A Review of the Traffic Safety Culture in Europe to Improve Pedestrian Safety in the U.S.: Lessons from France and Sweden

Jean Kim

A thesis
submitted in partial fulfillment of the
requirements for the degree of

Master of Urban Planning

University of Washington
2014

Committee:
Anne Vernez Moudon
Fritz Wagner

Program Authorized to Offer Degree:
College of Built Environments

©Copyright 2014

Jean Kim

University of Washington

ABSTRACT

A Review of the Traffic Safety Culture in Europe to Improve Pedestrian Safety in the U.S.: Lessons from France and Sweden

Jean Kim

Chair of the Supervisory Committee:
Professor Anne Vernez Moudon
Department of Urban Design and Planning

In the U.S., current pedestrian-vehicle crash prevention strategies are mostly focused on engineering interventions rather than measures for preventing unsafe road behavior (i.e. speeding and drunk-driving). This thesis aims to identify factors that affect pedestrian safety and explore how France and Sweden, as examples, have substantially reduced the number of pedestrian fatalities by implementing road safety programs. Based on the review of thirty-five existing studies that examined the factors associated with pedestrian-vehicle crashes, seven critical factors are classified as follows: driver factors, pedestrian factors, vehicle factors, neighborhood level environment factors, street level environment factors, other environment factors, and law/regulation/educational factors. However, the existing literature did not fully address the issues of measures for altering driver behaviors, allocating level of responsibility on road safety, improving built environmental factors, and safety campaigns and educational programs. In order to fill the research gaps, case studies of road safety programs in France and Sweden were conducted. Based on the case reviews, the main lesson for the U.S. is to alter the traffic safety culture of the society.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 | Introduction

For more than a decade, efforts to evaluate the impact of the built environment on human health have been central to the planning field in the United States (Ewing and Dumbaugh 2009). Substantial attention has been devoted to the areas of New Urbanism, Smart Growth, and Active Living (i.e. encouraging walking, biking, or using public transportation) to improve health conditions by increasing physical activity (Dannenberg, Frumkin, and Jackson 2011). However, less attention has been devoted to research focusing on traffic-related injuries and deaths.

According to the 2009 National Household Travel Survey, 10.4 percent of all trips taken in the U.S. were on foot. In the same year, 4,019 pedestrians were killed, accounting for nearly 12 percent of the total traffic fatalities (IRTAD 2011). By some measures, road safety has improved over decades. Traffic fatalities per kilometer of vehicle travel were five times higher in the U.S. in 1950 than today (Transportation Research Board 2011). More recently, the percentage of pedestrian fatalities decreased by 34 percent between 1990 and 2009. However, the probability of a pedestrian being killed in a pedestrian crash[1] (the average number of deaths per crash) significantly increased (NHTSA 2009). The National Pedestrian Crash Report revealed that, in 2009, the crash probability of pedestrians was 1 out of 100 motor vehicle crashes, but the fatality probability of pedestrians was 6 out of 100 pedestrian crashes (NHTSA 2009).

Moreover, according to a 2013 WHO report, between 1995 and 2009, annual traffic fatalities declined by fifty percent in the top fifteen high-income countries (excluding the U.S.), compared to nineteen percent in the United States. Although some states have fatality rates comparable to those nations with safer roads, no state matched the typical speed of improvement in road safety (Transportation Research Board 2011). The gap between safety progress in the U.S. and other high-income countries indicates that the U.S. may need more effective interventions to reduce pedestrian injuries and fatalities.

[1] The pedestrian fatality probability was obtained by the number of pedestrian crash fatalities divided by the total number of pedestrian crashes.

Many studies have found that improvements in physical environments (e.g., road design, area compactness) can successfully reduce transportation-related injuries. Also, many city and state leaders are promoting pedestrian-friendly developments, prioritizing more of their funding to non-motorized transportation infrastructure (Alliance for Biking and Walking 2014). However, crash prevention and safer behavior among road users (e.g., motorists, pedestrians) are becoming more critical, as there are increasing demands to proactively improve safety on roads (Gielen, Sleet, and DiClemente 2006). Rather than superimposing engineering and design solutions to address collisions where they have already occurred, there are now efforts to begin to develop our understanding of how to moderate pre-crash behaviors. Therefore, studies on identifying factors related pedestrian-vehicle collisions and examining the strategies of implementing interventions are needed to predict and to achieve a proper understanding of road injuries.

The principal goal of this research is to address factors that are associated with pedestrian safety and inform professionals of the safety strategies of European countries which could succeed in the U.S. The objectives of the research include: (1) reviewing and synthesizing current pedestrian-vehicle crash research results to identify associated factors; and (2) conducting case studies to examine how France and Sweden implemented pedestrian safety strategies through their road safety programs and explore potential implementations for the U.S. and other countries.

This thesis document began with a literature review of recently published pedestrian safety research to identify factors that are associated with pedestrian road injuries and fatalities, and to examine the gaps in knowledge in the field. Next, case studies of France and Sweden were conducted to identify how European high-income countries have improved pedestrian safety by implementing "traffic safety cultures" and to explore potential implementations for the U.S. or other low- and middle-income countries. Finally, the thesis concludes with a summary of findings and the implications of this research.

CHAPTER 2 | Literature Review

The literature review will include three areas: (1) factors related to pedestrian-vehicle collisions, (2) summary of the literature reviewed, and (3) conclusion of the literature review.

The author conducted a comprehensive literature review in January 2014 to identify key factors and issues discussed in pedestrian safety research. The review included national and international government reports and journal articles from urban planning, public health, transportation, and psychology fields. The author culled her research from the *ScienceDirect* (www.sciencedirect.com), *PubMed* (www.ncbi.nlm.nih.gov/pubmed), *SAGE Journals* (online.sagepub.com), *Transport Research International Documentation* (TRID, trid.trb.org), the University of Washington libraries' database (www.lib.washington.edu), and Google Scholar (scholar.google.com) by using the following key words: vulnerable road users, pedestrian safety, collision, crash, behavior, exposure, motor vehicle injury prevention, driver behavior, driving safety, social, and built environment.

The terms "collision" and "crash" are used throughout this section. These terms are assumed to mean crashes between motorized vehicles and between a pedestrian and a motorized vehicle. Also note that this study did not consider the cases of "exit-vehicle" type pedestrian crashes, in which a pedestrian was formerly a vehicle occupant.

2.1 Factors Related to Pedestrian-Vehicle Collisions

There are many factors associated with pedestrian-vehicle collisions. This paper primarily reviewed Zegeer et al. (2010)'s key factors (Figure 1): that were presented to Federal Highway Administration (FHWA) to develop a Pedestrian Safety Program Strategic Plan. This framework was derived from nearly 200 pedestrian safety studies from 2000 to 2010, including national and international articles published in *Transportation Research Records*, *Accident Analysis and Prevention,* and other transportation-related journals.

