

Support Initiatives to Enhance HOV and HOT-Facility Safety

A White Paper

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Collisions on High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) facilities occur when motorists are unable to negotiate these facilities as intended. The relationship between the safety performance of HOV and HOT lanes and the numerous variables that affect it is poorly understood in many cases. Data and information required to draw conclusions regarding causative factors is often not readily accessible or has not been collected. In other instances, the practices and techniques used to analyze and address safety issues may be incomplete or out of date. The objective of this white paper is to draw attention to these and other needs, gaps and opportunities associated with HOV and HOT safety.

The Federal Highway Administration, in conjunction with the HOV Pooled Fund Study Group, recently sponsored development of an *HOV-Lane Safety Considerations Handbook* that provides safety guidance for preferential facilities based on available research and practitioner experience. The support initiatives presented here were identified through a review of this body of knowledge. The purpose, facility type, principal stakeholders, potential sponsors, and anticipated product for each proposed project are indicated. Additionally, each initiative is evaluated according to its relative safety priority, time frame for completion, and cost. Initiatives are presented in a standardized format to facilitate comparisons and assist agencies in determining how to best leverage available resources to achieve desired safety goals. They are classified according to their focus on one or more of the following areas:

- Research
- Public outreach and awareness
- Personnel training

Table 1 summarizes safety support initiatives presented in this paper. The entries in the table indicate the researcher's assessment of 1) type of support initiative, 2) priority, 3) cost, and 4) time frame. Before examining these initiatives in detail, a brief explanation of the rationale for addressing HOV/HOT safety is in order.

Importance and Challenge of Addressing HOV/HOT Safety

Motor vehicle crash rates in the United States have declined for decades. The establishment of uniform roadway design and operational standards has contributed to this trend. But data indicate that the rate at which motor vehicle crashes are decreasing has slowed in recent years¹. Notwithstanding safety advances, vehicle crashes remain the leading cause of death in the United States for ages three through 33². Worsening traffic congestion and an expanding population of elderly drivers underscore the importance of continued development and diffusion of road safety techniques. This is particularly true with respect to burgeoning HOV and HOT networks, whose operations are affected by congestion and can present complex driving situations to motorists.

Table 1. Safety Support Initiatives.

Support Initiatives to Enhance HOV-HOT Safety	Focus Area	Priority	Cost	Time Frame
	 = Research  = Training  = Outreach	★ = Low ★★ = Medium ★★★ = High	\$ = Low \$\$ = Moderate \$\$\$ = High	⬇ = Short ⬇⬇ = Medium ⬇⬇⬇ = Long
1. Countermeasures to Address Major Safety Issues		★★★	\$\$ - \$\$\$	⬇⬇ - ⬇⬇⬇
2. Human Factors in HOV and HOT-Lane Design and Safety		★★★	\$\$	⬇
3. Safety Considerations for HOT Facilities in Extreme Winter Conditions		★★★	\$\$	⬇⬇
4. Improved Crash Reporting and Analysis Techniques		★★	\$\$	⬇ - ⬇⬇
5. Safety Implications of HOV/HOT Resentment Among Drivers in Mainlanes	 	★★	\$	⬇
6. Effect of Speed Limits on HOV/HOT-Facility Safety	 	★★	\$	⬇ - ⬇⬇
7. Safety Considerations in Enforcement and Data Collection	  	★★	\$ - \$\$	⬇
8. Use of Shoulder Rumble Strips to Mitigate Run-Off-The-Road Crashes		★★	\$ - \$\$	⬇
9. Use of Glare Screens to Reduce Driver Distraction and Safety Issues		★★	\$ - \$\$	⬇
10. Opening HOV Lanes to General-Purpose Traffic During Nights and Weekends		★★	\$	⬇
11. Opening HOV Lanes to General-Purpose Traffic During Mainlane Incidents		★	\$	⬇ - ⬇⬇
12. Use of Surrogates to Identify Safety Deficiencies		★	\$ - \$\$	⬇⬇ - ⬇⬇⬇
13. Safety Performance of Radial Versus Circumferential Facilities		★	\$ - \$\$	⬇⬇
14. Safety Impact of Allowing Heavy Trucks on HOV Lanes		★	\$\$	⬇ - ⬇⬇
15. Bicycle Use of Freeway HOV Lanes	 	★	\$	⬇

Thousands of crashes occur each year on U.S. HOV and HOT lanes, resulting in death, injury and property damage. Reducing crashes on these facilities entails the identification and integration of safety “best practices” into facility planning, design and operations, and the dissemination of safety information so that facility users and employees are aware of potentially dangerous situations.

