# White Papers for: *"Toward Zero Deaths: A National Strategy on Highway Safety"*

## —White Paper No. 5—

# Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users


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## FOREWORD

## (To be prepared by FHWA)

## NOTICE

## PREFACE

While many highway safety stakeholder organizations have their own strategic highway safety plans, there is not a singular strategy that unites all of these common efforts. FHWA began the dialogue towards creating a national strategic highway safety plan at a workshop in Savannah, Georgia, on September 2-3, 2009. The majority of participants expressed that there should be a highway safety vision to which the nation aspire, even if at that point in the process it was not clear how or when it could be realized. The Savannah group concluded that the elimination of highway deaths is the appropriate goal, as even one death is unacceptable. With this input from over 70 workshop participants and further discussions with the Steering Committee following the workshop, the name of this effort became "Toward Zero Deaths: A National Strategy on Highway Safety." The National Strategy on Highway Safety is to be data-driven and incorporate education, enforcement, engineering, and emergency medical services. It can be used as a guide and framework by safety stakeholder organizations to enhance current national, state, and local safety planning and implementation efforts.

One of the initial efforts in the process for developing a National Strategy on Highway Safety is the preparation of white papers that highlight the key issue areas that may be addressed as part of the process for developing a National Strategy on Highway Safety. Vanasse Hangen Brustlin was awarded a task order under the Office of Safety contract (DTFH61-05-D-00024) to prepare nine white papers on the following topics:

1. Future View of Transportation: Implications for Safety
2. Safety Culture
3. Safer Drivers
4. Safer Vehicles
5. Safer Vulnerable Users
6. Safer Infrastructure
7. Emergency Medical Services
8. Data Systems and Analysis Tools
9. Lessons Learned from Other Countries

The authors were challenged to be thought provoking and offer strategies and initiatives that, if implemented, would move the country towards zero deaths.

A certain group of road users are particularly vulnerable to becoming a fatality if involved in vehicle crash including pedestrians, especially those with disabilities, bicyclists, motorcyclists and all of those users who have diminished abilities due to aging. Strategies for addressing these groups are presented in this white paper by a team of experts in these areas including Charlie Zegeer, Janet Barlow, William Hunter, Frances Bents, and Loren Staplin.

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# INTRODUCTION

The term Vulnerable Road Users (VRU's) may be generally defined as the road users who are most at risk for serious injury or death when they are involved in a motor-vehicle-related collision. These include pedestrians of all ages, types and abilities, particularly older pedestrians and people with disabilities. VRU's also include bicyclists and motorcyclists. Older drivers may also be considered to fit into this same user group.

In terms of nationwide fatalities, pedestrians account for approximately 4,800 deaths each year, or about 11 % of total traffic fatalities each year, compared to about 700 bicyclist fatalities (2% of total fatalities). The number of motorcyclist fatalities, with approximately 5,200 per year, now exceeds the number of pedestrian traffic fatalities annually. Depending on how someone defines older drivers, more than 5,000 drivers aged 70 and above are also killed on our nation's highways. Therefore, VRU's account for nearly 16,000 highway –related deaths in the U.S. each year. Although there is not good exposure data for pedestrians, bicyclists, or motorcyclists on a nationwide basis, the pure numbers of traffic fatalities for VRU's reflects a serious safety problem for which aggressive and innovative solutions are needed.

The following is a compilation of four white papers which make up the overall category of Vulnerable Road Users. These include the following topics and authors:

- Pedestrians (including older pedestrians and pedestrians with disabilities)- Charles V. Zegeer, UNC Highway Safety Research Center and Janet Barlow, Accessible Design for the Blind
- Bicyclists- William W. Hunter, UNC Highway Safety Research Center
- Aging Road Users- Loren Staplin, TransAnalytics, LLC
- Motorcyclist Issues- Frances D. Bents and Richard Huey, Westat

These four separate, but related sections are given here.

# PEDESTRIAN ISSUES

### *MAGNITUDE OF THE PROBLEM*

Of all of the user groups on public streets and highways, pedestrians are among the most vulnerable, particularly in terms of fatalities and serious injuries. For example, in 2007, a total of 4,654 pedestrians died in traffic crashes, which represents 11 percent of all traffic fatalities that year. This number is 3 % lower than the 4,795 deaths in 2006. Also in 2007, an estimated 70,000 pedestrians were injured in the U.S., which represents an increase from 2006 by approximately 15 percent. Since 1995, however, total pedestrian injuries have dropped by approximately 17 percent. These trends in pedestrian fatalities and injuries are shown in Figures 1 and 2, based on information from NHTSA.

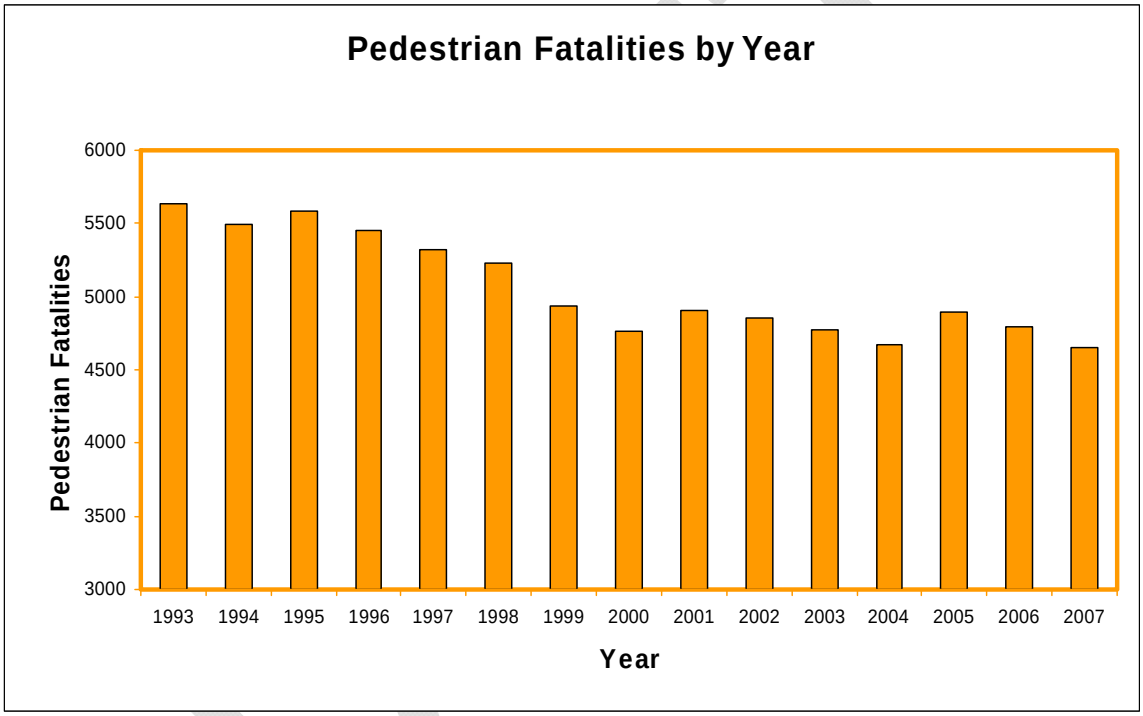


**Figure 1. Long-term pedestrian fatality trend.**

**(Source: NHTSA, 2007).**

There has been speculation and debate regarding the reasons for the decline in pedestrian deaths and injuries over the past decade. Questions have been asked regarding whether this reduction has been the result of improvements in the walking environment, improved behaviors by pedestrians and/ or motorists, or whether it is actually the logical result of reduced amount of walking among some or all pedestrian groups. In May of 2010, the "National Bicycling and Walking Study -15 Year Report" was released, which showed that the number of walking trips has more than doubled from 18 billion trips in 1990 to 42.5 billion in 2009. This total of 42.5 billion trips in 2009 also exceeds the 35 billion trips estimated in 2001. Furthermore, the percent of all trips has increased from 7.2 % in 1990 to 10.9 % in 2009.

Therefore, although the specific reasons are not known, there appears to be a clear reduction in pedestrian fatalities over the past two decades, with a considerable increase in the number and percentage of trips on foot. In spite of this encouraging trend, pedestrian deaths and injuries continue to be one of the leading types of traffic fatalities on our nation's highways and in need of dramatic improvement in order to take the next step toward the vision of zero deaths.

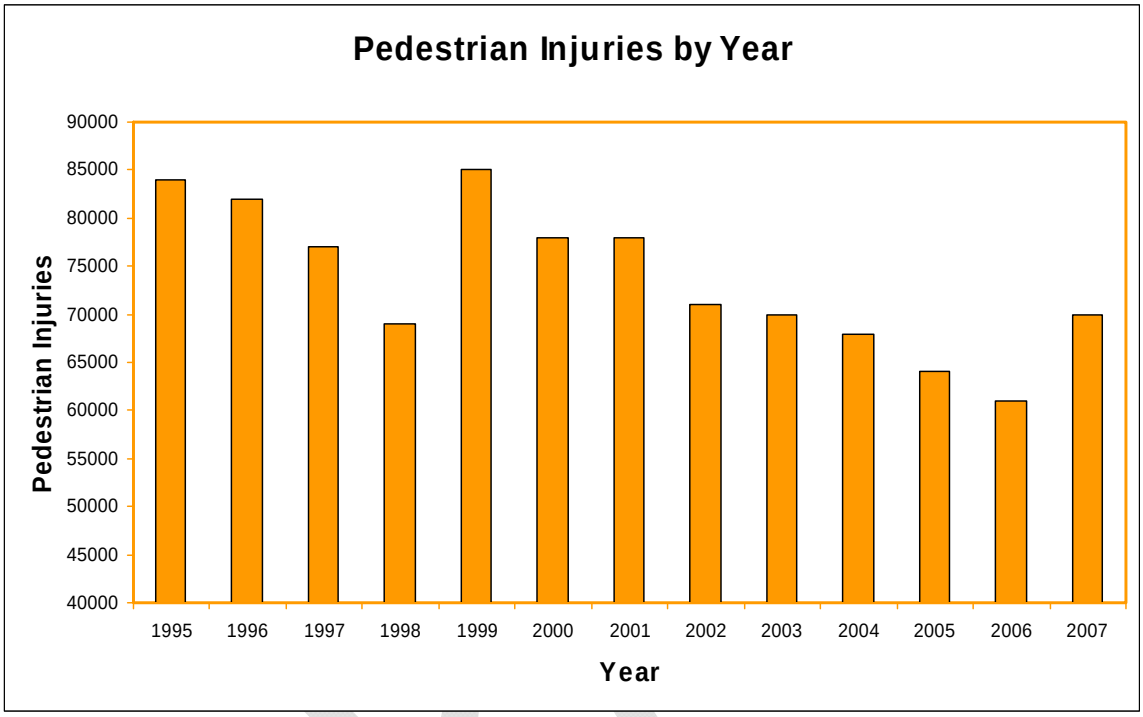


**Figure 2. Long-term pedestrian injury trend.**

(Source: NHTSA, 2007).

## *PEDESTRIANS MOST AT RISK*

**Age, Gender, and Ethnic Groups:** Pedestrian crash trends continue to show greater problems for children and older adult pedestrians. According to Chang (2008), between 1997 and 2006, children under age 15 accounted for about 21 percent of the U.S. population, and accounted for 23 percent of pedestrian crashes. According to FARS, children 15 years old or less account for 8 percent of pedestrian fatalities. Pedestrians over age 70 made up about 9 percent of the population but 16 percent of pedestrian deaths in 2007.

Males of all ages account for 70 percent of pedestrian deaths, and the pedestrian fatality rate was 2.19 (deaths per 100,000 population) for males compared to 0.91 for females. While it has been hypothesized that males may walk more than females, NHTS data from 2001 found that the number of walking trips to be roughly similar between males and females. However, there is some evidence that males may in general walk further per trip on average, which would increase their exposure to traffic (compared to females) and partly account for this difference (Clifton & Levi, 2005). Although there has been speculation that males may tend to walk in more dangerous locations or exhibit riskier behavior than females, little information is available to confirm or refute these assumptions. There is also evidence that immigrants and minority populations (e.g.,

Hispanic and African American pedestrians) are over-represented in pedestrian crashes, compared to their population (Chang 2008; NHTSA 2008b; U.S. Census Bureau, 2006)

Census Bureau projects that the number of Americans age 65 or older will be than 62 million by 2025. Based on the National Household Transportation Survey of 2001, more than one in five (21%) Americans age 65 and older do not drive. Some reasons include:

- Declining health, eyesight, physical or mental abilities;
- Concern over safety (self-regulation);
- No car or no access to a car;
- Personal preference (Bailey, 2004).

Crash involvement rates for older persons (age 65 and over) are lower than for most age groups, which may reflect greater caution by older pedestrians (e.g., less walking at night, fewer dart-outs) and a reduced amount of walking near traffic. However, older adult pedestrians are much more vulnerable to serious injury or death when struck by a motor vehicle than younger pedestrians. For example, the percentage of pedestrian crashes resulting in death exceeds 20 percent for pedestrians over age 75, compared to less than 8 percent for pedestrians under age 14 (Zegeer et al, 1993; Campbell et al, 1999).

### *PEDESTRIANS WITH DISABILITIES*

According to a 1992 U. S. Census study, there are 49 million Americans with disabilities. As the US population ages, number of persons with disabilities is expected to increase.

Individuals with disabilities may include individuals with mobility disabilities, using wheelchairs, walkers or canes, individuals who are blind or who have impaired vision, individuals with cognitive impairments from developmental disabilities, stroke or brain injury, and others. Individuals with disabilities may be the most vulnerable users of transportation facilities. Many are unable to drive and are dependent on transit and pedestrian facilities to travel to work and to family, shopping, medical, and recreation destinations.

The safety of persons with disabilities as road users is often dependent on the design of sidewalks and street crossings for usability and safety. Many people change their routes, or use paratransit services, or don't travel at all in response to poor roadway facilities, and statistics on crash involvement by persons with disabilities are not consistently recorded, so statistics on crashes and safety for persons with disabilities are not available. However, as the US population ages, the prevalence of disabilities such as impaired vision, mobility impairments, and cognitive impairments is increasing. (Statistics on common medical conditions of older users is provided in section on older road users paper). Safety of persons with disabilities is an essential part of improving roadway safety.

### *AREA TYPE AND ROAD TYPE OF CRASHES*

In terms of the types of areas and locations where pedestrian crashes occur, approximately 73 percent of pedestrian fatalities occurred in urban areas in 2007 (NHTSA, 2008a), largely because of the higher amount of pedestrian trips in urbanized areas. Although fewer pedestrian fatalities occur in rural areas, pedestrians are more than 2.3 times more likely to die from a pedestrian crash in rural areas than urban areas (Mueller, 1988). This trend is the result rural areas having higher vehicle speeds combined with fewer separated facilities for pedestrians, such as

sidewalks, trails, and paths, compared to urban areas. Also, crashes in rural areas are generally located further from quality emergency care, so more time is needed for Emergency Services to arrive at the scene of a crash (Mueller, 1988).

In terms of pedestrian fatalities by roadway type on urban and rural areas, urban arterials (26.15%) and urban local roads and streets (14.4%) and urban minor arterial (13.71%) had the highest incidence of fatal crashes, compared to rural areas on rural principal arterial (6.63%) and rural local roads (6.42 %), as shown in table 3. For total pedestrian injuries (right column of table 3), the road types with the greatest percent of crashes included urban principal arterials (20.5 %), urban local road/street (17.45 %), urban principal/interstate (11.63 %) and urban minor arterials (11.08%). No rural road type had more than 6 % of total pedestrian crashes. It should also be mentioned that approximately 77 percent of pedestrian fatalities happen at non-intersections (see Table 1).

**Table 1. Pedestrian fatalities and injuries by road type, 2008.**

| Road Type | Percent of total pedestrian fatalities | Percent of total pedestrian injuries |
|---|---|---|
| **Total** | | |
| Principal Arterial -Interstate | 11.68 | 15.51 |
| Principal Arterial - Other Expressways or Freeways | 11.37 | 10.25 |
| Principal Arterial | 30.34 | 26.04 |
| Minor Arterial | 18.76 | 16.07 |
| Collector | 5.66 | 4.99 |
| Local Road or Street | 20.82 | 23.27 |
| Unknown or Blank | 1.37 | 1.66 |
| **Rural*** | | |
| Rural Principal Arterial-Interstate | 3.62 | 3.88 |
| Rural Principal Arterial-Other | 6.63 | 4.43 |
| Rural Minor Arterial | 4.19 | 5.54 |
| Rural Major Collector | 5.05 | 4.99 |
| Rural Minor Collector | 1.41 | 1.66 |
| Rural Local Road or Street | 6.42 | 5.82 |
| Unknown Rural | 0.19 | 0.55 |
| **Urban*** | | |
| Urban Principal Arterial-Interstate | 8.06 | 11.63 |
| Urban Principal Arterial-Other Freeways or Expressways | 4.74 | 5.82 |
| Urban Other Principal Arterial | 26.15 | 20.50 |
| Urban Minor Arterial | 13.71 | 11.08 |
| Urban Collector | 4.25 | 3.32 |
| Urban Local Road or Street | 14.40 | 17.45 |
| Unknown Urban | 0.21 | 1.11 |

(Source: FARS, 2008). *Note: May not add up to 100 percent as blank responses were not available for the urban and rural strata.

### *PEDESTRIAN CRASH TYPES AND BEHAVIORS*

Specific pedestrian crash categories or types were defined in the 1970's by NHTSA to better define the sequence of events and actions by pedestrians and motorists which led to the crashes and for which countermeasures could be developed. In 1996, Hunter, et. al. applied these definitions to approximately 5,000 pedestrian crashes (and 3,000 bicycle crashes) from six states to update what is known about pedestrian crash types and the roadway conditions where they occur. Some of the most frequent pedestrian crash types include dart-out in first half of the street (24 percent), intersection dash (13 percent), dart-out in second half of the street (10 percent), midblock dart (8 percent), walking along roadway (7.4 percent), and turning-vehicle crashes (5 percent). Computer software and accompanying guide called PBCAT was developed to allow the user to classify (type) their pedestrian (and/or bicycle) crashes and then have a link to corresponding countermeasures. (PBCAT).

Also, although it is not a specific crash type, it should be mentioned that approximately two-thirds of pedestrian fatalities occur at night or under low-light conditions. The reduced ability of a of driver to see a pedestrian at night is a contributing factor to several of the pedestrian crash types listed above, such as the "walking along roadway" crash type. It should also be mentioned that the use of cell phones and other distractions, use of alcohol or drugs by drivers and/or pedestrians, and other behaviors can also increase the risks of a pedestrian crash.

