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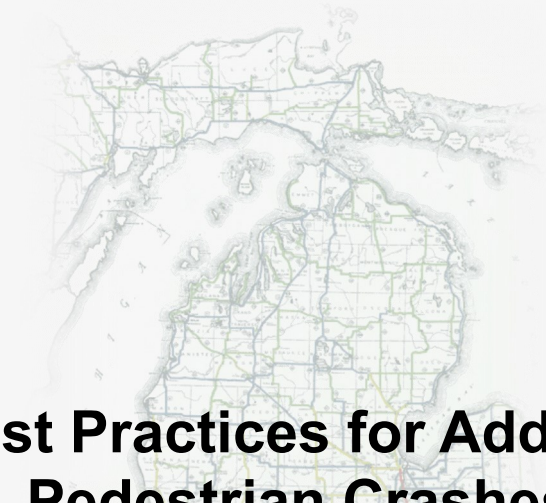
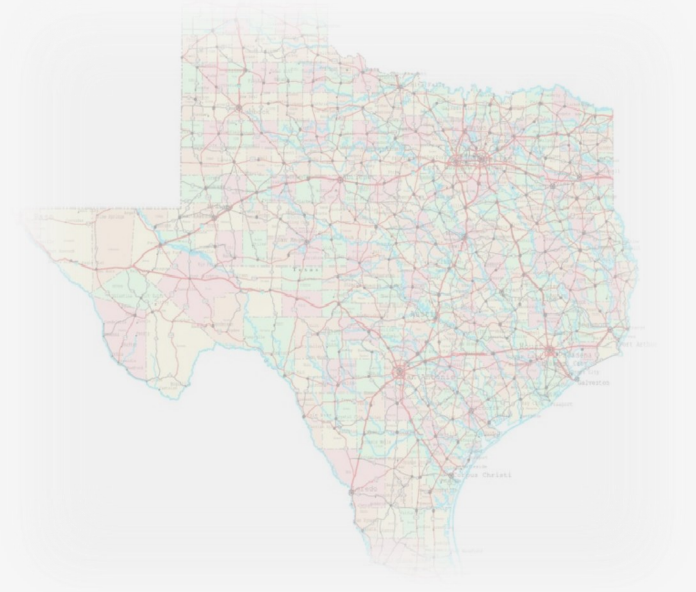


Best Practices for Addressing Pedestrian Crashes on High-Speed Roadways



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Best Practices for Addressing Pedestrian Crashes on High-Speed Roadways

Report: ATLAS-2015-09

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October 2015

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ACKNOWLEDGMENTS

This paper was developed through the support of the Center for Advancing Transportation Leadership and Safety (ATLAScenter.org), a University Transportation Center that is a collaboration between the University of Michigan Transportation Research Institute and the Texas A&M Transportation Institute. The Center is sponsored by the US Department of Transportation's Research and Innovative Technology Administration through Grant Number DTRT13-G-UTC54.

The authors thank all of the people who participated in the survey. We appreciate Tom Welch for allowing us to post questions on the State Highway Safety Engineers listserv. We thank Joanna Hunt for her work editing the final report and Barb Lorenz for coordinating the administration of the project. We especially thank the ATLAS Center for funding this project and for inviting us to present preliminary findings at the 2015 Texas Traffic Safety Conference.

Also, we are grateful for the guidance provided by Stephen Ratke with the Federal Highway Administration, who helped the research team refine the survey questions. Finally, we express appreciation to the project mentor, Will Bozeman with the Austin District of the Texas Department of Transportation, for his direction and support. He provided insights on issues, information about state departments of transportation that are actively addressing pedestrian safety, and encouragement to keep working toward possible solutions.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
ATLAS-2015-09		

4. Title and Subtitle	5. Report Date
Best Practices for Addressing Pedestrian Crashes on High Speed Roadways	October 2015
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Joan G. Hudson, Haotian Zhong, Maarit Moran, Vichika Iragavarapu, Vickie Vincent, Boya Dai	

9. Performing Organization Name and Address	10. Work Unit no. (TRAIS)
Texas A&M University Texas Transportation Institute College Station, TX 77843-3135	11. Contract or Grant No. DTRT13-G-UTC54

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Advancing Transportation Leadership and Safety (ATLAS) Center 2901 Baxter Rd., Room 124 Ann Arbor, MI 48109-2150	14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the U.S. Department of Transportation, OST-R, University Transportation Centers Program

16. Abstract

Texas ranks as the worst state in the nation for interstate pedestrian fatalities. Almost 600 pedestrians died on interstate roadways during the 5-year period between 2007 and 2011. Texas is the fourth-highest state in terms of interstate pedestrian fatalities per 100 million interstate vehicle miles traveled. Few studies have been conducted to investigate the causes and factors that contribute to pedestrian fatalities on very high-speed roadways.

For this study, the research team conducted a survey of 20 states to find out what they are doing or have done in terms of engineering, education, enforcement, and evaluation to address pedestrian safety on controlled or limited access urban interstate, freeway, and expressway main lanes where posted speed limits are 55 mph or higher. The design of the survey was based on a literature review that identified factors that correlated with pedestrian fatality rates, motivations for pedestrians entering high-speed roadways, and countermeasures that had been implemented to reduce fatalities or protect pedestrians.

Survey respondents reported being aware of pedestrian safety concerns on the main lanes of high-speed, controlled-access highways. Eighty percent responded that there is a law or policy that prohibits pedestrian access on the controlled-access highways in their states. Policies and practices aimed at unintended pedestrians were more frequently cited than those addressing intentional pedestrians. The survey respondents highlighted existing practices such as the construction of overpasses/underpasses, installation of fences along rights of way or medians, and use of roadside assistance programs.

In the end, researchers discussed best practices, opportunities for future research, and recommendations for increasing pedestrian safety on high-speed, controlled-access roadways.