Zegeer and his colleagues classified the pedestrian crash factors into five categories: (1) Driver factors; (2) Pedestrian factors; (3) Vehicle factors; (4) Roadway/ Environmental factors; and (4) Demographic/Social/Policy factors. The Roadway/ Environmental factors category contains all the neighborhood (i.e. population characteristics, land use), road level environment factors (i.e. traffic control, path condition), and other factors (i.e. weather, peak time) in one category. Thus, the author decided to expand the existing category into three subcategories (neighborhood environment factors, road environment factors, and other factors) for an in-depth review of literature. Also, the Demographic/ Social/Policy factors were renamed and restructured into Law/Regulation/Education category to clearly state the factors related to pedestrian safety. Therefore, the Zegeer et al.'s five categories were expanded into seven categories (Figure 2): (1) Driver factors; (2) Pedestrian factors; (3) Vehicle factors; (4) Neighborhood environment factors; (5) Road environment factors; (6) Other factors; and (7) Law/Regulation/Education factors.

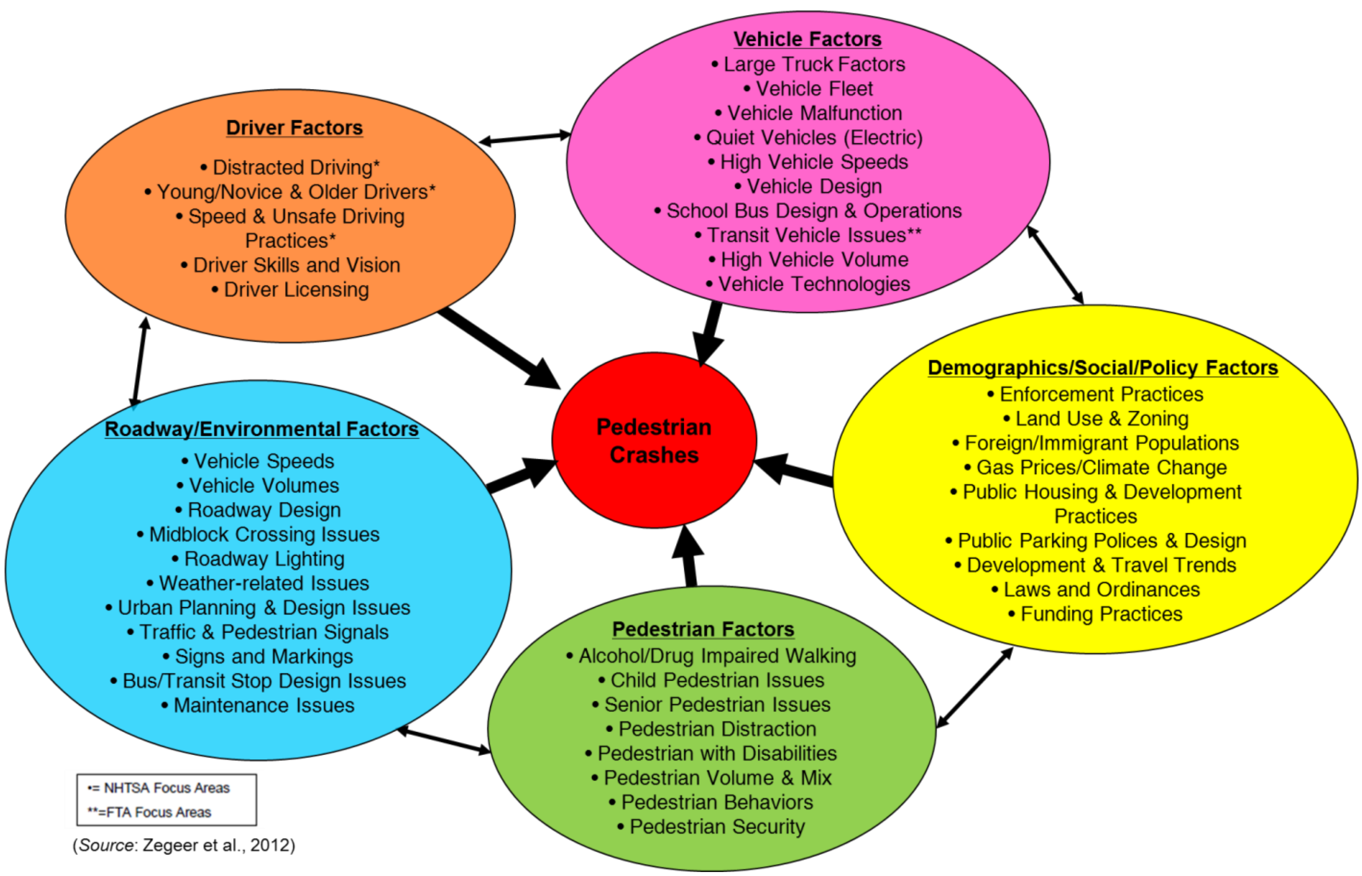


Figure 1 **Zegeer et al.'s illustration of factors associated with pedestrian crash risk, fatality, or severity**

Figure 2 Restructured Zegeer et al. (2012)'s factor framework by the author

2.1.1 Driver Factors

Recent studies have categorized driver behavior as one contributing factor of most pedestrian-vehicle crashes, rather than considering drivers as the sole cause of fatal collisions (Lerner, Singer, and Jennsess 2010). These driver factors are described in detail in the following.

Age

Many studies have analyzed vehicle collision rates in relation to a driver's age (Korner-Bitensky et al. 2009; De Craen et al. 2011; Ehsani et al. 2010). However, few studies have identified how a driver's age is associated with pedestrian-collisions in particular (Korner-Bitensky et al. 2009; Curry et al. 2011).

With regards to older driver groups, Lee and Abdel-Aty (2005) revealed that middle-aged (age 45-64) male drivers were correlated with more pedestrian crashes than other driver groups. This study, however, identified the problem of over-representation of middle-aged drivers in the total driver population. Holland and Hill (2007) found positive safety attitudes of older driver groups (age 60-74 and 75+), yet, there was no significant age effect on pedestrian injury, and the data showed wider variance in risky behavior of older age groups on potential pedestrian crashes than younger groups.

In terms of severity, Kim et al. (2010) observed that pedestrians involved in crashes were more likely to suffer less severe or no injury as drivers were older. The researchers asserted that this is possibly due to the older drivers' (age 65-74 and 75+) greater tendency of hitting pedestrians in low-speed areas (i.e., parking lots, public vehicular areas) compared to their younger counterparts. In contrast, Gaines et al. (2011) and Bao and Boyle (2009) asserted that pedestrian-collisions involving older drivers result from age-related physical deficits, such as loss of flexibility, vision, range of motion, and judgment.

Young (15-20 years old) and novice drivers are major contributors to fatal pedestrian-involved crashes (Chang 2008). According to the 2008 Pedestrian Crash Report, the majority of drivers in fatal pedestrian collisions were young males who were not speeding or drinking. Siddiqui, Chu, and Guttenplan (2003) found that young male drivers, being typically more aggressive, are likely to be involved in more severe pedestrian collisions at crossing locations than other age counterparts. Researchers (Oström and Eriksson 2001) in Sweden also found a large proportion of young male drivers involved in pedestrian crashes.

Gender

In regards to drivers' gender, all of the studies showed similar results: male drivers are more associated with pedestrian-involved collisions than female drivers in terms of injury severity (Siddiqui, Chu, and Guttenplan 2003; Kim et al. 2010), fatality (Oström and Eriksson 2001), and collision frequency (Lee and Abdel-Aty 2005; Nasar and Troyer 2013).