### *VEHICLE SPEEDING*

Higher vehicle speeds can increase the risks to pedestrians in several ways. First of all, vehicle stopping distance increases substantially as vehicle speed increases. Secondly, the risk of a pedestrian death occurring from a collision with a motor vehicle is much greater for higher vehicle speeds. According to 1987 study in the U.K., the probability of pedestrian death is 85 percent when the striking vehicle is traveling at 40 mph. This probability drops to about 55 percent for a 30 mph impact and drops further to 5 percent if the vehicle was traveling at 20 mph at impact. The percent of pedestrian injuries is also shown as a function of vehicle speed at the point of impact (see Figure 3).

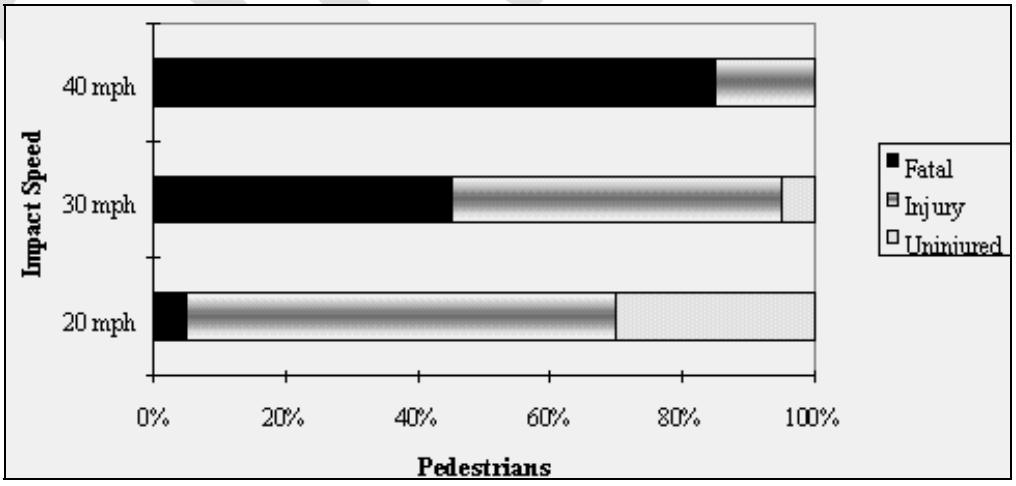


**Figure 3: Pedestrian injury severity based on vehicle speed (Source: Traffic Advisory Unit, 1993).**

### *ROADWAY FEATURES RELATED TO PEDESTRIAN CRASHES*

Before recommending strategies to address the vision of "zero pedestrian deaths", it is important to understand the traffic and roadway conditions that are associated with pedestrian crash occurrence. Based on decades of pedestrian safety research, it is clear that there are many geometric, traffic control, and site characteristics that affect pedestrian crashes. For example, a 2008 study by Harwood et. al. for NCHRP ("Pedestrian Safety Prediction Methodology") involved developing crash predictive models for signalized intersections in Toronto, Canada and Charlotte, N.C. Factors found to be associated with a higher likelihood of pedestrian crashes included higher traffic volume, greater volume of crossing pedestrians, ratio of minor road ADT to major road ADT, maximum number of lanes to cross (considering the presence of refuge islands), presence of bus stops within 300 m (1,000 feet) of the intersection, presence of public or private schools within 300 m, and greater number of alcohol establishments within 300m.

For unsignalized pedestrian crossings, a 2005 study by Zegeer et. al. found that pedestrian crash risk increased for increased traffic and pedestrian exposure, greater number of lanes, lack of a raised median or median island (for multi-lane roads) and for older pedestrians (65 years and older). The presence of a marked crosswalk alone (without other substantial treatments) was associated with higher pedestrian crashes when compared to an unmarked crosswalk, under certain conditions; i.e., multi-lane roads having traffic volumes greater than about 12,000 vehicles per day.

Pedestrian crashes involving "walking along roadway" were analyzed in a case-controlled 2002 study by McMahon et al., in terms of the roadway and socio-economic factors. Physical roadway features found to be associated with significantly higher pedestrian crash risk included higher traffic volume, higher speed limit, lack of a wide grassy walkable area, and absence of sidewalks. Higher risks of such pedestrian crashes were also related to high levels of unemployment, older housing, lower proportion of families within neighborhoods, and more single-parent households.

### *SUMMARY OF PEDESTRIAN CRASH FACTORS*

There are many factors that can affect the risk and/or severity of a pedestrian crash, and the discussion above mentions only a few of the relevant factors and issues. These pedestrian-related factors may relate to the pedestrian, driver, vehicle, roadway, and/or to a range of social/demographic factors that affect the amount and manner in which people travel. An overview of some of these factors is given in figure 4 of some of the key factors related to pedestrian crashes, as recently presented to FHWA by Zegeer, et. al. as part of the proposed Pedestrian Safety Program Strategic Plan (July, 2010).

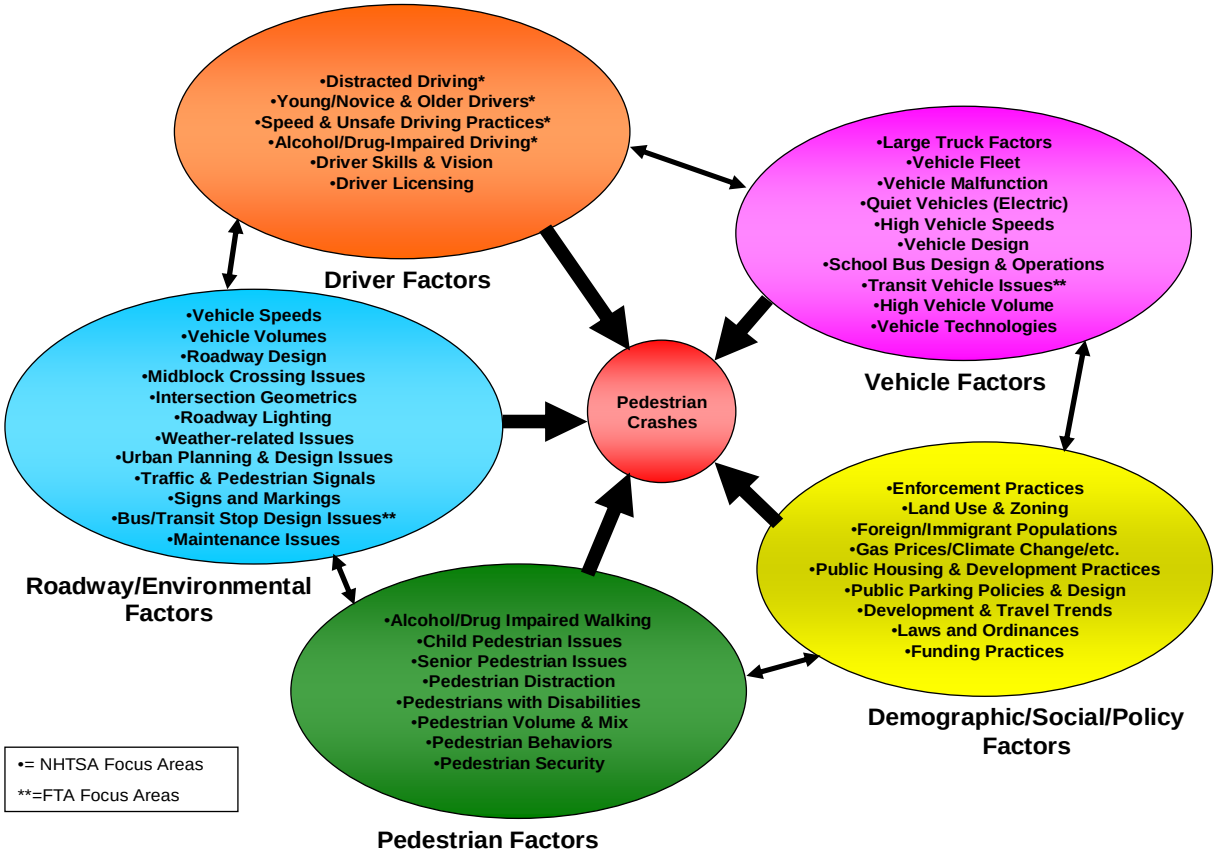


**Figure 4. Illustration of factors associated with pedestrian crash risk and/or severity.**

## *PROPOSED PEDESTRIAN STRATEGIES*

There are many types of specific safety improvements that can potentially improve pedestrian safety, depending on the situation. The following is not a compilation of all possible safety improvements, but a list of eight broad strategies that are considered to be most likely to result in a reduction in pedestrian deaths and injuries in helping to address the vision of zero traffic deaths involving pedestrians.

### 1. Complete and Market a Revised ASHTO Pedestrian Guide to Local and State Officials

If the US is really serious about reducing pedestrian fatalities, the highway infrastructure and facilities for pedestrians must be improved. **Complete Streets Policies should be a standard for all new roads and for all roadway reconstruction projects. Without having a requirement for Complete Streets Policies, some agencies are likely to continue to give a lower priority to the needs of pedestrians in the roadway and street environment.**

The first edition of the AASHTO Pedestrian Guide (2006) was a valuable contribution to the pedestrian safety field, since its development gives more prominence to pedestrians from a roadway design and safety standpoint among state and city engineers. It is questionable, however, how many engineers actually have a copy of the AASHTO Pedestrian Guide or how

many engineers are making regular use of the Guide. Efforts are now underway to identify needed improvements from the initial AASHTO pedestrian guide, for an upcoming revised version. The revised Guide should strongly encourage that a "Complete Streets" approach be used for all new roads and for retrofits to existing roads.

It is recommended that the next version of the AASHTO Pedestrian Guide provide more definitive guidance on geometric conditions which are beneficial and also which designs are harmful to pedestrians and should be avoided. For example, arterial streets with five or more lanes combined with high vehicle speeds and volumes can create major safety problems for pedestrians. Alternative designs (e.g., 2 lanes in each direction with raised median, left-turn pockets, plus bike lanes, sidewalks, and planting strips) can provide safer options for all road users, while maintaining vehicle capacity. Tighter intersection turning radii might be appropriate under many urban situations to slow speeds of turning vehicles and shorten the crossing distance for pedestrians.

Pedestrians, particularly children, older pedestrians, and those with disabilities, should not have to travel in the street because there is no sidewalk, or because there is no curb ramp to get to the sidewalk. Pedestrian facilities should include well-designed sidewalks, curb ramps at all crosswalks, appropriate cross slopes and proper driveway designs. Particular attention should be focused on facilities near bus stops and transit stations (see strategy 4 above). Improvements that benefit children, older pedestrians, and pedestrians with disabilities will improve the safety of all pedestrians. Raised crosswalks may be appropriate for midblock and roundabout crossing locations. Providing intersection crossing islands at the intersection of arterial streets can reduce pedestrian exposure time in the street.

It is particularly important for the revised AASHTO Pedestrian Guide to give special attention to the geometric measures that have been found in the safety literature to have a positive effect on pedestrian crash risk and/or crash severity. Some of the results are presented in the FHWA "Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes" (May, 2008). Some of the geometric treatments reported to significantly reduce various pedestrian crash types include:

- Convert unsignalized intersection to roundabout
- Install pedestrian overpass/underpass
- Install raised median or raised pedestrian crossing (refuge island)
- Install sidewalk
- Provide paved shoulder (of at least 4 feet)
- Narrow the roadway cross section from four lanes to three lanes (i.e., one through lane in each direction plus a center turn lane)

Improved design guidance for pedestrians and other road users should be promoted in the revised AASHTO Guide for new roadways and also for retro-fitting existing roads where feasible. As part of the effort to develop a revised AASHTO pedestrian Guide, an aggressive campaign is needed to market the new Guide so it becomes a routine part of the engineer's design work. This should involve a series of webinars and in-person training to educated engineers and planners on better street design for pedestrians. Such training may also be incorporated into the FHWA

training currently being offered by the FHWA Office of Safety on "How to Develop a Pedestrian Safety Action Plan."

### 2. Further Refine the MUTCD to Address Pedestrian Safety Problems

In the past two versions of the MUTCD, numerous new additions have addressed pedestrian safety concerns. Some of these additions include the pedestrian (HAWK) beacon, the countdown pedestrian signal (as a requirement for all new pedestrian signal installations), advance stop/yield line (with the signs reminding motorists to stop or yield at the line positioned 30 to 50 feet back from the crosswalk), the new signing at marked crosswalks (with the pedestrian warning sign and down arrow), the more detailed guidance on where it is acceptable to mark a crosswalk and where more substantial treatments are needed to accompany a marked crosswalk, based on the FHWA crosswalk study by Zegeer et al, among others.

In spite of these MUTCD pedestrian-related enhancements there are still many situations where pedestrians need assistance related to traffic control devices. For example, there are many signalized intersections in some states, particularly on suburban arterial streets, where pedestrian (WALK/DON'T WALK) signals are not used (i.e., for reasons such as "We don't want pedestrians to cross here because it is too dangerous."). There are also agencies where vehicle left –turn movements are not separated from pedestrian crossings (i.e., no separate left-turn phasing is used), even though patterns of collisions from left-turn motorists striking pedestrians (and also striking through motorists) exist every year. The reasoning is that providing separate left-turn phasing would increase motorist congestion and delay. Furthermore, some of the pedestrian-friendly traffic signal phasing, such as leading pedestrian intervals, are rarely used in the U.S., even though they may benefit pedestrian safety and mobility at busy signalized intersections. Accessible pedestrian signals should be included to meet the needs of pedestrians with visual disabilities.

Although some city and state engineers do a good job of trying to balance the needs of pedestrians, as well as motorists, this is not always the case. Based on promising research findings for some of these measures, more needs to be done to encourage agency officials to provide for the safety needs of pedestrians, particularly at signalized intersections and multi-lane (unsignalized) pedestrian crossings. We recommend the development of a "Best Practices Guide" based on recent research findings, which makes more specific recommendations providing signs, signals, and markings related to pedestrians. Information from this Guide should then be used in the next round of updates to the MUTCD, and also perhaps be added to the next update of the FHWA Traffic Control Devices Handbook" (last updated in 2001), which is a supplement to the MUTCD.

Traffic signal-related measures that have been found to significantly reduce pedestrian crashes include:

- Add exclusive pedestrian signals.
- Improve signal timing.
- Replace existing WALK/DON'T WAK signals with pedestrian countdown signals.
- Implement a leading pedestrian interval.
- Remove unwarranted signals (on one-way streets).

- Convert permissive or permissive/protected signals to protected only left-turn phasing.
- Convert permissive to permissive/protected left-turn phasing.

Examples of signs, markings, and operational countermeasures which can reduce pedestrian crashes include:

- Add intersection lighting.
- Add lighting along roadway sections.
- Improve pavement friction (e.g., which can reduce vehicle stopping distances).
- Increase police enforcement.
- Prohibit right-turn-on-red at intersections.
- Prohibit left turns.
- Restrict parking near intersections.

It should be understood that not all of these countermeasures are needed or even appropriate at all locations. Each countermeasure needs to be chosen to fit the types of pedestrian crash/safety problems and site conditions. There may also be other countermeasures that have been found in more recent pedestrian safety research to reduce pedestrian crashes (e.g., the pedestrian HAWK" beacon), and which may be appropriate under certain conditions (Fitzpatrick, et. al. 2009). More examples of countermeasure effectiveness can be found in such reports as NCHRP 500, Volume 10 "A Guide for Reducing Collisions Involving Pedestrians", Highway Safety Manual (including unpublished "Knowledge Report), NCHRP 617 "Accident Modification Factors for Traffic Engineering and ITS Improvements" (Harkey et. al. 2008), and others.

Improvements to the MUTCD must also consider the needs of people with disabilities. While the MUTCD now provides specifications for functioning of Accessible Pedestrian Signals (APS) are not required at locations where pedestrian signals are installed. Pedestrians with vision impairment should not have to guess when the walk signal is illuminated. Standards that require accessible pedestrian facilities, particularly transit related facilities, will improve the safety of pedestrians with disabilities. Accessible pedestrian signals and pushbuttons, and detection of pedestrians in the crosswalks are needed to provide time extensions for individuals who travel across crosswalk more slowly

**3. Expend Funding and Implementation of a National Safe Routes to School Program with National Safety Education Program**

The current Safe Routes to School (SRTS) legislation provides $612 million to the states to distribute to communities for providing safer child travel to school by bike or on foot. The intent of the funding is primarily (70 to 90 %) for infrastructure improvements, but is also intended to provide 10 to 30% for safety education and enforcement. While this is certainly landmark legislation by Congress in an attempt to increase the percent of school trips by bicycling or walking and to also improve safety for the school trip, this amount of funding, after full implementation, is estimated to only address approximately 7% of elementary and middle schools in the U.S. Even for schools where SRTS funding is provided, there may be many needs for infrastructure, education, and enforcement enhancements that may only be addressed to a

limited extent with the funding. It is recommended that SRTS funding be increased in the next transportation bill for elementary and middle schools.

It should also be mentioned that one of the recommendations in the February, 2010 FHWA/AASHTO report "Pedestrian and Bicyclist Safety and Mobility in Europe" (Pedestrian/Bike Scan report) was to "Institutionalize ongoing traffic safety education that starts at an early age, including knowledge and skill-based learning". Another report recommendation was to: "Unify all traffic safety campaigns (including bicycle and pedestrian safety) under a single national brand" (page 51). In addition, pedestrian (and bicycle) safety education has been taught sporadically in elementary schools, so it is recommended that the U.S. DOT (particularly NHTSA) work closely with the U.S. Department to work out a mechanism by which there is a nationally-accepted, well-coordinated effort to have some form of pedestrian safety education implemented in every school district in the nation within the next five years.

For example, a new NHTSA-sponsored child pedestrian safety education program, funded will be completed soon, which may be appropriate for wide-scale promotion to elementary schools on a national basis. Such a program should include not only safety education in the schools themselves, but also be coordinated with parents of school-age children. Developing a unified safety campaign, as recommended in the Pedestrian/Bike Scan report should also be made a part of this overall effort, to benefit not only school children, but all pedestrians (and bicyclists).Educational messages and campaigns should be developed in other languages (e.g., Spanish) to be appropriate for certain cities or parts of the country. Education and enforcement should be increased starting with school zones and expanding to other problem areas to help to reduce vehicle speeds, and also improve driver awareness of and yielding to pedestrians in crosswalks.

