14.66	14.66	14.66	14.66	14.66	14.66	14.66
45. Combination vehicle value-of-time per hour?	20.94	20.94	20.94	20.94	20.94	20.94	20.94
46. Light vehicle accident rate per LV MVM?	0.881	0.436	0.513	0.267	0.456	0.525	0.658
47. Single-unit vehicle accident rate per SU MVM?	1.358	0.380	0.315	0.486	0.708	1.258	3.211
48. Combination vehicle accident rate per CV MVM?	0.451	0.281	0.619	0.418	0.558	0.420	0.490
49. Accident costs per fatality accident?	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0
50. Accident costs per injury accident?	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862
51. Accident costs per PDO accident?	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427
52. Percent of total accidents blocking no lanes?	87%	87%	87%	87%	87%	87%	87%
53. Percent of total accidents blocking one lane?	11%	11%	11%	11%	11%	11%	11%
54. Percent of total accidents blocking two lanes?	2%	2%	2%	2%	2%	2%	2%
55. Ave. minutes to clear non-truck involvements?	67	155	105	145	52	52	116
56. Ave. minutes to clear truck involvements?	182	154	54	182	73	132	77
57. Maximum queue length before diversion (miles)?	4.99	9.99	3.84	4.96	2.93	2.79	3.67

NOTE: Values for the shaded blocks varied consistent with the four exclusive lane alternatives analyzed.

LEVEL 2 ANALYSIS INPUT DATA - I-81 (4-Lane Sections)								
General Site Information	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Rural, suburban, or urban highway R/S/U?	R	R	R	R	R	R	R	R
2. Current mixed-vehicle lanes in each direction (0-6)?	4	4	4	4	4	4	4	4
3. Future mixed-vehicle lanes in each direction (0-6)?								
4. Future light-vehicle lanes in each direction (0-6)?								
5. Future heavy-vehicle lanes in each direction (0-4)?								
6. Number of new lanes of right-of-way to acquire (0-4)?	0	0	0	0	0	0	0	0
7. Will exclusive vehicle lanes be barrier separated? (Y/N)? (y/N)?								
8. Length of section in miles (including decimal places)?	3.67	4.90	4.51	4.54	4.41	3.06	4.19	2.22
9. Number of interchanges along this section?	1	1	3	0	2	0	0	0
10. Ave. road gradient along section (typ. value = 0 %)?	-0.11	-0.01	-0.11	0.62	-0.45	3.40	0.19	2.93
11. Ave. curvature along section (typ. value = 2 deg.)?	0.46	0.37	0.38	0.36	0.88	1.24	0.90	0.65
Traffic Characteristics	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
12. Current ave. daily traffic (ADT) (one direction)?	21,546	24,273	22,970	21,240	20,045	20,000	20,000	20,000
13. Ave. annual increase in ADT (one direction)?	795	663	778	482	545	500	500	500
14. Current peak-period volume/hr. (3 hours/day)?	1,430	1,611	1,524	1,410	1,331	1,328	1,328	1,328
15. Future peak-period volume/hr. in 10 years?	1,959	2,051	2,041	1,746	1,693	1,660	1,660	1,660
16. Current off-peak volume/hr. (15 hours/day)?	1,150	1,296	1,227	1,134	1,070	1,068	1,068	1,068
17. Future off-peak volume/hr. in 10 years?	1,575	1,650	1,642	1,404	1,361	1,335	1,335	1,335
18. Speed limit for LV along this section (mph)?	65	65	65	65	65	65	65	65
19. Speed limit for SU and CV along this section (mph)?	65	65	65	65	65	65	65	65
20. Current LV percentage of total ADT?	78	79.5	75	74	74	69	69	69
21. Future LV percentage of ADT in 10 years?	78	79.5	75	74	74	69	69	69
22. Current SU percentage of total ADT?	2	3.5	4	4	4	5	5	5
23. Future SU percentage of ADT in 10 years?	2	3.5	4	4	4	5	5	5
24. Current CV percentage of total ADT?	20	17	21	22	22	26	26	26
25. Future CV percentage of ADT in 10 years?	20	17	21	22	22	26	26	26
Other Factors	**Southbound Sections**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
26. Length of analysis period (number of years)?	20	20	20	20	20	20	20	20
27. How many years of this period are construction? direction)?	1	1	1	1	1	1	1	1
28. Present value discount rate?	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Facility Construction and 4R Work Cost (in 1000's dollars)	Southbound Sections							
	1	2	3	4	5	6	7	8
29. Construction cost per lane mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0	$0
30. Construction cost per interchange (unseparated)? increase in	$0	$0	$0	$0	$0	$0	$0	$0
31. Right-of-way acquisition cost/mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0	$0
32. Construction cost per lane mile (w/barriers)?	$1,053	$892	$1,285	$1,075	$1,046	$855	$921	$1,137
33. Construction cost per interchange (w/barriers)?	$0	$0	$0	$0	$0	$0	$0	$0
34. Right-of-way acquisition cost/mile (w/barriers)?	$0	$0	$0	$0	$0	$0	$0	$0
35. Ave. cost per lane mile for major resurfacing?	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9
36. PSI parameter (delta) (in million 18-kip ESAL's)?	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
37. PSI parameter (beta) used as the power exponent?	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
39. PSI at which resurfacing is desired (0-5) scale?	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
40. Ave. ESAL's per light vehicle?	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
41. Ave. ESAL's per single-unit vehicle?	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
42. Ave. ESAL's per combination vehicle?	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28