Race

An unfamiliar driving environment, especially for immigrant driver groups, may cause higher collision rates. Surprisingly, only one study among the selected literature tested the impact of driver ethnicity—African American and Hispanic—on pedestrian injury severity, but found no statistical significance (Siddiqui, Chu, and Guttenplan 2003).

Driver Actions

Driver actions during and/or before collisions were found to be significantly related to higher pedestrian-vehicle collision rates and to more severe pedestrian injuries. Moudon et al. (2011) found higher collision frequency when vehicles were making a right or left turn. However, vehicles moving straight were significantly associated with more severe pedestrian injuries and fatalities than when vehicles were making a right turn in both highways and city streets in King County, Washington. They found that this may be caused by faster speeds along the roadway when driving straight than when making left and/or right turns. Also, Kim and his colleagues (2010) found that vehicle maneuvers such as turning, merging, or backing up decrease the probability of fatal injury for pedestrians in pedestrian-vehicle crashes.

Distraction

A limited number of studies have examined the impact of distracted driving on pedestrian collisions. Nasar and Troyer (2013) found an upward trend in mobile phone-related pedestrian injuries (increased from 559 to 1,506 injuries), while the total number of pedestrian injuries decreased (from 97,000 to 41,000) from the year 2004 to 2010 in the United States. The study identified that drivers' action of reaching for the phone accounted for 46.6 percent of the mobile phone use-related pedestrian crashes, followed by talking (37.8 percent) and texting (12.6 percent). Also, a high rate of younger (under 31) and women drivers were associated with pedestrian collisions due to distraction.

While current research has focused on driver distraction while in a vehicle (i.e., personal device use), less attention has been given to external-vehicle distraction sources, such as bright commercial signage and displays, because it is difficult to estimate such impacts on driver's attention levels (Lerner, Singer, and Jenness 2010; Perez et al. 2011). However, it is relatively easy to regulate physical signage systems compared to in-vehicle activities, and more studies are thus needed to find ways to regulate external-vehicle distractions.

Driver Inebriation

A number of laboratory studies revealed that alcohol-impaired driving slows drivers' reaction times, decreases hand steadiness, and reduces acute control (Fillmore, Blackburn, and Harrison 2008; Harrison and Fillmore 2005). In the United States, about 20 percent of vehicle drivers had consumed alcohol when a pedestrian was killed between 1997 and 2006. (Chang 2008).

While most reviewed studies simply found direct effects of drunk-driving on pedestrian injuries or fatalities, one study identified the combined influences of driver inebriation and other factors associated with pedestrian collision frequency. Lee and Abdel-Aty (2005) tested the impact of driver alcohol/drug use and light condition on pedestrian crash frequency. The study suggested that inebriated driving at night leads to more pedestrian crashes than driving with sufficient daylight.

Speeding

According to the 2012 National Survey on Drivers' Behavior and Attitude, speeding remains a common and socially acceptable driving behavior among drivers in the United States (Schroeder, Meyers, and Kostyniuk 2013). Lee and Abdel-Aty (2005), however, confirmed that drivers' speeding behavior increases the severity of pedestrian injury due to the higher impact of crashes. Also, Tefft (2013) found that high-speed impacts increase severe injury and fatality of collided pedestrians. In fact, the risk of death increased 3.2 percent per 1 mph increase when the vehicle speed was between 32.5-48.0 mph, with a 95 percent confidence interval.

In addition, a study conducted in Maine found a close relationship between speeding behavior and the pedestrian crash history of drivers (Gårder 2004). This study revealed that drivers with fatal pedestrian crash histories are likely to drive faster than typical drivers do.

2.1.2 Pedestrian Factors

Many studies have analyzed the wide range of pedestrian-related factors that result in pedestrian-vehicle collisions. The pedestrian factors are described in detail below.

Age

There is a preponderance of evidence showing that young (under age 16) and old (age 65+) pedestrians are more vulnerable on the road than any other age groups. According to the Traffic Safety Facts (NHTSA 2013a), children under age 16 accounted for about 21 percent of the US population, and about 10 percent of pedestrian fatalities are among children under 16. Also, between 1997 and 2006, pedestrians over the age of 64 accounted for 21 percent of pedestrian-fatalities, even though they only comprised 13 percent of the total population.

A study conducted in North Carolina found a close relationship between serious injuries and older pedestrians (Kim et al. 2008). Among 5,808 pedestrian-vehicle collisions, 15.6 percent and 21.8 percent of 65-74 and 75+ age groups were fatally injured in crashes, respectively. The researchers concluded that increased body fragility and the slower responses of older pedestrians are the leading causes of severe injury. Another report suggested that reduced hearing, impaired vision, and contrast sensitivity are important contributors of crashes between a vehicle and an elder pedestrian (Kim et al. 2010). In both studies, the researchers observed a greater range of health conditions among older pedestrians than their younger counterparts, suggesting that pre-collision health conditions may be an important factor that affects the severity of injuries and occurrence of fatalities.

With regards to younger pedestrians, it appears that children's (under 14 years) misjudgment are the main factors of severe injury at intersections (Lee and Abdel-Aty 2005). Moreover, Moudon et al. (2011) found that children under 4 years of age had a significantly increased risk of severe injury or fatality in crashes in crashes occurring on city streets.

Despite the high rate of severe injuries or death in these two age groups, when it comes to comparing injury recovery, children (under age 16) showed an increased likelihood of recovering from injuries in comparison with the older counterparts (age 65+) (Clifton, Burnier, and Akar 2009). Importantly, research examining the association between pedestrian age and collision risk has not specifically focused on very-old (age 85+) pedestrian age group. Since the average age of pedestrians is increasing, it would be crucial to examine this specific age group to improve total pedestrian safety.

Gender

Many studies have examined the substantial role of gender in rates of pedestrian-involved traffic crashes (Christoffel and Gallagher 2006). Males at all ages are at a greater risk of serious injury than women and accounted for 70 percent of collision deaths in the U.S. in 2011 (Chang 2008; Holland and Hill 2007; NHTSA 2013).

Some studies found that males may walk further per trip on average (Zegeer et al. 2010), walk in more dangerous locations (Clifton and Livi 2005), and tend to violate more rules (Rosenbloom 2009) compared to females. Moreover, Reed and Sen (2005) found that senior males are less likely to change their behavior due to pedestrian safety campaign compared to senior females in urban Baltimore City. These findings suggest that the travel behavior of male walkers may increase the risk of collisions themselves.

In terms of injury recovery, male pedestrians, who are more likely to be physically stronger than female walkers, showed a lower rate of sustaining severe injuries (Siddiqui, Chu, and Guttenplan 2003). Unfortunately, this study did not consider the exposure rate of each gender group, which might have impacted the results. All in all, the study results indicate that strategies to improve safe walking behavior among male pedestrians will effectively reduce the collision risk of the total pedestrian population.

Ethnicity

Previous research in this area is sparse. But in general, non-white populations who walk and take public transportation have greater exposure to the dangers of streets with vehicular traffic (Chang 2008).