17. Key Words	18. Distribution Statement
Pedestrian, interstate, safety, crash analysis, survey	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	

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Introduction

Approximately 450 pedestrians die each year on Texas roadways. During the 5-year period between 2007 and 2011, 2232 fatal pedestrian crashes were reported in Texas. Over half of these fatal pedestrian crashes (1163 crashes) occurred on the state's highest speed roadways (i.e., interstates or U.S. and state highways) (Iragavarapu et al., 2015). From 2007 to 2011, Texas had the highest number of interstate pedestrian fatalities (599 deaths) and ranked as the fourth-highest state in terms of interstate pedestrian fatalities per 100 million interstate vehicle miles traveled (VMT) (National Highway Traffic Safety Administration [NHTSA], n.d.).

More detailed evaluation of Texas's fatal pedestrian crashes indicates that of these 1163 fatal crashes on high-speed roadways, 40 percent (474 deaths) occurred on freeway main lanes and 82 percent occurred in dark conditions. The most common pedestrian actions of the 474 pedestrian crashes at the time of the crash were crossing or standing on the main lanes. A quarter of the pedestrian crashes on freeways involved persons out of the vehicle due to a stalled vehicle or a previous crash.

While Texas ranks among the worst states in the nation for pedestrian safety on interstate highways, states such as Minnesota, Illinois, and Tennessee have some of the lowest pedestrian fatality rates. This study documents what other states are doing or have done in terms of engineering, education, enforcement, and evaluation to address pedestrian safety on high-speed roadways. A survey of 20 states was conducted as part of this project to find out the answer to this question. This report documents the responses, provides lessons learned, and identifies future research needs.

Pedestrian safety is a concern for all high-speed roadways with posted speed limits greater than 45 mph. However, for the purposes of this study, researchers focused on controlled or limited access urban interstate, freeway, and expressway main lanes where posted speed limits are 55 mph or higher. The Federal Highway Administration (FHWA, 2013) describes limited and controlled-access below:

> Access control is a key factor in the realm of functional classification. All Interstates are "limited access" or "controlled-access" roadways. The use of the word "access" in this context refers to the ability to access the roadway and not the abutting land use—these roadways provide no "access" to abutting land uses. Access to these roadways is controlled or limited to maximize mobility by eliminating conflicts with driveways and at-grade intersections that would otherwise hinder travel speed. Access to these roadways is limited to a set of controlled locations at entrance and exit ramps. Travelers use a much lower functionally classified roadway to reach their destination.

Literature Review

Few studies have been conducted to investigate the causes and factors that contribute to pedestrian fatalities on very high-speed roadways where the posted speed limit is 55 mph or greater. The research team reviewed journal papers, reports, state laws, and practices that address pedestrian safety and identified those specifically focused on high-speed roadways. The majority of pedestrian research focuses on roadways where pedestrian activity is more commonly expected.

Research that did address high-speed roadways reviewed factors that correlate with pedestrian fatality rates, motivations for pedestrians entering high-speed roadways, and countermeasures that have been implemented to reduce fatalities or protect pedestrians. Factors including lighting conditions, pedestrian intoxication, and disabled vehicles have been identified as contributing factors to pedestrian fatalities on high-speed roadways (Johnson, 1997; Istre et al., 2007).

Seventy percent of fatal pedestrian crashes happened at night in 2011 (NHTSA, 2013). Visibility is a key factor in preventing pedestrian-vehicle crashes. Increased lighting intensity has shown association with a reduction in nighttime pedestrian crashes at pedestrian crossings (Pegrum, 1972; Polus and Katz, 1978). A 30 percent average reduction in nighttime pedestrian injury crashes was found based on 23 before-and-after studies (Commission Internationale de l'Éclairage [CIE], 1992). Although pedestrian crossings are not allowed on controlled-access roadways, Elvik (2004) found that road lighting has the same effect on safety in urban areas as it does in rural areas and on freeways. A study of Dutch crash statistics from 1987–2006 indicated that roadway lighting has a slightly larger effect on the reduction of nighttime fatal pedestrian crashes than the reduction of nighttime injury pedestrian crashes (Wanvik, 2009). Future road lighting could be developed into an adaptive mode (Wanvik, 2009) that automatically brightens when objects approach and dims when the roadway is vacant.

The number of interstate miles, the amount of VMT on interstates, and the posted speed limit on interstates have been shown to correlate with the pedestrian fatality rate:

- **Interstate System Mileage:** A study conducted in Florida found that a higher number of interstate miles increases the pedestrian fatality rate on interstate highways. An AAA Foundation for Traffic Safety (2014) sponsored report states that fewer miles of interstate highways may lead to lower pedestrian fatality rates.
- **VMT:** Other factors being equal, studies show positive association between VMT and crash risks (Ewing and Dumbaugh, 2009). Litman and Fitzroy (2005) found a roughly linear positive relationship between VMT and crash risks both on rural and urban area roads. Balkin and Ord (2001) found seasonal variation of crashes with variation in VMT. The above studies did not focus on interstate highways, but researchers from the AAA Foundation for Traffic Safety speculated pedestrian exposure increases as the VMT increases.
- **Travel Speed:** Travel speed is closely associated with the crash severity. Speed limits on interstates vary from 55 mph to 85 mph (Governors Highway Safety Association [GHSA], 2014). A 2013 study showed that the risk of death is 90 percent if a pedestrian is involved in a vehicle-pedestrian crash when the vehicle is moving at 55 mph, and the

chance of death increases with speed (Tefft, 2013). Johnson (1997) also pointed out that raising or abandoning speed limits could lead to more pedestrian fatalities.