Value-of-Time and Accident Costs (in dollars)	Southbound Sections							
	1	2	3	4	5	6	7	8
43. Light vehicle value-of-time per hour?	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70
44. Single-unit vehicle value-of-time per hour?	14.66	14.66	14.66	14.66	14.66	14.66	14.66	14.66
45. Combination vehicle value-of-time per hour?	20.94	20.94	20.94	20.94	20.94	20.94	20.94	20.94
46. Light vehicle accident rate per LV MVM?	0.525	0.561	0.763	0.404	0.698	0.681	0.715	0.720
47. Single-unit vehicle accident rate per SU MVM?	1.799	1.023	0.762	0.765	0.829	0.306	0.224	0.844
48. Combination vehicle accident rate per CV MVM?	0.191	0.111	0.238	0.365	0.309	0.565	0.455	1.108
49. Accident costs per fatality accident?	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0
50. Accident costs per injury accident?	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862
51. Accident costs per PDO accident?	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427
52. Percent of total accidents blocking no lanes?	90%	90%	90%	90%	90%	90%	90%	90%
53. Percent of total accidents blocking one lane?	5%	5%	5%	5%	5%	5%	5%	5%
54. Percent of total accidents blocking two lanes?	5%	5%	5%	5%	5%	5%	5%	5%
55. Ave. minutes to clear non-truck involvements?	89	81	68	39	112	108	54	102
56. Ave. minutes to clear truck involvements?	75	35	99	78	55	78	194	31
57. Maximum queue length before diversion (miles)?	3.37	2.80	3.01	4.54	4.07	3.40	7.59	9.81

NOTE: Values for the shaded blocks varied consistent with the six exclusive lane alternatives analyzed.