One study examined the safety-related behavioral differences among seniors (age 65+) in different racial groups in the City of Baltimore (Reed and Sen 2005). The regression analysis in this study revealed that African Americans and Asians residing in urban areas have a higher rate of positive responses regarding safe walking behavior than their Caucasian counterparts. For instance, for the questions asking (1) the level of awareness regarding crossing regulation and/or laws and (2) safer crossing behavior with their grandchildren, more than 10 percent of African Americans and 20 percent of Asians were more likely to respond “yes”. This indicates that the non-white seniors are more aware of pedestrian safety and have higher law compliance attitudes than white urban population.

Another study examined pedestrian crash severity near 163 public schools in the City of Baltimore, Maryland (Clifton and Kreamer-Fults 2007). With regards to the school-age population, the researchers found that the non-white population is significantly and positively associated with higher crash severity. The researchers asserted the need for more equitable planning processes to ensure pedestrian safety among children of color.

Distraction

Both cell phone and headphone use (i.e. listening to music) showed negative impacts on pedestrian safety (Lichenstein et al. 2012a; Hatfield and Murphy 2007). While mobile phones have life-saving effects on safety, allowing people to call for help (Nasar, Hecht, and Wener 2007), life-taking effects may dominate over life-saving effects as pedestrians continue to use cell phones while walking or crossing streets (Loeb and Clarke 2009).

Nasar et al. (2008) observed sixty pedestrians at crosswalks and identified that cell phone use reduces situation awareness and increases unsafe behavior, consequently putting them at a higher collision risk. A later study specified the impact of cell-phone use on pedestrian collision risk, with the finding that talking on the phone (69.5 percent) accounted for more dangerous behavior than texting (9.1 percent) for pedestrians (Nasar and Troyer 2013).

Neider et al. (2010) found that pedestrians who were conversing on a phone took longer to cross the street than pedestrians listening to music with headphones. This study result, however, showed no significant relationship between wearing personal music devices and pedestrian crossing behavior. In contrast, Lichenstein et al. (2012) found that youths (under 18 years) comprised more than a third of 116 cases of pedestrian-vehicle crashes that involved headphone use.

Pedestrian Inebriation

As noted earlier, many studies have measured the effect of alcohol on driver behavior, but some researchers also identified that a substantial proportion of pedestrian deaths and injuries are possibly related to inebriated pedestrians.

Australian researchers Oxley, Lenné, and Corben (2006) tested road-crossing decisions of intoxicated pedestrians (25-35 years old) with a driving simulator. Alcohol substantially interfered with pedestrians' sound judgment and perceptions of safety. Spainhour et al. (2006) identified that drunk pedestrians tended to exercise poor judgment in all pedestrian-related activities (e.g., perceiving approaching vehicles, exhibiting any inhibition in their ability to safely cross a roadway). While both studies showed risky behaviors of inebriated pedestrians, Moudon et al. (2011) found that pedestrian inebriation was a significant factor related to severe injury or death of pedestrians on state highways, but not on city streets in King County, Washington. This indicates that alcohol-impaired walking can exacerbate the severity of pedestrian injury or fatality.

Pedestrian Behavior

Not only the behavior of drivers, but also the behavior of pedestrians contributes to their own safety. A study conducted in Florida identified pedestrian behavior as one contributing factor that significantly impacted pedestrian crashes (Spainhour et al. 2006). Besides pedestrian inebriation (36 percent), pedestrian decision errors (13 percent) (e.g., poor judgment to cross) and perception errors (9 percent) (e.g., does not perceive approaching vehicles) were the most common factors related to collisions that involved pedestrians. With regard to pedestrian decision errors, 19 percent of the crashes happened while pedestrian 'crossing at the intersection' and 10 percent when pedestrian crossing 'not in crosswalk (mid-block crossing)'.

In terms of road-crossing behaviors, Johnston and Peace (2007) examined the differences in the behavior among twelve male pedestrians (18-29 years old) who were familiar and unfamiliar with the direction of approaching vehicles in New Zealand. Their results showed no significant difference in the ratio of unsafe road crossings in familiar and unfamiliar traffic directions. However, the participants who were in unfamiliar environments crossed the road with more caution (e.g., longer waiting time or crossing gaps before crossing the road), and repeated virtual crossing tests have enhanced participants' crossing behaviors. Moreover, all participants reported being comfortable at the end of the experiment. This result shows the immediate effectiveness of road crossing practice and the positive impact of pedestrian training for unfamiliar road settings.

Pedestrian Clothing Type

Little is known about the safety interventions of clothing worn by pedestrians during day and nighttime. Siddiqui, Chu, and Guttenplan (2003) categorized reflective clothing as an indirect determinant to pedestrian injury risk since drivers are more able to see pedestrians with reflective clothing, especially at night. The researchers excluded the effect of pedestrian reflective clothing in their final analysis model to focus on crossing location and light condition attributes.

Other study result runs counter to some strategies of encouraging pedestrians to wear light or reflective clothing. pedestrians wearing dark-colored clothing were found to be at a lower risk of collision and fatality than pedestrians wearing light-colored or mixed clothing (Clifton, Burnier, and Akar 2009). However, this may be due to the fact that 70 percent of the crashes occurred during days or inconsistency in police reporting.

2.1.3 Vehicle Factors

Previous studies have shown that improvements in vehicle design and technology (for both automobiles and trucks) may be more effective at preventing serious pedestrian crashes than other safety devices. However, there is a paucity of studies that have examined the impact of vehicle design on pedestrian safety. Additionally, there is limited research on the impact of motorcycles on pedestrian safety. The vehicle factors affecting pedestrian collisions are described in detail below.

Vehicle Type

The type of vehicle (e.g., sedan, SUV, light truck) involved in pedestrian-vehicle collisions has an impact on the severity of injury sustained. Clifton, Burnier, and Akar (2009) found that collisions involving motorcycles or emergency vehicles result in more severe pedestrian injuries and fatalities than those involving sedan type vehicles due to their higher travel speeds. Moreover, the researchers found that light trucks, vans, and buses were associated with more fatalities than sedans due to heavier vehicle weights. Similarly, one Japanese study found one-box or SUV-type vehicles were more likely to cause severe child pedestrian (under age 13) injuries compared to sedans, but the differences were only significant for head injuries (Kawato et al. 2013). This is because children's heads usually hit straight the front of one-box and SUVs. Therefore, not only vehicle type, but also vehicle design is closely associated with pedestrian injury risk.

Vehicle Design

Some research discovered that certain types of vehicle design exacerbate the severity of pedestrian collisions. According to Retting and Knipling (2010), the raised bonnet design in vehicles helps reduce severe injury and fatality by creating more crush-space between the pedestrian's head and torso. For light trucks and vans, including SUVs, pickup trucks, and vans, pedestrians have a higher probability of serious chest injury than pedestrians colliding with sedans (Lefler and Gabler 2004). Overall, vehicle frontal geometry and impact speed during collision were contributing factors in pedestrian safety.

However, Hitosugi et al. (2013) found no significant difference in the injury severity between child pedestrians who had been hurt in specific body regions (e.g., chest, head) with specific design of vehicles. However, the researchers finally revealed the complexity of determining the factors that affect injuries with child pedestrian collisions because children are in the process of developing mobility behavior and still lack awareness of crash risks.

