Research Report
Research Project T9903, Task 89
ITS for Safety on Urban Roadways

Technology and Safety on Urban Roadways:

The Role of ITS for WSDOT

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Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

February 2000

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 460.2		

4. TITLE AND SUBTITLE	5. REPORT DATE
Technology and Safety on Urban Roadways: The Role of ITS for WSDOT	February 2000
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Edward D. McCormack and Bill Legg	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Transportation Center (TRAC) University of Washington, Bx 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631	11. CONTRACT OR GRANT NO. Agreement T9903, Task 89

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Research Office Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370 Jim Schafer, 360-705-7403, <schafej@wsdot.wa.gov>	Research report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This report examines the relationship between Intelligent Transportation Systems (ITS) and safety from an urban perspective.

Existing urban ITS systems are either system-level or site-level applications. System-level ITS, such as freeway management systems or traffic signal networks, address safety concerns only indirectly. These systems are designed to improve traffic flows and thus indirectly reduce collisions caused by congestion. Other system-level ITS used to increase the efficiency of transit, commercial vehicle, and emergency service operations also benefit safety indirectly. Site-level ITS applications, such as railroad/highway crossing warnings or work zone systems, are installed to directly address safety concerns. However, these applications are limited to specific locations identified as hazardous.

Most urban crashes in Washington involve multiple vehicle collisions caused by driver error at locations that have not been identified as hazardous. Future ITS systems known collision avoidance systems (CAS) hold considerable promise for urban roadway safety because these in-vehicle devices will inform drivers of judgment errors and can do so at many locations along an urban roadway system.

A handful of ITS applications are so well tested that they can be aggressively pursued by WSDOT as tools to reduce urban crashes. Most of these applications include the various systems, such a ramp meters and incident detection, used for freeway management. Other ITS safety applications, while promising, still need to be fully documented and are best used as demonstration applications. Most of these applications involve sensor technology used to warn drivers about road and roadside hazards at specific sites. The greatest safety benefit from ITS may come from in-vehicle collision warning systems. These applications should evolve from a number of large federal research projects and private industry initiatives that are under way. Given their potential impact on safety, WSDOT should monitor applications of these projects.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Roadway safety, ITS, urban, Washington state	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None		

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EXECUTIVE SUMMARY

Increasingly, transportation professionals are using information processing, communications, and electronic technology, known as Intelligent Transportation Systems (ITS), to address transportation problems. ITS have many potential applications to safety issue. ITS should be of interest to transportation professionals at the Washington State Department of Transportation because of a need, as outlined in policy objectives, to continually reduce crashes and increase safety. Unfortunately, relatively little documentation directly outlines ITS s potential safety benefits. This paper addresses this issue by examining the relationship between ITS and safety from an urban perspective. This process is guided by crash statistics from the State of Washington s standard accident report form so that the ITS applications can be discussed in light of the situation on WSDOT s urban roadways.

Most of the urban crashes in Washington have involved the collision of two or more vehicles. Many of these crashes have been caused by driver s error such as a failure to yield, impaired driving, or exceeding a safe speed. These crashes can occur at any location on an urban roadway and can not necessarily be tied to a location with a history of being hazardous. The majority of ITS applications in use today are <u>not</u> oriented toward addressing this type of crash. Existing ITS system tends to be either system-level or site-level applications. System-level ITS are typically designed to reduce congestion, which in turn reduces the opportunity for vehicles to occupy the same place at the same time, but they do not necessarily address crashes due to poor driver judgment. Site-level ITS applications provide information that can promote better driver judgment, but this information is limited to specific locations. The distinction between system- and site-level ITS serves as a useful framework for exploring ITS and urban safety.

System-Level ITS Applications

A common type of system-level ITS application found in many urban areas is a freeway management system. These systems use technology to improve traffic flows and to reduce congestion. These systems safety benefits are indirect because reducing traffic volumes have been found to reduce crashes.

A freeway management system is typically composed of several ITS elements. Ramp meters are well used, and a number of studies have concluded that they can result in a significant reduction in freeway crashes. Incident management programs, which often depend more on policy and less on technology, affect safety by reducing congestion and congestion-related secondary crashes. Urban traveler information systems allow drivers to avoid problem areas and can also result in lower levels of congestion and crashes. As weather forecasting systems become more accurate, it is likely that traveler information systems will reduce crashes caused by slippery roads and other weather hazards.

ITS technology applied to computers helps to link and control traffic signals and has been found to improve traffic flow. Smoother traffic flow has a potential safety benefit because it may result in fewer rear-end collisions.

While truck crashes are relative uncommon in Washington, truck crashes tend to be more severe and to result in higher levels of urban congestion. ITS programs to automate safety inspections and other aspects of commercial vehicle safety may indirectly improve urban roadway safety by ensuring that safer drivers and vehicles are on the roads in urban areas.

Emergency management systems (EMS) can benefit from ITS. One well-proven application is the roadside emergency call box. Emergency vehicle management systems are also increasingly common and may use automatic vehicle location devices to assist in optimal vehicle dispatching. This may help to reduce the time necessary for an EMS vehicle to get to a crash scene. Other sophisticated EMS systems use in-ambulance video and other technologies to link emergency vehicles to hospitals. After a crash, ITS can be used to automate the police reporting process resulting in better crash analysis data and more efficient clearance of a crash scene.

Transit can use automatic vehicle identification (AVI) systems to locate vehicles rapidly in an emergency. If AVI is used as part of an information system, riders may be able to reduce the time necessary to wait for transit.

Site-Level ITS Applications

ITS can be used to address problems at specific locations that have been identified as hazardous. Speeding is a common cause of urban crashes. Automatic enforcement systems using cameras can be installed at locations with a history of speeding. Similar systems can be used for red light violators. Installation of these systems has resulted in notable reductions in violations.

One important aspect of ITS is the ability to link a variety of types of sensors to roadside warning signs. Safety in work zones can be improved by using laser-based work site intrusion alarms. Similar sensors can be used at intersections to warn drivers about cross traffic. A range of sensor-based systems being tested at railroad/roadway crossings should be available soon.

Pedestrian accidents are particularly problematic in urban areas. ITS systems can help address this issue. One simple approach is to install recessed run-way lights activated by the pedestrian to provide warning to motorists. Systems that detect pedestrians in the crossing and adjust the signal accordingly are also becoming available.

WSDOT and ITS Policy

For WSDOT staff the use of ITS for safety is best guided by the state s Advanced Technology Policy with its three levels of implementation. These three levels are to aggressively pursue the implementation of applications that have proven effective, demonstrate applications supported by substantial research and monitor applications that have the potential to create substantial benefits.

Based on the state s policy framework, a handful of ITS safety applications are so well tested that they can be aggressively pursued as tools to reduce rural crashes. Most of these applications include the various systems, such a ramp meters and incident detection, used for freeway management.

However, other ITS safety applications, while promising, still need to be fully documented and are best used as demonstration applications. Most of these applications involve sensor technology used to warning drivers about road and roadside hazards at specific sites. ITS safety applications designed for railroad crossings and intersections are examples of these promising systems. Installation of some of the currently available in-vehicle safety systems, such as smart cruise controls, in the state motor pool could serve as a technique to demonstrate and support further development of these applications.