While safety is often cited as a top priority for transportation projects, it is only one of many concerns competing for limited resources and attention. Costs, physical constraints or operational issues may preclude adoption of the “safest” facility design or practice in a given circumstance. In some cases, mobility and safety goals may conflict, further complicating the integration of safety elements into a project. Safety considerations may be overlooked or diluted in the complex stakeholder tasks and interactions required to develop and operate HOV and HOT lanes. Facilities that meet minimum geometric design standards may be assumed to be safe in the absence of obvious evidence to the contrary. The challenge for facility planners, designers and other project stakeholders is to remain informed about HOV and HOT safety issues and achieve the highest possible level of safety within the project’s physical, financial and operational constraints³.

Challenges in HOV/HOT Safety Analysis

Historically, crashes on HOV and HOT facilities have not been well documented or consistently classified. Some safety evaluations of these facilities have been compromised due to the quality and quantity of crash data available to researchers. This has occasionally produced inconclusive or contradictory findings with respect to the safety of specific HOV or HOT policies and treatments. If a facility is suspected of being less safe than an alternative design or conditions prior to the facility’s implementation, there may be reluctance on the part of project stakeholders to publicize safety information. Even facilities that meet or exceed geometric design standards may exhibit high crash rates, frequencies and severities. Developing a better understanding of the factors affecting HOV and HOT safety is an important and challenging task.

There is growing awareness among transportation professionals regarding the need for better safety information and coordination, and more explicit consideration of the safety consequences of planning, design, and operational decisions. These stakeholders are charged with the responsibility of understanding the operational and design context that allows preferential facilities to operate safely rather than simply developing facilities that appear to be a low-cost solution or can be made to fit an existing cross section⁴. The involvement of facility operations personnel and user outreach initiatives are also critical to the long-term safety and viability of these projects. The following safety support initiatives seek to address outstanding HOV and HOT research, training and awareness needs with a view to improving stakeholder understanding of key safety problems and promoting the development of more effective countermeasures and remedies.

1. Countermeasures to Address Major Safety Issues

Purpose/Need: Intensify research on major causes of HOV and HOT-lane collisions and potential remedies

Area(s) of Focus: Research

Facility Type(s): All Preferential Facilities (particularly buffer-separated HOV lanes)

Safety Priority: High

Cost: Moderate-High

Time Frame: Medium-Long

Product(s): Research Reports, Pilot Implementation Projects

Participant(s): Facility Planners, Design Engineers, Traffic Engineers

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Facility Operators

Description: One of the challenges of integrating safety into the design of preferential facilities is the relative scarcity of research into safety problems and potential countermeasures. For example, merging and weaving at access points has been identified as a common element in many HOV-lane crashes. Various alternatives, such as limiting access to strategically-located points; separating ingress and egress; incorporating acceleration, deceleration and weave lanes; and providing unlimited access have been proposed and implemented to reduce crash rates at access locations. Further research is required to quantify the safety effect of adopting these access treatments in specific contexts.

A related cause of crashes on preferential facilities is congestion, which often results in mainlane slowdowns and the development of dangerous speed differentials between HOV and general-purpose traffic flows. Most collisions that occur during congested conditions are rear-end crashes. The remaining crashes are often sideswipes, possibly resulting from drivers attempting to avoid rear-end collisions. There is a need to intensify research in this area, and to develop and test countermeasures that address these problems. Design tradeoffs associated with narrowed buffer width versus narrowed inside shoulder in constrained cross section conditions need further examination. The use of plastic tubular markers to improve lane delineation and reduce encroachment on non-barrier-separated preferential facilities is a countermeasure worthy of further study. Increased use of software packages to evaluate the safety and operational impacts of access designs in specific contexts also holds promise for assessing and enhancing HOV and HOT-lane safety.