LEVEL 2 ANALYSIS INPUT DATA - I-81 (4-Lane Sections)							
General Site Information	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
1. Rural, suburban, or urban highway R/S/U?	R	R	R	R	R	R	R
2.Current mixed-vehicle lanes in each direction (0-6)?	4	4	4	4	4	4	4
3. Future mixed-vehicle lanes in each direction (0-6)?							
4. Future light-vehicle lanes in each direction (0-6)?							
5. Future heavy-vehicle lanes in each direction (0-4)?							
6. Number of new lanes of right-of-way to acquire (0-4)?	0	0	0	0	0	0	0
7. Will exclusive vehicle lanes be barrier separated? (Y/N)? (y/N)?							
8. Length of section in miles (including decimal places)?	4.53	5.00	4.26	4.54	4.68	4.71	3.67
9. Number of interchanges along this section?	0	0	2	0	3	1	1
10. Ave. road gradient along section (typ. value = 0 %)?	-1.92	-1.80	0.37	-0.89	-0.20	-0.15	0.40
11. Ave. curvature along section (typ. value = 2 deg.)?	0.68	1.39	0.75	0.32	0.40	0.44	0.48
Traffic Characteristics	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
12. Current ave. daily traffic (ADT) (one direction)?	20,000	20,000	20,045	21,2404	22,970	24,273	21,546
13. Ave. annual increase in ADT (one direction)?	500	500	545	482	778	663	795
14. Current peak-period volume/hr. (3 hours/day)?	1,328	1,328	1,331	1,410	1,524	1,611	1,430
15. Future peak-period volume/hr. in 10 years?	1,660	1,660	1,693	1,746	2,041	2,051	1,959
16. Current off-peak volume/hr. (15 hours/day)?	1,068	1,068	1,070	1,134	1,229	1,296	1,150
17. Future off-peak volume/hr. in 10 years?	1,335	1,335	1,361	1,404	1,642	1,650	1,575
18. Speed limit for LV along this section (mph)?	65	65	65	65	65	65	65
19. Speed limit for SU and CV along this section (mph)?	65	65	65	65	65	65	65
20. Current LV percentage of total ADT?	69	69	74	74	75	79.5	78
21. Future LV percentage of ADT in 10 years?	69	69	74	74	75	79.5	78
22. Current SU percentage of total ADT?	5	5	4	4	4	3.5	2
23. Future SU percentage of ADT in 10 years?	5	5	4	4	4	3.5	2
24. Current CV percentage of total ADT?	26	26	22	22	21	17	20
25. Future CV percentage of ADT in 10 years?	26	26	22	22	21	17	20
Other Factors	**Northbound Sections**						
	9	**10**	**11**	**12**	**13**	**14**	**15**
26. Length of analysis period (number of years)?	20	20	20	20	20	20	20
27. How many years of this period are construction?	1	1	1	1	1	1	
28. Present value discount rate?	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Facility Construction and 4R Work Cost (in 1000's dollars)	Northbound Sections						
	9	10	11	12	13	14	15
29. Construction cost per lane mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0
30. Construction cost per interchange (unseparated)? increase in	$0	$0	$0	$0	$0	$0	$0
31. Right-of-way acquisition cost/mile (unseparated)?	$0	$0	$0	$0	$0	$0	$0
32. Construction cost per lane mile (w/barriers)?	$917	$855	$1,053	$1,074	$0,1998	$1,030	$1,048
33. Construction cost per interchange (w/barriers)?	$0	$0	$0	$0	$0	$0	$0
34. Right-of-way acquisition cost/mile (w/barriers)?	$0	$0	$0	$0	$0	$0	$0
35. Ave. cost per lane mile for major resurfacing?	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9	$39.9
36. PSI parameter (delta) (in million 18-kip ESAL's)?	2.0	2.0	2.0	2.0	2.0	2.0	2.0
37. PSI parameter (beta) used as the power exponent?	1.2	1.2	1.2	1.2	1.2	1.2	1.2
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	1.5	1.5	1.5	1.5	1.5	1.5
39. PSI at which resurfacing is desired (0-5) scale?	2.5	2.5	2.5	2.5	2.5	2.5	2.5
40. Ave. ESAL's per light vehicle?	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
41. Ave. ESAL's per single-unit vehicle?	0.37	0.37	0.37	0.37	0.37	0.37	0.37
42. Ave. ESAL's per combination vehicle?	1.28	1.28	1.28	1.28	1.28	1.28	1.28

Value-of-Time and Accident Costs (in dollars)	Northbound Sections						
	9	10	11	12	13	14	15
43. Light vehicle value-of-time per hour?	6.70	6.70	6.70	6.70	6.70	6.70	6.70
44. Single-unit vehicle value-of-time per hour?	14.66	14.66	14.66	14.66	14.66	14.66	14.66
45. Combination vehicle value-of-time per hour?	20.94	20.94	20.94	20.94	20.94	20.94	20.94
46. Light vehicle accident rate per LV MVM?	0.881	0.436	0.513	0.267	0.456	0.525	0.658
47. Single-unit vehicle accident rate per SU MVM?	1.358	0.380	0.315	0.486	0.708	1.258	3.211
48. Combination vehicle accident rate per CV MVM?	0.451	0.281	0.619	0.418	0.558	0.420	0.490
49. Accident costs per fatality accident?	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0	$2,450,0
50. Accident costs per injury accident?	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862	$19,862
51. Accident costs per PDO accident?	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427	$4,427
52. Percent of total accidents blocking no lanes?	87%	87%	87%	87%	87%	87%	87%
53. Percent of total accidents blocking one lane?	11%	11%	11%	11%	11%	11%	11%
54. Percent of total accidents blocking two lanes?	2%	2%	2%	2%	2%	2%	2%
55. Ave. minutes to clear non-truck involvements?	67	155	105	145	52	52	116
56. Ave. minutes to clear truck involvements?	182	154	54	182	73	132	77
57. Maximum queue length before diversion (miles)?	4.99	9.99	3.84	4.96	2.93	2.79	3.67

NOTE: Values for the shaded blocks varied consistent with the six exclusive lane alternatives analyzed.