The greatest safety benefit from ITS may come from future applications that will address crashes caused by human behavior as a vehicle moves along the urban roadway network. Such applications, which mainly involve in-vehicle collision warning systems, should evolve from a number of the large federal research projects and private industry initiatives that are under way. These systems are still a number of years away from providing benefits on a wide scale. Given their potential impact on safety, WSDOT should monitor applications of these projects.

INTRODUCTION

In Washington State, policy requires that staff aggressively pursue, demonstrate, and monitor the application of advanced technology to transportation systems (1). This technology, applied as Intelligent Transportation Systems (ITS), has become a viable alternative to more traditional engineering approaches, in part because of increased federal support but also because ITS has been shown to be effective.

Nationally, a commonly stated goal for using ITS is to increase safety for travelers. Because more than 40,000 people are killed on the roads in this country each year, and because losses due to crashes cost billion of dollars, improving roadway safety is a pervasive component of most transportation professionals jobs (2). The growth of interest in ITS, combined with a continuous need under policy objectives to improve roadway safety, suggests that many transportation engineers and planners in Washington may want to be aware of the potential safety benefits of ITS.

While a frequent justification for using ITS in urban areas has been safety, relatively little documentation directly outlines ITS s potential safety benefits. Because transportation professionals in WSDOT and other public agencies may want to consider ITS s role in improving safety on the transportation system, this paper examines the relationship between ITS and Safety from an urban perspective.

THE ADVANTAGES OF ITS

ITS apply information processing, communications, and electronics to transportation problems (3). ITS are meant to provide information that helps travelers make safer decisions and that helps improves the safety and efficiency of different elements of the transportation system (4). The federal government s national ITS programs specifically highlight safety as a major reason for supporting ITS. Many ITS articles, documents, and implementation plans mention safety as one benefit of ITS. For example, ITS America promises that ITS will save lives and move goods and people more safely (5). Given that safety is a common justification for ITS, an obvious question is to ask how does ITS technology have the potential to address urban safety problems?

The World Road Association recognizes 33 ITS user services, which are organized into eight main categories (Figure 1) (6). Direct and indirect safety issues permeate this list of user services. Three of the main categories are explicitly oriented toward safety (**Safety**, **Emergency Management** and **Advanced Vehicle Control and Safety Systems**). Two of the user groups under the main categories also include safety: **public travel security** and **commercial vehicle on-board safety monitoring.** Finally, many of the user groups such as **route guidance** and **ride matching and reservation** that reduce congestion and increasing mobility can be expected to indirectly increase safety. In fact, safety is an element of most of the ITS user services.

Clearly there is a widespread expectation that ITS will improve safety. The challenge for a transportation professional is to determine how and where ITS can realistically be used as a tool to address safety.

Traveler Information (ATIS)

1. Pre-trip Information
2. On-trip Driver Information
3. On-trip Public Transport Information
4. Personal Information Services
5. Route Guidance and Navigation

Traffic Management (ATMS)

6. Transportation Planning Support
7. Traffic Control
8. Incident Management
9. Demand Management
10. Policing/Enforcing Traffic Regulations
11. Infrastructure Maintenance Management Vehicle

Advanced Vehicle Control Systems

12. Vision Enhancement
13. Automated Vehicle Operation
14. Longitudinal Collision Avoidance
15. Lateral Collision Avoidance
16. Safety Readiness
17. Pre-crash Restraint Deployment

Commercial Vehicle (CVO)

18. Commercial Vehicle Pre-clearance Commercial
20. Vehicle Administrative Processes
21. Automated Roadside Safety Inspection
22. Commercial Vehicle On-board Safety Monitoring
23. Commercial Vehicle Fleet Management

Public Transport

24 . Public Transport Management
25. Demand Responsive Transport Management
26. Shared Transport Management

Emergency Management

27. Emergency Notification and Personal Security
28. Emergency Vehicle Management
29. Hazardous Materials and Incident Notification

Electronic Payment

30. Electronic Financial Transactions

Safety

31. Public Travel Security
32. Safety Enhancement for Vulnerable Road Users
33. Intelligent Junctions

Figure 1. ITS User Services

ITS, SAFETY, AND URBAN ROADS: OTHER REVIEWS

Most ITS applications are based on recent advances in technology. As a result, only a few ITS applications have been used long enough for their safety benefits to be appraised in detail, especially in comparison to traditional engineering solutions. Fortunately, several, mostly federal, studies do give some indication of the expected overall safety benefits of ITS.

An FHWA sponsored review of ITS applications at locations across the country (7) explored their benefits. One section of the study focused specifically on safety. Unfortunately, the conclusions about safety benefits were based on only a few measured cases and were for the most part derived from anecdotal information or predictions based on analysis and simulation. Traveler information systems were found to help drivers avoid situations where the risk of crashes would be greater because of traffic, roadway, or environmental conditions. Such systems would also reduce driver stress perhaps resulting in smoother and safer traffic flow. Traffic management systems were anecdotally found to increase safety by reducing conflicts between vehicle streams and by improving compliance with traffic control devices. This report suggested that proposed vehicle control systems could reduce the likelihood of crashes but this conclusion was not based on any actual applications.

Another more recent FHWA report (8) provided an overview of ITS benefits and mirrored some of the conclusions of the previous report. The report noted that ITS can improve safety in metropolitan areas by improving traffic flow and preventing crashes. ITS could also improve urban emergency response by detecting incidents earlier and clearing the roadways faster. In addition, ITS were found to improve safety by improving transit security (8).

A 1997 analysis of the benefits and costs of ITS concluded that safety would be the biggest single benefit of the deployment of a basic metropolitan ITS infrastructure over the next 20 years (9). Such deployment would result in an estimated 42 percent benefit due reduction of accidents. Such a metropolitan ITS infrastructure would also substantially increase the safety and responsiveness of transportation systems in everything from single car accidents to hurricane evacuation. (3,9). The report indicated that a number of ITS safety systems would be in-vehicle devices that would come from the private sector. The report concluded that potential of these systems will not be fully realized until later (after 2006) when the technology has matured.

A literature-based review of the safety benefits of ITS, completed for the Virginia Department of Transportation, was undertaken because of the belief that safety was an underestimated benefit of ITS (10). The authors reviewed a number of national studies that evaluated different ITS applications. They concluded that advanced traffic management systems, which include loop detectors and video surveillance to examine traffic flow and to detect incidents, improve safety mainly because crash risk increases as congestion increases. The authors noted that a major cause of congestion is incidents. ITS technology that reduces crashes and other incidents reduces congestion and thus further reduces crashes. Another ITS application area reviewed was advanced traveler information systems, but the report concluded that the impact of these systems on safety is difficult to measure.

A strategic plan to implement ITS in Washington, Venture Washington, suggested another perspective from which to view the safety benefits of ITS (11). The plan included a benefit/cost analysis of a number of ITS elements. The elements included many urban ITS applications such as traffic management centers, traveler information systems, changeable message signs, ramp meters, and highway advisory radio. With the exception of ramp metering, the level of crash reduction could not be quantified for any ITS applications. This highlights the historical difficulty of linking ITS applications to quantifiable safety results. Venture Washington also suggested that an ITS program might not have a measurable cost to benefit ratio but could be evaluated in terms of criticality. In other words, an incident management system might have a minimal effect on total statewide travel but could greatly affect a few travelers. This viewpoint suggests that the prevention of a few injuries or fatalities might warrant an ITS application even if the standard cost to benefit approach indicated otherwise. However, such projects would be difficult to fund under Washington s current priority-based funding system.