Pedestrian Classifications

Johnson (1997) defined pedestrians involved in crashes on high-speed roadways in two categories: intentional pedestrians and unintended pedestrians (Johnson, 1997; Istre et al., 2007). Intentional pedestrians refer to persons entering controlled-access, high-speed roadways on purpose, such as crossing the interstate as a shortcut to destinations. See Figure 1 and Figure 2 for examples of intentional pedestrians.

Figure 1. Intentional Pedestrian Walking on I-35 (Source: Joan Hudson).

Figure 2. Intentional Pedestrian Walking a Bicycle on I-37 (Source: Joan Hudson).

Unintended pedestrians refer to persons who exit a vehicle on the roadway, such as when repairing a flat tire on the roadside, assisting another stranded motorist, or being involved in a crash (see Figure 3 and Figure 4). Previous studies found that over one-third of the pedestrian fatalities on interstates involve unintended pedestrians and half involve intentional pedestrians (Johnson, 1997; Istre et al., 2007). In many cases, the reason the pedestrian was on the highway was unknown.

Figure 3. Unintended Pedestrian Repairs Tire along Roadside (Source: TTI Communications).

Figure 4. Unintended Pedestrian Walking around Truck (Source: Joan Hudson).

As stated above, more than one-third of pedestrian fatalities occurring on interstates involve unintended pedestrians. One possible reason that an unintended pedestrian would be present on the interstate is because of a disabled vehicle (PEDSAFE, 2014).

Many states have implemented programs to aid unintended pedestrians, such as adding emergency call boxes and funding roadside assistance programs. The potential benefits of these programs can be limited due to limited service areas (Johnson, 1997). A PEDSAFE (2014) report suggests that roadway lighting and police surveillance could also help to address pedestrian safety. However, no proven countermeasures are identified in the literature. Several reports recommend educating drivers on appropriate actions when the vehicle is disabled, which includes remaining in the vehicle and making themselves visible (Istre et al., 2007; AAA Foundation for Traffic Safety, 2014; PEDSAFE, 2014).

Countermeasures

Countermeasures designed for pedestrian safety on high-speed roadways are not prevalent in the existing literature. Some suggestions to restrict pedestrian activity on the interstate were identified from surveys and studies. Generally, these suggestions can be divided into five categories: educating pedestrians, building barriers to discourage pedestrian travel, accommodating pedestrians, warning drivers, and fining pedestrians. Specific countermeasures include:

- **Education Programs:** Educational campaigns and public announcements were advocated by several respondents in Johnson's (1997) survey. In a 2002 study by Duperrex et al., researchers indicated that pedestrian safety education can alter the road crossing behavior. Another study indicated that the language and timing of the educational messages need to target the vulnerable population. For example, to reduce the crash rate caused by undocumented persons in San Diego, researchers found that making announcements in Spanish and concentrating efforts on weekends were efficient methods (Emry et al., 1991).
- **Pedestrian Barriers:** Right-of-way fencing and median barriers can be built to keep pedestrians off the roadway (Johnson, 1997; Dewey et al., 2003; Fegan, 1978; Retting, 1999). See Figure 5.

Figure 5. Example of Chain Link Fence Barrier along Main Lanes (Source: Will Bozeman).

- **Pedestrian Accommodations:** To accommodate pedestrians, the PEDSAFE (2014) system redesigned an interstate interchange in Englewood, Ohio, to make it a safer place for travelers using all transportation modes. Another suggested accommodation is a grade-separated crossing, such as an underpass or overpass that provides an alternative pathway for pedestrians, as shown in Figure 6. On a system level, Johnson (1997) suggested providing a well-connected street network. Using land use regulations to discourage the construction of residential properties adjacent to freeways has also been suggested (Johnson, 1997).

Figure 6. Example of Pedestrian Overpass (Source: Joan Hudson).

- **Pedestrian Violation Penalty:** Many states and regions have enacted laws that specifically prohibit pedestrians from entering controlled-access roadways. Connecticut, Washington, and the City of New York have statutes in place. Fines can create a disincentive to pedestrians who may otherwise enter the interstate.
- **Driver Warning Signs:** In some cases, states have recognized that pedestrians cross the interstate and have installed warning signs to alert drivers of the possible crossing of pedestrians (Johnson, 1997). Nighttime signs with graphics are claimed to be more effective than text signs (Emry et al., 1991). High-intensity lighting is identified as an effective way to warn drivers of a pedestrian crossing.

The effectiveness of the above countermeasures has not been confirmed. Fegan (1978) stated that traditional pedestrian or roadway-oriented engineering countermeasures such as those listed can reduce up to 50 percent of the pedestrian crashes investigated, but Johnson (1997) later claimed that there are no proven engineering countermeasures for unintended pedestrians.

Survey

This project surveyed model state departments of transportation (DOTs) about strategies and regulations used to reduce pedestrian crashes on high-speed roadways. The literature review provided the background to design a survey based on existing practices related to pedestrian safety on high-speed roadways.

Survey Methods

Target states to be surveyed were selected based on a set of criteria and input from partner agencies. A low pedestrian fatality rate on interstate highways was a central criterion of selecting survey participants. This was based on the assumption that states with lower fatality rates would be more likely to implement countermeasures or practices to address pedestrian safety on interstate highways. Additional measures used to select states for the survey included:

- Ratio of pedestrian fatalities on urban interstate highways per highway mile of interstate highways.
- Ratio of pedestrian fatalities on urban interstate highways per vehicle mile traveled on interstate highways.
- Walk-to-work mode share.

States were divided into low, medium, and high populations and selected from each category so that a variety of state populations would be represented. In addition, researchers pulled from different geographic regions to gain a better representation of experiences. Based on these criteria, the states shown in Table 1 were identified.

Table 1. States Selected Based on Criteria.