2. Human Factors in HOV and HOT-Lane Design and Safety

Purpose/Need: Explore opportunities to leverage human factors research and driving simulator technology to advance HOV and HOT-lane design and safety

Area(s) of Focus: Research

Facility Type(s): All HOV, HOT Facilities (particularly HOT and HOV facilities with complex signage/designs)

Safety Priority: High

Cost: Moderate

Time Frame: Short

Product(s): Research Report, HOV/HOT Driving Simulation Software

Participant(s): Driving Simulator and Human Factors Specialists, HOV and HOT Facility Users, Facility Planners and Designers

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Facility Operators

Description: Many HOT and HOV facilities are characterized by complex driving environments that require motorists to quickly process information. The decision-making process to use an HOV facility may involve consideration of hours of operation, vehicle eligibility, and occupancy requirements. HOT-lane utilization can include additional considerations related to price, transponder placement, lane selection (depending on vehicle occupancy), and other issues. Decisions and actions associated with these considerations often depend on facility signage and design and are may be performed while traveling at a high rate of speed or changing lanes. Given the relative complexity of driving on HOV and HOT facilities and the potential for driver confusion and distraction, clear signage, enforcement setups and facility designs are essential.

Optimization of HOV and HOT-facility designs and operations reduces human errors and enhances safety. Interactive driving simulators can provide a useful tool for studying and improving facility design and operations based on human reactions. This technology can be programmed to replicate existing or potential driving environments to determine the safest and most effective characteristics and practices. Considerable potential exists to leverage human factors research and driving simulator technology to advance safety of preferential facilities.

3. Safety Considerations for HOT Facilities in Extreme Winter Conditions

Purpose/Need: Determine safety considerations associated with HOT facilities in extreme winter conditions

Area(s) of Focus: Research

Facility Type(s): HOT Facilities affected by Extreme Winter Conditions

Safety Priority: High

Cost: Moderate

Time Frame: Medium

Product(s): Research Report

Participant(s): Safety Analysts, Researchers, Facility Operators

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: Until 2005, the only HOT facilities in the United States were located in southern California and southern Texas. The relatively mild winter climates at these locations create few operational and safety concerns beyond those experienced at other times of the year. However, growing congestion in urban areas and the drive to improve efficiency and capacity utilization on HOV networks has prompted cities throughout the nation to consider implementing HOT facilities. In the summer of 2005, the I-394 HOT facility was opened in Minneapolis, Minnesota. Other metropolitan areas that can be affected by extreme winter conditions, such as Washington DC, Denver and Seattle, are presently pursuing HOT facilities.

There has been no experience to date regarding safety considerations associated with HOT operations in extreme winter conditions. A limited body of knowledge exists with respect to HOV-lane performance in winter weather, but this may not be transferable to the unique operational and enforcement environment that exists on HOT facilities. Heavy snowfall or icy conditions can significantly impact the performance and safety of general-purpose lanes and HOT facilities alike. These conditions may markedly raise HOT-facility demand, increase violation rates, impact technology operations, and affect overall facility safety. Issues related to the safety and practicality of HOT-facility enforcement during extreme winter conditions may also arise. There is a need to examine these issues and monitor the safety performance of new HOT facilities in extreme winter conditions to develop a better understanding of these considerations and enhance the safety of future HOT facilities.