Each of these studies clearly found that ITS has the potential to address safety problems on urban roadways. However, they also clearly indicate that many of these safety benefits are indirect and hard to quantify.

URBAN ROADS AND CRASHES

What is an urban road? In Washington State, all highways are considered rural unless they are within an area that has been designated urban. Urban areas include towns or cities with a population of 50,000 or more, plus other areas as designated by the Bureau of the Census, state, and local officials.

These urban areas are a small proportion of Washington s total area; only 4 percent of Washington is urban. Because so little of the state s land is urban, only 15 percent (1,058 miles) of the state s roadways are urban. However, these urban roads carry the majority of the state s traffic, 15.9 million annual vehicle miles on urban roads as compared to 11.2 million annual vehicle miles on rural roads.

On all of Washington s state highways between 1993 and 1996, 63,100 crashes per year were reported on the Police Traffic Collision Report form. Of these crashes, 71 percent (44,800) were in urban areas. In terms of exposure rates, urban accidents (2.1 accidents per million miles of travel) were almost twice as frequent as rural accidents (1.2 accidents per million miles of travel) but were also less likely to be fatal (Table 1).

Table 1: Statewide Crashes per Million Miles of Travel, 1993-1996

Severity	Rural	Urban
Property Damage Only	7.09	11.35
Injury Crash	5.37	9.47
Fatal Crash	.17	.06

Source: WSDOT Data Office

Table 2: Principal Urban Crash Causes: 1993-1996

Contributing Causes	Percent of All Crashes
Exceeding safe speed	22.6%
Following too close	19.3%
Failure to yield	16.5%
Inattention	6.5%
Under the influence of alcohol	5.1%

Source: Washington State Collision Report Form

The most frequent contributing causes of crashes on urban state roadways in Washington are shown in Table 2.

From 1993 to 1996, exceeding safe speed contributed to more that 20 percent of all crashes on state highways in urban Washington. Next in frequency were crashes due to following too close, and then failure to yield. Similar in frequency were crashes due to inattention and alcohol impairment.

The nature of the crashes on the WSDOT s urban roadways is shown in Table 3.

Rear-end collisions were the most common type of crashes on the state urban roadways. Next in frequency were different types of side and sideswipe crashes. These two types of multi-vehicle crashes made up almost 70 percent of all urban crashes. Most urban crashes (84 percent) involved a collision between two or more vehicles (in contrast, only 47 percent of rural crashes involved two or more vehicles).

Table 3: Principal Urban Crash Types: 1993-1996

Types	Percentage of All Vehicles
Multi-Vehicle Crashes	
Rear end collision	47.9%
Side and sideswipe collision	29.2%
Front end collision	5.6%
Other	1.1%
Total	**83.8%**
Single Vehicle Crashes	
Strike object	10.9%
Overturn	2.1%
Other	3.2%
Total	***16.2%***

Source: Washington State Collision Report Form

ITS AND SAFETY

A former Federal Highway Administrator evaluated the potential safety benefits of ITS and found that these benefits were indirect and included: *a general enhancement of user safety by reducing driver stress and indecision, achieving smoother vehicle flow and generally providing for a driving environment which yields improved safety as one of its by products.*

In some cases the benefits apply directly to: *specific safety issues where ITS technology is being developed as a countermeasure.* (12)

The first type of ITS safety benefit involves system-level ITS applications and is an indirect, general enhancement to safety. For example, ramp metering systems are not primarily installed as safety systems but increase safety as a by-product. ITS installed specifically for safety issues tends to be site-level applications. For example, a flashing ice warning sign linked to sensors on a freeway overpass directly addresses a safety hazard at one specific site.

This distinction between system- and site-level ITS benefits provides a useful starting point for exploring the role that ITS may play in improving safety on urban roadways in Washington. These two categories are used in this paper to frame a discussion of ITS because they mirror the way transportation professionals might consider using ITS. System-level ITS applications are not installed specifically for safety reasons, but transportation professionals should be aware that their indirect safety benefits can be used as an additional justification for these systems. However, at hazardous sites, transportation professionals may want to be aware of ITS s potential as a tool to address a problem, perhaps more effectively than traditional engineering solutions would.

An additional further category of ITS applications comprises systems that, for the most part, remain untested or under development. These applications, which include in-vehicle collision warning and avoidance systems, are designed to directly address safety concerns and to do so on a system-wide level. Such ITS have perhaps the greatest potential for reducing common urban crashes and are discussed in light of Washington s urban crash patterns.

System Level Applications

This section discusses the safety benefits of system-level ITS applications. The largest and most obvious ITS application in many urban areas is the freeway management system. These systems include elements such as ramp metering, incident management programs, and traveler information systems. They produce indirect safety impacts that relate mainly to these elements ability to improve network-level transportation performance. Other system-level ITS applications that affect urban safety include traffic signal management, commercial vehicle operation (CVO) programs, and emergency management service (EMS) systems.

Freeway Management Systems

The interstates in Washington carry 33 percent of all urban travel and are the location of almost 40 percent of all urban crashes (13). The importance of these roadways is such that WSDOT has traffic system management centers operating or planned for several of the state s larger urban areas. Many urban areas national have some type of freeway management system. These management systems include ITS technology to give transportation professionals the ability to monitor traffic flows, identify incidents, implement traffic control, and provide information to travelers about freeway conditions. While these systems are primarily designed to address congestion, safety is an important secondary benefit.

Freeway management systems improve traveling efficiency and increase mobility. The safety benefit from freeway management systems is due to the relationship between roadway congestion and crashes. As traffic volumes increase, crash risk also increases (14,15,16). Once a crash, or any other type of incident occurs, the probability of a secondary crash increases. One study, for example, found that crash rates increase by more that 60 percent in the presence of a previous crash (15). Another study of a freeway in Minnesota found that 13 percent of all peak period crashes were caused by previous incidents (17). As a result, congestion, incidents, and crashes have a cyclic relationship. ITS applications can affect this cycle, either by reducing congestion or by limiting the impacts of incidents. Each outcome results in fewer crashes.

Elements of freeway management systems and their safety benefits are discussed below. Because Washington State is a national leader in ITS applications, these elements are all in use by WSDOT. For the most part, the safety benefits of such systems are recognized in this state but have not been quantified.

Ramp meters are installed mainly on higher volume roadways to smooth traffic flows, reduce congestion and reduce the number of incidents. The greater Seattle area includes numerous ramp meters, and the safety benefits of ramp metering are fairly well recognized in Washington. A study completed by WSDOT found that crashes were reduced by 62 percent during peak hours after ramp meters were installed (18). A 1995 national survey of ramp metering explored 23 systems and included a review of their safety benefits. The report concluded that these systems resulted in an accident rate reduction of 24 to 50 percent (19).