Low Population	Medium Population	High Population
Vermont	Kansas	Tennessee
North Dakota	Connecticut	Massachusetts
Delaware	Kentucky	Indiana
Montana	Minnesota	Ohio
New Hampshire	Wisconsin	Illinois
Maine		New York

A review by the Texas Department of Transportation (TxDOT) and FHWA staff resulted in the addition of eight more states: Arizona, California, Colorado, Florida, Minnesota, North Carolina, Oklahoma, and Utah.

Based on the literature review findings, researchers worked with partner agencies to draft questions pertaining to education, enforcement, engineering, and evaluation. Topics considered included the following: design standards for freeways; distance between pedestrian crossing opportunities; laws surrounding sleeping or loitering on public rights of way; educational messages to encourage safe behavior during vehicle breakdowns; fencing, walls, and barriers; incident clearance services; and prima facie or typical speed limits on freeways. Questions asked were about the prevalence of existing practices in education, enforcement, engineering, and

evaluation as well as open-ended responses related to issues of pedestrian safety on controlled-access highways. Appendix A presents the survey questions.

Researchers took advantage of an opportunity to send the survey to all state DOTs through the State Highway Safety Engineers listserv. The survey was administered by the research team. The team documented the results, creating a spreadsheet to synthesize the qualitative information from the surveys. Survey responses were received from representatives of 20 state transportation agencies including TxDOT.

Survey Results

Survey respondents reported being aware of pedestrian safety concerns on the main lanes of high-speed, controlled-access highways. As seen in Table 2, three-quarters of respondents were aware of pedestrians exiting a vehicle (i.e., after a breakdown or collision) as a concern, and 40 percent (8 out of 20) mentioned pedestrians crossing the highway. One respondent noted the main focus of pedestrian safety on highways is for individuals who try to assist others after a crash. Another respondent reported findings that about 60 percent of pedestrian fatalities on his/her state's highway system occur on controlled-access roadways and do not appear to involve unintended pedestrians. Some respondents suggested that since pedestrians were not authorized to be on controlled-access highways, they did not have significant issues.

Table 2. Pedestrian Safety Concerns (Survey Questions 2).

Survey Question		**Response (n=20)** Count (%)		
		Yes	**No**	**N/A, Other**
What pedestrian safety concerns are you aware of on the main lanes of your controlled-access highways?	Pedestrian crossing highway	**8 (40%)**	**11 (55%)**	**1 (5%)**
	Pedestrian exiting vehicle (i.e., after breakdown)	**15 (75%)**	**3 (15%)**	**2 (10%)**

The survey asked respondents about various strategies and tools that were identified in the literature as relevant to addressing pedestrian safety on high-speed roadways or other controlled-access roadways. Eighty percent (16 out of 20 surveyed) responded that there is a law or policy that restricts pedestrian access to controlled-access highways in their state. Most states support this policy with one or more enforcement, engineering, or educational strategies. In contrast, several respondents suggested that because this access is unauthorized or restricted, formal practices or countermeasures to address this particular pedestrian issue were unknown or not applicable. Some survey respondents noted that the acknowledgement of pedestrians on highways (i.e., through sign installation or actions directed at pedestrians) risks the inadvertent consequence of inducing this unauthorized and risky activity.

The survey respondents highlighted existing practices. The practices have been organized into a matrix (Table 3) illustrating countermeasures credited most for improving and/or maintaining low pedestrian crashes on high-speed roadways.

Table 3. Summary of Practices.

Practices	Pros	Cons	Implementation
Underpasses/Overpasses	Keeps pedestrians from exposing themselves to traffic. Has a high potential to reduce crashes, if pedestrians use it. Can be multi-functional.	Usage could be low. Construction cost could be an issue. Crime safety can be an issue.	Locate along logical pedestrian routes. Connect with pedestrian infrastructure. Inviting design.
Barriers and Fences	Can prevent pedestrians from trespassing to some extent.	Can be easily traversed sometimes.	Serve as channelization tool where alternative safe routes exist.
Lighting	Increases visibility at night.	Increased electricity cost.	Consider adaptive lighting.
Signing	Warns drivers.	May induce pedestrians.	NA
Shoulder Width and Design	Provides space for emergency vehicles, broken down vehicles.	High construction cost.	NA
Move Over Laws	Avoids conflicts between vehicle and unintended pedestrians.	The effectiveness relies on education and enforcement.	Focus on young, older, and African American drivers. Use explicit yet reasonable provisions and appropriate qualifying language to support enforcement. Get support from affected agencies.
Collision Clearance Laws	Reduces possibility of secondary crashes.	Drivers may worry about liability.	Educate to ensure drivers are aware of laws.
Roadside Assistance Program	Reduces possibility of secondary crashes.	Implementation cost may be an issue.	Coordinate between agencies for increased effectiveness.

The most common strategies noted were the use of overpasses/underpasses, installation of fences along rights of ways or medians, and use of roadside assistance programs. Other practices include installing signs, incorporating design elements like frontage roads and adequate

shoulders, and passing move over laws. The remainder of this section discusses in more detail the survey responses with regard to these strategies.

Overpasses and Underpasses

Seventy percent (14 out of 20) of respondents reported that their state does have overpasses or underpasses that provide passage across highways. Only one reported that his/her state has either a specific policy or practice of continuing streets over or under controlled-access highways without an interchange (i.e., a grid pattern continues across the highway without a connection to that highway).

Many respondents noted that they do not have pedestrian volume data to evaluate the use of pedestrian overpasses/underpasses. Overpasses were constructed in response to local agency request, stakeholder demand, visual observations, public feedback, and rail corridor trails. One respondent noted that overpasses and underpasses are not funded by the safety program but are supported by guidance in the Highway Design Manual.

Some respondents noted that pedestrians are expected to use crossings wherever they exist. Others noted that they have observed pedestrian fatalities in proximity to pedestrian crossings. Underpasses were noted as a strategy that can be successful in contexts where they are well traversed and secure but unsuccessful if they are underutilized and uncomfortable for pedestrians. Another respondent suggested that the value of a life saved would likely outweigh the cost of overpass construction.