Vehicle Technology

Enhanced vehicle safety features (e.g., improved side impact protection) and related crash avoidance technologies (e.g., side object detection or night vision enhancement system) are necessary elements to reduce pedestrian fatalities (Retting and Knipling 2010). However, none of the reviewed literature considered improved vehicle technology as one of the factors that help reducing pedestrian injuries or fatalities. Backing Collision Warning system, for example, is effective to help drivers avoid backing into pedestrians by warning and reducing vehicle speeds when a pedestrian is detected.

Most importantly, such improved vehicles should be driven by well-trained drivers, and more studies should examine driver interactions to develop effective instructions for drivers on how to use safety features equipped in vehicles or how drivers should react to warnings.

2.1.4 Neighborhood Level Factors

Many studies have found that the neighborhood built environment is associated with pedestrian-vehicle collision frequency and level of pedestrian injury. However, it is still unclear whether each variable influence pedestrian crash directly or indirectly. The neighborhood-level factors and their impact on pedestrian collisions are presented in the following.

Crashes in Suburban or Rural Neighborhoods

While most crashes involving pedestrians occur in urban areas, rural and suburban areas are known to generate more fatal collisions, generally because of higher vehicle speeds (Ewing and Dumbaugh 2009). Some studies, however, have a different perspective on the cause of pedestrian fatalities in rural areas.

Spainhour et al. (2006) found that 57 percent of the walking-along-road (either with traffic or against traffic) type pedestrian crashes were lacking sidewalks and more than 50 percent of these crashes were happened on suburban roadways in Florida in 2000.

In regard to injury severity, Lee and Abdel-Aty (2005) found that despite the lower collision frequency in rural intersections in Florida (between 1999 and 2002), the severity of pedestrians' injuries were higher in rural than in urban settings. The authors explained that higher vehicle speeds that collided with pedestrians in rural areas increased the severity of pedestrians' injury due to higher crash impacts. The researchers also suggested that relatively fewer medical facilities in rural areas (thus the victims are less likely to receive timely treatment) may have increased the severe pedestrian injury rates.

More specifically, Zajac and Ivan (2003) observed in rural Connecticut that more pedestrian collisions with more severe injuries occurred in low-density residential areas (i.e. downtown fringes) than in compact residential and low-and medium-density commercial areas (i.e. downtowns). The researchers concluded that compact building layouts (e.g., close spacing of residences, closeness to the road) in urban areas may increase driver awareness of pedestrian activity and reduce vehicle speeds, which results in less severe crashes.

Neighborhood Wealth

It is known that lower-income residents rely more on walking for their daily travel mode and are more likely to be involved in severe collisions than high-income residents (Chang 2008). Some studies considered neighborhood wealth as a compound attribute which may interact with other factors such as land use mix and pedestrian exposure rate. Moudon et al. (2011) found a strong association between residential property values and injury severity on city streets: the area with lower property value ($ 68,000-$120,000) was associated with more severe injury risk compared to its counterpart in neighborhood with higher value properties. However, the authors eventually found limitation to confirm a strong association between the neighborhood environment as a whole and injury severity on city streets, since correlation between some variables exists (e.g., correlation between lower neighborhood wealth and low land use mix and higher pedestrian exposure).

In line with previous studies, Noland, Klein, and Tulach (2013) examined the relationship between low-income areas and higher number of pedestrian casualties. However, other factors such as vehicle ownership and population density were correlated with area income and obstructed the precision of the regression analysis.

While the studies focused on identifying the relationship between neighborhood wealth and area collision rates, the relationship between area wealth and youth pedestrian injury is poorly understood. In their study of four California communities, LaScala, Johnson, and Gruenewald (2004) found that higher youth population densities, more unemployment, and a higher percentage of households with annual incomes of less than $20,000 had a direct impact on higher annual pedestrian collision rates than more affluent communities (incomes greater than $60,000). The researchers concluded that lower income households may tend to have no choice but to have their young children (middle-school age) walk to school without an adult accompanying them, which can result in greater exposure and collision risks. Also, children in low-income households tend to use public transit more often, which usually includes walking both to- and from the transit stop (Johnson et al. 2004).

Development Patterns

Area or population density is one of the easiest variables to measure from census and other available data (Forsyth et al. 2007). Also, area density plays an important role in planning regulation. However, findings among studies are inconsistent and closer examination of neighborhood characteristics is needed to understand the results.

Interestingly, Cho, Rodríguez, and Khattak (2009) examined the relationship between residents' perception of neighborhood crash risk and actual collision risks to predict potential crashes in Montgomery County in Washington D.C. The researchers revealed that residents of lower-density non-mixed neighborhood are more likely to perceive their neighborhood as dangerous, compared to the counterparts living in higher-density mixed-use area. Finally, this study found that low-density and non-mixed land uses increase residents' perception of crash risk, and the increased risk awareness reduces actual crash rates as a result of behavioral changes of the residents.

With regards to residential density in particular, only Moudon et al. (2011) tested the association with pedestrian injury risk. They found that residential density significantly increased the severity of pedestrian injury and death only on city streets, but not on state highways.

Other studies examined the association between population density and collision rates, and found conflicting results. Clifton, Burnier, and Akar (2009) found no significant association between area population density and pedestrian injury severity. However, Clifton and Kreamer-Fults (2007) found that population density adjacent to elementary schools is significantly associated with pedestrian collision risk and severity, meaning that high numbers of people can generate high collision rates near schools.

In contrast, Ewing and Dumbaugh (2009) discovered an association between high population density and low pedestrian casualties. The researchers argued that, while control the socio-demographic differences across the metropolitan areas, sprawled Sunbelt Metro environments (e.g., Orlando, Memphis, and Atlanta) generate higher collision risks. Whereas, higher density, finer mix, and more centered development patterns generate fewer highway fatalities per capita.

Employment Density

Noland, Klein, and Tulach (2013) found that higher employment densities consistently lead to more pedestrian-vehicle casualties in New Jersey. They found that higher employment density was associated with higher pedestrian casualties.

Employment density is also often used as "proxy" variables to predict pedestrian activity. One Los Angeles study used population and employment density as proxy variables for pedestrian exposure and found significant impacts on pedestrian collision density (Loukaitou-Sideris, Liggett, and Sung 2007a).

Commuting Behaviors

Commuting via walking was not a significant predictor of pedestrian activity in the U.S., while employee population was a significant proxy variable for pedestrian activity in a multivariate model at a census tract level in San Francisco (Wier et al. 2009). About a 15 percent increase in area employee population predicted a 3 percent increase in pedestrian-vehicle collision rates. Correspondingly, Ukkusuri et al. (2012) found that transit ridership (explained as a proportion of commuters who travel to work by transit or non-motorized modes) was directly linked to collision frequency and pedestrian fatality rate. This is because transit supply and demand were the major determinants of pedestrian activity.

Land Use Mix

The current literature is replete with identifying the relationships between area diversity (i.e. the number of different land uses in an area) and pedestrian safety (Ewing and Dumbaugh 2009): more pedestrian crashes in more dense mixed-use developments. In contrast, when it comes to measure the association between the mixture of land uses and perceived collision risk, it was not the case (Cho, Rodríguez, and Khattak 2009). Residents in neighborhoods with diverse land use types were more likely to perceive the environment as safer than their counterparts in neighborhoods dominated by monotonous land use patterns. However, the researchers found higher actual collision risks in areas with more diverse land uses.