Incident management systems are designed to respond to the crashes, vehicle breakdowns, and unexpected blockages that are common on many urban roadways. Washington State s Incident Response Guide (20) estimates that the number of lane blocking incidents in the state could be as high 25,000 per year. These incidents result in an estimated 33 million hours of delay and congestion. While many incidents are crashes themselves, as discussed above, any incident greatly increases the possibility of secondary crashes. Incident management programs typically include traffic operation centers, efficient roadway clearance and accident investigation systems, improved emergency vehicle access, and service patrols (21).

While incident management programs are often considered an ITS application, many aspects of these programs are more dependent on policy decisions and traditional engineering tools than they are on technology. However, ITS technology still contributes to incident management programs in a number of ways. Many freeway management centers use a range of technologies to detect incidents. These systems often include a computer based incident detection program or algorithm linked to roadway loops, video based image processors, or other technologies such as acoustic and infrared detectors. (22). As discussed later in the paper, ITS technology can also facilitate accident investigations, resulting in faster site clearance.

Traveler information systems warn drivers of roadway hazards and difficult driving conditions. Congestion decreases when drivers take alternative routes or forego a trip altogether. Traveler information systems include a wide range of technologies, many of which have been used in the Seattle area, such as the Internet, roadside radio, commercial radio, variable message signs (VMS), in-vehicle devices, kiosks at office and shopping centers, pager watches, and dedicated TV channels. Most of these technologies have been used in urban areas for a considerable time and have been evaluated. For example, a review of VMS systems in United States and other countries clearly noted that their use over time has reduced congestion and accident rates (21).

Traveler information in urban areas often focuses on incident and congestion information but can also provide weather information. Weather has a notable impact on travelers by reducing roadway traction, visibility, and vehicle stability. Weather reporting systems with information designed for travelers can reduce travel during bad conditions and can encourage those that who do travel at these times to be cautious. In Washington State, between 1993 and 1996, about 5 percent of urban crashes were on roadway surfaces covered with snow or ice. Although large area weather forecasts are common, they typically contain little information on road conditions. More sophisticated weather system are being developed that should produce forecasts that are more specific to individual roadways. In Washington, a project is tying a number of existing weather stations together to create a tighter forecasting grid. This, in turn, will result in much better road-level weather data and better traveler information on urban road conditions.

Traffic Signal Management

Traffic signal control systems coordinate signals on urban streets. By responding to the time of day, special events, and incidents, such systems result in smoother traffic flow and fewer stops (21). This may reduce rear end collisions, which make up the most common type of urban crash. One Japanese program that installed computer controls for traffic signals at 719 intersections found that, after five years, these upgrades had reduced crashes by 75 percent while also improving travel times (22).

Commercial Vehicle Systems

In Washington, 4.9 percent of all vehicles involved in urban crashes are trucks. Although the percentage is not high, such crashes tend to be more severe and to have a greater impact on congestion (23). Because weather conditions such as snowy or icy roads may have a greater impact on trucks than on other vehicles, ITS weather warning systems may have a correspondingly greater positive effect on trucks than on other vehicles. Another development that may help reduce truck crashes is found in current efforts to develop an on-board safety monitoring system that senses tires, brakes and perhaps driver alertness. This monitoring will occur automatically at highway speeds.

Indirect urban safety improvements may come from Commercial Vehicle Operations (CVO) programs that improve regulatory compliance. These permit a state to automate portions of the vehicle inspection process and thus should increase efficiency and ensure that safer vehicles are on the road. A number of large CVO projects are under way in this country, and many have a safety component (3). Washington State is involved in a program to develop an information system that supports commercial vehicles (known as CVISN, for Commercial Vehicle Information Systems and Networks). This program includes a safety element that will use electronic technology to ensure that drivers and vehicles have acceptable safety records (24).

CVO programs may eventually result in quick, electronic access to truck cargo manifests. In urban areas with higher population densities, such information may be of particular concern because of hazardous materials. Automated cargo information may help in hazardous material identification and cleanup (21).

EMS Systems

Any decrease in emergency service response times to crashes has been shown to reduce injury severity and fatalities (7). While many urban crashes are now reported on cellular phone, emergency notification technology oriented still holds value for safety. Such ITS systems range from site-specific roadside call boxes to area-wide in-vehicle mayday systems. As with most ITS technology, the viability of emergency notification systems depends on the coverage and technology of communication networks.

Emergency call boxes have been installed in a number of urban areas across the country, including Washington State (25) and boxes have used both standard wired phone lines and wireless cellular. Call boxes are designed to address specific locations where notification has historically been a problem. Studies of call boxes in urban areas suggest that in many areas they work well (25). Call boxes may also provide additional benefits as multi-purpose ITS data stations (26). For example, the California Department of Transportation investigated the use of call boxes as traffic counting and hazardous weather detection stations.

In-vehicle mayday systems using cellular technology have been tested in Washington and other areas. This area-wide system allows drivers to request emergency assistance from their vehicles while an in-vehicle global positioning system relays their location. A related EMS system uses in-vehicle sensors to detect when a collision has occurred and then automatically informs EMS providers where the crash is located (27). These systems may even relay information on the severity and type of crash. The NHTSA is performing an operational test of these systems. Several of these systems are available from vehicle manufacturers and have seen growing usage.

Another ITS system is emergency vehicle management, which attempts to reduce the time required to get an EMS vehicle to a scene. This type of system can use an automatic vehicle location system to track EMS vehicles and facilitates optimal dispatching (28). A system in San Antonio (Lifelink) uses a wireless network to link EMS crews with emergency management centers. The system includes two-way teleconferencing facilities so that early assessment and treatment of patients can be initiated in the field instead of when an EMS vehicle arrives at an emergency room. The network is owned and installed by the Texas Department of Transportation and involves radio equipment and a fiber optic system along the roadway system (29).

Traffic signal systems designed to be preempted by emergency vehicles also have a safety impact in urban areas. Such preemption systems are used in a number of urban areas in Washington. These systems make the signal responsive to emergency vehicles and can optimize the signals along an emergency vehicle s route. A variety of technologies are available, including sound (sonic) and strobe activated systems.

Crash Documentation

Crash documentation is an area in which ITS applications might indirectly improve safety by helping to provide more accurate and complete reporting of crashes and faster incident removal. This would help transportation engineers better identify and address recurring safety problems. In Washington, total station surveying equipment carried in police cars permits officers to complete crash investigations more completely and more quickly and addresses a common problem of correctly locating a crash for the accident report (30). An additional benefit is that total station equipment helps personnel clear the roadway more quickly. Another example of this type of system is the use of laptops and portable computers in police vehicles in Minnesota (31). This system is expected to reduce paperwork and to locate accident sites more accurately.

The increasing accuracy of global positioning systems, combined with new GIS and crash recording software, as well as powerful portable computers, suggests that the ability of law enforcement personnel to quickly collect accurate data at crash scenes will continue to improve. One recent FHWA study evaluated a range of technologies for traffic accident reporting in four states (32). While the authors found that the tested systems needed refining and did not necessarily reduce the time required to complete an accident form, they concluded that, with training, such technology could reduce errors and omissions on the report forms.

Transit Systems

ITS applied to transit (5) is mainly designed to increase transit efficiency but also can have some safety impacts. Transit systems can use automatic vehicle identification (AVI) technology to electronically monitor vehicle locations. Such a system, for example, is used by King County Metro. These systems are designed for fleet management and to provide information to riders. However, the ability to locate a transit vehicle in an emergency is considered a major benefit of an AVI system (33). Once a transit vehicle has been located, police or medical help can be sent to the transit vehicle (34). AVI systems may also provide safety benefits when they are linked to en-route transit information systems that inform riders of buses arrival times at transit stops. Riders can use this information to reduce the time that they have to wait at stops in bad weather or after dark (35).