**4. Develop and Implement Specific National Guidelines for Safer Bus Stop Design and Placement**

As discussed previously, bus stop locations account for a substantial number of pedestrian crashes. This is not only because of the greater volume of pedestrians who cross the street at bus stop sites, but partly because of the behaviors of pedestrians who may cross the street in an unsafe manner to catch the bus and/or who cross after leaving the bus. This is combined with the fact that many bus stops are located along high-speed and high-volume collector and arterial streets, which present a challenge for pedestrians to cross safely, particularly for older pedestrians and pedestrians with disabilities.

There have been guidelines developed related to bus stop location and design, such as Report 19: Guidelines for the Location and Design of Bus Stops" (1996) and the more recent FHWA report "Pedestrian Safety Guide for Transit Agencies" (Feb. 2008). The 2009 MUTCD, AASHTO Pedestrian Guide, and other documents also provide guidelines that should be considered at bus stop locations and for getting pedestrians to and from transit stops. Many of the principles found in these and other guides should be used to produce a model set of recommended guidelines for providing sidewalks and street crossings, and bus stop waiting areas that can be applied by all transit agencies to all of their bus stop networks. FHWA and FTA should form a task force to develop clear and specific guidance for transit stops, and then FTA should provide funding and follow up with all transit agencies to make sure that their transit stops are in compliance with these guidelines.

### 5. Promote and Advance the Use of Photo Enforcement

Photo enforcement for speeding and red-light running has been use in some areas of the U.S., but has been met with considerable resistance in other areas, for various reasons (e.g., driver privacy issues, costs and responsibility for system installation and operation), and is therefore seldom if ever used in many states. One of the recommendations from the FHWA "Pedestrian and Bicyclist Safety and Mobility in Europe" (February, 2010) report is: "Promote the use of photo enforcement as a tool to improve pedestrian and bicyclist safety." Although FHWA and NHTSA both promote photo enforcement on their web sites (http://safety.fhwa.dot.gov/index.cfm and http://safety.fhwa.dot.gov/speedmgt), more aggressive actions are needed to encourage states to implement photo enforcement programs in every state. This might involve convening an expert panel of interested organizations (e.g., ITE, FHWA,NHTSA, Chief's of Police, legal groups) to develop a strategy to encourage more and improved implementation of photo enforcement. This strategy could essentially pay for itself from revenue generated by fines from violators.

### 6. Expand Pedestrian Safety Training to Engineers, Planners, and Other Professionals Nationwide (supported by pedestrian safety research)

Providing a roadway system for safer pedestrian requires that planners and engineers at the state and local levels are familiar with (and motivated to provide) geometric and traffic control measures that balance the safety needs of all road users, including pedestrians. Such knowledge has not been widely provided at the college and university level to date, so professional training is needed to reach safety professionals with the latest, research-based information possible on how to reduce pedestrian crashes through roadway improvements.

There have been efforts in recent years to provide some of this training and technical assistance on pedestrian safety. One of the best examples is the FHWA Office of Safety technical assistance to the 13 pedestrian focus states and 4 focus cities (i.e., states and cities which have been identified by FHWA as having the greatest number or rate of pedestrian fatalities). This technical assistance contract has to date resulted in the development of the "How to Develop a Pedestrian Safety Action Plan" Guide in February, 2007, which contains information on planning and engineering policies. The Guide was updated in May, 2008 to include details on education and enforcement countermeasures. Since 2007, more than 140 training courses (2-days each) on "How to Develop a Pedestrian Safety Action Plan" and Designing for Pedestrian Safety have been presented in face-to-face training to more than 4,000 engineers, planners, educators, enforcement officials, public health officials, and local and state safety officials, advocates and community leaders.

In order to continue and broaden the successes of this technical assistance to date, the training and technical assistance should be expended to the other 37 states where pedestrian safety problems are substantial. Furthermore, courses on accessible pedestrian facilities, accessibility through design and courses aimed at improving pedestrian safety at transit stops should also be taught in a coordinated manner, in conjunction with the other safety courses. Recent research on access for pedestrians with disabilities should be integrated into these courses. (Cheong, Geruschat, & Congdon, 2008; Harkey, Carter, Barlow, Bentzen, Myers, & Scott, 2007; Schroeder, Rouphail, & Hughes, 2009; Scott, Barlow, Bentzen, Bond, & Gubbe, D. , 2008. Seward, Ashmead, & Bodenheimer, 2007). Such courses should continue to be led by FHWA, in partnerships with NHTSA and FTA.

As a part of this effort, there should also be efforts to closely monitor pedestrian crashes, injuries and deaths in each state of the 50 states with resources in place to target pedestrian training and/or other resources to selected cities and states to counter pedestrian crash problems.

Furthermore, to educate planners, engineers, and other future safety leaders, several versions of a Pedestrian (and bicycle) planning and design training course has been developed (e.g., course developed by UNC HSRC) and taught on a limited basis. However, such courses have not yet been widely implemented into university curriculum, so efforts should be made to closer communication between U.S. DOT, AASHTO, and U.S. colleges and universities to make in-roads into having the latest course(s) adopted into the planning and/or engineering departments at key universities nationwide.

In support of the training and technical assistance activities discussed above, an aggressive, on-going pedestrian safety research program is needed by FHWA, NCHRP, and NHTSA to continually evaluate potential measures to reduce pedestrian crashes under a variety of site conditions. The results from this research should be immediately incorporated into the training and technical assistance to cities and states, and into new versions of the MUTCD, AASHTO Guidelines, and other FHWA and NHTSA Guides and web-based information.

**7. Improve the Reflectorization/Conspicuity of Pedestrians**

Because of the high percentage of pedestrian collisions and deaths that occur at night or under low lighting conditions, one of the strategies with a potential to reduce a large number of pedestrian injuries and deaths is to make pedestrians more visible to motorists. Implementing this strategy will require several key activities. Walking in the travel lane or crossing a high-speed street at night while wearing dark clothing and without watching for oncoming motor vehicles creates a high probability of a pedestrian death. Pedestrians need to be made better aware of the fact that they are nearly invisible to drivers when walking under dark conditions if they are not carrying a flashlight or wearing retro-reflective material/clothing.

Efforts should be made by the U.S. DOT to work closely with sporting goods companies (e.g., REI, Dick's Sporting Goods, Target, Walmart) to offer low-cost reflective vests and flashlights. NHTSA should work with such suppliers to provide informational brochures reminding walkers, joggers, and bicyclists to wear retro-reflective vests when along roads at night. More PSA's and other educational messages should be directed to pedestrians and motorists (slow down at night in urban, residential and suburban areas, etc.) and pedestrians (be visible and assume that motorists cannot see you). FHWA should review available Guidelines, policies, and practices on roadway lighting and develop an informational guide for engineers and planers to assist them with identifying roadway corridors and crossing sites which should be considered for enhanced nighttime lighting. This Guide should also discuss white lighting, smart lighting (activated by pedestrian movement), various lighting options, and other helpful information.

**8. Develop and Implement Pedestrian-Friendly ITS Vehicle and Roadway Features**

Pedestrian safety cannot be adequately achieved without also considering the potential for improving motor vehicles to make them more pedestrian friendly. Vehicle technology needs to be developed and/or implemented to:

- Equip electric (or silent) motor vehicles with noise-making equipment, so that pedestrians, particularly those with visual impairments, will be able to hear the vehicles approaching or idling nearby.

- Further develop pedestrian-sensing devices on motor vehicles which would, for example, sense a pedestrian walking in the roadway ahead at night, and alert the driver, so the driver can slow down and take evasive action top avoid striking the pedestrian, or automatically apply brakes if collision is imminent.
- Pedestrian/object detectors equipped on motor vehicles which can detect, for example, a child playing behind a parked car or van in a driveway, which sends a warning to the driver (who cannot see the child while sitting in the driver's seat).
- Pedestrian (and bicycle)-friendly front ends of cars and trucks to reduce the injury severity of a vehicle colliding with a pedestrian. Some auto companies and European countries have already begun implementing safer front-end vehicle designs.

ITS technology could also have applications at least in part to the roadway environment to help promote pedestrian safety. One example would be to install automatic pedestrian detectors at hundreds or thousands of urban signalized intersections nationwide where appropriate, to help pedestrians to more safely cross the street. For example, as used extensively in Europe, automatic pedestrian detectors can detect pedestrians waiting to cross the street and provide a red light to motorists (and a WALK signal to pedestrians) without the pedestrian having to push the button. It can also assist slower moving pedestrians by extending the clearance interval (flashing don't walk) until pedestrians are safely on the other side of the street.

ITS vehicle detection systems could be used to provide information to pedestrians at unsignalized pedestrian crossings, to alert them when there is an acceptable gap in traffic and therefore safe to cross the street (Of course, such a system is intended to offer assistance, but would not be intended to completely relieve the pedestrian judgment in when and how to cross the street).

### *SUMMARY*

There are many types of driver, pedestrian, roadway, and other factors that contribute to pedestrian deaths and injuries, and it often takes a combination of engineering enforcement, end education measures to be effective. The eight strategies presented in this white paper are intended to represent some "broad brush" measures and are summarized in Table 2, along with some information on the target group of pedestrian fatalities, the strategy cost, who bears responsibility for implementing it, the specific strategy activity and obstacles to implementation. It is believed that the eight strategies described in this paper represent some of the best opportunities to reduce pedestrian deaths and serious injuries in the foreseeable future. It will also take many dedicated professionals and other stakeholders to work together to make a real difference.

**Table 2. Initiatives to reduce pedestrian deaths.**

| STRATEGY | AIMED AT | POTENTIAL FATALITY REDUCTION | WHO BEARS COST | COSTS (IMPLEMENT/ MAINTAIN) | OBSTACLES TO IMPLEMENTATION |
|---|---|---|---|---|---|
| 7. Improve the Reflectorization/Conspicuity of Pedestrians | Nighttime Pedestrian Fatalities | Potentially up to 10 to 15 % of nighttime pedestrian fatalities (5 to 7% of total pedestrian fatalities) | Individual citizens (pedestrians) would need to purchase retro reflective material. City and State DOT's would implement lighting enhancements | Costs of vests and flashlights, etc. are needed, along with marketing campaign on risks and solutions for nighttime safety. Appropriate overhead and ITS lighting would need to be purchased and installed by DOT's. | Funds for purchasing overhead lighting are needed. Reaching the right pedestrians and convincing them to make themselves more visible will be a challenge. |
| 8. Develop and Implement Pedestrian-Friendly ITS Veicle and Roadway Features | Pedestrian fatalities associated with vehicle issues and the need for driver awareness of pedestrians. Also, fatalities related to pedestrian information needs at street crossings | Unknown | Auto industry would bear the cost for equipping motor vehicles, and such costs would be passed on to those who purchase cars and trucks. State DOT's would be responsible for some roadway ITS technologies such as automated pedestrian and vehicle detectors. | ITS R & D costs are needed, and vehicle costs would increase for vehicles with this ITS technology. | Fully developing and marketing his ITS technology will take time. Also, not all motorists would be willing to Pay the additional cost for a motor vehicle, in order to protect others outside their motor vehicle (pedestrians). |

## BICYCLIST ISSUES

### *BACKGROUND*

A review of Fatality Analysis Reporting System (FARS) data for 1998-2008 (Table 3) shows the following number of bicyclist and other cyclist fatalities (includes riders of two-wheel non-motorized vehicles, tricycles, and unicycles powered solely by pedals) (NHTSA Traffic Safety Facts, 2008):

**Table 3. Number of Fatalities 1998 – 2008.**

| Year | Number of Fatalities |
|---|---|
| 1998 | 760 |
| 1999 | 754 |
| 2000 | 693 |
| 2001 | 732 |
| 2002 | 665 |
| 2003 | 629 |
| 2004 | 727 |
| 2005 | 786 |
| 2006 | 772 |
| 2007 | 701 |
| 2008 | 716 |

Other highlights from the FARS data include:

- An additional 52,000 pedalcyclists were injured in traffic crashes in 2008.
- The 716 fatalities in 2008 represent 2 percent of all traffic fatalities for that year.
- The average age of pedalcyclists killed in traffic crashes in 2008 was 41, compared to 32 in 1998. An upward trend in average age has been in place since 1998.
- 12 percent of the pedalcyclists killed in traffic crashes were 5 to 15 years of age.
- 87 percent of the pedalcyclists killed in traffic crashes were male.
- 23 percent of bicyclists had a BAC level of 0.08 g/dL or higher.
- 69 percent of the fatalities occurred in urban areas.
- 36 percent of the fatalities occurred at intersection locations.
- 28 percent of the fatalities occurred between the hours of 5 p.m. and 9 p.m.

North Carolina has an extensive bicycle crash data base. Each year all bicycle-motor vehicle crashes are examined and crash typed. During the period from 1997 to 2008 the most prevalent crash types for which there was a bicyclist fatality were (www.pedbikeinfor.org, 2010):

- Motorist overtaking bicyclist – 33 percent.
- Bicyclist left turn/merge – 14 percent.
- Bicyclist failed to yield, midblock – 10 percent.
- Head on (one of the parties traveling wrong way) – 8 percent.
- Bicyclist failed to yield at a sign-controlled intersection – 7 percent.
- Bicyclist right turn/merge – 6 percent.

The National Electronic Injury Surveillance System (NEISS), maintained by the U.S. Consumer Product Safety Commission, represents a national probability sample of hospitals in the United States and its territories. Using product codes for bicycles or accessories and mountain or all-terrain bicycles or accessories, an estimated average of 498,000 injuries pertaining to these products were treated in hospital emergency rooms nationwide between 1999 and 2009. The estimated number of injuries declined from 2000 to 2005 and has been increasing since then (National Electronic Injury Surveillance System, 2010). Thus, the number of pedalcyclists killed and injured each year is sizable.

The 1994 National Bicycling and Walking Study, with goals of doubling the percentage of total trips made by bicycling and walking and simultaneously reducing by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes, was instrumental in bringing bicycling and walking issues to prominence within the U.S. Department of Transportation (USDOT) (FHWA, 1994). The Federal Highway Administration (FHWA) has now released a 15-year status report for the National Bicycling and Walking Study (FHWA, 2010). Based on the 2009 National Household Travel Survey, the study notes that 11.9 percent of all trips are made by bicycling and walking, up from the 7.9 percent reported in 1994 but less than the goal of 15.8 percent. The status report also notes that from 1994 to 2008 the number of pedestrian fatalities decreased by 22.3% and the number of bicyclist fatalities decreased by 12%. Coupled with the increase in the trips taken on foot or on bike in the same period, the reductions in fatalities could represent safety gains. For bicycling in particular, the mode share has increased from 0.7 percent in 1990 to 1.0 percent in 2009, with the number of bicycle trips increasing from 1.7 to 4 billion during the same period. The estimate of bicyclist injuries in crashes has decreased from 61,000 to 52,000 from 1995 to 2008, a 14.7 percent decline. These are much lower than the NEISS product-related estimates, and the Stutts and Hunter study in 1999 pointed out that State data fail to capture many bicycle (and pedestrian) crashes, particularly those occurring in parking lots or other off-road locations (Stutts and Hunter, 1999).

In April 2010 the U.S. Secretary of Transportation announced a commitment to a more thorough inclusion of bicycling and walking in the planning process (USDOT, 2010):

> The DOT policy is to incorporate safe and convenient walking and bicycling facilities into transportation projects. Every transportation agency, including DOT, has the responsibility to improve conditions and opportunities for walking and bicycling and to integrate walking and bicycling into their transportation systems. Because of the numerous individual and community benefits that walking and bicycling provide –

including health, safety, environmental, transportation, and quality of life – transportation agencies are encouraged to go beyond minimum standards to provide safe and convenient facilities for these modes.

### *STRATEGIES THAT HAVE POTENTIAL FOR REDUCING BICYCLE FATALITIES*

The following strategies are offered as ways to decrease the number of bicyclist fatalities in the United States. There is no sense of priority in the order of presentation.

#### Strategy 1- Reduce Motor Vehicle Speed in Urban and Suburban Areas

There seems to be agreement that motorist speeding is a problem in the United States. The court system is burdened, and the current enforcement policy in many jurisdictions for issuing a speeding ticket is for 15 mi/h over the posted speed limit. The consequences are less reaction time for motorists when encountering a slower moving bicyclist traveling in the same direction or a bicyclist crossing the path of the motorist and potentially severe outcomes if speeding is accompanied by small intervals of driver inattention. Errors will inevitably occur when bicyclists are sharing the roadway, especially given that their riding technique is not always predictable. For example, bicyclists may ride on the street in the same direction of traffic; on the street in the opposite direction of traffic; or on sidewalks from which they may enter the traffic stream, whether midblock or at an intersection. In addition, some bicyclists ride close to the curb or edge of roadway while others may take control of the lane by riding in the middle if they feel it is unsafe to be passed. Errors are not eliminated even when facilities like bicycle lanes or wide outside lanes are provided. Slower motorist speeds increase the time to anticipate the actions of bicyclists. Greater motorist speeds increase the likelihood of a bicyclist fatality or serious injury in the event of a crash.

Greater emphasis on speed enforcement, including the use of automated speed and red-light-running cameras, is recommended. In addition, there are other countermeasures that can be used to decrease motor vehicle speed. These include narrowing travel lanes, adding on-street parking or other objects close to the roadway, various traffic calming measures such as serpertining, and others. Employing such countermeasures does not necessarily fit with provision of a safer roadway or roadside; however, such efforts should increase the need for attention to the driving task. In addition, attempts to decrease motor vehicle speeds does not fit well with the philosophy of increasing motor vehicle capacity and decreasing delay. It may require a fundamental shift in the transportation engineering approach of designing for a forgiving roadway to designing for speed control to accomplish practical reductions in motor vehicle speeds.

**Estimate of Fatality Elimination:** Unknown

**Costs:** Communities would bear the costs of changes to speed limit signs on local roads. Some savings could emerge if a communitywide speed limit were adopted, reducing the number of signs needed. Local communities or States and a vendor would likely bear the costs of any photo enforcement cameras and processing of violations, although the revenues derived from the fines generally offset these costs. Costs related to roadway or roadside design changes would be borne by local, State, or federal funds, depending on who controls the roadway.

**Obstacles to Full Implementation:** Transportation engineers would not likely accept the premise of applying measures that traditionally are in opposition to a forgiving roadway design. Another substantial challenge would be to overcome the opposition to how decreasing motor

vehicle speeds would impact capacity and delay. There is fundamental opposition to the use of speed and red-light-running cameras for enforcement in many jurisdictions. Passage of national laws permitting the use of these devices may be necessary to lead to widespread use. An extensive dialogue between roadway designers, transportation engineers, and policy makers will be necessary to understand the public health consequences of speeding and to adopt strategies to reduce operating speeds.