Commercial Land Use

Commercial land uses frequently showed more pedestrian crashes compared to other land use types. Three studies that were conducted in large urban areas confirmed the significant impact of commercial areas on not only pedestrian collision rates but also fatality (Wier et al. 2009; Ukkusuri et al. 2012; Kim et al. 2008). However, some studies showed opposite results. For example, one Canadian study found that commercial land use significantly increase pedestrian activity and thus, increase the risk of pedestrian crash frequency (Miranda-Moreno, Morency, and El-Geneidy 2011). The study also shows that commercial land use and the number of bus stops were related to pedestrian activity: each variable was highly correlated with pedestrian volume. This result implies that not a single land use factor, but rather combined built environment factors (e.g., a bus stop at commercial area), may have a stronger impact on reducing pedestrian collision risks.

Moreover, Zajac and Ivan (2003) found low injury severity in low- and medium-density commercial areas. They concluded that drivers may travel at lower speeds in commercial areas due to more commercial attractions and number of driveways.

Other studies examined specific uses, such as restaurants and liquor stores, to identify the precise impact of commercial areas on pedestrian safety. Moudon et al. (2011) found that as the number of restaurants (within a 0.5 km or 0.3 mile buffer of a collision) increases, the rate of severe injury increase on city streets. LaScala, Johnson, and Gruenewald (2001) found that more alcohol-involved pedestrian injuries observed in areas with greater concentrations of retail alcohol outlets (i.e. bars, restaurants, supermarkets, convenience stores, and liquor stores).

Residential Use

Ukkusuri et al. (2012) found that a higher proportion of residential land use in the City of New York significantly reduces the likelihood of pedestrian crashes, whereas it is insignificant for fatality. The finding shows that residential land use may be associated with lower speed limits and less pedestrian activities when compared to other land use types, such as retail uses.

Interestingly, Zajac and Ivan (2003) predicted how specific area characteristics, such as housing setback, availability of sidewalks, or building arrangement, impact pedestrian crashes in residential zones. They found that compact residential areas are safer than downtown fringe and rural areas (Table 1). This implies that close spacing of housings and proximity to the road (lesser setback) may increase the driver awareness of pedestrians and reduce vehicle speeds. In other words, drivers may drive with more caution in compact residential zones.

Area Type	Description
Downtown	Areas that are characterized by larger buildings abutting one another and abutting sidewalks.
Compact residential	Areas that predominantly have houses close together and these houses are generally visible from the road. Most often there are sidewalks.
Village	Areas that consist of smaller buildings and residences set back from the road. Sidewalks may or may not be present.
Downtown fringe	Areas that are similar to village areas, but are slightly more developed and are located within close proximity to downtown areas.
Medium-density commercial	Areas that consist almost entirely of commercial development, often with sidewalks. This area type includes commercial attractions such as gas stations, fast food outlets, and supermarkets.
Low-density commercial	Areas that have lower density commercial development than that of medium-density commercial areas, and residences are more common.
Low-density residential	Areas that have houses that are spaced far apart and are often not visible from the road. Sidewalks are rare in these areas.

Table 1 **The definition of seven area types used in article. (*Source*: Zajac and Ivan, 2003, 370)**

School

In many studies, school locations contributed to high pedestrian collision rates, but did not affect injury severity or fatalities (Ukkusuri et al. 2012; Clifton, Burnier, and Akar 2009; Wier et al. 2009; LaScala, Gruenewald, and Johnson 2004). LaScala, Gruenewald, and Johnson (2004) found that the number of schools in a given area (within four communities in California) associated with more injury collisions of the youth population. Schools in this study were a stable geographic areas that associated with complex and congested traffic patterns with less experienced young pedestrians.

Moudon et al. (2011) examined the association between schools (elementary and middle school) and injury severity, and the association was not significant. The authors suggested that lower vehicle speed limits in school zones may reduce the severity of injuries.

Interestingly, the presence of recreational facilities (i.e. playgrounds, courts, or fields) near schools were found to be significantly associated with both pedestrian crash occurrence and injury severity in Baltimore City, Maryland (Clifton and Kreamer-Fults 2007). The researchers suggested that recreational facilities might attract large numbers of younger children who are highly vulnerable on the roads during or after school times.

2.1.5 Road Level Factors

While recent literature indicates that modifications in the built environment can considerably decrease pedestrian collisions, there has been little research on how and what design elements influence pedestrian and driver pre-crash behavior to reduce injury risk. These road level factors are described below.

Road Width

A number of recent studies have found that eliminating lanes, significantly improved pedestrian safety. Wider roads, which allow higher vehicle speeds, are presumed to be more forgiving of driver error and lead to more severe injuries of both drivers and pedestrians (Ewing and Dumbaugh 2009). Likewise, Zajac and Ivan (2003) found that roadway width significantly associated with severe injuries of pedestrians who are struck while crossing the road, since roadway width affects vehicle speeds: wider road allows higher vehicle speeds than narrow roads.

Dumbaugh (2005), however, identified that it is not narrower lanes that reduce injury risk solely by themselves, but that other combined design elements (e.g., trees or aesthetic streetscapes) may alleviate the pedestrian fatality. In addition, Gårder (2004) found a strong opposition to very narrow streets among the general population in Maine. Other road environment interventions, such as more street trees or safety-focused roadside design, should be investigated to foster positive attitudes among road users toward street environments that are effective at reducing vehicle speeds.

Road Type

As mentioned above, higher speed roads are associated with more fatal pedestrian injury risk. Kim et al. (2008) reported that while two-way divided roads in North Carolina have better geometric design (e.g., curve, level) than one-way or two-way undivided roads, pedestrians are more likely to receive fatal injuries when pedestrian-vehicle collisions happen on divided roads, mostly due to higher vehicle speeds.

Similarly, a study conducted in Florida found more pedestrian collision records on undivided roads with more lanes than divided roads with fewer lanes (Lee and Abdel-Aty 2005). The result shows that the road type influences vehicle speeds and has potential impacts on the severity of pedestrian injury. However, the studies did not consider the safety benefits of medians on divided roads: the width, visibility, or height of the medians may influence pedestrian safety (Ewing and Dumbaugh 2009).

In regard to road level, Moudon et al. (2011) found mixed results for state routes and city streets in King County, Washington. The risk of being severely injured or dying was significantly high at intersections without signals on state routes, but not on city streets. Also, the researchers found that the number of inebriated pedestrians significantly increased the risk of severe injury or fatality on state routes, while only inebriated drivers significantly associated with severe injury or death on city streets.

Presence of Parking Spaces

Zajac and Ivan (2003) found a weak association between on-street parking and pedestrian injury, despite the fast vehicle speeds when pulling in and out of parking spaces in parking areas.

In North Carolina from 1997 to 2000, a significant number of senior (age over 65) pedestrians were struck on off-street parking (or parking lots) compared to their younger counterparts (Kim et al. 2010). Therefore, more special consideration is needed for the elderly age group.