Providing a safe environment for transit users can also be addressed with security cameras at transit stations, park and ride lots, bus stops and on buses. Devices linked to a remote alarm can also be installed at these locations.

Site-Level Applications

This next section discusses ITS applications that are installed to directly address safety concerns at hazardous or problem locations.

Automatic Enforcement

Speeding or exceeding safe speeds is implicated in over 25 percent of all urban crashes in Washington. While this category is a catch-all for many crash causes, speeding is still a problem. ITS technology to address this issue is limited, and reducing speed in urban areas may depend more on education or enforcement. However, one technology-based enforcement tool used in some states is a roadside photo camera with radar. Vehicles exceeding the speed limit are photographed and identified by their license plate, and a citation is then mailed to the registered owner (36). British Columbia has a similar system, except that it uses optical character recognition to read license plates.

An additional 3.5 percent of urban crashes in Washington involve vehicles running signals or stop signs, and automatic enforcement designed to catch red light runners can partially address this problem. This system uses pavement loops linked to a microprocessor and a camera on a pole. The system becomes active when the signal turns red. The camera then takes a photo if any vehicles enter the intersection. Often the system takes several pictures from different angles to capture a driver face and license plates. Such systems have dramatically reduced violation rates (37). Installation in San Francisco of such systems at five intersections resulted in a drop in red-light violations of 42 percent. A similar system in New York saw a drop in violations of 62 percent. These types of systems usually require some legal or legislative changes to allow citations to be issued. As a result of these and other institutional issues, automated enforcement has an uncertain future in Washington State.

Work Zones

Of all urban crashes in Washington, 5 percent were in construction areas. Between 1993 and 1996, 13 fatalities were associated with construction zones. A variety of ITS systems have been developed to address such situations. One simple approach is to use variable message signs at work sites. These signs are relatively inexpensive, can be altered via telephone, and are adaptable to changing work site conditions (31). A more complex portable system, developed by a vendor, includes variable message signs and highway advisory radio with real-time information on work zone conditions and detours (31).

Other ITS systems for work zones control drivers speed by linking radar to warning signs and beacons. One system applied to a work zone by the Indiana DOT links electronic occupancy sensors to lane drop signs. As traffic volume increases, more signs are activated, smoothing vehicle merging (3). The National Cooperative Highway Research Program is funding the test of another system that warns workers when lasers detect that a vehicle has intruded into the work zone (38).

ITS were recently applied in an interesting manner during the reconstruction of a busy highway interchange in New York City (39). Because of the challenges of this location and the great potential for system level disruption due to incidents, the department of transportation installed an advanced traffic management center. The center was intended to reduce the impact of the construction on congestion and motorist safety and included operation of incident detection, roadway clearance systems, and traveler information. The system worked well and prevented any increase in crashes due to the construction activity. Because of the success of the system, the DOT decided to keep the center in operation after the construction was completed.

Indirectly, ITS traveler information systems may also increase work zone safety by informing drivers about alternative routes that permit them to avoid construction areas.

Hazardous Locations and Warning Signs

ITS can be installed at hazardous locations to inform drivers of hazardous situations. A simple example of this type of system in Seattle is the use of radar to detect vehicle speeds before a sharp curve (31). If a vehicle approaches at a speed that is too fast to safely make the curve, a beacon on a sign flashes a warning. This system uses widely available equipment.

Another ITS system that indirectly addresses excessive speeds is a variable speed limit that can be changed in response to driving conditions. One extensive review of variable speed limits in urban areas noted that these systems can be expected to smooth traffic flow, resulting in fewer accidents due to stop-and-go traffic and where high speed traffic encounters a slow speed queue (40). This study also discussed a cost/benefit analysis of an urban variable speed system in Maryland. In the first year of use, the benefit of the system, due just to reduced crashes, was more than 3 times the cost of installing the system. One such (rural) system with 13 variable message signs is installed over Snoqualmie Pass in Washington (41).

Spot locations that are particularly hazardous to trucks can be equipped with vehicle classification detectors linked to warning signs. Such systems have been applied in several states where curves and grades are hazardous to trucks. One interesting CVO safety system in Oregon is located at a weigh station just before a steep downhill grade. The truck s weight is used to calculate a safe speed that is then flashed on a message sign for the truck s operator.

Another example of an ITS warning system at a problem location is an ice detection sensor hooked to warning signs. Such a system was tested in Washington State and used ice sensors on a bridge linked to a beacon on an ice warning sign (31). This system was removed, in part, because of concerns about liability if an ice-related accident occurred during a system malfunction. This highlights the concern that that the perceived liability of such systems may create a cost that outweighs their benefit.

While snow plowing is often associated with rural areas, WSDOT also plows urban areas. In Washington, collisions with snowplows occasionally occur. ITS technologies that warn travelers about snowplows ahead may prevent this type of crash. This type of system could involve automatic warning signs or a short range, portable radio (known as an electronic flare) carried on the plows to broadcast a warning message received over nearby vehicles radios.

Intersections

About 30 percent of all urban crashes in Washington involve roadway intersections. ITS can warn drivers about to cross an unsignalized intersection, particularly crossings at higher speed roads, about a dangerous situation. One example of such a system is a collision countermeasure system being evaluated by the FHWA in Virginia (42). This system is designed as an alternative approach for rural intersections where the cost and traffic delays of a fully signalized intersection would be difficult to justify. The system uses sensors and flashing signs to warn a driver traveling on the major through road when a vehicle on the cross-street is prepared to enter the intersection. Drivers waiting to cross the through road are warned with an animated sign when traffic is approaching.

Railroad Crossings

Nationally, crashes at railroad crossings are considered a serious problem and kill more people each year then do commercial airline disasters (21). As result, a number of ITS applications oriented toward railroad crossings are available or are under development. While urban crashes involving trains on Washington s urban state roadways resulted in only 12 non-fatal crashes between 1993 and 1996, the public and policy makers still perceive these locations as hazardous and in need of preventive measures.

Half of the railroad grade crossing crashes that occur nationally occur at crossings where warning devices already exist. As result, automated enforcement systems with cameras and roadway loops (similar to those discussed for traffic signals) have been used to deter violators. Projects testing this type of system are under way in California, Arkansas, and Los Angeles (21).

The Federal Railroad Administration is testing a crossing system that detects the presence of on-coming trains and broadcasts that information to a display inside specially equipped vehicles (such as school buses). This system requires equipping locomotives with a system such as a GPS, an onboard computer, a data radio, and track-side transponders that would identify and monitor train operations at critical points. In New York a similar system is being developed to inform drivers via variable message signs that trains are approaching. (21).

A Minnesota project is testing an in-vehicle signing system that places an alarm inside a school bus to focus the driver's attention on an approaching train (21). The system uses wireless vehicle-to-roadside communication antennas built into the railroad crossing sign and the bus license plate, a vehicle-to-roadside communication unit, transponders, and a warning display system.