4. Improved Crash Reporting and Analysis Techniques

Purpose/Need: Standardized procedures for collecting and analyzing crash data related to preferential facilities

Area(s) of Focus: Research, Training

Facility Type(s): All HOV, HOT Facilities

Safety Priority: Medium

Cost: Moderate

Time Frame: Short-Medium

Product(s): Research Report, Training Course

Participant(s): Safety Analysts, Enforcement Personnel, Crash-data Coding Personnel, Safety Analysts, Researchers

Potential Sponsor(s): State Department of Transportation, State Department of Public Safety

Description: Traffic safety problems can be identified and evaluated in an accurate and timely manner only through the systematic collection and maintenance of crash data⁵. The value of HOV or HOT-lane crash data can be compromised by deficient data collection, reporting and analysis techniques. Crash reports prepared by law enforcement personnel constitute the principal source of information used to populate crash databases. Each state has its own report form, which is completed by filling in blanks or multiple choice bubbles, and preparing diagrams and comments that describe crash characteristics. The lack of a checkbox, bubble or other crash report indicator denoting that a crash was related to a preferential facility obliges analysts to use more tedious methods of identifying and retrieving HOV and HOT crash records. These typically involve inputting milepost values and information on the number of lanes in the segment of freeway where each facility is located. A simpler means of distinguishing HOV and HOT-related collisions on crash reports would facilitate the identification and analysis of these collisions. Electronically archiving this information would enable pertinent crash records to be quickly filtered, sorted and shared with other jurisdictions for more meaningful safety analysis.

In addition to developing and disseminating improved means of identifying HOV and HOT-lane collisions, opportunities exist to incorporate more valuable safety information into crash reports. For example, crash databases often lack sufficient detail on the geometrics of facilities to enable proper safety analysis. Methods for improving communication and coordination between personnel that analyze crash information and those that collect it would enable HOV and HOT safety data to be used more

productively. Finally, there is a need to examine ways of enhancing the consistency of crash-data analysis procedures. Crashes occurring on general-purpose lanes are sometimes directly related to adjacent preferential facilities. Development of standardized procedures for the identification and analysis of these collisions would provide a more accurate view of the safety of these facilities. Best practices in the collection and analysis of HOV and HOT crash-data could be incorporated into a training program to improve the dissemination and adoption of these techniques.

5. Safety Implications of HOV/HOT Resentment Among Drivers in Mainlanes

Purpose/Need: Formal investigation of safety issues related to the resentment of preferential facility users by non users

Area(s) of Focus: Research, Public Outreach and Awareness

Facility Type(s): All HOV, HOT Facilities

Safety Priority: Medium

Cost: Low

Time Frame: Short

Product(s): Research Report, Public Outreach Campaign

Participant(s): Facility Operators, Enforcement Personnel, Facility Users/Non Users

Potential Sponsor(s): State Department of Transportation, Local Governments, Federal Highway Administration, Metropolitan Planning Organizations, Facility Operators

Description: HOV and HOT facilities can impart substantial travel time and reliability benefits to users. These benefits generate feelings of resentment on the part of some non-HOVs, particularly among drivers that do not use these facilities and do not support the HOV or HOT concepts. A slow-moving single-occupant vehicle on a congested mainlane may be reluctant to yield to the user of a preferential facility that has been traveling in free-flow conditions and wishes to merge into the mainlanes. This attitude is most prevalent during periods of extreme congestion, where few natural openings in mainlane traffic exist. Feelings of frustration, resentment and related aggressive driving practices among some mainlane drivers make it more difficult for users of HOV and HOT lanes to safely merge with general-purpose traffic at egress points. This contributes to sideswipe and rear-end crashes at egress sites. Evidence of this phenomenon comes primarily from crash victims and enforcement personnel and is largely anecdotal. Formal investigation would help define and quantify this potential safety issue and, if appropriate, assist in the identification of possible mitigation strategies. This initiative should include a public outreach component to apprise motorists of safety issues associated with aggressive HOV/HOT-related driving practices.

6. Effect of Speed Limits on HOV/HOT-Facility Safety

Purpose/Need: Investigation of relationship between speed limits and dangerous driving practices that affect HOV and HOT safety

Area(s) of Focus: Research, Public Outreach and Awareness

Facility Type(s): All HOV, HOT Facilities (particularly single-lane facilities)

Safety Priority: Medium

Cost: Low

Time Frame: Short-Medium

Product(s): Research Report, Public Outreach Campaign

Participant(s): Safety Analysts, Researchers, Facility Operators, Facility Users, Enforcement Personnel