**Strategy 2 - Reduce Distracted Driving by Motorists and Distracted Riding by Bicyclists**

The USDOT web site focused on driver distraction indicates that distraction may involve a variety of activities, including eating and drinking, talking to passengers, personal grooming, reading, using a navigation system, watching a video, changing the vehicle sound system, and using a cell phone (www.distraction.gov, 2010). A driver who performs any of these tasks and looks away from the roadway may be less likely to notice a bicyclist when their view returns to the roadway.

It would appear that distracted driving is involved in an increasing number of crashes in the United States. General System Estimates (GES) data show that 5,870 people were killed in crashes involving driver distraction (16% of total fatalities) in 2008, and an estimated 21 percent of 1,630,000 injury crashes were reported to have involved distracted driving (www.distraction.gov, 2010).

A telephone survey conducted by the Pew Research Center showed that 47 percent of adults using cell phones in the United States have sent or received text messages while driving as compared to 34 percent of teens aged 16-17 (Madden and Rainie, 2010). This translates to 27 percent of the general population of adults who have sent or read text messages and 26 percent of teens who have sent text messages while driving. Thus, the problem is widespread.

To examine risk, a driving simulator was used to compare driving performance when using a cell phone versus being impaired by ethanol at the 0.08 level. Controlling for driving conditions and the amount of time on task, the researchers concluded that a cell phone driver exhibited the same impairments as a drunk driver (Strayer et al, 2005). As with speeding, a small amount of driver inattention can have tragic consequences.

Inattention was shown to be a primary factor in 38 percent of bicycle fatalities in Florida from 1998 to 2000, although when deemed a primary factor in the crash, bicyclists were more likely than motorists to be inattentive (Spainhour et al, 2005). Fatal crash types such as ride outs from driveways or failing to yield in midblock situations involving children may involve inattention. Older bicyclists are not averse to using cell phones while riding or engaging in other acts of inattention.

Legislation will be needed to curtail the amount of cell phone use and other forms of distraction by motorists and bicyclists. Enhanced public awareness is also necessary. To this end, the USDOT held a “Distracted Driving Summit” in the fall of 2009. The National Highway Traffic Safety Administration (NHTSA) now has a distracted driving program in place. Special law enforcement programs could be implemented, and NHTSA has funded pilot distracted driving programs in Connecticut and New York State. Collecting more information on crash report forms pertaining to distracted driving would help to define the magnitude of the problem and give impetus to legislative efforts.

**Estimate of Fatality Elimination:** Unknown

**Costs:** Communities would bear the costs of local enforcement programs unless funded by the Governor's Highway Safety Program or a federal pilot program. States would bear the costs of a change in the crash report form to gather more data on distracted driving or bicycling if a statewide form is in place. Costs associated with public awareness efforts could apply to federal, state, or local agencies.

**Obstacles to Full Implementation:** Legislation attempts would likely be confronted by those who desire no further intrusion by government into personal decisions. The consequences of distracted driving and riding would have to be carefully documented and explained. However, progress is already being made. An Executive Order in October 2009 by President Barack Obama prohibits text messaging by government employees and federal contractors while on official business. A report issued by the Governor's Highway Safety Association indicates that 28 States, the District of Columbia, and Guam had passed legislation to prohibit all motor vehicle drivers from text messaging while driving. Other States had passed laws applicable to specific drivers, such as school bus drivers, but the laws were variable. Legislation pertaining to distracted driving has been introduced in 42 states (Vermette, 2010). It will be difficult to develop uniform laws across the States, although efforts have been made to develop a sample texting-while-driving law. Federal incentive funds are also available to states which pass laws prohibiting texting while driving.

### Strategy 3 – Educate Motorists about How to Share the Road with Bicyclists

Motorist education about how to share the road with bicyclists involves several issues. One issue involves motorists simply being made more aware that bicyclists are on the road, being observant for bicyclists, and taking due care in various motor vehicle movements. Examples of potentially dangerous motorist actions include pulling out of driveways or side streets and making left turns. For the latter, the motorist tends to be concerned with finding an appropriate gap based on other motor vehicles and may not pay enough attention to approaching bicyclists. Motorist right turns are another problem, especially after having overtaken a bicyclist traveling in the same direction. Known as the "right hook" crash, these could be prevented with motorist recognition of the speed of the bicyclist and the proximity of the intersection or junction for the right turn.

Overtaking crashes where the motorist strikes the bicyclist from the rear tend to be very serious. The speed differential places the bicyclist at increased risk for fatality. Many of these crashes occur under conditions of darkness or poor visibility and with poor bicyclist conspicuity. Vision enhancements to vehicles could be beneficial, as reported by eSafety Forum (2005) and cited by Bayly, Fildes, Regan, and Young (Bayly et al, 2007). Lind, Lindqvist, and Persson predicted that vehicle vision enhancement systems that include adaptive headlights could reduce bicyclist fatalities in Sweden by 8 percent by 2015 (Lind et al, 2003).

Dooring crashes result when bicyclists ride close to parked vehicles and are struck by a door being opened by a motorist. Such crashes are becoming a problem in urban areas and can result in serious bicyclist injury or death.

Another issue is the freedom of movement that bicyclists exhibit. Bicyclists may be riding with traffic at the edge of the roadway or in the middle of the lane. They may be moving from the edge of the traffic lane or a bicycle lane into adjacent traffic lanes so as to be able to make a left turn. They may be riding wrong way, or against traffic. They may ride into an intersection from a sidewalk or pull into traffic from a midblock position. Some of these bicyclist movements are

done safely and some are not. Nevertheless, we need to educate motorists to be more aware of bicyclists wherever they may appear in the traffic stream.

Motorist awareness of bicyclists would logically increase when many more bicyclists are on the roadways, whereby motorists are conditioned to be aware of the presence of the bicyclist and hopefully operate with the appropriate standard of care. However, this may take some time to accomplish. In the interim, several steps could be taken. These include information about bicyclist rights and how they ride in traffic both in driver license handbooks and on driver license exams. Videos could be developed for use in driver license offices or other suitable locations that show dangerous situations involving motorists and bicyclists, such as the motorist passing a bicyclist and then abruptly turning right or the opening of the door of a parked vehicle. Public service announcements could also be developed for the same types of situations. Fines could be increased whenever a motorist is guilty of causing a crash.

**Estimate of Fatality Elimination:** If the Lind et al. prediction of 8 percent reduction of bicyclist fatalities in Sweden by 2015 due to enhanced vehicle vision systems were to hold for the United States, this would amount to 50 to 60 fewer fatalities.

**Costs:** Costs to change the driver license handbooks or driver license test would likely be borne by States. Development of videos would likely be handled by States and could be done without huge expense. Governor's Highway Safety Program funds could be used to develop the videos. Costs of any public service announcements would be variable and depend to a large extent on message content and distribution to media outlets. Costs for vehicle vision enhancement systems would be initially borne by manufacturers and then passed on to consumers.

**Obstacles to Full Implementation:** It will be necessary to educate motorists who think bicyclists should not be allowed to ride on the road as a vehicle. Updating of driver license handbooks and tests would entail significant costs to States. Any large increase in fines for motorists guilty of causing a crash with a bicyclist would be met with considerable debate and, if enacted, should be evaluated for effectiveness.

### Strategy 4 - Educate Bicyclists about How to Ride in Traffic and the Use of Proper Equipment

Many bicyclists need education about how to skillfully ride in traffic. This includes:

- Basic riding skills such as how to properly control and brake a bicycle.
- Riding in the same direction as traffic and proper yielding behavior when entering streets at midblock and at intersections and driveways.
- Proper lane placement in various traffic situations, such as not staying to the right of a right turning motor vehicle and taking control of a lane that is too narrow to share.
- Avoiding the dooring situation.
- Being aware of turning vehicles and vehicles approaching from behind.
- Knowledge about how to negotiate complex intersections, such as riding straight through when there are multiple right turn lanes, and making a left turn when there are multiple through lanes.

Bicyclists also need education about maintaining their bicycle and using proper riding equipment. This includes:

- A properly fitted bicycle with matched wheels and adequate brakes.
- Proper lights at night, rear reflector, and perhaps a rear view mirror.
- Wearing conspicuous clothing and a bicycle helmet.

The Florida study of fatal crashes showed approximately 60 percent of the fatal bicyclist crashes occurring in non-daylight conditions, and that more than 45 percent of the bicycles involved in nighttime crashes had no lighting (Spainhour et al, 2005).

In regard to bicycle helmets, Thompson, Rivara, and Thompson found that riders with helmets had an 85 percent reduction in their risk of head injury and an 88 percent reduction in their risk of brain injury (Thompson et al, 1989). This remains an oft-quoted reference for helmet effectiveness. A meta-analysis by Attewell, Glase, and McFadden for all research studies between 1987 and 1998 indicated that bicycle helmets reduced fatalities by approximately 73 percent and overall head injuries by approximately 60 percent (Attewell et al, 2001). These findings were confirmed by Thompson et al. through a subsequent meta-analysis (Thompson et al, 2006).

Helmet related statistics from the Bicycle Helmet Safety Institute indicate the following (bhsi.org, 2010):

- Currently, 21 states, the District of Columbia and numerous localities have enacted some form of bicycle helmet legislation, most of which cover only young riders.
- Various studies have shown bicycle helmet legislation to be effective at increasing bicycle helmet use and reducing bicycle-related death and injury among children covered under the law. Police enforcement increases the effectiveness of these laws.
- One recent study reported that the rate of bicycle helmet use by children ages 14 and under was 58 percent greater in a county with a fully comprehensive bike helmet law than in a similar county with a less comprehensive law.

Currently, basic bicycling skills are taught in a variety of ways, including elementary school classes, parks and recreational programs, videotapes, and courses taught by skilled instructors. An expansion of these efforts to make it easier for bicyclists to learn how to ride in traffic is recommended. Instructional material could be drawn from the numerous courses that already exist. FHWA or NHTSA could fund the development of a model course.

In addition, bicyclists should remain attentive and avoid the use of cell phones, alcohol, and drugs. In the Florida study of fatal crashes from 1998-2000, one-third or more of fatally injured Florida bicyclists had some alcohol or drug use (Spainhour et al, 2005). From 1997-2008, approximately 18 percent of the bicyclists fatally injured in North Carolina had been using alcohol (www.pedbikeinfo.org, 2010). A fact sheet from the Insurance Institute for Highway Safety (IIHS) indicates that 26 percent of bicyclists killed in 2008 had blood alcohol concentrations (BACs) at or above 0.08 percent (www.iihs.org, 2010). The Florida study also found that inattention was a primary factor in 39 percent of the crashes, with the inattention predominately on the part of the bicyclists (Spainhour et al, 2005). At the least, educational messages should be developed to highlight the risks associated with the behaviors.

**Estimate of Fatality Elimination:** Based on FARS data, the IIHS bicycle fact sheet indicates that 91 percent of the bicyclists killed in 2008 reportedly were not wearing helmets (www.iihs.org, 2010). Applied to the 716 fatalities in crashes for 2008 equates to 652 bicyclists. If one assumes a 50 percent helmet effectiveness (perhaps conservative) in prevention of death, 326 fatalities could be prevented if all bicyclists used appropriately fitted helmets. Although a precise estimate is not possible, a sizable number of fatalities could also be prevented with reduced alcohol and drug use by bicyclists.

**Costs:** Costs would apply to efforts to develop a mandatory helmet use law at the local, State, or federal level. Individuals would bear the costs of a helmet purchase; sometimes supplemental funds are available to offset the cost. The cost of reflective materials such as vests and straps for the wrist and ankle for individual bicyclists would be low. Effective front and rear lights are relatively inexpensive. Comprehensive bicyclist riding skill courses could be developed at the local, State, or federal level.

**Obstacles to Full Implementation:** There is considerable discussion regarding the effectiveness of bicycle helmets; thus, passage of comprehensive statewide laws or a federal law applicable to all age groups would be difficult.

### Strategy 5 – Reduce Intersection Conflicts

FARS data indicate that nearly 40 percent of bicyclist fatalities in crashes occur at intersections (NHTSA Traffic Safety Facts, 2008). Part of this problem relates to the movements made by bicyclists at intersections (e.g., coming off the sidewalk into the path of a motorist) and their relative location (e.g., incorrect positioning relative to a right-turning motor vehicle). Bicyclist fatalities are also associated with motor vehicle turning movements (e.g., striking a bicyclist when making a left turn or making a right turn shortly after passing a bicyclist). Collisions at driveways and other junctions are also a problem.

Candidate physical or engineering countermeasures for intersection conflicts include:

- Reduction of speed limits in high-use bicycle corridors.
- Striping dashed bicycle lanes or colored paths through complex intersections.
- More widespread use of color for bicycle lanes in high-use bicycle corridors.
- More widespread use of bike boxes, advanced stop bars, or leading bicycle green signal phase in situations where it is beneficial for the bicycle to proceed first (e.g., straight through bicyclist followed by motorist right turn). Restrictions on motorist right-turn-on-red should also be considered.
- Use of enhanced detection systems so that the green phase could be extended for a slow moving bicyclist.
- Use of convex mirrors where there are sight distance problems, longitudinal bike symbols at driveways and stop-controlled cross streets, and other such treatments from abroad as noted from the latest FHWA pedestrian and bicycle international scan (Fischer et al, 2010).
- Use of bicycle signals where shared use paths intersect with roadways.

- Widespread use of shared lane markings (sharrows) next to parked vehicles, in wide outside lanes, and where bicyclists should take control of the lane.
- Reduction in signal cycle lengths which increase impatience and the likelihood of red light running.
- Addition of or improvement of lighting in high-use bicycle corridors.

Application of these treatments should heighten awareness of bicyclists in the traffic stream. However, it is recognized that some of these treatments need more research to determine the most appropriate application. It is important that any new treatment not give a false sense of security to the bicyclist. Other intersection problems could be mitigated with adoption of the preceding strategies – a reduction of motor vehicle speeds, reducing distracted driving and riding, improved motorist education about how to share the road with bicyclists, and improved bicyclist education about how to ride in traffic and the use of proper equipment.

**Estimate of Fatality Elimination:** Unknown

**Costs:** Costs of the evaluation of on-street treatments would likely be borne by FHWA. Costs related to implementation of treatments would be borne by local, State, or federal funds, depending on who controls the roadway.

**Obstacles to Full Implementation:** There would be some opposition to the full complement of on-street countermeasures due to the lack of effectiveness evaluations. Costs for the countermeasures would be substantial. Communities with full time pedestrian and bicycle coordinators would be the most receptive to the intersection improvements.

### *OTHER ACTIVITIES IN SUPPORT OF THE STRATEGIES*

A number of other activities would logically supplement the five strategies discussed above:

- Continue with the implementation of bicycle facilities – These include on-street bicycle lanes, wide outside lanes, paved shoulders, sharrows, and bicycle signals, among others. Cycle tracks that are popular in Europe could be used but may need to be phased in gradually. Off-street shared use paths are popular and can provide important links but need to be properly designed.
- Maintain bicycle facilities and shared roadways – Proper maintenance of bicycle facilities and shared roadways where bicycling is frequent is a necessity. This includes rough pavement and pavement discontinuity repair, and removal of debris.
- Increase enforcement for dangerous behaviors – Enforcement could be more active for bicyclists making dangerous movements, including ride outs, wrong way bicycling, and sidewalk riding if prohibited. Enforcement for motorists would include passing bicyclists too closely, abrupt right turns immediately after passing bicyclists, speeding, and distracted driving in the vicinity of bicyclists.
- Examine legislation – Determine if laws pertaining to bicycling, driver distraction, and motor vehicle speeding should be updated. Presently some states are working to develop laws defining the safe passing of bicyclists.
- Embrace the Complete Streets concept – Complete Streets has been a rapidly growing movement and is predicated on the notion of making streets friendlier for all users,

including motorists, bicyclists, pedestrians, and users of transit. This concept can blend well with any bicyclist, pedestrian, and road user strategies associated with "Toward Zero Deaths."

- Continue funding of Safe Routes To School (SRTS) initiatives – The SRTS program continues to grow. Funding should be continued to support the efforts to make it safe for children to bicycle or walk to school.

### *SUMMARY*

Coupled with the commitment of the USDOT to a more thorough inclusion of bicycling and walking in the planning process, the strategies and the support activities identified above have the prospect of greatly increasing the number of bicyclists on our roadways and fit with the desire of individuals to have more livable communities where there are safe places to bicycle (and walk). This should lead to a greater awareness of bicyclists and hopefully a paradigm shift where bicyclists are truly seen as vulnerable road users by motorists. Even though exposure to risk is increased, there is evidence that increases in the number of bicyclists and pedestrians lead to safety gains (Jacobsen, 2003). The "strength in numbers" or "awareness in numbers" is indicated as a motivator behind bicycling and walking promotions in the European countries visited as part of the 2009 FHWA international scan. Two other features noted from the scan were: (1) regular performance reports regarding bicyclist and pedestrian safety and mobility that could be used to refine strategies, and (2) a single national brand to unify safety campaigns (Fischer et al, 2010). In regard to the latter, working under a banner of "Toward Zero Deaths" should fit nicely.

## AGING ROAD USERS

### *INTRODUCTION*

As older Americans make up an increasing proportion of those who use our nation's streets and highways, it is clear that meaningful progress toward zero deaths from motor vehicle fatalities will depend significantly upon ensuring safe mobility for this segment of society. The challenge here does not reflect a deficit in knowledge or attitude, as may be associated with novice drivers: older persons bring a lifetime of learning about safe practices, as well as an appreciation of their own vulnerability for traffic-related injuries. The challenge of ensuring safe mobility for older road users derives from the functional decline in visual, cognitive, and psychomotor abilities needed to drive (and walk) safely on modern facilities. Compounding this situation, alternative transportation options are often lacking for our older citizens; this may compel some who are only marginally competent to stay behind the wheel, to preserve their vital connections with their communities.

From a strictly demographic standpoint, this challenge is unprecedented – 25% of drivers will be age 65 or older by 2030, according to recent estimates. And, this is a cohort of Americans that relies to an overwhelming extent on the private automobile to meet everyday mobility needs; one recent survey places this figure at 90%. Based on the National Household Travel Survey (NHTS), the miles driven by people age 70 and older have increased 32% since 1995, and 6% just since 2001; and meanwhile, those age 85 and up have increased their driving by 91% since 1995, and 42% since 2001.

This trend toward increased exposure is fueled in part by population growth among older Americans. People 85 and older are both the fastest growing segment of the population, and the fastest growing group of drivers. But changes in driving habits among this cohort are evident as well. In 1995, when there were roughly 3.7 million Americans 85 and older, two out of five (40%) in this group continued to drive, but of the 5.7 million citizens 85 and older in 2008 more than half were still driving. At least in part this trend reflects the fact that a greater proportion of older women remain licensed and continue to drive than among previous cohorts of seniors.