APPENDIX F

CONSUMER PRICE INDEX (CPI)

Consumer Price Index (CPI)

	TO																									
FROM	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
1970	1	1.043	1.078	1.144	1.270	1.386	1.466	1.561	1.680	1.869	2.122	2.342	2.486	2.566	2.675	2.770	2.824	2.927	3.046	3.195	3.368	3.509	3.615	3.723	3.819	3.922
1971	0.958	1	1.033	10.97	1.217	1.328	1.405	1.496	1.609	1.791	2.035	2.245	2.382	2.485	2.563	2.654	2.708	2.806	2.921	3.064	3.229	3.365	3.467	3.570	3.662	3.761
1972	0.928	0.968	1	1.062	1.179	1.286	1.361	1.448	1.599	1.735	1.971	2.174	2.307	2.381	2.482	2.571	2.620	2.717	2.828	2.964	3.124	3.256	3.354	3.454	3.543	3.638
1973	0.874	0.911	0.941	1	1.110	1.211	1.281	1.364	1.467	1.633	1.856	2.047	2.173	2.243	2.338	2.421	2.469	2.558	2.662	2.793	2.944	3.068	3.161	3.255	3.339	3.429
1974	0.787	0.821	0.848	0.901	1	1.091	1.154	1.229	1.322	1.472	1.672	1.844	1.956	2.019	2.105	2.180	2.224	2.305	2.399	2.516	2.652	2.764	2.847	2.932	3.007	3.088
1975	0.721	0.752	0.777	0.826	0.916	1	1.058	1.126	1.212	1.349	1.532	1.690	1.792	1.850	1.929	1.997	2.038	2.112	2.198	2.306	2.430	2.533	2.609	2.687	2.756	2.830
1976	0.682	0.712	0.736	0.781	0.866	0.945	1	1.065	1.145	1.275	1.449	1.598	1.696	1.750	1.824	1.889	1.926	1.997	2.078	2.180	2.297	2.393	2.465	2.539	2.604	2.675
1977	0.641	0.668	0.690	0.733	0.814	0.888	0.939	1	1.076	1.198	1.361	1.501	1.594	1.645	1.715	1.776	1.809	1.876	1.952	2.047	2.157	2.248	2.316	2.385	2.446	2.512
1978	0.595	0.621	0.642	0.682	0.756	0.825	0.873	0.929	1	1.113	1.265	1.395	1.479	1.527	1.592	1.648	1.681	1.742	1.813	1.902	2.005	2.089	2.152	2.216	2.273	2.334
1979	0.535	0.588	0.576	0.612	0.679	0.741	0.784	0.835	0.898	1	1.135	1.253	1.330	1.373	1.431	1.482	1.511	1.566	1.630	1.710	1.802	1.878	1.934	1.992	2.043	2.098
1980	0.471	0.491	0.508	0.539	0.598	0.653	0.690	0.735	0.791	0.881	1	1.103	1.171	1.209	1.260	1.305	1.331	1.379	1.436	1.506	1.587	1.654	1.704	1.755	1.800	1.848
1981	0.427	0.445	0.460	0.489	0.542	0.592	0.626	0.666	0.717	0.798	0.907	1	1.062	1.096	1.142	1.183	1.206	1.250	1.301	1.364	1.438	1.499	1.544	1.590	1.631	1.675
1982	0.402	0.420	0.434	0.460	0.511	0.558	0.590	0.628	0.676	0.752	0.853	0.942	1	1.032	1.075	1.114	1.136	1.178	1.226	1.285	1.355	1.412	1.454	1.498	1.536	1.578
1983	0.390	0.406	0.420	0.446	0.495	0.540	0.571	0.608	0.655	0.728	0.827	0.913	0.970	1	1.043	1.080	1.100	1.141	1.187	1.245	1.312	1.367	1.408	1.450	1.487	1.528
1984	0.374	0.390	0.403	0.428	0.475	0.518	0.548	0.584	0.628	0.699	0.793	0.876	0.930	0.960	1	1.036	1.056	1.094	1.139	1.195	1.259	1.312	1.352	1.392	1.428	1.466
1985	0.361	0.376	0.389	0.413	0.458	0.500	0.529	0.564	0.606	0.675	0.766	0.846	0.898	0.926	0.966	1	1.019	1.057	1.100	1.153	1.215	1.266	1.304	1.343	1.378	1.415
1986	0.354	0.369	0.382	0.405	0.450	0.491	0.519	0.553	0.595	0.662	0.751	0.829	0.880	0.909	0.947	0.981	1	1.036	1.079	1.131	1.193	1.243	1.208	1.318	1.352	1.389
1987	0.342	0.356	0.368	0.391	0.434	0.474	0.501	0.533	0.574	0.639	0.725	0.800	0.849	0.876	0.914	0.946	0.965	1	1.041	1.092	1.151	1.199	1.235	1.272	1.305	1.340
1988	0.328	0.342	03.54	0.376	0.417	0.455	0.481	0.512	0.552	0.614	0.697	0.769	0.816	0.842	0.878	0.909	0.926	0.960	1	1.048	1.105	1.151	1.186	1.221	1.253	1.287
1989	0.313	0.326	0.337	0.358	0.397	0.434	0.459	0.489	0.526	0.585	0.664	0.733	0.778	0.804	0.837	0.867	0.884	0.916	0.954	1	1.054	1.098	1.131	1.165	1.195	1.227
1990	0.297	0.310	0.320	0.340	0.377	0.411	0.435	0.464	0.499	0.555	0.630	0.695	0.738	0.762	0.794	0.823	0.839	0.869	0.905	0.949	1	1.042	1.073	1.106	1.134	1.164
1991	0.285	0.297	0.307	0.326	0.362	0.395	0.418	0.445	0.479	0.533	0.605	0.667	0.708	0.732	0.762	0.790	0.805	0.834	0.869	0.910	0.960	1	1.030	1.061	1.088	1.117
1992	0.277	0.288	0.298	0.316	0.351	0.383	0.406	0.432	0.465	0.517	0.587	0.648	0.688	0.710	0.740	0.767	0.781	0.810	0.843	0.884	0.932	0.971	1	1.030	1.056	1.085
1993	0.269	0.280	0.289	0.307	0.341	0.372	0.394	0.419	0.451	0.502	0.570	0.629	0.668	0.690	0.718	0.744	0.758	0.786	0.819	0.858	0.904	0.943	0.971	1	1.026	1.053
1994	0.262	0.273	0.282	0.300	0.333	0.363	0.384	0.409	0.440	0.489	0.556	0.613	0.651	0.672	0.700	0.726	0.740	0.767	0.798	0.837	0.882	0.919	0.947	0.975	1	1.027
1995	0.255	0.266	0.275	0.292	0.324	0.353	0.374	0.398	0.428	0.477	0.541	0.597	0.634	0.655	0.682	0.707	0.720	0.747	0.777	0.815	0.859	0.895	0.922	0.949	0.974	1