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: HOV and HOT lanes are designed to provide fast, reliable transportation options in congested corridors. Facilities that offer a high level of service often enable drivers to travel at speeds well above the posted speed limit, especially through reduced speed zones. Regular facility users may consistently exceed speed limits in the absence of enforcement and meaningful penalties. Some facilities are often not designed to safely accommodate vehicles traveling at excessive speeds, particularly at access points and on curves and ramps. Drivers that become frustrated with motorists traveling at or slightly below the posted speed limit may engage in aggressive maneuvers such as tailgating, flashing of high-beam headlights or other unsafe driving practices. Research examining the relationship between speed limits and activities that affect HOV and HOT safety is needed. This initiative should include a public outreach component to apprise motorists of safety issues associated with speeding on HOV and HOT facilities.

7. Safety Considerations in Enforcement and Data Collection

Purpose/Need: Identify the safest and most effective designs and practices for conducting enforcement and data collection activities on HOV and HOT facilities

Area(s) of Focus: Research, Training, Public Outreach and Awareness

Facility Type(s): Freeway HOV, HOT Facilities

Safety Priority: Medium

Cost: Low-Moderate

Time Frame: Short

Product(s): Research Report, Training Course

Participant(s): Safety Analysts, Researchers, Enforcement Personnel, Facility Planners, Design Engineers, Facility Users

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: The enforcement of HOV-lane occupancy regulations and the collection of violation data can be difficult and dangerous. In order to count the number of persons in a vehicle, officers must position themselves in close proximity to the traffic stream. Standing next to moving vehicles involves inherent safety risks that demand careful attention on the part of enforcement personnel and drivers. Enforcement-area designs and procedures also affect the safety of these activities. Given that an automated solution for determining the number of human beings in a moving vehicle is not currently available, manual occupancy enforcement and data collection is required on all HOV and HOT facilities. Further investigation of the safest and most effective designs and practices for conducting enforcement activities is required. Research should examine procedures applicable to a range of facility types and designs and include an assessment of techniques and scenarios both in the field and in controlled environments. This initiative should also include a public outreach component to apprise motorists of HOV/HOT enforcement safety issues.

8. Use of Shoulder Rumble Strips to Mitigate Run-Off-The-Road Crashes

Purpose/Need: Examine the safety benefits and consequences of using rumble strips on non-barrier separated HOV and HOT facilities to mitigate run-off-the-road crashes

Area(s) of Focus: Research

Facility Type(s): Non-barrier separated HOV/HOT Facilities

Safety Priority: Medium

Cost: Low-Moderate

Time Frame: Short

Product(s): Research Report

Participant(s): Safety Analysts, Researchers, Facility Operators, Facility Users

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: Run-off-the-road crashes can be severe due to the high rate of speed at which vehicles are normally traveling at the time of impact. Motorists on HOV lanes are more susceptible to running off the road because they the lane in which they are traveling is generally located at edge of the roadway. In addition, HOV facilities constructed for retrofit projects may be implemented in highly constrained environments that result in geometric design compromises such as narrow shoulders. Safety devices such as barriers, guardrails and energy-absorbing devices are frequently used to reduce the severity of run-off-the-road crashes on HOV lanes. The use of shoulder rumble strips may further enhance the safety performance of these facilities.

Studies examining the safety impact of rumble strips in freeway environments have demonstrated their effectiveness in addressing run-off-the-road crashes. Several HOV lanes in the Seattle area have recently been retrofitted with shoulder rumble strips to mitigate potential safety issues associated with the opening of these facilities to general-purpose traffic during nights and on weekends. Further examination of the safety benefits and consequences of using milled or raised rumble strips on HOV and HOT facilities is required. Questions regarding their impact on crash rates, types and severity should be addressed. Additional topics of investigation might include HOV/HOT-lane rumble-strip effectiveness by time of day, weather conditions, and vehicle class; and whether the introduction of shoulder rumble strips on select HOV/HOT facilities in a region increases crash rates on other facilities where this treatment is not applied.