In San Antonio, four trains will be equipped with monitors, and an unspecified number of crossings will be equipped with infrared cameras. Wireless communications will enable the train operator to see obstacles such as stopped vehicles in the crossing and to stop the train if necessary (21).

Pedestrian Safety

Pedestrian deaths are a major problem in urban areas. Between 1993 and 1996, 0.8 percent of the crashes on WSDOT s urban roadways involved pedestrians. While this is a relatively low percentage of all crashes, almost every one of these 1062 crashes resulted in injuries, and 74 resulted in deaths.

ITS pedestrian safety applications typically improve the ability of motorists to detect pedestrians, make a transportation system more responsive to pedestrians at crossings, or enhance existing systems (43). One increasingly common tool that improves the ability of motorists to detect pedestrians is the installation of recessed in-pavement airport runway lights that pedestrians activate. Another system that is available provides a countdown clock that indicates to pedestrians how long before signal changes from walk to don t walk .

Pedestrian systems may use infrared technology, microwaves, or pressure sensitive mats to detect a pedestrian at a curb and activate a crossing signal. Similar technology and video detection systems, may be used to detect pedestrians in the crosswalk and extend the crossing time as long as necessary (44, 45).

Another system used in Europe detects the presence of pedestrians as well as vehicles. The signal then coordinates the data from these two detectors to adjust crossing time for maximum safety (44).

In areas where a problem may exist, some inexpensive, low technology systems can simply warn drivers of bicyclists or pedestrians ahead. The systems are activated by the pedestrian or bicyclist and are linked to a sign or flashing light that turns off after a set period of time. Examples of such self-activated systems include a BICYCLES ON HIGHWAY sign and beacon in Colorado and a PED/BICYCLE IN TUNNEL WHEN FLASHING sign in Washington (31). A more complex system could use sensors in place of self-activation.

FUTURE ITS

Over 70 percent of the urban crashes in Washington have involved the collision of two or more vehicles. Most of these crashes have been caused by driver error such as a failure to yield, impaired driving, or exceeding a safe speed. These crashes have not necessarily been related to identified hazardous locations. However, the majority of ITS applications in use by transportation professionals today are not oriented toward addressing this type of crash. Future ITS systems known as advanced vehicle control system or collision avoidance systems (CAS) may inform drivers of judgment errors or may even correct their actions. These systems will be in-vehicle and will work at many points along the roadway system, not just at specific site that have been identified as hazardous. So far these systems have seen only limited use with most still under development. Because they will require in-vehicle devices, many of these systems will have to come from the vehicle manufacturers.

Never the less, even if CAS are developed by the federal government and are installed by the vehicle industry, WSDOT s transportation professionals should be aware of these systems. They have the potential to notably affect urban safety. The following section discusses several type of CAS and relates them to the patterns of urban crashes found on Washington State s urban roadways. Several other ITS applications that are currently under development and that may reduce urban crashes are also mentioned.

Collision Avoidance Systems

Collision avoidance systems employ technology to inform drivers that dangerous conditions exist, warn drivers that a collision is imminent, or actually activate an automatic vehicle reaction to avoid a collision hazard. The anti-lock braking system (ABS) available on many vehicles is a simple example of this type of ITS system.

A number of studies have suggested that CAS have great potential to reduce crashes. For example, one federal study of systems designed to address rear-end, lane change, and single-vehicle run off the road crashes calculated that nationwide CAS could reduce the number of these crashes by more than half (46).

It should be noted that collision avoidance systems may have technical and operational limitations (47). Any CAS system has to be designed so that the system detects all possible crashes while minimizing false alarms that might lead to drivers to ignore the system. It is also possible that CAS may lead to behavioral changes as drivers come to count on CAS to cover for driver errors (48). For example, one study of ABS brakes found that once drivers became accustomed to ABS they drove faster than drivers without ABS, compromising any safety benefits.

CAS can be placed into general categories that reflect the types and causes of crashes (47). These categories and their relationship to urban crashes in Washington are as follows.

Forward Looking Obstacle Detection: These collision avoidance systems use sensor technology to detect a vehicle in the road ahead. They can be designed to address the most common type of crash on Washington s urban road — the rear-end collision. Such systems are have been used on buses and transit for years, and laser-based systems are now available on cars in Japan (49). Several American manufacturers have versions of these systems under development (21), and existing systems are rapidly coming down in price (49). Typically, such systems use sensors based on ultrasound, radar, or video to warn the driver if danger is detected. More sophisticated systems will also have the ability to automatically slow the vehicle if a driver does not react to a warning. A simple version of this type of CAS is **intelligent cruise control**, also known as adaptive cruise control, which uses a forward detection system to maintain a safe following distance between vehicles. (21,49).

Side-Zone and Rear-Zone Obstacle Detection: About 11 percent of the crashes on the state s urban roads occur while vehicles are changing lanes. An additional 1 percent involves vehicles that are backing. Obstacle detection systems designed for the sides or backs of vehicles should reduce this type of collision. Such systems employ various methods of distance and proximity detection, such as radar or ultra-sound, to detect vehicles in blind spots. Blind spot detectors for lateral lane changes are available and have been demonstrated on transit buses. Backing sensors hooked to warning devices have been used on trucks and buses for a number of years (50).

Lane Detection Systems: Nine percent of the crashes on Washington s urban state highways involve a single vehicle running off the road into highway appurtenances, ditches, and other obstacles. This type of crash might be reduced by systems that detect road or lane markers and warn drivers if roadway departure is imminent. Such systems possibly could also inform drivers of curves ahead. Lane detection has been an important part of finding ways to guide snowplows, since they need to know where lanes are in conditions of poor visibility (51). Versions of such systems that have used a magnetic fog line tape or embedded sensors have been tested. Another relevant system being developed by the NHTSA is a road departure warning system (27). This system could use a range of technologies to either inform drivers that their vehicle has crossed the lane onto a shoulder or warn drivers that the vehicle is about to run onto the shoulder.

Vision Enhancement Systems: Recognizing that more than half of all fatal crashes in this country occur at night and during conditions of poor visibility, NHTSA is investigating the feasibility of vision enhancement systems (27). While these systems tend to have a rural emphasis, they can be relevant for urban roadways since 6 percent of Washington urban crashes have occurred at night in areas without streetlights. Such systems use infra-red and other systems to enhance visual images of roadway obstacles and features. An American vehicle manufacturer currently offers a simple windshield mounted thermal sensing enhancement system.

Roadside to Vehicle Communication: This communication system uses roadside sensors to provide real-time safety information to an in-vehicle receiver. Potential applications include intersection-warning systems, traffic gap detection, and pavement sensors that warn of ice. A simple version of this type of system which avoided the need for in-vehicle equipment was tested in Germany (52). The system used LED equipped roadside posts hooked to fiber optic backbone and was designed to reduce multi-vehicles collision. The posts could be changed to warn of different hazardous conditions and were determined to reduce crashes significantly. Other such roadside-to-vehicle systems using in-vehicle devices would require coordination between public agencies responsible for the roadway infrastructure and the vehicle manufacturers for the in-vehicle devices. Few examples of this type of ITS application currently exist.