Given that the older population is growing, and at the same time they are driving more than ever before, what are the implications for safety? An analysis reported in 2008 in the Journal of Safety Research revealed that, compared to the safest group of drivers (those between the ages of 30 and 60) drivers 85 and older are themselves at an eight times higher risk of death per mile traveled, and pose a slightly higher (1.5 times) per-mile risk of death to other road users. These figures primarily underscore the frailty of older individuals, who are more likely to be seriously injured and die from trauma of given severity than a younger person.

This analysis then adjusted these figures to take into account the relatively lower number of miles driven by older persons, based on NHTSA data, to develop estimates of 'total risk' for passenger vehicle travel in this country. With these adjustments, the 85-and-older group was roughly three times more likely to die from a crash, themselves, but only half as likely to cause the death of other road users, as the middle-aged comparison group. This suggests a *declining* risk for older road users. But will this trend continue when older persons make up an increasing share of road users, when not only the 'at-fault' driver but also the 'other road user' in a crash is more likely to be old and frail?

The data presented in Figure 5 add another perspective. While there is indeed a recent trend showing fewer fatal crashes among drivers age 70+, their incidence as a percentage of all traffic fatalities is increasing.

A strategy to reach zero deaths among this group must examine more closely how the changes we all can expect as we grow older affect our ability to safely use our streets and highways, even as our independence and quality of life remain tied to automobile use. This strategy will rest upon complementary, coordinated changes in current policies and practices with respect to drivers/pedestrians, vehicles, and roads/infrastructure. It also must acknowledge the need to facilitate a graduated retirement from driving, with a transition to alternative transportation for a growing number of Americans in the coming decades.

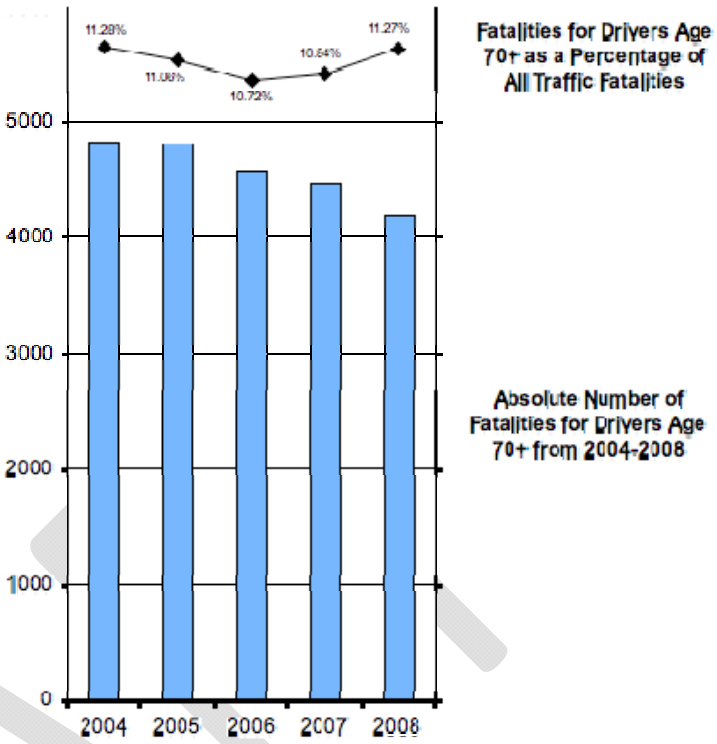


**Figure 5. Five-year trend in older driver fatalities.**

## *Special Issues And Challenges With Older Road Users*

While underlying medical conditions or the medications used to treat them can result in functional loss, we also experience a loss in our abilities to drive safely through normal aging alone. But neither age nor disease *per se* determines fitness to drive. And of course, medications often *improve* function, enhancing mobility for those who would otherwise be more severely incapacitated. The key point is that it is our functional status, not the diseases we are diagnosed with nor the drugs we are prescribed, that relates directly to our risk of causing a crash.

Furthermore, an interesting thing happens as we grow older: our individual differences are magnified. Some 75-year-olds are every bit as capable to safely operate a motor vehicle as the average 55-year-old. Therefore, while chronological age is used in some jurisdictions as a trigger for other actions (e.g., a vision exam for license renewal), it should never be determinative. It is in our society's, as well as individuals,' best interest for older people who are fully capable to keep driving as long as they wish.

### Which Capabilities Influence Crash Risk?

There is now a body of evidence pointing to losses in specific "functional capabilities" as the most important predictors of (at-fault) crash risk among older drivers. These include aspects of vision (contrast sensitivity—also including visual acuity); perceptual/cognitive ability (attention, processing speed, working memory, visual search, visuospatial organization, and executive function); and physical fitness (head/neck flexibility and lower limb strength and range of motion). A decline in any of these abilities increases the likelihood of a host of critical driving

performance errors, which in turn can result in the types of incidents that disproportionately characterize the (fatal) crash experience of older operators.

Such decline is to be expected with 'normal aging' – albeit at vastly different rates for different people – but driving impairments can be exacerbated by the diseases that are more common among older people, and by the medications used to treat them. Before exploring these issues, it must be reiterated that one's functional status, *whatever* their medical conditions and the drugs they take, is what determines their risk of causing a motor vehicle crash.

**Common Medical Conditions Among Older Persons**

There are many medical conditions that can lead to diminished capability and driver impairment, and which become increasingly prevalent with advancing age. The most common medical conditions affecting vision among older drivers are cataracts, macular degeneration, and glaucoma, which can be screened or detected by primary care physicians using brief in-office methods. The medical conditions that most commonly affect cognitive abilities needed to drive safely are dementia, stroke, and sleep apnea. In 2007, 2% of Americans ages 65 to 74 had Alzheimer's disease (AD), compared with 19% of those ages 75 to 84, and 42% of those ages 85 and older; the number of Americans age 65 and older with AD could increase from 11 million to 16 million by the year 2050.

Impairments in psychomotor (physical) functioning that occur with increasing prevalence among older persons may be the result of musculoskeletal diseases—especially arthritis—that result in weakness, frailty, and/or restricted range of motion, or may have a neurological origin (e.g., Parkinson's disease). In the latter case, however, the side effects of medications commonly used to treat Parkinson's may be of greatest concern. These medications often produce sleepiness, dizziness, blurred vision, and confusion, and one class (anticholinergics) can be especially dangerous, producing confusion and sedation along with memory impairment.

**Increased Use of Medications and Polypharmacy**

Research has examined the extent to which medication use among older persons is related to crash experience, and in particular, classes of medications that have been identified as "potentially driver impairing" (or 'PDI') because of their effects on the central nervous system, blood sugar levels, blood pressure, vision, or other functions that have the potential to interfere with driving skills. This has special relevance for this discussion because of the disproportionate share of prescription and over-the-counter medications consumed by older persons.

Overall, a recent national survey found that among community-dwelling (noninstitutionalized) adults age 65 and older in the United States, 90% use at least one prescription medication each week, 40% use five or more, and 12% regularly use 10 or more. A case-control study found that drivers were 1.2 to 7.5 times more likely to have been crash-involved if they had taken medications in 35 of 90 PDI medication classes. As shown in Table 4, a NHTSA-sponsored data mining effort to analyze the relationship between driver age, PDI drug use, and crash involvement found that the rate of use of multiple PDI medications by crash-involved drivers climbed with each 5-year increase in driver age above 50, until leveling off at age 65.

**Table 4. Potentially driver impairing medications at time of crash, by driver age.[12]**

| | Driver age group | | | | | | |
|---|---|---|---|---|---|---|---|
| | 16-49 | 50+ | 55+ | 60+ | 65+ | 70+ | 75+ |
| Number in database | 18,837 | 3,737 | 2,212 | 1,208 | 643 | 474 | 299 |
| Mean number of PDI medications | 0.42 | 1.28 | 1.43 | 1.56 | 1.63 | 1.66 | 1.64 |

### *PRIORITIZING STRATEGIES TO IMPROVE SAFETY*

There remains a legacy of highway design and engineering practices from the middle of the 20th century that creates serious safety problems for older drivers and pedestrians. For example, until recent editions of the Manual on Uniform Traffic Control Devices (MUTCD), the legibility of highway signs reflected the same standard of one inch of letter height for every 40 feet of desired reading distance that dates back to the 1940's, based on research conducted with college students. For decades now, it has been understood that older drivers require larger letters, and a new standard of '30 feet per inch' has been incorporated into the current FHWA design manual.

Similarly, changes in geometry, operating rules, traffic control devices, markings and delineation that make streets and highways more accommodating to older users have been identified by researchers, and are incrementally being incorporated into national and State-level design guides (see FHWA's *Highway Design Handbook for Older Drivers and Pedestrians*). But such infrastructure upgrades cannot be implemented quickly across-the-board. Because of their cost, these enhanced design practices are most commonly introduced in new construction, reconstruction, or as 'spot treatments' to address site-specific crash problems.

Innovative vehicle design practices also hold significant promise for protecting older occupants. Enhanced side impact protection will be of special benefit to older drivers who, as a group, are killed most often in angle crashes at intersections. 'Smart' SRS/airbag systems that deploy according to the height, weight, and position of the front seat occupants will reduce the rates of serious injuries and deaths of older persons in crashes—assuming that they are also properly belted. Headlight lenses with a cutoff that limits glare for oncoming drivers, and mirrors that adjust automatically to the level of incident illumination, will aid nighttime driving by older persons.

However, there are certain 'innovations' that may carry unintended consequences for this group. Any driver interface that imposes a greater real-time demand on divided attention and working memory—for example, the menu-driven controls for navigation and entertainment devices in newer vehicles—will place an older user at disproportionately higher risk, due to age-related declines in these functional abilities. Less obvious, it appears that an expected benefit (reduced "eyes away from the road" time) from the presentation of vehicle status and warning information using a 'head's up display' (HUD) on the windshield may be outweighed by the potential for 'cognitive capture' associated with such displays; older people, in particular, can be susceptible to focusing their attention exclusively on the HUD, and ignoring hazards that are in plain sight ahead of them.

**Beyond Vehicles and Infrastructure**

At least from the Tri-Level Study in the 1970's onward, traffic safety researchers to an overwhelming extent have attributed crash causation to 'operator error.' This points to solutions focused on older road users themselves as having the greatest potential to achieve progress toward zero deaths.

Three avenues to reducing operator error 'beyond vehicles and infrastructure' appear to hold significant promise: 1) education to increase awareness of how changes as we age place us and other road users at higher risk; 2) rehabilitation of functional loss coupled with demonstrable gains in the ability to safely use current facilities; and 3) regulatory practices that fairly, objectively, and uniformly can identify those who lack a minimal level of competence to safely drive a motor vehicle (or to use pedestrian facilities) under everyday operating conditions.

**Driver Education—A Lifelong Need**

A large majority of aging road users will not have received any formal education about safe operating practices since the time of their initial licensure, if ever. Safe driving courses are offered to older adults, often providing the incentive of a 5% or 10% reduction in insurance rates, depending on the state of residence. A combined total of slightly under one million people a year participate in such courses offered by the two largest providers, AARP and AAA[1]; although it should be noted that many of these are repeaters, who take the course every few years to retain the insurance discount.

Are these offerings meeting the need for education among aging road users? Only a fraction of those eligible participate in classroom courses, but online versions are now available that could potentially increase course participation. The didactic format limits the utility of such courses, however, even if delivered via the Internet. More interactive instructional elements are needed if older persons are to learn the skills they need—and gain a true appreciation of how the changes they experience with aging affect their abilities—to continue to drive safely in today's traffic conditions. More effective education also promises benefits for older pedestrians and cyclists. Coupling classroom instruction with one-on-one, behind-the-wheel instruction to reinforce and apply the lessons learned in the course significantly improves performance gains.

**Preserving Safe Mobility Through Rehabilitation of Functional Loss**

Driver rehabilitation includes training for those recovering from stroke or trauma, to regain the use (often with adaptive devices) of their vehicles; seniors also depend on rehabilitative services to regain mobility following surgery to recover from a fall. Such services will continue to be important in preserving safe mobility for older Americans. But a plethora of new products and services in 2010 promise to improve driving safety for seniors through "cognitive rehabilitation," touting training benefits that lead to better recognition of hazards and quicker responses in emergencies when behind the wheel. An expanded 'lifespace' for pedestrians is also suggested.

Many interventions designed to help older persons remain safely mobile—among other quality of life benefits—have been directly validated. These include more timely and effective vehicle control responses after gaining facility with adaptive devices, and improved hazard detection and

[1] *pers. comm.* to L. Staplin, *TransAnalytics*, from Mr. Frank Carroll, Senior Project Manager, AARP Driver Safety Program, and Dr. William van Tassel, Manager, Driver Training Operations, AAA National Office.

lower crash involvement rates that are associated with gains in contrast sensitivity following cataract surgery. In comparison, claims for the efficacy of the recent wave of "brain training" products marketed to older persons appear premature. Can such do-at-home exercises truly enable seniors to perform as well as their younger counterparts when negotiating a busy suburban intersection, either walking or driving? Evidence that such interventions produce results that go beyond improved performance on the training task itself, and translate to real-world safety gains that are sustained over time, would be a welcome development. A process for certification of such products by driver rehabilitation specialists is also needed.

**Licensing Policy for an Aging Society**

Anecdotally, many older persons characterize loss of licensure as a *de facto* death sentence. This is understandable in light of their dependence on private automobiles. While new approaches in this arena will therefore be quite sensitive, politically, a critical analysis of licensing policies across the U.S. shows not only a striking inconsistency in requirements for renewal from one jurisdiction to another, but a near-system-wide disregard for changes in key mental and physical abilities that significantly predict the risk of at-fault crashes. Even vision retesting for renewal is required in only a few States.

The pending implementation of Real ID by States could encourage more uniform licensing standards. It is troubling when an individual can be licensed in one jurisdiction with lax standards then cause a crash in another, where s/he would have failed to meet the qualifications for licensure. A prerequisite for such an advance in licensing policy is a minimum standard for driver qualifications that is based on sound science, can be practically administered, and is perceived to be fair and objective by the public. Aside from improved vision standards, a brief screen for cognitive impairment is at the top of this list.

### *SPECIFIC RECOMMENDATIONS*

- As each highway design and engineering change proven to assist older drivers and pedestrians is incorporated into national standards such as the MUTCD and the AASHTO *Green Book*, its adoption into State-level design manuals within a reasonable (e.g., 5 year) period should be mandated as a condition for public funding of infrastructure projects.
- A one-time 'refresher' course for older persons wishing to retain an unrestricted driving license should be mandatory in the U.S., implemented at an age determined by each State for its own residents. In addition to teaching safe practices, this should include demonstrations of how abilities needed to safely use roads and highways decline with advancing age; exercises to remediate age-related losses (including cognitive retraining) if proven effective; and, lessons learned in the classroom should be reinforced with one-on-one, behind the wheel instruction.
- As a condition for every driver's license renewal in the U.S. *without regard to age*, individuals should be required to demonstrate minimal levels of visual, mental, and physical capability, using a tiered system that refers those flagged due to poor performance for more in-depth review before a licensing decision is made. This screening could be performed by States or by private sector providers—assuming there is appropriate protection for individuals' privacy, and adherence to common standards and procedures for test administration and scoring.

- Physicians and other medical and health professionals in a position to identify individuals with medical conditions that significantly impair driving should be provided with immunity from tort liability for voluntarily reporting such drivers to their State motor vehicle administration (DMV).
- A national system for labeling prescription and over-the-counter medications indicating the risk for impairment of driving should be adopted, that improves upon the present vague message "*may cause drowsiness – caution is advised when driving*" to instead reflect a comparative level of risk specifically for driving impairment: *slight*, *moderate*, or *severe*. [It may be noted that such a system has been developed in France and is expected to soon be in use in the EU.]

### *ANTICIPATED COSTS AND BENEFITS*

The costs of vehicle engineering changes to improve occupant protection and the usability of controls and displays will be paid with private, not public funds. Manufacturers understand that "safety sells" to older consumers. While new federal standards could accelerate the process, it is likely that market forces will drive manufacturers to include design features preferred by older people, simply to remain competitive with this, the wealthiest group of consumers. As noted earlier, such advances will not only prevent fatalities among older drivers and passengers, but vehicle occupants of all ages.

Design changes to streets and highways to accommodate older road users are a different matter. Arguably, the "design driver" (and the "design pedestrian") is now an individual in the eight decade of life, who—on average—cannot see as well, process information as efficiently, or react and move as quickly as s/he used to. Benefits to older road users for the most part also improve safety for all others, too; and obviously there are broad economic benefits from the associated job creation. But as a rule infrastructure changes entail massive public expenditures. And, not everyone with (age-related) diminished capabilities can—or should—be accommodated. Costs to the public, as well as exposure to legal liability by States for design deficiencies, must be capped at some level, so it raises the question: "How much is enough?"

The answer lies in the recommendation to require a minimum level of those visual, mental, and physical capabilities that predict the risk of at-fault crashes among older drivers for license renewal. If adopted as a uniform requirement across all States, this would set the bar for the "design driver" that publicly funded infrastructure projects must accommodate. With the exception of walking speed, the same performance thresholds may guide the design of pedestrian facilities, too. Of course, this policy should not limit States that wish to exceed the standards that follow from establishing an older "design road user."

The expense to States of implementing a brief functional screen at license renewal is expected to be a pass-through cost to drivers. An automated process is certainly feasible with existing technology; therefore, apart from the fixed costs of installing, operating, and maintaining networked test stations (kiosks), the incremental cost in terms of labor hours to a State should be quite modest. Because the need for test stations will be driven by population, an increase in licensing fees per driver would be an equitable funding mechanism. It is projected that a $2.00 increase in license renewal fees per driver would fund implementation in a given jurisdiction.

Providing physicians and others with immunity from tort liability for voluntary reporting of medically unfit drivers should carry no direct cost to government, and there are significant public

health and safety benefits from increased reporting by those who are in the best position to identify such individuals. At the same time, it is emphatically *not* the case that physicians should be given immunity for *failing* to report those who they have reason to believe are medically unfit drivers; such a policy would be contrary to public safety. Nor is mandatory physician reporting likely to be effective. This can discourage patients from seeing their doctors, which carries many negative consequences.

The cost of current 'mature operator' driver education courses is borne largely by the providers, who charge only a nominal fee and recover their costs through other mechanisms. It seems feasible that the recommended 'refresher course' for all older drivers could be funded through public-private partnerships with insurance providers, for whom it could become an important risk management tool.