Barriers and Fences

Fourteen respondents (70 percent of surveyed) reported that fences are routinely placed along controlled-access highways. The placement of fences varies by state, but the most common location reported was along the right of way. Other strategies include fencing along the median (one respondent) and on the outside edge of the highway (one respondent). One respondent reported that fencing is typical along rural rights of way and installed selectively in urban areas with a high pedestrian crash rate attributed to new development on both sides of the freeway. Fencing or other barriers are used for channelization (channeling pedestrians toward safe crossings), but they can sometimes be easily traversed.

Frontage Roads

Eight respondents (40 percent) reported that frontage roads are typical on highways or interstates. Nine respondents reported frontage roads are not typical. Two respondents noted that frontage roads are typical only on interstates in urban areas.

Shoulder Design

Providing adequate space along controlled-access highways was cited by two respondents as a countermeasure that may reduce pedestrian exposure to possible crashes. This design feature provides a safe area for travelers who have broken down or been involved in a collision and may contribute to lower occurrences of pedestrian crashes.

Lighting

Lighting as a practice was only cited by one respondent. However, the literature suggests that visibility is a key factor in preventing pedestrian-vehicle crashes across roadway types.

Roadside Assistance Programs

Thirteen respondents (65 percent of surveyed) reported that a roadside assistance program exists to aid travelers stranded (after a collision or breakdown) along the highways or interstates. This service includes patrols or other available assistance to help with incident management and clearing the road after breakdowns or collisions, which addresses unintended pedestrian safety.

Collision Clearance Policies

Respondents cited requirements for motorists to address disabled vehicles after a crash, breakdown, or other incident. The policies suggest that motorists clear disabled vehicles from the main lanes and follow other precautions after a breakdown on a highway. Many reported that these regulations are heavily advertised and promoted to drivers. Colorado's Revised Statute 42-4-1602 (2) states, "When an accident occurs on the traveled portion, median, or ramp of a divided highway and each vehicle involved can be safely driven, each driver shall move such driver's vehicle as soon as practicable off the traveled portion, median, or ramp to a frontage road, the nearest suitable cross street, or other suitable location to fulfill the requirements of section 42-4-1603."

Signage

Nine states reported that they have posted signs to warn motorists of pedestrian crossings on highways. Two respondents suggested that installing signs as a safety strategy is controversial because signs that warn drivers could inadvertently induce pedestrian crossings. Some respondents mentioned the use of signs placed at highway ramp entrances to keep pedestrians from entering the highways. Sign installation is more commonly used to address unintended pedestrian safety. Respondents reported that states use regulatory signs and changeable message signs to instruct drivers to clear the road and/or pull off the travel lanes after minor collisions. One respondent reported that signage on interstates and freeways advises motorists to move to the next exit.

Survey Summary

Each strategy discussed above was used by at least one state, although several responses suggested a lack of documentation, evaluation, or monitoring for many of these tools in relation to pedestrian activity. Strategies to protect unintended pedestrians, those who find themselves on a highway after a breakdown or collision, were more common. Strategies to address intentional pedestrians were cited less frequently by respondents, suggested as ad hoc in many cases, and rarely supported by clear policies or guidance. Table 4 shows the responses to the survey.

Table 4. Survey Response Summary.

Survey Question		Response (n=20)		
		Yes Count (%)	No	N/A, Other
What pedestrian safety concerns are you aware of on the main lanes of your controlled-access highways?	Pedestrian crossing highway	**8 (40%)**	**11**	**1**
	Pedestrian exiting vehicle (i.e., after breakdown)	**15 (75%)**	**5**	**1**
Are there laws or policies prohibiting pedestrians on controlled-access highways?		**16 (80%)**	**1**	**3**
Are there signs posted that warn motorists on interstates or controlled-access highways of pedestrian crossings?		**9 (45%)**	**4** (1=not common practice)	**7**
Are people exiting vehicles on controlled-access highways for breakdowns, post vehicle crashes, etc. a contributor to pedestrian crashes along these highways?		**16 (80%)**	**2**	**2**
Do you have a roadside assistance service along your highways/interstates?		**13 (65%)**	**5**	**2**
Are fences routinely placed along the median, outside edge of the controlled-access highways, or along the right of way?		**14 (70%)** (12=along right of way; 1=along median; 1=outside edge)	**4**	**2**
Do your highways/interstates have frontage roads as a general rule?		**8 (40%)**	**9**	**3**
In locations with frontage roads, are fences or barriers placed between the frontage road lanes and the main lanes, or another location?		**8 (40%)**	**6**	**6** (3=N/A 3=yes but varies by location)
Has your state installed overpasses/underpasses for pedestrians?		**14 (70%)**	**2**	**4** (1= unknown)
Is there a policy or practice for continuing streets over or under controlled-access highways without an interchange (i.e., a grid pattern continues across the highway without a connection to that highway)?		**1 (5%)**	**15**	**4** (3=N/A 1=exist but limited)

Discussion of Best Practices

The majority of surveyed states prohibit pedestrians on controlled-access highways and have limited evidence of specific practices or countermeasures focused on pedestrian safety on high-speed roadways. Lessons from the survey results and literature review are discussed here. In some cases, the research team gathered additional evidence nationally and internationally to further identify and evaluate practices mentioned in the survey results.

Overpasses and Underpasses

The survey results indicated that while overpasses or underpasses are used in many states, most states do not evaluate their use or collect the pedestrian volume data to do so. While some respondents noted that pedestrians are expected to use crossings wherever they exist, others noted that they have observed pedestrian fatalities in proximity to pedestrian crossings, suggesting this expectation is not always realistic. Underpasses were noted as a strategy that can be successful in contexts where they are well traversed and secure but unsuccessful if they are underutilized and uncomfortable for pedestrians. Studies suggest that the amount of time is takes to cross a roadway plays a key role in the use of under/overpasses. A longer crossing time to use an under/overpass leads to a higher probability of the pedestrian crossing at ground level (American Association of State Highway and Transportation Officials [AASHTO], 2004). Table 5, adopted from a study by Nemeth et al. (2014), shows that longer crossing times can reduce the use of underpasses and overpasses.