Drowsy/Impaired Driver Detection: Eight percent of the urban crashes on state highways in Washington have been attributed in the collision report to driver inattention or sleeping. Another 5 percent of the crashes have involved impaired drivers. ITS systems designed to address this problem use in-vehicle technology to monitor drivers. One example of a drowsy driver monitoring system is being explored by NHSTA (27). This system works by tracking how well the vehicle stays within lanes and other factors such as eye movements, steering wheel motion, and sideways movement.

ITS strategies to address impaired driver crashes may be similar to drowsy driver systems. Other limited systems are available now that use in-vehicle devices such as simple coordination tests or breath analyzers. Such technology would most typically come from the private sector, but the courts can mandate the application of such technology. In Washington, new legislation allows the courts to require individuals with a history of impaired driving to install breath analyzers with ignition interlock in their vehicle (53).

Other Future ITS

The majority of Washington s urban crashes have involved drivers using poor judgment, such as a failure to yield, improper passing, improper signaling, and U-turns. Few ITS applications that directly address drivers judgment errors are currently available.

Judgment related crashes not linked to impairment due to drugs or alcohol, might involve driver inexperience or declining mental and physical ability related to aging. An examination of driver age in relation to judgment-related crashes in Washington found that these crashes were most common for younger drivers. The number of crashes in this category declined with age until about age 55, after which there was an increase in crashes. This trend matches national findings. NHTSA notes that younger and older drivers share the distinction of having more crashes per mile driven than other age groups (54).

An ITS tool that may address these types of problems but that is probably beyond the reach of most transportation professionals is technologically advanced driver training. This type of training could depend on computer-based techniques such as computer simulation. Such tools are used for military and flight training but have yet to be widely used for driver training.

For elderly drivers, computer-based techniques that enhance or improve their ability to receive roadside information may indirectly address safety. NHTSA is examining advanced technology crash-avoidance counter-measures to determine which have the greatest safety potential for older drivers (55). Another project sponsored by the FHWA is using a computer-based system for developing and improving the design of roadside symbol signs for easier viewing by the elderly (55).

Note that ITS techniques that benefit most drivers may also reduce the number of crashes involving impaired drivers. Impaired drivers are the same as unimpaired drivers except with slower reaction times and with worse judgment. Impaired drivers may be more prone to crashes, but they also may benefit more from ITS applications such as speed control signs or NHSTA s road departure warning system.

Safety may also be improved by the use of data recorders in cars. General Motors is already installing these devices which are similar to the black boxes found in airplanes. Several other automobile manufacturers have indicated plans to install similar recorder systems (56). These recorders could assist in the design of safer vehicles and help focus the design of collision avoidance and other ITS systems.

CONCLUSIONS

This paper explores the use of ITS to address safety on urban roadways. It is clear from the ITS literature and studies of ITS benefits that many urban ITS applications have a safety component. It is also clear that these safety benefits are sometimes indirect and hard to measure. This paper examines ITS systems and attempts to highlight their direct and indirect safety benefits. This process is guided by statistics from the State of Washington s standard accident report form so that the safety benefits can be discussed in light of the pattern of urban crashes on WSDOT s roadways. The paper also discusses the direction ITS is heading in the future and how this may affect urban safety.

The majority of the urban crashes in Washington have involved the collision of two or more vehicles. Many of these crashes have been caused by drivers error such as a failure to yield, impaired driving, or exceeding a safe speed. Because these crashes are tied to driver error, they often occur at locations that have not been identified as hazardous. The majority of ITS applications in use today are <u>not</u> oriented toward addressing this type of crash. Existing system-level ITS applications such as freeway management systems reduce congestion, which reduces the opportunity for vehicles to occupy the same place at the same time, but they do not directly address crashes due to poor driver judgment. Existing site-level ITS applications provide information that can promote better driver judgment, but this information is typically limited to specific locations that have been identified as hazardous.

Table 4 summarizes the crash types found on WSDOT s urban roadways and matches them with potential ITS applications to reduce the crashes. The main factors that contribute to these crash types are also presented. The ability of ITS to mitigate the effects of these contributing factors or to prevent certain crash types is suggested in the last three columns. One column suggests which system-level ITS applications may be able reduce a crash type. The next column suggests site-level ITS applications that may help. The final column suggests future ITS applications, which are mainly collision avoidance systems that could be used to reduce crashes.

Table 4: Urban Crashes in Washington and ITS Approaches

Crash Type	% of Crashes	Key Contributing Factors	System Level ITS Approaches	Site Level ITS Approaches	Future ITS Approaches
Rear-End	47.9%	Follow too close (7 %) Exceed safe speed (6 %) Impaired driver (3 %) Snow/Ice (2 %)	Freeway management Signal control systems Weather related traveler info	Intersection warnings Automated speed enforcement	Forward obstacle detection Drowsy or impaired driver warning ITS driver training Roadside-to-vehicle pavement info
Single Vehicle	12.4%	Exceed safe speed (14 %) Snow/Ice (14 %) Impaired driver (14 %) Inattention (11 %)	Weather related traveler info	Automated speed enforcement	Drowsy or impaired driver warning Roadside-to-vehicle pavement info
Lane Change	10.6%	Failure to yield (44 %) Exceed safe speed (12 %) Following too close (8 %)		Automated speed enforcement	Lateral obstacle warning Lane detection Vision enhancement
Side and Sideswipe	29.3%	Failure to yield (20 %) Disregard sign/signal (7 %) Exceed safe speed (7 %) Snow/Ice (5 %)	Weather related traveler info	Automated speed enforcement Red light running enforcement	Lateral obstacle warning ITS driver training Roadside-to-vehicle pavement info
Opposing Direction	5.7%	Failure to yield (16 %) Impaired driver (6 %) Snow/Ice (6 %)	Weather related traveler info	Automated speed enforcement	ITS driver training Forward obstacle detection Roadside-to-vehicle pavement info
Backing	0.9%	Failure to yield (49 %)			Obstacle detection ITS driver training
At inter-sections	38.4%	Failure to yield (21 %) Exceed safe speed (12 %) Disregard sign/signal (9 %)	Signal control systems	Intersection warnings Automated speed enforcement Red light running enforcement	Forward obstacle detection lateral obstacle warning ITS Driver Training

Most of the existing system- and site-level ITS applications presented in the table can partially address the contributing factors that lead to crashes. However, these applications have some notable limitations as safety tools. In general, system-level ITS increase safety only indirectly by reducing the opportunities for drivers to crash when they use poor judgment or make errors. Site-level applications address safety directly but these applications are only appropriate at limited locations.

For transportation professionals in Washington responsible for urban safety, ITS applications that are just arriving on the market or that are still under development hold considerable promise. These applications, known as collision avoidance systems, employ technology to inform drivers that dangerous conditions exist, warn drivers that a collision is imminent, or actually activate an automatic vehicle reaction to avoid a collision. Such systems, for example, may use forward looking obstacle detection sensors and in-vehicle warning devices to reduce rear end crash which are the most common type of urban crash in Washington. The advantage of these systems is that they directly address crashes due to driver error at many locations. The disadvantage for transportation planners and engineers from public agencies is that these systems depend heavily on in-vehicles installation and will require considerable involvement by vehicle manufacturers.

Policy Framework for ITS and Urban Safety on WSDOT s Roads

WSDOT is a leader in the use of ITS, and many of this state s urban areas have seen the use of ITS to solve urban transportation problems. WSDOT s ITS use is guided by an Advanced Technology Policy designed to minimize the uncertainty and risk of deploying ITS (1). This policy has three levels of implementation for ITS.