With regards to younger pedestrians, there was no significant impact of parking lots located in public schools on young pedestrian collision frequency (Clifton and Kreamer-Fults 2007). The author states that school parking lot is not a relevant place to examine safety issues since it is not a place where children often get dropped off or picked up. In contrast, parking lots in recreational facilities (e.g., playgrounds, pools, or tracks) near schools might be associated with child collisions because children often get dropped off or on at parking lots near these facilities.

Intersections

The vast majority of pedestrian crashes are at intersections. According to the 2011 Pedestrian Safety Facts (National Highway Traffic Safety Administration 2013), 19 percent of pedestrians were killed intersections in the U.S. Also, several studies have shown that near intersections, the crash frequencies were prevalent because of the high volume of vehicles, yet pedestrian injuries were less severe (Ewing and Dumbaugh 2009). However, this finding was not generalizable for all road classes. Moudon et al. (2011) found significantly higher pedestrian fatalities and injury severity at intersections without signals in state routes, though this finding was not significant in city streets.

Some studies have identified the safety impact of intersection location. Loukaitou-Sideris, Liggett, and Sung (2007) examined the micro-environment of collision-prone intersections in Los Angeles. They found that most of the high collision intersections were those at the end of long blocks, with narrow sidewalks, multiple driveways, locations in commercial areas, and multiple visual impairments (e.g., a bus standing near intersections) for both pedestrians and motorists.

Siddiqui and his colleagues identified the stronger effect of lighting, including both daylight and street lighting, at intersections compared to midblock locations (Siddiqui, Chu, and Guttenplan 2003). The probability of pedestrian fatality was lower at intersections with better lighting conditions. It appears that there might be a combined effect of intersection location and other environmental factors that needs to be considered.

Presence of Streetlights

Dark roads impair both driver and pedestrian visibility and consequently increase collision risks. For instance, darkness may lead to more severe crashes by reducing drivers' and pedestrians' abilities to notice each other.

In terms of pedestrian fatality, streetlights reduced the probability of fatal injuries by 5.5 percent at mid-block locations and by 7.3 percent at intersections in Florida between 1986 and 2003 (Siddiqui, Chu, and Guttenplan 2003). Kim et al. (2008) also found that darkness (without streetlights) leads to a significant increase in the probabilities of pedestrian fatality (148 percent) and incapacitating injury (338.1 percent) in North Carolina between 1997 and 2000. Surprisingly, this study found that 42 percent of total pedestrian-involved crashes occurred under dark conditions.

However, none of the studies have evaluated detailed information of streetlights (i.e., quantity or quality of the light). Also, other variables (e.g., pedestrian position on the road, clothing reflectance, and weather) may play a significant role in the visibility of pedestrians at night (Spainhour et al. 2006). Therefore, the results may have problems in generalizing the collision issues, and researchers should examine the precise impact of streetlights on pedestrians' and drivers' visibility.

Presence of Traffic Signals

Traffic signals are one of the most common traffic control strategies. Kim et al. (2010) have found that traffic signals decreased fatal pedestrian injuries by 34 percent. This result implies that both pedestrians and drivers respect traffic signals, leading to a safer walking environment.

In contrast, signalized crosswalks were more dangerous than un-signalized crosswalks in varying environments throughout Maine (Gårder 2004). The researchers discovered more frequent pedestrian crash records (6 crashes) at signalized crosswalks compared to uncontrolled crosswalks (16 crashes) between 1994 and 1998.

Interestingly, Spainhour et al. (2006) have identified indirect effects of the location of traffic signals on pedestrian collisions. They have found that the distance from the crossing points to the nearest traffic signals influences pedestrians' crossing behaviors at midblock (non-crosswalk) location. Forty seven percent of the midblock crossings occurred within 600 feet of a signalized intersection where the signal was clearly visible at night, thus the pedestrians regarded their crossing choice as a safe choice. The study also revealed that elderly pedestrians (mean age 79.8) accounted for the majority of collisions that occurred near signal intersections. The researchers concluded that the slow walking speed of older pedestrians at signalized crossings was one of the contributing factors, followed by the ability to make decisions.

Presence of Bus Stops

Generally, bus stops generate larger pedestrian volumes and thus, expect to generate higher risks of pedestrian collisions. In contrast, Clifton, Burnier, and Akar (2009) found that an increased number of bus stops (within 1/4 mile buffer from each crash area) is negatively and significantly associated with severe pedestrian injuries in Baltimore City. The researchers found that the likelihood of less severe injuries in the study area may be due to slower vehicle speeds or better lighting conditions.

Other factors can also lead to higher risks of pedestrian crashes near transit stops. Loukaitou-Sideris, Liggett, and Sung (2007) found that standing buses on the road act as a visual impairment for both pedestrians and motorists and thus, increase the risk of pedestrian-vehicle collisions at bus stops. Furthermore, Miranda-Moreno, Morency, and El-Geneidy (2011) discovered a strong correlation between commercial areas and the number of bus stops on pedestrian activity and crashes. The findings suggest the need for urgent improvements of transit stops (e.g., safety focused transit stop design) near commercial areas.

Road Conditions

Studies by DiMaggio and Durkin (2002) and Zajac and Ivan (2003) have found that the condition of paths did not appear to have significant impacts on pedestrian safety. In terms of road surface, wet or snowy surfaces were not associated with pedestrian injury risks in urban settings. Moreover, other researchers identified that path materials (Cho, Rodríguez, and Khattak 2009) and markings on crosswalks (Gårder 2004) were insignificant in explaining the pedestrian collision rates.

2.1.6 Other Environmental Factors

Many studies discovered that individual behaviors on the road were frequently affected by environmental factors. These environmental factors are presented below.

Weather

While weather conditions may affect road condition, some researchers found that adverse weather conditions (i.e. rain, snow, or fog) do not have a significant effect on pedestrian-vehicle crashes (DiMaggio and Durkin 2002; Gårder 2004). Also, approximately 89 percent of pedestrian deaths occurred in the U.S. when there were no adverse weather conditions (NHTSA 2013).

Daylight

Daylight is an important environmental factor that affects pedestrian collisions indirectly. In 2011, more than 70 percent of pedestrian deaths occurred at nighttime when the light condition was dark or insufficient (NHTSA 2013). Kim et al. (2010) confirmed that darkness, whether with or without street lights, significantly increased the probability of pedestrian fatal injury and incapacitating injury (137 percent and 325 percent respectively). The researchers concluded that driver's ability to notice pedestrians in reduced by darkness, which can lead to drivers braking later leading to greater severity if a crash occurs. Moudon et al. (2011) also found that dark road conditions significantly increased the risk of severe pedestrian injuries and fatalities in city street models.

Siddiqui, Chu, and Guttenplan (2003) examined the role of crossing locations and daylight conditions in the severity of pedestrian injuries. The empirical results showed that daylight significantly reduces the probability of a fatal pedestrian injury by 10 percent at mid-blocks and 12 percent at intersections. Based on the 1986-2003 crash data in Florida, it is likely that less pedestrian collisions occurred under the circumstance of daylight than street-lights. Therefore, road users should be aware and walk and drive more cautiously during nighttime.