The principal costs associated with developing the recommended labeling system for drugs sold in this country are in carrying out the research that must underlie it. Again, public-private partnerships may provide a viable funding mechanism, with pharmaceutical companies being charged with the responsibility to complete pharmacological, toxicological, epidemiological, and/or behavioral testing as needed to establish a scientific basis for classifying a medication's likely risk for driving. A standard investigational protocol is essential for assigning risk levels; this should be established by the federal Government.

The expected benefits from implementing the present recommendations include a reduction in fatalities, coupled with an increase in mobility that will maintain the independence of older persons while preserving their role in the cultural and economic vitality of their communities.

The complete elimination of traffic fatalities among this group is not a realistic expectation. Some fraction of (fatal) crashes are indeed 'accidents' that are largely random in nature. There is also the possibility that older persons will adopt high-risk behaviors like motorcycle riding in substantially greater numbers. However, given our current understanding of the mobility needs and preferences of older Americans, cutting their number of preventable fatal crashes by 50% or more is judged an appropriate and reachable target for these interventions.

### *SUMMARY*

Simply because of their growing numbers fatalities among older road users will be a determining factor in the success of efforts to move toward zero deaths on our nation's streets and highways. The good news is that a "safety culture" is already ingrained in this group. On the down side, a decline in key abilities needed to drive safely is inevitable with normal aging, and is exacerbated by the diseases that are more common as we age, and by the medications use to treat them. The dependence of senior citizens on the private automobile to maintain a semblance of quality of life in most communities further complicates matters.

We clearly need continuing improvements in vehicle occupant protection, to counter the frailty of older drivers and passengers. Infrastructure upgrades designed to accommodate losses in visual, mental, and physical capacity experienced by most older persons also must continue; and these investments will benefit not only older but all road users. With these changes defining a baseline—in that they represent merely the acceleration of initiatives already underway—it falls to an entirely new set of policies to accomplish the desired goals in crash and fatality reduction: mandates for adult driver education; labeling of medications to provide explicit warnings about the risk of driving impairment; protections for health care professionals who report medically

unfit drivers; and a practical system for screening the most functionally (especially cognitively) impaired individuals seeking license renewal—most of whom will be of advanced age—that is deemed fair and objective by the driving public.

Only in the case of infrastructure improvements does it appear that significant expenditures of public funds are needed to fulfill the present recommendations to move toward zero deaths among older road users. And again, these are funds that will be spent in any case; the key is to build new facilities and upgrade existing ones according to design standards that explicitly recognize the needs of older drivers and pedestrians. Private enterprise or public-private partnerships should provide access to the resources needed to implement the policy innovations recommended in this paper.

Finally, success in moving toward zero highway deaths among our older citizens will critically depend upon improving the availability of alternative transportation (AT) options that offer this group a replacement for the private automobile, i.e., secure and convenient ("24/7") mobility within their communities at a cost they can afford. This does not suggest the need for large public expenditures for transit system upgrades. A considerable number of competing AT models now are in operation, in communities across the U.S. Without offering any specific recommendations, in general the following strategy appears promising: provide time-limited 'start-up' grants from the federal Government, contingent on matching funds from private stakeholders in the community (or from philanthropic interests), to expand those current models and programs that are most sustainable, with the highest user satisfaction, into areas where such "24/7" services presently do not exist.

# MOTORCYCLIST ISSUES

## *ISSUES AND SIGNIFICANCE*

Motorcyclist crash-related fatalities increased dramatically during the past decade, peaking at 5,290 deaths in 2008 (GES). The causes for the estimated decline in such deaths to an estimate 4,762 in 2009 are uncertain, but the toll remains tragic especially since safety has been improving for occupants of all other vehicle types (Hedlund, 2009). Overall, motorcyclists represent only about 3 % of registered motorists, but 13% of crash-related fatalities. A number of factors have been proposed as potential causes for the rising number of motorcyclist fatalities. Among them, changes in the vehicle and rider populations (bigger motorcycles, greater power/weight ratio, young/older riders, and military veterans) have been hypothesized; however, there has been little research focused on motorcycle crash causation, or on the potential safety benefits of related countermeasures.

**Table 5: Motorcycle Rider Safety Data**

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fatalities | 2,294 | 2,483 | 2,897 | 3,197 | 3,270 | 3,714 | 4,028 | 4,576 | 4,837 | 5,174 | 5,290 |
| Injured persons | 48,974 | 49,986 | 57,723 | 60,236 | 64,713 | 67,103 | 76,379 | 87,000 | 88,000 | 103,000 | 96,000 |
| Motorcycles involved in crashes | 54,477 | 57,322 | 68,783 | 73,342 | 76,004 | 79,131 | 85,538 | 103,000 | 104,000 | 123,000 | 114,000 |
| Vehicle-miles (millions) | 10,283 | 10,584 | 10,469 | 9,639 | 9,552 | 9,577 | 10,122 | 10,454 | 12,049 | 13,621 | 14,484 |
| Rates per 100 million vehicle-miles | | | | | | | | | | | |
| Fatalities | 22.3 | 23.5 | 27.7 | 33.2 | 34.2 | 38.8 | 39.8 | 43.8 | 40.1 | (R) 38.0 | 36.5 |
| Injured persons | 476.3 | 472.3 | 551.4 | 624.9 | 677.5 | 700.7 | 754.6 | 832.2 | 730.4 | 756.2 | 662.8 |
| Motorcycles involved in crashes | 529.8 | 541.6 | 657.0 | 760.9 | 795.7 | 826.3 | 845.1 | 985.3 | 863.1 | 903.0 | 787.1 |

Source: Research and Innovative Technology Administration (RITA) Website

## *CURRENT STATUS*

Motorcyclists represent a unique facet of the motoring public because they can operate vehicles at high speeds, are integral to the traffic mix on all road types, require specialized driving skills, and are virtually unprotected by their vehicle's design. As such, they may be especially

vulnerable users because of their exposure to significant hazards presented by other vehicles, road infrastructure design and condition, and their own potentially inadequate riding skills and inappropriate behaviors. There has been little focus on motorcycle crash causation in the U.S. in recent years. Europe and Australia have initiated targeted programs. In order to reduce the number and severity of motorcycle crashes, changes in rider training and behavior, infrastructure design and maintenance, motorcycle conspicuity and driver behavior should be considered.

**Infrastructure Issues**

***Awareness*** - Motorcycles generally have not been considered in roadway design, construction and maintenance practices in the U.S. There are no recommendations from the Federal Highway Administration (FHWA) or guidelines from the American Association of State Highway and Transportation Officials (AASHTO) regarding the accommodation of motorcycle operational issues. As an example, the design and installation of currently prescribed guard rails and breakaway poles and standards may provide better crash survivability for passenger vehicle occupants but present a greater hazard for riders than having no such devices on the roadside. Likewise, the *first* placard specifically designed to draw the attention of motorcyclists to a roadway hazard, such as a milled surface, was approved in the 2009 amendments to the Manual on Uniform Traffic Control Devices (MUTCD).

***Guardrails*** - A study done by Samaha and Ouellet (2009) showed that roadside hazards accounted for 50% of riders killed in single vehicle motorcycle crashes for the period 1994 – 2007. The objects most frequently struck include poles/posts/trees, curbs/embankments/culverts, and guardrails. Clearly running off the road is a major hazard for motorcyclists. Safer guardrails could reduce this hazard.

The Euro Guardrail standard EN1317 defines several containment levels for safety barriers, depending on the vehicle type to be restrained. Motorcycles are not included in these specifications. However, in 1998 two motorcyclist, guardrail-impact, sled tests were developed. Current regulations require that these tests be conducted whenever a motorcyclist protection system is installed. When the motorcyclist protection system is added to an existing road safety system, the containment level must be unchanged, the only vehicle test to be performed being the test with the heaviest vehicle. Some nations including France, Spain, Germany and Italy have begun adding modified barriers in selected locations such as sharp curves to more safely prevent motorcycle run-off road crashes. Using the standards referred to above, these improvements were made without detriment to barrier crash performance for all other vehicle types.

Although vehicle miles travelled (VMT) is one of the key exposure measures for highway safety data, the facility to stratify passenger vehicles by type generally is lacking in automated data collection devices. And, although manual counts sometimes are taken to help calibrate the collected VMT data, the location of data collections used for these estimates may not reflect the true traffic picture. This is especially so for motorcycles since they often fall victim to intentional or unintentional filtering from the dataset due to size, lane position, sensor sensitivity thresholds, rider evasion, or combination of their counts with other passenger vehicle traffic. In addition, historically traffic counts were often conducted during the work week when motorcycle riding is less common. Motorcycle riding patterns often favor rural areas or group events on major highways – again challenges for standard data collection methods. At issue, is the use of VMT to assess the proportion of motorcycles in the traffic mix when establishing program priorities and its application in calculating estimates, such as fatality rates per miles traveled. More accurate

VMT data may well reflect higher motorcycle usage which could both help to justify greater emphasis on motorcycle safety issues, and better define safety risks. Recent federal requirements for State surveys may help to correct these limitations, but improvements may not be fully realized for years without much greater penetration of improved data collection technology and practices, and innovation in data collection and interpretation for all road types.

***Protected Lanes*** - Motorcycle access to HOV/HOT lanes provides a less dense traffic mix in which riders potentially face fewer hazards. Such safety benefits of motorcycle access to roadways constructed with federal funding is recognized in (23USC102 (b); 23 USC102 (a) (1), 23USC166 (b)). Perhaps the manner in which HOV lanes are designated should be modified to include only vehicles for which some minimum percentage of their capacity (i.e., seating) is being used. For example, requiring at least 50% seating capacity usage for HOV lane use might be more reasonable than a fixed number such as 2 or 3 occupants. Such a ruling would perhaps further reduce the HOV usage levels of large sport utility vehicles (SUVs) or vans with only a small percentage of their available capacity in use from reaping the benefits of these lanes. It may also encourage additional carpooling and transit use while reducing traffic congestion for motorcycle operators. It should be noted that States and local jurisdictions interpret the federal statute in different ways, and that motorcyclists are not universally allowed to ride in HOV/HOT lanes.

Fully dedicated motorcycle travel lanes with impenetrable barriers designed to minimize rider impact injury would provide a safe haven for motorcycles where currently none exists. This option, while potentially very effective, also represents a costly roadway solution.

***Shoulders*** - With protected lanes in mind, what engineering options are available to highway designers to enhance the safety of motorcycling? The use of roadway shoulders by riders may be effective on limited access highways and arterials. Not only could this provide a relatively safe environment for riders from among the passenger vehicle streams, but in many cases rumble strips or similar subtle treatments may serve as an implied Physical but crossable barrier from the stream. Also expanding the availability of improved shoulders across all road types may reduce the number and severity of motorcycle run-off-road crashes by providing a location where riders leaving the travel lanes could regain control of their vehicles. In addition shoulder maintenance such as sweeping or vacuuming should be encouraged to minimize debris.

***Road Condition*** - Road surface condition is a critical aspect of safe motorcycle riding. There are permanent features such as type of road material, shoulder presence, and striping products that can affect riding safety. Maintenance practices of concern include issues such as incorrect placement of warning signs, temporary lane detour positions that include multiple surfaces, milled surface type, and excessive application of repair materials. In addition, temporary road condition hazards would include debris such as shorn tire treads and lost cargo, weather-related gravel, mud, and treatment chemicals that are not promptly removed. All of these factors, especially when unanticipated, can present the motorcycle rider with a potentially critically dangerous environment. Highway departments can address these issues through thoughtful design and targeted maintenance practices. For example, the State of Florida now requires that Thermoplastic used for road striping in pedestrian areas include friction enhancers. The purpose of this requirement is to help prevent slipping while pedestrians are crossing streets. This same treatment could be applied to all thermoplastic and paints that are used at intersections (such as wide stop bars) and around toll plazas since motorcyclists are also subject to slipping when they come to a stop and put down their feet at these types of locations.

***Increased Communication*** - Potential surface hazards can also be addressed through promoting the availability of reliable information about road conditions. Many States have employed Web sites and other social networking technology to notify the traveling public about roadway issues and planned construction (Motorcyclists Advisory Council). Likewise, some States also allow motorists and riders to post notices about road condition concerns that are then directed to maintenance staff. Such real time communication and response can be useful in identifying and rectifying potentially hazardous road condition problems. When reporting functions are created, the means to report must be publicized through roadside and other media.

***Traffic Controls –*** Intersection-related collisions represent nearly half of all fatal motorcycle crashes (GES. Although detailed analyses of motorcycle crash causation are not currently available, one common motorcyclist complaint is that protected left turns are often not possible because some technology does not detect a motorcycle waiting in the left turn lane. It is possible that improvements in such detection technology could reduce the number of intersection-related collisions, especially those where oncoming drivers do not recognize that motorcyclists are crossing their path while making left turns.

***Advisory Councils*** - The Motorcyclist Advisory Council (MAC) to the FHWA is comprised of representatives from advocacy groups, State highway departments, and industry representatives. The MAC-FHWA has been instrumental in raising issues of importance to the federal roadway design and operations decision makers. It also obtained an AASHTO commitment to encourage consideration of motorcycle issues. As a result of the MAC-FHWA efforts, greater awareness of motorcyclist safety is present within the FHWA and AASHTO. A brochure and marketing campaign are targeting State and local highway agencies to consider motorcycles in their design, construction and maintenance practices. Areas of special interest include:

- Traffic control devices (traffic actuated signals, traction/striping, intersection design, cattle guards)
- Work zones, roadway debris, road cut/grinding practices, and metal bridge grating, and other surface conditions
- Crash barriers, sign posts, and other roadside furniture
- Dedicated motorcycle hazard signage

Some States such as Minnesota, Virginia, Ohio, and Montana have designated motorcyclist advisory groups. Much like the MAC-FHWA, these groups provide information and guidance to the State Highway Administrations on issues related to motorcycle operation and safety. They have been credited with improving such safety within their States. The importance of these committees or councils is evident when elected, appointed and regulatory officials, who know nothing about motorcycles, the motorcycling community, or motorcycling issues, make legislative, regulatory and policy decisions that may cause more harm than good. The committees or councils serve as an excellent resource at the State level, just as the MAC-FHWA serves the interests of the riding community at the federal level, at least with regard to highway engineering issues.

In 2007, the Federation of European Motorcyclists' Associations (FEMA) was granted liaison status with CEN, the European standards organization. FEMA is taking a lead role in advancing motorcyclists safety issues in Europe by hosting conferences, conducting surveys of rider experiences, and serving as a clearinghouse for motorcycle safety information.

**Motorcycle/Vehicle Issues**

***Definition of Vehicle Type*** - What a motorcycle is and who is required to be licensed to ride one on the road was once a fairly simple equation. However, the lines are being blurred with the advent of more scooter types, 3-wheeled vehicles, micro-sized cars, ATV's (some of which are possible to register as roadworthy vehicles), etc. The definition of what constitutes a motorcycle has been left in the hands of state agencies responsible for registering them, defining necessary protective equipment, and licensing the riders. However, this creates a problem when trying to quantify and understand the statistics surrounding motorcycle use and crashes at the national level. Specifications to allow more universal understanding of national norms, levels of use, and crashes are desirable, but how should vehicles be stratified? Currently, the rules for stratification typically include engine displacement, speed capability (to differentiate them from small scooters, etc.), length, weight, and/or number of wheels to define a vehicle as part of the motorcycle class. Though these are often correct at capturing the vast majority of conventional vehicles in the class, the unconventional products may be misclassified and their crash and other data applied inappropriately, thus skewing statistical results. Perhaps other factors should replace or be included in a more uniform definition that captures the essence of why a separate class is needed and/or how it should be treated in terms of licensing, occupant protection rules, tolling, taxation, lane use, etc. Definitions could include some combination of speed capability (e.g., > 35mph), the ability to self balance, width/length (e.g., girth), and whether riders or passengers are afforded some level of side impact protection. The Federal Highway Administration is beginning to address this issue through its proposed update to guidance regarding State reporting of motorcycle registration information (FHWA Docket No. FHWA-2010-0010).

***Improved Braking Systems*** – Unlike other vehicle types, motorcycles offer little crash protection for riders. Improved braking capabilities appear to be an area where pre-crash performance can be enhanced. Both the Insurance Institute for Highway Safety and FEMA have issued policy statements supporting the progressive introduction of affordable advanced braking systems for motorcycles (IIHS, 2010; FEMA, 2010). These systems include combined braking and antilock braking (ABS). It should be noted that ABS could increase the crash risk for off-road riding, or when riding on a dirt or gravel surface.

***Conspicuity*** – Daytime running lights (DRL) and other passenger and commercial fleet vehicle factors (lower, wider A-pillars, etc.) are making motorcycles harder to see or easier to lose to background clutter and visual obstructions. A recent NHTSA-sponsored study performed by Westat (unpublished) suggested that fleet DRL use may well lessen the distinction and conspicuity of motorcycles (NHTSA, 2010).

Conspicuity vs. conformity of motorcycle lighting and design may also be an issue. Some use of distinctive light patterns in motorcycle OEM designs and aftermarket options has the potential of making motorcycles more visible and recognizable to other drivers encountering them on the road. Various theories exist about the ideal configurations and necessity of creating distinctive visual signatures of front and rear profiles of the motorcycle population to make them more immediately identifiable. Doing so may have the effect of making it less likely that a motorcycle blends unrecognizably into the vehicle stream. Manufacturers have adopted facial analogs and triangular arrangements of headlight and auxiliary lamps in efforts to exploit these theories and perhaps make their particular arrangement the de facto industry standard. Increased conspicuity should be considered a priority in motorcycle design, as a means of achieving reductions in multi-vehicle crashes.

**Motorcycle Rider Issues**

Motorcycle riders have a greater responsibility and need for self protection than do the operators of any other vehicle type. Because their vehicles provide virtually no crash protection, and only limited capabilities for crash avoidance, it is incumbent upon the rider to define and adopt an approach that will maximize survivability when riding.

***Distraction*** - Driver distraction is recognized as an increasing factor in crash causation. In a recent Harris Interactive survey, 38% of the respondents reported being hit or nearly hit by a cell phone-using driver; 40% of the respondents indicated they still use their smart phones while driving (Zieman, 2010) for talking, texting, email, etc. The same technologies available to the driving population are also available to the motorcyclist population. Rider distraction, although perhaps not yet as pervasive as in other vehicle types, may well increase. Many motorcycles are outfitted with phones, radio or MP3 players, GPS, intercoms, etc. and all the hands-free technology available to other vehicle drivers. Texting may not become common, but the other technologies may, at times, lead the rider to take eyes off the road and hands off the handlebars for some period. Shrinking device size and ever more pervasive wireless and hands-free technologies will make them more compatible and thus more appealing as motorcycle equipment.