- Aggressively pursue the implementation of applications that have proven effective through research, demonstration projects, and broad scale development elsewhere.
- Demonstrate applications supported by substantial research and an indication of strong demand but whose benefits have not yet been fully documented.
- Monitor applications and projects nationwide that have the potential to create substantial benefits for travelers, shippers, and transportation agencies.

These levels of implementation can be related to the findings in this report. The result is a policy framework that can provide some general guidance to WSDOT planners and engineers who need to evaluate ITS applications for urban safety. The following section discusses this framework.

Aggressively Pursue

According to Washington s technology policy, proven and effective ITS should be aggressively pursued. In general, WSDOT has aggressively applied many ITS that improve freeway travel and is currently working on a large traffic signal control network in north Seattle. While these systems are installed to increase the efficiency of traffic flow, they also reduce crashes. From a safety perspective, system-level freeway management and traffic signal systems are effective, so they should continue to be aggressively applied to urban roadways. While these systems probably would not be installed for safety reasons alone, safety could be used as a one justification or benefit for such systems.

A similar situation is WSDOT s active and commercial vehicle operations program. This program has a safety benefit but the overall system is justified for many reasons beyond safety.

Demonstrate Applications

Many of the ITS urban safety applications discussed in this paper that address safety issues at specific sites have undergone significant research and tests, but their benefits have yet be fully proven and documented. Such systems include warning systems at railroad crossings, intersections, and pedestrian crossings. Therefore, WSDOT staff should demonstrate and prove their feasibility in this state using smaller or more limited applications. If these applications are shown to be effective alternatives to traditional engineering approaches, they can then be aggressively pursued as part of WSDOT s safety program.

WSDOT may be able to support the growth of in-vehicle ITS by demonstrating their use in the large state fleet. This demonstration could include systems such as advanced cruise control, windshield mounted thermal sensing enhancement, and other collision avoidance systems that are currently available but are not commonly installed in private automobiles.

Monitor Applications

WSDOT staff should be monitoring a number of ITS safety research programs. These federal and industry programs mainly involve collision avoidance systems, such as NHTSA s drowsy driver warning systems, or the automobile industry s forward obstacle detection systems. These systems involve the sophisticated in-vehicle or automatic vehicle control systems and have considerable promise for addressing urban crashes caused by driver behavior. While these systems probably will not come from WSDOT or other public transportation agencies, that may affect the way these agencies deal with safety issues. For example, collision avoidance systems may not only reduce urban crashes but also has the potential to free up resources for other safety projects. Some applications, such as roadway departure warning systems, may also affect WSDOT because they may require roadside infrastructure. Other ITS systems, such as variable speed limits, may eventually affect standards.

Other ITS system discussed in this paper, such as those used with transit or with EMS, mainly involve agencies other that WSDOT. WSDOT transportation professionals are probably not in a position to actually implement or install such systems but should support these systems.

Sources for Further Information

While Washington s Advanced Technology Policy provides guidance on implementing ITS, another challenge facing WSDOT staff is determining what urban ITS applications are available and worth considering for implementation. Fortunately, up-to-date information about ITS projects and programs is readily available on a number of ITS oriented Internet sites. Because many ITS applications are initially supported or demonstrated by the federal government, the FHWA s sites are often relevant. The addresses of relevant ITS Internet sites, along with some other sources of information, are listed in Appendix A. Publications are another source of information about ITS in general, and some major publications are listed in Appendix B.

Within the WSDOT, another information source concerning ITS is the Advanced Technology Branch (ATB). This branch is responsible for developing and deploying

ITS, and its staff are available to assist WSDOT personnel in learning about and applying ITS.

One perceived problem that may hinder WSDOT s use of ITS is liability. While concerns about legal issues are best passed along to the experts, one attorney well versed in this area indicated that ITS is not fundamentally different legally from existing vehicle and highway systems (57). ITS America has a legal committee, and its Internet page is a good source of general ITS legal information (58).

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APPPENDIX A:
SOURCES OF INFORMATION ON ITS IN URBAN AREAS

This appendix lists sources that would be of use to WSDOT staff seeking additional information on ITS and safety in urban areas. Benefiting the technological orientation of ITS, many of the sources are Web pages.

ITS America http://www.itsa.org	ITS America s Web site provides a wide range of ITS related information. There is a discussion area for safety topics.
http://www.its.dot.gov/new.htm	This FHWA Web site includes information on the ITS in metropolitan areas and has links to other ITS sites.
California PATH database http://www.nas.edu/trb/about/path1.html	The Web site includes a large bibliographic database pertaining to ITS.
http://www.path.berkeley.edu/~leap/	LEAP provides information on the ITS user groups and includes a detailed descriptions of the technologies and the sites where they have been implemented.
Intelligent Transportation Systems (ITS) Projects Book http://www.its.fhwa.dot.gov/cyberdocs/welcome.htm	The annual Intelligent Transportation Systems (ITS) Projects Book identifies ITS projects that have been partially or completely funded with federal money. This large document serves as a good source for tracking down contacts for ongoing ITS projects.

National Highway Traffic Safety Administration http://www-nrd.nhtsa.dot.gov	NHTSA has an active ITS program focusing on issues such as crashes due to running off the road and drowsy drivers. While many of the projects involve a high level of technology and are not the type of program directly usable by transportation professionals from public agencies, these projects may eventually have an impact on safety.
Arnold, James A. Rural Versus Urban, A Communications Infra-structure Perspective ITS America. Proceeding of the Annual Meeting of ITS America 6th, Vol. 2, 1996, pp. 1045-1051.	A good overview of the important role that communication plays in ITS. There is a discussion of various communications technologies and their eventual impact on ITS.
National Work Zone Safety Information Clearinghouse http://tti.tamu.edu/clearinghouse/wzsafety/	The site for the National Work Zone Safety Information Clearinghouse includes information on technology as applied to work zone safety.
National ITS Architecture http://www.odetics.com/itsarch/	A Web site for the Odetics Corporation, which concerns the national ITS architecture. This technically oriented page provides an overview of different types of ITS services and technologies that may someday be available. While this site includes information on safety systems such as the warning devices for highway railroad intersections and post-crash emergency notification. For more information on the national ITS architecture, also visit the U.S. DOT's ITS web site at http://www.its.dot.gov/.
National Associations Working Group for ITS http://www.nawgits.com/icdn/	Created by the National Associations Working Group for ITS (NAWG), the ITS Cooperative Deployment Network (ICDN) is an Internet-based resource for transportation professionals.

APPPENDIX B:
MAJOR ITS PUBLICATIONS

ITS World Advanstar Communications, http://www.itsworld.com	This magazine is published eight times a year and concerns technology and applications for transportation systems.
ITS International Route One Publishing, http://www.itsinternational.com	This British magazine is published six times a year and focuses on international applications of the deployment of advanced technology for efficient surface transportation.
ITS Quarterly ITS America	A journal published four times a year as the forum for ITS America. The emphasis is on the social, legal, economic, and policy ramifications of ITS.
Traffic Technology International UK and International Press.	A British magazine published six times a year with an international emphasis and number of articles related to ITS.