Table 5. Pedestrians Using Underpasses or Overpasses.

Percent of Pedestrians Using Underpasses or Overpasses			
	Travel Times	**Overpass**	**Underpass**
	Equal	15 to 60%	95%
	30% Longer on Under/Overpass	0%	25 to 70%
	50% Longer on Under/Overpass	0%	0%

International evidence also indicates that 60 percent of pedestrians will not use an overpass for reasons such as travel time, high stairs, health problems, and safety concerns (Abojaradeh, 2013). Females and children use overpasses more often than males and adults, respectively (Abojaradeh, 2013). Under/overpasses should provide a logical route for pedestrians and connect with other pedestrian facilities, such as sidewalks and wayfinding signs. A before-and-after study conducted in Japan shows that pedestrian-vehicle crashes decreased 91 percent within 100 m and 85 percent within 200 m of an overpass, while other vehicle crashes increased 14 percent within 100 m of the structure and 23 percent within 200 m (Japan Road Association, 1969).

Only one survey respondent reported that his/her state had a specific policy or practice of continuing streets over or under controlled-access highways without an interchange. California's Streets and Highway Code 888 states, "The department shall not construct a state highway as a

freeway that will result in the severance or destruction of an existing major route for nonmotorized transportation traffic and light motorcycles, unless it provides a reasonable, safe, and convenient alternate route or such a route exists." Instead, respondents reported that over/underpasses were often the result of case-by-case studies or projects and not a general policy or practice. One respondent noted that overpasses and underpasses are supported by guidance in the Highway Design Manual but are not funded by the safety program.

Barriers and Fences

Barriers and fences were mentioned by many survey respondents; none were able to provide documented evidence of their success or failure to protect pedestrians. Early studies showed a significant reduction of pedestrian-vehicle crashes after installing barriers (Berger, 1975; Stewart, 1988). Those studies did not focus on high-speed roadways, so it is plausible that the pedestrians had alternative crossings in the urban street network, such as signalized intersections with pedestrian amenities.

Fencing or other barriers are used for channelization, but that they can sometimes be easily traversed. One of the respondents commented that residential development and other destinations divided by roadways means that pedestrians will cross that roadway and in many cases will go to extreme measures to get across. One state has developed new design standards for pedestrian channelization barriers intended to encourage pedestrians to cross at designated locations (Florida DOT, 2014). Another suggestion was that noise walls, often constructed on interstates and freeways, could have an additional function as a pedestrian barrier. Crash data do not typically provide information on the motivations that brought pedestrians to controlled-access roadways. This could be a focus of future research, particularly for intentional pedestrians.

Lighting

Lighting as a practice was only cited by one respondent despite evidence that many fatal pedestrian crashes happen at night. Future road lighting could be developed into an adaptive mode (Wanvik, 2009) that automatically brightens when objects approach and dims when the roadway is vacant. Adaptive lighting could reduce operational costs and potentially have better warning effect due to its changeable lighting.

The majority of pedestrian fatalities on high-speed roadways occur in dark conditions, but the marginal improvement from the addition of artificial lighting on high-speed roadways would need to be empirically evaluated.

Move Over Laws

Many respondents discussed move over/slow down laws or policies present in their state. A move over law stipulates that drivers must take precautions such as slowing down or moving over when approaching and passing an emergency vehicle along the roadway. Precautions that are suggested or required in such laws can include slowing down, changing lanes, or giving a signal. These are commonly advertised and/or communicated through signs on roadways (see Figure 7).

Figure 7. California DOT Move Over Signs.

TxDOT displays messages about moving over or slowing down on dynamic message signs, as shown in Figure 8.

Figure 8. A TxDOT Variable Message Sign Instructing Drivers to Move Over or Slow Down for Emergency Vehicles on the Sam Houston Beltway in Houston, Texas (Bierling and Li, 2009).

However, move over laws rely on drivers' awareness and cooperation. A national survey of U.S. drivers shows that 71 percent of Americans have not heard of move over laws (Move Over, America, 2007). A survey conducted in Texas showed that 42.5 percent of drivers had never heard of it and 34 percent of drivers heard something about it but were not familiar with it (Bierling and Li, 2009). The authors of this Texas study also statistically analyzed the factors that increased or decreased the likelihood that a Texas driver was aware of the move over law (see Table 6). Based on the information in Table 6, there is a need to implement education campaigns that focus more on elderly drivers and African American drivers.

Table 6. Factors That Increase or Decrease the Likelihood of Awareness.

Increase the Likelihood of Awareness	Decrease the Likelihood of Awareness
1. Have a commercial driver license	1. Increasing population density of the zip code of residence
2. Age 46–65	2. Was cited in Texas for passing a stopped emergency vehicle that had its emergency lights on
3. Increased time as a licensed driver in Texas	3. African American/Black ethnicity
4. Age 26–35	4. Age 66 years or older
5. Age 36–45	5. Increasing median value of owner-occupied housing in zip code of residence
6. Completed associate's degree or trade school	
7. Age 21–25 and has taken defensive driving	

In addition to education, enforcement of move over laws may increase effectiveness as well, as suggested by a national review of incident management programs (Carson, 2008). In the report, the author concluded that model legislation should provide explicit yet reasonable provisions that set clear standards for enforcement providers. For example, "yield right-of-way by moving to a lane that is not adjacent to the authorized emergency vehicle" (Alabama, California, Georgia, Indiana, Iowa, North Dakota, South Carolina, Tennessee, Virginia, and West Virginia) and "reduce speed to 20 mph under the posted speed limit" (Florida, South Dakota, Texas, and Wyoming) are specific and reasonable. Moreover, unified support from law enforcement agencies and law enforcement partners is essential to successful and effective move over laws (Carson, 2008).