9. Use of Glare Screens to Reduce Driver Distraction and Safety Issues

Purpose/Need: Assess the safety and non-safety impacts of adopting glare screens on HOV/HOT facilities and to define appropriate deployment strategies

Area(s) of Focus: Research

Facility Type(s): Barrier-Separated HOV/HOT Facilities

Safety Priority: Medium

Cost: Low-Moderate

Time Frame: Short

Product(s): Research Report, Case Study Report

Participant(s): Safety Analysts, Researchers, Facility Operators, Facility Users/Non Users

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: The installation of glare screens on concrete barriers has the potential to reduce both glare and driver distraction. Where traffic streams on a freeway are not separated by barriers with glare screens, the potential exists for motorists traveling on one portion of the facility to be distracted by events occurring on another. Crashes, enforcement activities, disabled vehicles, and other events draw attention away from the driving task and increase the risk of a crash. Glare screens may also prevent congestion from arising on HOV or HOT facilities due to speed differentials and voluntary slowing. By blocking the view of taillights in the general-purpose lanes, glare screens can reduce the tendency for drivers on barrier-separated facilities to slow down unnecessarily due to congestion in adjacent lanes. Glare screens are currently being considered on barrier-separated HOV facilities in northern Virginia due to excessive rubbernecking and unwarranted slowdowns on HOV facilities in that region. Potential safety drawbacks associated with the use of glare screens include a reduction of sight distances around curves and at other areas. Additional research is required to fully assess the safety and non-safety impacts of adopting glare screens on barrier-separated HOV/HOT facilities and to define appropriate deployment strategies.

10. Opening HOV Lanes to General-Purpose Traffic During Nights and Weekends

Purpose/Need: Evaluate the safety impact of allowing non-HOVs to utilize HOV lanes at night and on weekends

Area(s) of Focus: Research

Facility Type(s): All HOV Facilities (particularly full-time non-separated and buffer-separated HOV lanes)

Safety Priority: Medium

Cost: Low

Time Frame: Short

Product(s): Research Report, Case-Study Report

Participant(s): Safety Analysts, Researchers, Facility Operators, Enforcement Personnel, HOVs, Non HOVs

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: Some HOV lanes are underutilized or closed during off-peak periods such as nights and weekends. Increasing traffic volumes and slower speeds have been noted at these times on many adjacent general-purpose lanes. Opportunities may exist to increase utilization of HOV facilities during nights and weekends by temporarily suspending occupancy restrictions and allowing access by general-purpose traffic. The objective of this initiative is to reduce congestion in the mainlanes without unduly affecting the safety or performance of the HOV facility.

A 2002 HOV study undertaken in Seattle, Washington recommended that a number of HOV lanes in that region be opened to general-purpose traffic between 7 PM and 5 AM. Prior to adoption of the recommendation, the Washington State Department of Transportation completed a number of safety improvements on the HOV lanes to mitigate safety impacts. These included the installation of left-hand rumble strips, the provision of increased clear zones, and the addition of guardrails⁶. Evaluation of the safety impact of allowing single-occupant vehicles on HOV lanes at night (including an analysis of before and after crash data, crash-prone locations, and the frequency and severity of crashes) is currently ongoing. Additional research is necessary to assess the safety implications of adopting similar policies in other regions.

11. Opening HOV Lanes to General-Purpose Traffic During Mainlane Incidents

Purpose/Need: Determine net safety impact of temporarily converting HOV lanes to general-purpose lanes during mainlane incidents

Area(s) of Focus: Research

Facility Type(s): ALL HOV Lanes (particularly non-barrier-separated facilities)

Safety Priority: Low

Cost: Low

Time Frame: Short-Medium

Product(s): Research Report

Participant(s): Safety Analysts, Researchers, First Responders, Facility Operators, HOVs, Non HOVs

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: Incidents on general-purpose lanes often result in the closure of one or more lanes so that responders have a safe area in which to work. HOV lanes that are not blocked due to the incident may be opened to general-purpose traffic for congestion-relief

purposes. Most jurisdictions and facility operators do not have formal policies with respect to the opening of HOV lanes during incidents. Decisions may be made on a case-by-case basis by the facility's operations supervisor or through consultation among operations, enforcement and traffic management personnel. Where formalized guidelines do exist for opening HOV-lanes to general-purpose traffic during incidents, they vary by jurisdiction. Factors such as the number of mainlanes blocked or the duration of the blockage may be considered.