***Rider Training and Licensing*** – The ability to operate a motorcycle safely must include skills for successfully maneuvering in all traffic conditions. Introductory rider training may teach basic riding skills, while advanced classes stress concepts of situational awareness, and emergency response. Research on the lasting effects of rider training shows mixed results, although training seems to have a very beneficial effect for the first six months. It is understood is that there is often a large demand for basic training early in the riding season and experience lifecycle, and that advanced classes are generally undersubscribed.

Currently 47 States offer basic rider education. Many states currently require a basic course before licensure, but may allow new residents with relevant licenses to transfer in without testing or training requirements or training validation. Some even allow a one-day license- testing waiver course. Requiring riders to train on a motorcycle that is similar in size and maneuvering characteristics to the one which they will ultimately ride are enforced in some jurisdictions. However, many States allow training on much smaller and more maneuverable motorcycles than riders own or intend to ride.

Clearly riders need to concentrate on defensive driving and emergency maneuvering in order to be prepared for roadway and traffic challenges. A new program sponsored by the Italian motorcycle association ANCMA focuses on both car drivers and motorcycle riders. The motorcyclists are tasked with increasing their conspicuity, using turn signal indicators, always passing on the left, and never assuming they will be seen. If widely adopted, such behaviors would make the presence of motorcycles in traffic more obvious and predictable. Updated training at regular intervals is required for the operators in other specialized transportation modes such as airplane pilots and commercial vehicle drivers. The skill sets and riding strategies for motorcyclists can also be expected to benefit from periodic instruction. Financial incentives could help to make advanced rider training more popular. One effective approach would be to have all States (as some now do) require insurance companies to offer policy discounts for riders who take such training.

Rider licensing, in conjunction with vehicle registration, obviously serves a variety of needs for each state, including revenue generation, ensuring a minimum level of competence, tracking the status of the vehicle fleet, generating rider and motorcycle statistics, providing user data to enforcement officials, and providing credentials as valid members of the transportation fleet. Unfortunately, some weaknesses and loopholes exist that allow unlicensed riders and/or unregistered motorcycles on the road. There are the cases where "new" riders are allowed to repeatedly obtain temporary permits and some riders do this each Spring, without ever becoming fully licensed. Riders who gave up riding for  years while maintaining their license, and then resumed riding without refresher training are representative of some of the baby boomers who first purchased their motorcycles in the 1970s, and have returned to riding  in middle age. Such a riding hiatus may adversely affect the rider's ability to be ready in the event of a potentially challenging situation. Perhaps periodic or event-based triggering or re-triggering are reasonable for motorcyclists to ensure a minimum level of competence and a refreshed view of the current rules of the road and defensive practices.

Recently adopted by Utah, but repealed by Washington State, tiered motorcycle licensure could take a step by step approach to full approval with an interim step of a restricted, provisional license.  Collecting a citation or having a crash within that provisional period might, as with other provisional licenses, trigger remedial training, extended provisional period(s), or harsher sanctions than would otherwise be delivered to a fully licensed rider. Tiered licenses could also specify the type (sports bike, cruiser, etc.) or engine displacement for which a rider is certified (with relevant training requirements), since motorcycles vary greatly in their handling characteristics.

***Impaired Riding –*** In their 2009 study, (Samaha and Ouellet, 2009) compared the ratios of alcohol use in motorcycle crashes in Japan, Europe and the U.S. Using Japan as the baseline of 1, the usage rate in Europe is 3.5, and in the U.S. it is 6. Clearly alcohol usage, at 44% of all single vehicle motorcycle fatal crashes, is present to a significant degree in U.S. motorcycle crashes as compared to that of other nations. Drunk driving is largely an enforcement issue, but increased education and awareness among motorcyclists of the dangers of riding under the influence may help to curb such usage among riders. In addition, installing alcohol ignition interlocks as standard equipment on all vehicles including motorcycles could have a deterrent effect. This approach is being considered for automobiles by the U.S. Congress as part of the Motor Vehicle Safety Act of 2010.

***Personal Protective Equipment*** – Safety equipment (e.g., helmets, body armor, inflatable jackets, retro-reflective gear, proper gloves and footwear) plays a key role in the safety of motorcyclists. Unfortunately, style and safety for some segments of the rider population are on disparate paths. Minimalist engineering and safety gear avoidance define some segments of the population (e.g., stiff mounting of rear wheels to the frame, no padded armor in clothing or helmets if helmets are used at all, and avoidance of anything that suggests engineering over nostalgic bike heritage). This simplistic model, though attractive and stylish, puts these riders in greater danger when exposed to the same hazards as riders using the latest product enhancements in bike features, accessories, and apparel. As such, finding a way to bring these paths back toward each other could have great benefits in terms of crash avoidance and biker survivability in the event of a crash. However, the use of personal protective equipment my provide a false sense of safety and lead to riskier riding practices without related rider education.

The use of a compliant helmet has been proven as the most effective means of preventing serious head injury and death in a motorcycle crash. States pass and repeal laws requiring helmet use, largely based upon the effectiveness of various lobbyists rather than on the merits of the legislation. Riders' freedom to choose whether to wear a helmet must be measured against the societal costs of caring for riders who are seriously injured and permanently disabled in crashes when such disabilities could have been prevented by helmet use. Their costs affect insurance premiums and healthcare costs for everyone. Thus, raising the issue of mandated helmet use to the national level may overcome the burden faced by State legislators, and allow for a comprehensive level of protection unaffected by geographic boundaries. This, alone, may be the single most effective means of reducing motorcyclist fatalities in America.

***Emergency Response*** – Emergency medical service (EMS) training that stresses the differences between motorcycle versus passenger vehicle crash dynamics and victim kinematics and injury norms is important. For example, helmet removal should only be done after transport, unless necessitated by other treatment needs. First responder activities that are not tailored to typical motorcyclist injuries may well worsen rider survivability and/or incapacitation rather than improve it if likely injury patterns are not properly understood and appropriate stabilization and transport methods executed.

**Intelligent Transportation Systems (ITS)**

One of the key challenges for implementing the new technology and processes envisioned for ITS, is to give adequate consideration for *all* the stakeholders likely to need or take advantage of the features and benefits that it offers. Current development and evaluation efforts have focused on passenger and commercial vehicles that make up the bulk of the motor vehicle fleet. Incorporating motorcycles into ITS programs may require special accommodation because of their limited size and capacity for add-on devices. It is important to ensure that motorcycles are included for key technology components that may improve safety by making other users more aware of their presence and movements and to ensure that critical vehicle and infrastructure information is made available to motorcyclists as well.

Motorcycle factors to consider include smaller payload capacity, storage space, electrical power, more challenging display and control interface options, and abilities to support physical sensors in terms of size and mounting means. Motorcycles also experience a broader range of vehicle dynamics compared to those of a passenger vehicle-like platform. These are challenges for creating a sensor/communication package for any given vehicle to vehicle (V2V), vehicle to infrastructure (V2I), or infrastructure to vehicle (I2V) interface.

ITS systems must be able to respond to and communicate with passing motorcycles reliably. That is, recognize that they are there, that they are motorcycles instead of a passenger vehicle (with special information needs), and to respond with information that is properly tailored to those needs. With the current challenges, just in terms of collecting valid VMT data that captures motorcycles, the ability to collect even richer data and disseminate it in a timely fashion will be even more critical.

***Operator Communication*** - Current automobiles and trucks have been engineered to offer the smoothest possible ride with minimal road feel, absence of outside noise, luxurious seats, power assisted steering, braking, and seat positions, etc. As such, they have removed the operator from sensory contact with and awareness of the driving environment. These "sensory deprivation" vehicles are so easy to drive, that cell phones, texting, and other infotainment systems have

become antidotes to driver boredom. In addition, drivers no longer have a sense of being part of the traffic flow, and behind their tinted windows can demonstrate selfish, offensive, and even aggressive driving tactics. ITS may help to remedy this dilemma of over-engineering by providing a means for rider to driver communications (perhaps even verbal). If a motorcycle rider were able to speak (perhaps via a microphone and a Bluetooth radio connection) to the car driver ahead and announce that he was approaching and planning to pass on the left, the driver would then be made aware of the presence of the motorcycle and could respond appropriately. In commercial shipping, captains are required to make Intent Agreement Signals which are contacts with neighboring vessels when preparing to alter their course. Reintroducing the human connection within the traffic fleet could foster a greater sense of commuting community, and break down the isolation that luxury engineering has created. Giving the other guy a break might become more than highway folklore.

### *STRATEGIES THAT HAVE POTENTIAL FOR REDUCING MOTORCYCLIST FATALITIES*

The following strategies, as discussed above, are offered as the most promising ways to decrease the number of motorcyclist fatalities in the United States. There is no inherent priority in the order of presentation.

**Table 6. Strategies to reduce motorcyclist fatalities.**

| STRATEGY | AIMED AT | POTENTIAL FATALITY REDUCTION (% OR #) | WHO BEARS COST | COSTS (IMPLEMENT/ MAINTAIN) | OBSTACLES TO IMPLEMENTATION |
|---|---|---|---|---|---|
| Advisory Councils for the Federal and State Governments | Highway design and maintenance agencies | 10% | Government agencies and advisors | Labor hours for government agencies. Volunteer time for advisors. | Public and political acceptance of motorcyclist advisors |
| AASHTO Highway Design Handbook for Motorcyclists | Highway design and maintenance agencies | 10% | AASHTO Members | R&D and production costs | Establishing motorcyclist safety as an AASHTO priority |
| National Motorcycle Helmet Law | Unhelmeted or non-compliant helmeted motorcyclists | 20% of Unhelmeted Fatalities | Motorcyclists | Federal legislation, law enforcement initiatives | Consumer resistance |
| Rider to Driver Communication | All drivers and riders | 20% of Vehicle to vehicle collisions | Consumer using Bluetooth technology | Development of standard technology base for inter-operator communication | Added vehicle costs, and time required for fleet penetration |
| Standard Motorcycle Lighting Displays | All motorcycles and scooters | 5% of Vehicle to Vehicle Collisions | Motorcycle manufacturers | Development of lighting standards, and industry retooling | Resistance to standard designs; time needed for fleet penetration |
| More Rider Training and Cerification | All motorcycle riders | 10% | Motorcycle riders and/or insurers | Motor vehicle administration tracking and research | Resistance from riders and motor vehicle administrations |

## REFERENCES

AASHTO. (2004). AASHTO guide for the planning, design, and operation of pedestrian facilities, 1st edition. Washington, D.C.: American Association of State Highway Transportation Officials. Retrieved from http://www.walkinginfo.org/library/details.cfm?id=2067

Attewell, R., Glase, K. and McFadden, M. (2001). Bicycle Helmet Efficacy: A Meta-Analysis, *Accident Analysis and Prevention*, 33,345-352.

Axelson, P.W., Chesney, D.A., Galvan, D.V., Kirschbaum, J.B., Longmuir, P.E., Lyons, C., et al. (1999). Designing sidewalks and trails for access, part I: Review of existing guidelines and practices. Washington, D.C.: Federal Highway Administration. Retrieved from http://www.fhwa.dot.gov/environment/sidewalks/

Bailey, L. (2004). *Aging Americans: Stranded Without Options*. Washington, DC: Surface Transportation Policy Project. Retrieved from http://www.apta.com/resources/reportsandpublications/Documents/aging_stranded.pdf

Bayly, M., Fildes, B., Regan, M., and Young, K. (2007). *Review of Crash Effectivveness of Intelligent Transport Sytems.* Traffic Accident Causation in Europe, Project No. 027763. http://www.trace-project.org/publication/archives/trace-wp4-wp6-d4-1-1-d6-2.pdf Accessed May 13, 2010.

Blomberg, R.D., Hale, A. & Preusser, D.F. (1984*). Conspicuity for Pedestrians and Bicyclists: Definition of the Problem, Development and Test of Countermeasures*. (DTNH22-C-07052. National Highway Traffic Safety Administration.

Bowman, B.L., & Vecellio, R.L. (1994). Investigation of the impact of medians on road users. (FHWA-RD-93-130). McLean, VA: Federal Highway Administration. Retrieved from http://www.walkinginfo.org/library/details.cfm?id=2675

Bureau of Transportation Statistics. (2009 – Forthcoming). 2008 National Household Travel Survey. Washington, D.C.: U.S. Department of Transportation. Retrieved from http://nhts.ornl.gov/

Campbell, B. J., Zegeer, C. V., Huang, H. H., & Cynecki, M. J. (2004). A review of pedestrian safety research in the United States and abroad. (FHWA-RD-03-042). McLean, Va.: Federal Highway Administration. Retrieved from http://www.walkinginfo.org/pdf/PedSynth/Ped_Synthesis_Report.pdf

Carter, D. L., Hunter, W. W., Zegeer, C. V., Stewart, J. R., & Huang, H. F. (2006). Pedestrian and bicyclist intersection safety indices: Final report. (FHWA-HRT-06-125). McLean, VA: Federal Highway Administration. Retrieved from http://www.tfhrc.gov/safety/pedbike/pubs/06125/06125.pdf

Chang, D. (2008). *National Pedestrian Crash Report (DOT HS 810 968)*. Washington, DC: National Highway Traffic Safety Administration. Retrieved from http://www.walkinginfo.org/library/details.cfm?id=4396

Cheong, A. M. Y., Geruschat, D. R., & Congdon, N. (2008). Traffic gap judgment in people with significant peripheral field loss. *Optometry & Vision Science*. *85(1)*, 26-36.

Fatalities and Injuries 1975-2007: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Traffic Safety Facts, Final Edition, (Washington, DC: Annual issues), table 10, available at http://www-nrd.nhtsa.dot.gov/ as of March 2009.

Fatalities and Injuries 2008: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Traffic Safety Facts, Early Edition, (Washington, DC: Annual issues), table 10, available at http://www-nrd.nhtsa.dot.gov/ as of Dec. 2, 2009.

Fatality Analysis Reporting System (FARS). (2008). *National Rates: Fatalities.* Retrieved from http://www-fars.nhtsa.dot.gov/Main/index.aspx.

Fayish, A.C. & Gross, F. (2009). Safety effectiveness of leading pedestrian intervals using the empirical Bayes method. Presented at the 2009 Annual Meeting of the Transportation Research Board. Washington, D.C.: Transportation Research Board.

Federal Highway Administration (1994). *The National Bicycling and Walking Study, Transportation Choices for a Changing America* (FHWA-PD-94-023), Federal Highway Administration, Washington, D.C.

Federal highway Administration (2010). *The National Bicycling and Walking Study: 15-Year Status Report*, Federal Highway Administration, Washington, D.C.

Federal Highway Administration. (1994). *The National Bicycling and Walking Study: Transportation Choices for a Changing America*. Washington, DC: Author.

Federal Highway Administration. (1999). The National Bicycling and Walking Study, Five Year Status Report. Washington, D.C.: Author. Retrieved from http://www.fhwa.dot.gov/environment/bikeped/study.htm#s1

Federal Highway Administration. (2001). *Traffic Safety Facts: Rural/Urban Comparison.* Washington, DC: NHTSA National Center for Statistical Analysis. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/809524.PDF

Federal Highway Administration. (2003). Pedestrian safety campaign. Washington, D.C.: Author. Retrieved from http://safety.fhwa.dot.gov/local_rural/pedcampaign/

Federal Highway Administration. (2004). The National Bicycling and Walking Study, Ten Year Status Report. Washington, D.C.: Author. Retrieved from http://www.bicyclinginfo.org/library/details.cfm?id=5

Federal Highway Administration. (2006a). *Highway Statistics: Finance.* Retrieved from http://www.fhwa.dot.gov/policy/ohim/hs06/finance.htm.

Federal Highway Administration. (2006b). Travel characteristics of new immigrants. *NHTS Brief.* Washington, DC: Author. Retrieved from http://nhts.ornl.gov/briefs/Immigrant%20Travel.pdf

Federal Highway Administration. (2007). *Traffic Safety Facts: Rural/Urban Comparison*. Washington, DC: NHTSA National Center for Statistical Analysis. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/810996.PDF.

Federal Highway Administration. (2008). Toolbox of countermeasures and their potential

effectiveness for pedestrian crashes. Issue Briefs. (FHWA-SA-014). Washington, D.C.: Author. Retrieved from http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_tctpepc/index.cfm

Federal Highway Administration. (2009d). Pedestrian safety focus cities/states webconference. Washington, D.C.: Author. Retrieved from http://safety.fhwa.dot.gov/ped_bike/ped_focus/webinar.cfm

FEMA. *A European Agenda for Motorcycle Safety: The Motorcyclists' Point of View* Federation of European Motorcyclists' Associations (FEMA). April 2009
FEMA. Position Statement: With regard to the new Framework Regulation on European vehicle approval for two and three wheels vehicles. Federation of European Motorcyclists' Associations. March 1, 2010.

Fischer, E., Rousseau, G., Turner, S., Blais, E., Engelhart, C., Henderson, D., Kaplan, J., Keller, K., Mackay, J., Tobias, P., Wigle, D., and Zegeer, C. (2010). *Pedestrian and Bicyclist Safety and Mobility in Europe* (FHWA-PL-10-010), Federal Highway Administration, Washington, D.C.

Fisher, E.L., Rousseau, G.K., Turner, S.M., Blais, E.J., Engelhart, C.L., Henderson, D.R., Kaplan, J.A., Leller, V.M., Mackay, J.D., Tobias, P.A., Wigle, D.R., and Zegeer, C.V. (2010). *Pedestrian and Bicyclist Safety and Mobility in Europe*. Federal Highway Administration. Report No. DTFH61-99-C-005.

Fitzpatrick, K. & Park, E.S. (2009). Safety effectiveness of the HAWK pedestrian treatment. Presented at the 2009 Annual Meeting of the Transportation Research Board. Washington, D.C.: Transportation Research Board.

Fitzpatrick, K., et. al.. (1996). *Guidelines for the Location of Bus Stops*. Transportation Research Board. Report 19.

Fitzpatrick, K., Turner, S., Brewer, M., Carlson, P., Ullman, B., Trout, N., et al. (2006). Improving pedestrian safety at unsignalized crossings. ( TCRP Report 112/NCHRP Report 562). Washington, D.C.: Transportation Research Board. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w91.pdf

General Estimate System, (GES). Data collection began operation in 1988 from a nationally representative probability sample selected from all police-reported crashes. The GES sample includes only crashes where a police accident report was completed and the crash resulted in property damage, injury, or death. The resulting figures do not take into account crashes that were not reported to the police or that did not result in property damage.