Collision Clearance Laws

Policies related to clearing vehicles from the roadway are called collision clearance, driver removal, Clear the Road, and Move It policies. The Central Texas Regional Mobility Authority (CTRMA, 2011) operates a collision clearance program called the Highway Emergency Response Operator (HERO) Program from 6:00 a.m. to 8:00 p.m. Monday through Friday along two stretches of highway in Austin, Texas. The primary reason for the HERO Program is to maintain roadway capacity such that congestion resulting from collisions or disabled vehicles is minimized. One of the goals of the HERO Program is to reduce secondary collisions. As noted in its 2011 Performance Report, CTRMA noted that the benefit of HERO is an 11 percent decrease in crashes on I-35 in the patrolled area.

Survey respondents cited requirements for motorists to clear disabled vehicles from the main lanes and other precautions to follow after a breakdown on a highway. Many reported that these regulations are heavily advertised and promoted to drivers. According to FHWA (2008), about half of all U.S. states have a collision clearance policy, but few actively publicize or enforce these laws. Although these policies are often focused on high-speed roadways, the priority is reducing congestion and delay rather than ensuring safety.

Collision clearance laws can reduce congestion triggered by vehicle accidents. Second, they can reduce traveler exposure to and reduce secondary crashes. The benefits of collision clearance are well documented (Pennsylvania DOT, 2009). However, evaluation of its effectiveness and strategies for implementation are not. Future research could investigate the most effective aspects of public campaigns and focus on safety benefits.

Roadside Assistance Program

Roadside assistance was cited by a majority of the survey respondents, with a focus on addressing unintended pedestrians. This service includes patrols or other available assistance to help with incident management and clearing the road after breakdowns or collisions. Effectiveness of a roadside assistance program was evaluated on the Penn-Lincoln Parkway in the Pittsburgh metropolitan area in 1999 (Donnell et al., 1999). The study did not directly evaluate the reduction in secondary crashes, but it indicated that incidents were cleared 8.3 minutes faster than before implementation of the roadside assistance program. As the exposure time was reduced, secondary crashes were less likely happen. In addition, the study showed that the public was in favor of the roadside assistance program. Additional research could focus on the potential safety benefits.

Conclusions and Future Direction

Policies and practices aimed at unintended pedestrians were more frequently cited than those addressing intentional pedestrians. These strategies include move over and collision clearance laws and campaigns or design features that try to reduce friction between unintended pedestrians and highway drivers. Several states offer roadside assistance programs to aid travelers in support of these policies. Often, these strategies are implemented through clear policies, roadway signing, and/or educational campaigns. In contrast, other than enforcement, ongoing or systematic practices addressing intentional pedestrian safety strategies on highways, such as evaluation of pedestrian crossings, were hardly mentioned.

This analysis of countermeasures to address pedestrian safety on high-speed roadways suggests that some countermeasures are promising but may require improvements to be effective, such as designing overpasses or underpasses that are easily accessible and inviting for pedestrians. Fences or barriers can be used to guide pedestrian crossing behavior but must be made so that pedestrians cannot climb or otherwise circumvent them.

In the shorter term, effective education and enforcement efforts may be critical to successful implementation of existing practices. Education and enforcement were commonly mentioned in the survey responses as tools for managing pedestrian safety on controlled-access highways. For example, signs and media campaigns are used to promote move over/slow down laws. According to the literature, different groups are not equally aware of existing laws and programs. More effective education programs need to be developed to focus on hard-to-reach and vulnerable groups.

Additional suggestions for future efforts to increase understanding of pedestrian safety issues on high-speed, controlled-access roadways and improve mitigation efforts are discussed here.

Expand Move Over Laws

Generally, move over laws are designed to protect emergency responders and enforcement officers on the road. The evidence of unintended pedestrian fatalities on high-speed roadways suggests that the dangers facing emergency and enforcement agents are a problem for everyday travelers as well. Extending this law to include all vehicles could greatly expand the benefits and would be unlikely to increase costs significantly. However, it may require regulatory changes at the state level.

Evaluate Intentional and Unintended Pedestrian Activity Independently

The survey respondents were more likely to state that unintended pedestrians, versus intended pedestrians, were a concern. However, crash data suggest that intended pedestrians walking or standing on the roadway make up a higher proportion of pedestrian fatalities on high-speed, controlled-access roadways. The survey results and the existing crash data suggest a disconnect between some transportation agencies' perception of freeway pedestrian activity (e.g., it is not allowed, so it is rare) and the high proportion of incidents that the data suggest. Only one survey respondent stated that post-breakdown crashes on highways are infrequent in his/her state, while the majority of pedestrian crossing fatalities are associated with high-speed urban arterials.

Intentional pedestrians pose a more complicated issue for transportation agencies. A major challenge is how to deal with an activity that is caused by pedestrians entering a roadway where their presence is illegal or formally prohibited. Respondents expressed concerns with the potential for practices that may inadvertently induce pedestrian crossings, such as pedestrian warning signs. Others suggested that it was not something they felt equipped to address. Those states that reportedly did attempt to address intentional pedestrians used overpasses, underpasses, barriers, fencing, and signing, but with varying frequency. Few respondents cited a comprehensive program or formal evaluation of the frequency, use, or accomplishments of goals.

The practices and countermeasures identified in this research reinforce the distinction between unintended pedestrians and pedestrians who intentionally attempt to stand, walk along, or cross controlled-access roadways. Table 7 identifies which practices are aimed at which category of pedestrians.

Table 7. Practices Aimed at Different Categories of Pedestrians.