The safety implications of opening HOV lanes to general-purpose traffic during mainlane incidents have not been extensively studied and are not well understood. Safety in the HOV lane may be jeopardized by increased traffic levels, a sudden influx of drivers unfamiliar with HOV-lane operations or vehicles that are incompatible with facility design. The possible creation of an "incident island" surrounded by lanes of moving traffic may exacerbate safety problems for incident responders if the HOV lane remains operational and is opened to mixed traffic. Once the incident has been addressed, it may be difficult and dangerous to close the HOV lane to general-purpose traffic. Research is necessary to determine the net safety impact of temporarily converting HOV lanes to general-purpose lanes during mainlane incidents. Safety considerations could be studied in conjunction with the numerous equity issues surrounding this topic.

12. Use of Surrogates to Identify Safety Deficiencies

Purpose/Need: Examine utility of safety analysis techniques and metrics that do not rely exclusively on crash statistics

Area(s) of Focus: Research

Facility Type(s): All HOV, HOT Facilities

Safety Priority: Low

Cost: Low-Moderate

Time Frame: Medium-Long

Product(s): Case Study Report

Participant(s): Safety Analysts, Researchers

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Facility Operators

Description: The use of advanced crash study techniques and technologies enables researchers, analysts and practitioners to better understand the causes of collisions on HOV lanes. They also provide a tool for identifying crash-prone locations and developing and evaluating remedies. But there are limitations to the use of crash data for estimating

the safety of HOV facilities. Crash statistics only indicate the failure of drivers, vehicles and roadway elements to function together as intended. They do not account for the potentially larger number of events that result in near misses or possible conflicts. If a crash does not result in an injury or property damage over a specified amount (\$1000 in many states) it may not be reported by law enforcement. In other cases, motorists are reluctant to report crashes for fear of increasing their insurance rates⁷. Crash reports may also contain erroneous information or lack necessary elements for valid safety analysis. Mistakes related to distance estimates at crash scenes are common, as are errors introduced when crash reports are coded.

These problems have prompted the development of alternative measures of safety, called surrogates. Surrogates do not depend on crash data. They are useful for identifying potentially unsafe conditions that result in frequent near misses. One surrogate that has proven to be an effective proxy for safety is the time-to-collision analysis method. When measured in the micro-simulation environment, time-to-collision indicates time that it would take for one vehicle to collide with another vehicle if they were to continue at the same speed without taking evasive action⁸. In the context of HOV or HOT operations, this method would involve video surveillance of potentially dangerous sections of the facility where vehicles might collide, such as access points. Given that video monitoring of these facilities and congested corridors is already widely accepted for traffic and incident management purposes, potential privacy issues associated with this safety analysis technique may be minimized. A pilot test and case study should be undertaken to examine the effectiveness of using the time-to-collision method of safety analysis to supplement traditional crash-data analysis techniques at crash prone locations on preferential facilities.

13. Safety Performance of Radial Versus Circumferential Facilities

Purpose/Need: Compare the safety performance of radial and circumferential HOV/HOT facilities

Area(s) of Focus: Research

Facility Type(s): Freeway HOV/HOT facilities

Safety Priority: Low

Cost: Low-Moderate

Time Frame: Medium

Product(s): Research Report

Participant(s): Safety Analysts, Researchers, Facility Operators

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: HOV and HOT facilities can be implemented in radial corridors that branch out from a central business district, or on circumferential beltways or other non-radial roadways. Regardless of the type of facility that is selected, its safety performance may be affected by considerations related to its location on a radial or circumferential route. Radial corridors are often characterized by unequal traffic distribution patterns caused by large numbers of commuters traveling inbound to a central business district or activity center in the morning and returning in the afternoon. This may create excessive peak-period demand and associated safety concerns.