Source: Adapted from "Monthly Labor Review" and estimated.

APPENDIX G

BENEFIT/COST SUMMARY AND STATISTICS SUMMARY

COST SUMMARY
(In $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Costs
Resurfacing Lanes	1814	1620	9065	7445
Vehicle Operation	177281	213609	213609	0
New Construction	0	0	0	0
Right of Way	0	0	0	0
Total	$179095	$215229	$222674	$7445

BENEFIT SUMMARY
(in $1000s)

Travel Time	65752	79235	79239	-4
Accident Costs	12864	15501	-545	16045
Accident Delays	0	0	0	0
Total	$78617	$94736	$78694	$16042

BENEFIT/COST RATIOS

With Vehicle Operating Costs			Without Vehicle Operating Costs		
Net Present Value	=	$8597	Net Present Value	=	$8597
Benefit/Cost Ratio	=	2.155	Benefit/Cost Ratio	=	2.155

Press enter to invoke menu

1 = Benefit/Cost Summary 2 = Statistics Summary Press any other key to exit

STATISTICS SUMMARY

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Diff.
Total VMT (in 1000s)	697734	872197	872197	0
Total Accidents	504	630	17	-613
Avg. Accident Cost	$44526	$44526	-$58800	-$103326
Avg. Delay Cost	$0	$0	$0	$0
Avg. Travel Speed	65.00	65.00	65.00	0.00

LOCATION: I-81 SB: (Sect. 4)

General Site Information:

1. Is this a rural. suburban, or urban highway section?	R/S/U	R
2. Current mixed-vehicle lanes in each direction?	(1-6)	4
3. Future mixed-vehicle lanes in each direction?	(0-6)	1
4. Future light-vehicle lanes in each direction?	(0-4)	3
5. Future heavy vehicle lanes in each direction?	(0-4)	0
6. Number of new lanes of right-of-way to acquire?	(0-4)	0
7. Will exclusive vehicle lanes be barrier separated?	(Y/N)	N
8. Section length in miles (including decimal places)?		4.5
9. Number of interchanges along this section?		0
10. Average road gradient along section (typical value = 0%)?		1%
11. Average curvature along section (typical value = 2 deg.)?		1

Press enter to invoke menu

1 = Benefit/Cost Summary   2 = Statistics Summary   Press any other key to exit