Practices for Unintended Pedestrians	Practices for Intentional Pedestrians
• Move over laws	• Overpasses and underpasses
• Collision clearance laws	• Barriers and fencing
• Roadside assistance	• Signs
• Shoulder width and design	• Enforcement
• Enforcement	

Increase Data Collection, Evaluation, and Monitoring of Practices

The survey responses revealed a lack of information about addressing intentional pedestrian safety on high-speed roadways. State DOTs either do not see pedestrian safety on interstates as an issue or are not equipped to address these concerns. The survey also revealed that transportation agencies in several states are struggling or are unable to find solutions for addressing pedestrian safety on high-speed roadways.

Overpasses and underpasses may offer a promising solution, but few states have evaluated their effectiveness. Empirical evidence is needed to support future development of these facilities. A comprehensive comparison of existing over/underpasses would allow researchers to find the factors that lead to safe and well-trafficked overpasses and underpasses. In addition, pedestrian count or activity data in proximity to the infrastructure, aided by lower-cost collection technologies, may expose relevant pedestrian behavior.

Even where a strategy is being implemented, the implementation process is often ad hoc and unevaluated. A number of countermeasures are reportedly widely used, often to achieve other objectives, but their safety benefits for pedestrians have not been well documented. Roadside assistance programs' main purpose is to ensure the mobility of a roadway. Evaluating the safety impacts of roadside assistance could further justify the tax cost of the programs and provide more insights into how to best implement the practices. Even if the countermeasures are

effective, the costs of implementation must be considered in the evaluation of the potential benefits. Implementations should include evaluation and monitoring of results that can inform ongoing campaigns.

Research and Develop Guidelines for Pedestrian Crossing Opportunities along Urban Interstates

Survey respondents discussed some of the broader land use and transportation planning themes that contribute to and/or could address pedestrian highway safety. One respondent suggested that part of the problem stems from the challenge of achieving a high level of access control on an at-grade highway or interstate corridor. If access to a roadway cannot be completely controlled, then that roadway should be classified as an urban arterial. This respondent suggested that the majority of the state's pedestrian fatalities and injuries occur on high-speed urban arterials where pedestrians have limited or inconvenient options for safe crossing. Another respondent argued that pedestrian highway collisions are going to be a problem anywhere high-speed, at-grade roadways are present near high-activity or developed areas with few safe crossings. People will cross if the safe alternative is too cumbersome or takes too much time. In these areas, pedestrians are more willing to risk a dangerous crossing than take a longer path with long walk times.

Commercial and residential development along high-speed roadways will continue to create a demand for getting to destinations across a roadway. It is unrealistic to simply stop pedestrians from crossing highways, especially in high-activity urban areas. Instead, efforts need to be made to understand how to correlate land use and transportation planning to accommodate pedestrian activity safely.

The survey results suggest that practices are not different between states with higher fatality rates and those with lower fatality rates, as was assumed in the design of the survey. No state demonstrated a comprehensive or directed program for addressing this particular issue of pedestrian safety. This suggests that the built environment, including differences between urban and rural environments, and roadway design of each state may be a factor in this type of crash. As safety interventions to address effects of the built environment would require long-term efforts, a first step would include further analysis of crashes in relation to the surrounding urban environment.

Population growth, urbanization, and land use development along high-speed corridors will likely increase these deadly interactions between pedestrians and vehicles. Existing practices that have demonstrated success, such as move over laws, could be expanded to protect pedestrians who find themselves on a high-speed roadway after a crash or breakdown. Other practices should be further evaluated with better data analysis and post-evaluation of intervention efforts.

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Appendix

Email Interview Script—Version 2
Best Practices for Addressing Pedestrian Crashes on High Speed Roadways
IRB2014-0763

Dear Mr./Ms. _____,

My name is _____ and I work for the Texas A&M Transportation Institute. We are conducting a study of best practices to address pedestrian crashes on high-speed roadways such as controlled-access highways. Would you be willing to answer some questions about how your state DOT has maintained or achieved low pedestrian fatality rates on high-speed roadways, specifically controlled-access roadways? If so, please make sure to review the information sheet I attached to this email. If not, would you recommend another person in your state to contact?

Questions:

1. What pedestrian safety concerns are you aware of on the main lanes of your controlled-access highways?

2. What, if any, programs, policies, practices or countermeasures has your agency considered or implemented to address pedestrian safety along controlled-access highways?

3. What specific laws related to pedestrians on controlled-access highways does your state have?

4. Are there policies to install signs prohibiting pedestrians on controlled-access highways?

5. Are there signs posted that warn motorists on interstates or controlled-access highways of pedestrian crossings?

6. A. Are people exiting vehicles on controlled-access highways for breakdowns, post vehicle-vehicle crashes, etc. a contributor to pedestrian crashes along these highways?

   B. Do you have a roadside assistance service along your highways/interstates? Please describe its operational concepts and benefits.

   C. Are other operational strategies employed/laws in effect to reduce exposure of motorists exiting vehicles? (i.e., move off the road laws, crash investigation sites). How are those communicated to public?

7. Are fences routinely placed along the median, outside edge of the controlled-access highways, or along the right of way?

8. A. Do your highways/interstates have frontage roads as a general rule?

B. In locations with frontage roads, are fences or barriers placed between the frontage road lanes and the main lanes, or another location?

9. Has your state installed overpasses/underpasses for pedestrians? What policies or warrants are used to consider overpasses or underpasses? If they have been installed, what evidence do you have that they are or are not being used?

10. Is there a policy or practice for continuing streets over or under a controlled-access highway without an interchange (i.e., a grid pattern continues across the highway)?

11. What other countermeasures related to pedestrian safety on controlled-access highways have you implemented or considered that I haven't mentioned?

Thank you for your time today. We are very grateful for your assistance in this project.

Researcher name and contact info