Gibbons, R. B., Edwards, C. J., Williams, B., & Andersen, C. K. (2008). Informational report on lighting design for midblock crosswalks. (FHWA-HRT-08-053). McLean, VA: Federal Highway Administration. Retrieved from http://www.walkinginfo.org/library/details.cfm?id=4290

Harkey, D.L., Carter, D., Barlow, J., & Bentzen, B.L. (2007). Accessible pedestrian signals: A guide to best practices. National Cooperative Highway Research Program. Washington, DC: Transportation Research Board. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w117a.pdf

Harkey, D.L., Carter, D.L., Barlow, J.M., Bentzen, B.L., Myers, L. & Scott, A.(2007) *Guidelines for accessible pedestrian signals final report.* Contractor's Final Report for NCHRP Project 3-62, National Cooperative Highway Research Program Web-Only Document 117B, Washington,

DC: National Cooperative Highway Research Program;

Harkey, D.L., Srinivasan, R., Baek, J., Council, F.M., Eccles, K.A., Lefler, N.X., et al. (2008). Accident modification factors for traffic engineering and ITS improvements. National Cooperative Highway Research Program (NCHRP) Report, Number 617. Washington, D.C.: Transportation Research Board.

Harkey, D.L., Tsai, S., Thomas, L., & Hunter, W. (2006). Pedestrian and Bicycle Crash Analysis Tool (PBCAT) (Version 2.11) [Software]. Washington, D.C.: Federal Highway Administration. Retrieved from http://www.bicyclinginfo.org/facts/pbcat/index.cfm

Harkey, D.L.. & Zegeer, C.V. (2004). PEDSAFE: The pedestrian safety guide and countermeasure selection system. Washington, D.C.: Federal Highway Administration. Retrieved from http://www.walkinginfo.org/pedsafe/

Harwood, D.W., Torbic, D.J., Gilmore, D.K., Bokenkoger, C.D., Dunn, J.M., Zegeer, C.V., Srinivasan, S., Carter, D., Raborn, C., Lyon, C., and Persaud, B. (2008). *Pedestrian Safety Prediction Methodology*. NCHRP web docuent 129, Phase III. Project 17-26. National Cooperative Highway Research Program (NCHRP). Washington, D.C.: Transportation Research Board.

Hedlund, J. *Motorcycle Traffic Fatalities by State, Preliminary 2009 Report*. Governors Highway Safety Association, Washington, D.C.

http://bhsi.org/stats.htm accessed June 24, 2010.

http://www.distraction.gov/stats-and-facts accessed June 24, 2010.

http://www.iihs.org/research/fatality_facts_2008/bicycles.html accessed June 24, 2010.

http://www.pedbikeinfo.org/pbcat accessed July 1, 2010

http://www.pedbikeinfo.org/pbcat accessed June 24, 2010

Huang, S., Yang, J., & Eklund, F. (2008). Evaluation of remote pedestrian sensor system based on the analysis of car-pedestrian accident scenarios. Safety Science, 46(9), 1345-1355. Retrieved from http://www.sciencedirect.com/science/article/B6VF9-4PYMWPS-4/1/17894b0cdf99c8fff212ea21803a57ec

Hurt, H., J. Ouellet, and D. Thom. *Motorcycle Accident Cause Factors and Identification of Countermeasures Volume 1: Technical Report.* Contract No. DOT-HS-5-01160. U. S. Department of Transportation, 1981.

Institute of Transportation Engineers (ITE). (2001). Traffic Control Devices Handbook. Washington, D.C.: Author.

Institute of Transportation Engineers (ITE). (2001). Alternative treatments for at-grade pedestrian crossings. ITE Pedestrian and Bicycle Task Force. Washington, D.C.: Author. Retrieved from http://www.ite.org/emodules/scriptcontent/Orders/ProductDetail.cfm?pc=LP-629

Jacobsen, P.L. (2003). Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling, *Injury Prevention*, 9:205-209.

Jensen, C. *Congress Considers Funding Of In-Car Alcohol Detection System*. Wheels Blogs, NY Times.

Kirschbaum, J.B., Axelson, P.W., Longmuir, P.E., Mispagel, K.M., Stein, J.A., & Yamada, D.A. (2001). Designing sidewalks and trails for access, part II: Best practices design guide. Washington, D.C.: Federal Highway Administration. Retrieved from http://www.fhwa.dot.gov/Environment/sidewalk2/

Kwan, I. & Mapstone, J. (2006). Interventions for increasing pedestrian and cyclist visibility for the prevention of death and injuries. Cochrane Database of Systematic Reviews, 4.

Langham, M. P., & Moberly, N. J. (2003). Pedestrian conspicuity research: A review. Ergonomics, 46(4), 345-363. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=2009458482&site=ehost-live

Laplante, J., & McCann, B. (2008). Complete streets: We can get there from here. ITE Journal, 78(5), 24-28. Retrieved from http://www.completestreets.org/documents/CompleteStreets_ITEMay2008.pdf

Leaf, W.A, & Preusser, D.F. (1999). Literature review on vehicle travel speeds and pedestrian injuries among selected racial/ethnic groups. Publication No. DOT HS 809 021. Washington, DC: National Highway Traffic Safety Administration. Retrieved from www.nhtsa.dot.gov/people/injury/research/pub/HS809012.html

Lind, G., Lindqvist, E., and Persson, S. (2003). Short Descriptions of ITS Safety Applications and their Potential Safety Benefits. Published by *Stratega* and *Transek.*

Lu, G. & Noyce, D.A. (2009). Intersection signal systems with intelligent pedestrian accommodation: Dynamic pedestrian timing. Presented at the 2009 Annual Meeting of the Transportation Research Board. Washington, D.C.: Transportation Research Board.

Lynott, J., Haase, J., Nelson, K., Taylor, A. Twaddell, H, Ulmer, J. et al. (2009). *Planning complete streets for an aging America.* Washington, DC: American Association of Retired Persons. Retrieved from http://assets.aarp.org/rgcenter/il/2009_02_streets.pdf.

Madden, M. and Rainie, L. (2010). *Adults and Cell Phone Distractions*, Pew Internet and American Life Project, Washington, D.C.

*Manual on Uniform Traffic Control Devices.* Federal Highway Administration. December, 2009. http://mutcd.fhwa.dot.gov/kno_2009.htm

Markowitz, F.M., Sciortino, S., Fleck, J.L., and Yee, B.M. (2006). *Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation.* Institute of Transportation Engineers, ITE Journal.

McMahon, P.J., Zegeer, C.V., Duncan, C., Knoblauch, R.L., Stewart, J.R., & Khattak, A.J. (2001). An analysis of factors contributing to "walking along roadway" crashes: Research study and guidelines for sidewalks and walkways. (FHWA-RD-01-101). McLean, VA: Federal Highway Administration. Retrieved from http://drusilla.hsrc.unc.edu/cms/downloads/WalkingAlongRoadways_Study_Guidelines.pdf

Minnesota Motorcycle Safety Advisory Committee (MMSAC)http://www.motorcyclesafety.state.mn.us/latest/MMSCHomeSecondary.asp?cid=2&mid=52&scat=6

Montana Motorcycle Safety Advisory Committee http://motorcycle.msun.edu/advisory.htm

Morris, C. *Motorcycle Trends in the United States*. Bureau of Transportation Statistics Publication SR-014. U.S. Department of Transportation, 2009.

*Motorcycle Conspicuity and the Effect of Fleet Daytime Running Lights*, National Highway Traffic Safety Administration, Contract DTNH22-05-D-01002, unpublished data, 2010.

*Motorcycles Involved in Crashes 2005-07*: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Traffic Safety Facts, Final Edition, (Washington, DC: Annual issues), table 35, available at http://www-nrd.nhtsa.dot.gov/ as of March 2009.

*Motorcycles Involved in Crashes 2008*: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Traffic Safety Facts, Early Edition, (Washington, DC: Annual issues), table 36, available at http://www-nrd.nhtsa.dot.gov/ as of Dec. 2, 2009.

*Motorcycles Involved in Crashes:1975-2004*: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Fatality Analysis Reporting System Database and General Estimates System Database, personal communication, May 25, 2006.

Motorcyclists Advisory Council to the Federal Highway Administration. http://safety.fhwa.dot.gov/mac/

Mueller, B.A., Rivara, F., Bergman, A. (1988). Urban-rural Location and the Risk of Dying in a Pedestrian-vehicle Collision. *Journal of Trauma.* Baltimore, MD: The Williams & Wilkins Co. Retrieved from PubMed database.

Nabors, D., Gibbs, M., Sandt, L., Rocchi, S., Wilson E., & Lipinski, M. (2007). Pedestrian road safety audit guidelines and prompt lists. (FHWA-SA-07-007). Washington, D.C.: Federal Highway Administration. Retrieved from http://drusilla.hsrc.unc.edu/cms/downloads/PedRSA.reduced.pdf

Nabors, D., Schneider, R.J., Leven, D., Lieberman, K., & Mitchell, C. (2008). Pedestrian safety guide for transit agencies. (FHWA-SA-07-017). Washington, D.C.: Federal Highway Administration. Retrieved from http://www.walkinginfo.org/library/details.cfm?id=4231

National Center for Statistics and Analysis (accessed June 10, 2010). *Traffic Safety Facts 2008 Data, Bicyclists and Other Cyclists*, National Highway Traffic Safety Administration, Washington, D.C.

National Committee on Uniform Traffic Control Devices. (2003 and 2009 Editions). Manual on Uniform Traffic Control Devices for Streets and Highways. Washington, D.C.: Federal Highway Administration. Retrieved from http://mutcd.fhwa.dot.gov/pdfs/2003r1/pdf-index.htm

National Electronic Injury Surveillance System On-line (accessed June 10, 2010).

National Highway Traffic Safety Administration. (2008a). Traffic Safety Facts, 2007 Data: Pedestrians. Washington, DC: Author. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/810994.PDF

National Highway Traffic Safety Administration. (2008b). Traffic Safety Facts, 2007 Data: Race and Ethnicity. Washington, DC: Author. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/810995.PDF

National Transportation Safety Board (NTSB). (2002). Safety Report: Transportation Safety Databases. Washington, DC. Retrieved from http://www.ntsb.gov/publictn/2002/SR0202.pdf.

NCHRP Report 500, Volume 22: *A Guide for Addressing Collisions Involving Motorcycles*. Transportation Research Board. Washington, D.C.
NHTSA. *National Agenda for Motorcycle Safety*. U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA), Motorcycle Safety Foundation. 2000.

Ohio State Motorcyclists Safety Advisory Council
http://www.dot.state.oh.us/news/Pages/ODOTimprovingTrafficSignalSafetyforMotorcyclesandScooters.aspx

Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations (2010). US Department of Transportation, www.fhwa.dot.gov/environment/bikeped/policy_accom.htm

Potts, I.B, Harwood, D.W., & Richard, K.R. (2007). Relationship of lane width to safety for urban and suburban arterials. Journal of the Transportation Research Board, Number 2023, 63-82. Washington, D.C.: Transportation Research Board.

Research and Innovative Technology Administration (RITA). U.S. Department of Transportation (US DOT) 1200 New Jersey Avenue, SE. Washington, DC 20590. 800.853.1351Schneider, R.J., Khattak, A.J., & Zegeer, C.V. (2001) Method of improving pedestrian safety proactively with geographic information systems: Example from a college campus. Journal of the Transportation Research Board, Number 1977. Washington, D.C.: Transportation Research Board.

Schroeder, B. J., Rouphail, N.M., & Hughes, R.G. A working concept of accessibility - performance measures for the usability of crosswalks for pedestrians with vision impairments. Transportation Research Record: Journal of the Transportation Research Board, 2140, 103-110;

Scott, A.C., Barlow, J. M., Bentzen, B.L., Bond, T.L.Y. & Gubbe, D. (2008) Accessible pedestrian signals at complex intersections: Effects on blind pedestrians. *Transportation Research Record: Journal of the Transportation Research Board,* No. 2073, 94–103 Seward, E.A., Ashmead, D.H., & Bodenheimer, B. (2007). Using virtual environments to assess time-to-contact judgments from pedestrian viewpoints. *ACM Transactions on Applied Perception,4(3),*Article 18,1-19.

Seward, E.A., Ashmead, D.H., & Bodenheimer, B. (2007). Using virtual environments to assess time-to-contact judgments from pedestrian viewpoints. *ACM Transactions on Applied Perception,4(3),*Article 18,1-19.

Shurbutt, J., Van Houten, R., & Turner, S. (2008). An analysis of the effects of stutter flash LED beacons to increase yielding to pedestrians using multilane crosswalks. Presented at the 2008 Annual Meeting of the Transportation Research Board. Washington, D.C.: Transportation Research Board.

Spainhour, L., Brill, D., Sobanjo, J., Wekezer, J., and Mtenga, P. (2005). *Evaluation of Traffic Crash Fatality Causes and Effects: A Study of Fatal Traffic Crashes in Florida from 1998-2000 Focusing on Heavy Truck Crashes,* Department of Civil Engineering, Florida A&M University-Florida State University, Tallahassee, FL.

*State Departments of Transportation Lead the Way Using New Media.* American Association of State Highway and Transportation Officials (AASHTO).AreWeThereYet.transportation.org. February 2010

Strayer, D., Drews, F., and Crouch, D. (2006). A Comparison of the Cell Phone Driver and the Drunk Driver. *Human Factors*, Vol. 48, No. 2, Summer 2006, pp. 381-391.

Stutts, J. and Hunter, W. (1999). *Injuries to Pedestrians and Bicyclists – An Analysis Based on Hospital Emergency Department Data* (FHWA-RD-99-078), Federal Highway Administration, Washington, D.C.

*Effectiveness of Antilock Braking Systems in Reducing Motorcycle Fatal Crash Rates.* Insurance Institute for Highway Safety, Arlington, Virginia, January, 2010.

Thompson, R.S.; Rivara, F.P.; and Thompson, D.C. (1989). A Case-Control Study of the Effectiveness of Bicycle Safety Helmets. ***New England Journal of Medicine*** 320:1361-67.

Thompson, R.S.; Rivara, F.P.; and Thompson, D.C. (2006). Helmets for Preventing Head and Facial Injuries in Bicyclists, *The Cochrane Database of Systematic Reviews*, Issue 2.

Transportation Research Board. (2005). Crash reduction factors for traffic engineering and intelligent transportation system (ITS) improvements: State-of-knowledge report. NCHRP Research Results Digest, Number 299. Washington, D.C.: Author.

Turner, S., Sandt, L., Toole, J., Benz, R., & Patten, R. (2006b). FHWA university course on bicycle and pedestrian transportation. (FHWA-HRT-05-133). Washington, D.C.: Federal Highway Administration. Retrieved from http://www.tfhrc.gov/safety/pedbike/pubs/05085/pdf/combinedlo.pdf

U.K. Department of Transportation, *Killing Speed and Saving Lives*, London, 1987.

U.S. Census Bureau. (2006). *United States population estimate 2006*. Washington, DC: Author. Retrieved from http://factfinder.census.gov

U.S. Census Bureau. (2009). *Population estimates: Metropolitan and micropolitan statistical area estimates population change and rankings*. Retrieved from http://www.census.gov/popest/metro/CBSA-est2008-pop-chg.html

U.S. Census Bureau. (2009, March 19). Raleigh and Austin are fastest growing metro areas. *U.S. Census Bureau News*. Washington, DC: United States Department of Commerce. Retrieved from http://www.census.gov/Press-Release/www/releases/archives/population/013426.html

US Department of Transportation. (2008b). Safe routes to school guide. Washington, D.C.: National Highway Transportation Safety Administration, Federal Highway Administration, Centers for Disease Control and Prevention, and Institute of Transportation Engineers. Retrieved from http://www.saferoutesinfo.org/guide/

Van Houten, R., & Malenfant, J.E.L. (2004). Effects of a driver enforcement program on yielding to pedestrians. Journal of Applied Behavior Analysis, 37(3), 351-363. Retrieved from http://dx.doi.org/10.1901/jaba.2004.37-351

Vehicle-miles: 1970-2008: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics (Washington, DC: Annual issue), table VM1, and similar tables in earlier editions, available at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm as of Feb. 17, 2010.

Vermette, E. (2010). *Curbing Distracted Driving: 2010 Survey of State Safety Programs,* Governor's Highway Safety Association, Washington, D.C.

Virginia Governor's Motorcycle Advisory Council http://www.motorcycleva.com/about.cfm

Zegeer, C. V., Henderson, D., Blomberg, R., Marchetti, L., Masten, S. V., Fan, Y., et al. (2008a). Evaluation of the Miami-Dade pedestrian safety demonstration project. (Report No. DOT HS 810 964). Washington, D.C.: National Highway Traffic Safety Administration. Retrieved from http://www.nhtsa.dot.gov/portal/nhtsa_static_file_downloader.jsp?file=/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/810964.pdf

Zegeer, C., Sandt, L., Scully, M., Ronkin, M. Cynecky, M., and Lagerwey, P. Lagerwey (2008). How to develop a pedestrian safety action plan. Washington, D.C.: Federal Highway Safety Administration. Retrieved from: http://www.walkinginfo.org/training/collateral/resources/howtodevelop_guide2008.pdf

Zegeer, C.V., Nabors, D., Gelinne, D., Lefler, N., and Bushell, M. (2010). *FHWA Pedestrian Program Strategic Plan. Draft final report.* Federal Highway Administration, Washington, D.C.

Zegeer, C.V., Stewart, J.R., Huang, H., Lagerwey, P.A., Feagan, J., & Campbell, B. J. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. (FHWA-HRT-04-100). Washington, D.C.: Federal Highway Administration. Retrieved from http://www.tfhrc.gov/safety/pubs/04100/04100.pdf

Zegeer, C.V., Stutts, J., Hunter, B., Pein, W., Feske, D., Cheeney, D., et al. (1994). The National Bicycling and Walking Study, Transportation Choices for a Changing America. Washington, D.C.: Federal Highway Administration. Retrieved from http://www.bicyclinginfo.org/library/details.cfm?id=4311

Zegeer, C.V., Stutts, J.C., & Huang, H. (2004). Guidance for implementation of the AASHTO strategic highway safety plan. Volume 10: A guide for reducing collisions involving pedestrians. NCHRP Report 500. Washington, D.C.: Transportation Research Board. Retrieved from http://gulliver.trb.org/publications/nchrp/nchrp_rpt_500v10.pdf

Zeiman, E. *Cell Phones are Still Driving Us to Distraction*. A report on a recent poll by Harris Interactive for Nationwide Mutual Insurance Company. Information Week, July 2, 1020.