Circumferential HOV lanes typically exhibit smoother traffic patterns, but may be affected by other safety-related considerations such as trip type. Motorists using circumferential HOV and HOT facilities often make short trips that require numerous access points. This generates turbulence within the traffic stream, which can result in increased crash potential. Conversely, HOV and HOT facilities implemented on radial freeways are often line-haul facilities that serve longer-distance trips. They are characterized by fewer access points and less weaving to and from the HOV lane. Additional research is required to determine the safety impact of these corridor considerations on the overall safety performance of HOV and HOT facilities.

14. Safety Impact of Allowing Heavy Trucks on HOV Lanes

Purpose/Need: Determine the net safety impact of allowing heavy trucks on HOV lanes

Area(s) of Focus: Research

Facility Type(s): HOV facilities with heavy truck restrictions

Safety Priority: Low

Cost: Moderate

Time Frame: Short-Medium

Product(s): Research Report, Case-Study Report

Participant(s): Safety Analysts, Researchers, Facility Operators, Commercial Motor Carriers, HOVs, Non HOVs

Potential Sponsor(s): Trucking Associations, Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: The use of HOV lanes by heavy trucks is a concept that has yet to be thoroughly tested or examined. Currently, heavy trucks are restricted from virtually all HOV facilities in the United States. An exception is Virginia, where state legislation permits heavy trucks to drive on HOV lanes on interstate highways that have more than two lanes in each direction, provided occupancy requirements are met. This enables heavy trucks to utilize the I-95/395 and Dulles Toll Road HOV lanes. Other jurisdictions have indicated an interest in examining the use of heavy trucks on HOV lanes during all or a portion of their operating period. This would likely reduce truck traffic on general-purpose lanes and may decrease the number of conflicts and collisions between heavy trucks and passenger vehicles. However, such a measure would require public acceptance, approval from facility sponsors, and extensive safety planning and analysis.

The unique characteristics of heavy trucks (including their weight, dimensions, acceleration and deceleration characteristics, and turning radii) could require design, maintenance and operational considerations that diverge from those of existing HOV facilities. The potential for increased crash severity as a result of the mixing of passenger vehicles and heavy trucks on HOV lanes poses additional concerns. Other potential safety-related issues include degradation of facility performance and responder access; sight-distance deficiencies; enforcement difficulties; and conflicts with supporting facilities such as direct ramps. Further research is needed to understand the net safety impact of allowing heavy trucks on HOV lanes. This research could include a case study of heavy-truck utilization of Virginia HOV lanes and an analysis of the safety impact of different classes of heavy trucks on HOV facilities.

15. Bicycle Use of Freeway HOV Lanes

Purpose/Need: Examination of the feasibility, requirements and safety implications of allowing bicycles on freeway HOV lanes

Area(s) of Focus: Research, Public Outreach and Awareness

Facility Type(s): Freeway HOV Facilities

Safety Priority: Low

Cost: Low

Time Frame: Short

Product(s): Research Report

Participant(s): Safety Analysts, Researchers, Facility Operators, Bicyclists, Facility Users

Potential Sponsor(s): Federal Highway Administration, State Department of Transportation, Metropolitan Planning Organizations, Local Governments, Facility Operators

Description: The use of bicycles as a travel mode achieves many of the same objectives as carpooling or taking the bus. Bicycles represent a cost-effective travel option that reduces transportation-related fuel consumption and pollution, and may alleviate traffic congestion. Currently, bicycles are permitted on several arterial-street HOV facilities in the United States. However, a comprehensive assessment of safety issues associated with bicycle use of arterial and freeway HOV lanes has yet to be undertaken.

Various factors contribute to the lack of safety knowledge regarding bicycle use of HOV lanes. Studies indicate that crash statistics significantly underestimate bicycle collision and injury rates. This is due in part to the scarcity of reliable trip data for the bicycle mode. In addition, collisions involving bicycles are often less costly than motor-vehicle crashes and may not be reported to the police or insurance companies. Unless hospitalization is required, injuries stemming from bicycle crashes may also go unreported. Although bicycles are generally viewed as incompatible with freeway HOV-facility design, a detailed study of bicycle use on freeway HOV lanes has not been conducted. An examination of the feasibility, requirements and safety implications of allowing bicycles on freeway HOV lanes should be undertaken.

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