2.1.7 Laws/Regulations/Education Programs

To date, numerous studies have been conducted to identify the impact of alcohol consumption and speed limit on pedestrian-vehicle collisions. Only a few studies examined the impact of such regulations on pedestrian collisions. These laws and regulations are detailed in the following.

Alcohol Enforcement

Loeb and Clarke (2009) examined the influence of State Blood Alcohol Consumption (BAC) laws on pedestrian deaths in the U.S. They found a positive and highly significant impact of BAC legislation on collision fatalities. This indicates that more stringent BAC limits will considerably reduce pedestrian fatalities related to alcohol-impaired drivers.

Speed Limit

Since information on collision speed is difficult to collect for pedestrian crashes, some studies used posted speed limit as a predictor variable for vehicle moving speeds (Siddiqui, Chu, and Guttenplan, 2003). Zajac and Ivan (2003) also used speed limits as one of the proxy variables to evaluate the impact of vehicle speeds on pedestrian injury severity. In their study in rural Connecticut, they found that the speed limit does not significantly influence injury severity. This result may imply that drivers in rural areas are likely to violate speed limits.

According to the 2013 Traffic Safety Culture Index survey (AAA Foundation, 2014), more than 40 percent of drivers said they have violated the speed limit on freeways (42.1 percent) or residential streets (44.5 percent). As has been widely noted, vehicle impact speed can highly impact serious pedestrian injury. Therefore, it is urgent to regulate speeding behavior more stringently to reduce pedestrian severe injuries and fatalities on the road.

Safety Campaigns

The impact of safety campaigns on behavior change was tested in only one study (Reed and Sen 2005). Approximately 25 percent of a sample group of older urban pedestrians residing in Baltimore City reported that they modified their behavior due to public safety campaigns.

In terms of campaign type, there were large differences among demographic groups: while 41 percent of the general population reported that TV advertisements are most effective at altering behavior, African American groups preferred billboard campaigns (25 percent) and Caucasians supported fines (34 percent). Since safety campaigns showed the possibility of improving urban senior pedestrian behaviors, further efforts to implement campaign strategies that are appropriate for different racial groups will help reduce pedestrian collisions more effectively.

Safety Education

According to Gårder (2004), engineering combined with education and enforcement is the most effective way to improve pedestrian safety.

One study evaluated the effects of two different types of Road Safety Education (RSE) program (Table 2) for 1,874 young adolescent pedestrians and cyclists (Twisk et al. 2014): (1) 'Cognitive' programs that aim to deter youngsters from taking risk by improving their understandings of road safety; and (2) 'Fear-Appeal' program that aim to deter participants from taking risks by eliciting fear. According to the study, 'Traffic Market', 'Driver Instructors in School', and 'Victim Aid' programs significantly improved self-reported safety behaviors. About 58 percent of the program participants changed their behavior in desired direction and the Fear-Appeal programs yielded a slightly higher percentage of participants improving their behavior than did the Cognitive programs. The finding implies the need for evidence-based interventions to develop effective safety education programs for the non-motorized youth population.

RSE Program		Description
Cognitive programs	**Traffic Market** (age group 12-13)	This program was a one-day course that aimed to raise awareness of risky behavior, to improve understanding of hazards, to stimulate empathy and the ability to "put oneself in another person's shoes". • Experiencing the influence of alcohol on stability by wearing 'alcohol goggles' • Watching a traffic situation from another person's perspective
	Traffic Education for Young Adolescents (age group 12-13)	This program consisted of three lessons of 50 minutes each. Targeting pupils who had just started secondary school, it aimed to improve risk awareness and behavioral intentions with the aid of interactive materials (i.e., a traffic quiz) and videos. • 'Music player test' to raise awareness of the risks of listening to music when on the road • A test of the technical status of the bicycles, including safety features such as working brakes and bicycle lights.
	Driver Instructors in School (age group 12-13)	This program consisted of two lessons of 50 minutes each. From the perspective of car drivers, driver instructors educated youngsters in their first years of secondary school about dangerous cycling behavior. • The driver instructors had received special training for delivering the programs for this age group.
Fear-Appeal programs	**Traffic Informers** (age group 15-25)	In this half-day program, youngsters who had sustained injuries in a road crash and still suffered the consequences in terms of visible injuries and disabilities, spoke about their crashes and how the injuries affected their lives.
	Victim Aid (age group 15-18)	This half-day program focused on the long term and far-reaching consequences of unsafe behavior. The coordinator of the local Victim Aid organization gave an introduction, and further supported message with pictures from crashes, emotionally-loaded videos, and testimonies from victims and their relatives. • No practical exercises were involved in this program

Table 2 **Classification and descriptions of Road Safety Education program interventions (Source: Twisk et al. 2014, 26)**

2.2 Summary of Literature Review

Driver Factors

- Only a limited number of studies examined driver factors compared to the studies that tested pedestrian factors on pedestrian-vehicle collisions.
- A few studies have identified how **driver age** is associated with pedestrian involved collisions (Korner-Bitensky et al. 2009; Curry et al. 2011). There is evidence that young drivers are involved in more crashes.
- **Male drivers** are more likely to be associated with pedestrian injury severity (Siddiqui, Chu, and Guttenplan 2003; Kim et al. 2010), fatality (Öström and Eriksson 2001), and collision (Lee and Abdel-Aty 2005; Nasar and Troyer 2013), partially due to their aggressive driving behavior.
- Only one study examined the impact of driver's **ethnicity**, and there was no significant impact of unfamiliar driving environment on collision rates (Siddiqui, Chu, and Guttenplan 2003).
- **Driver actions during collisions** (i.e., right and left turn, backing) were found to be a significant factor that affect severe and fatal pedestrian injuries (Moudon et al. 2011; Kim et al. 2010).
- A limited number of studies has examined the impact of **distracted driving** on pedestrian collisions: more basic changes in social norms (i.e. considering phone use as socially unacceptable behavior) are required to reduce possible crashes.
- **Drunk-driving** is a key element in pedestrian crashes and have combined factors (i.e., driver inebriety at nighttime, youth drivers' alcohol consumption) on crashes involving pedestrians.
- **Speeding** is another key element in severe injuries following pedestrian crashes, but still remains a common and socially acceptable driving behavior (Schroeder, Meyers, and Kostyniuk 2013).

Pedestrian Factors

- **Young and old pedestrians** are disproportionately at risk of severe injury and fatality.
- **Male pedestrians** at all ages tend to violate more rules (Rosenbloom 2009) compared to their female counterparts.
- **African American and Asian seniors** showed a higher rate of pedestrian safety awareness and better attitudes towards compliance with the law than their Caucasian counterparts in Baltimore City (Reed and Sen 2005).
- It is important to reduce **distracted walking behaviors** (e.g., cell phone use, headphone use) of young pedestrians.
- **Alcohol-impaired walking** increases the likelihood of severe and fatal pedestrian injuries (Spainhour et al. 2006; Moudon et al. 2011).
- There was no significant difference in the proportion of **unsafe road crossing behaviors** in the familiar and unfamiliar environments (Johnston and Peace 2007).

- The safety impact of pedestrian **clothing** color is mixed (Siddiqui, Chu, and Guttenplan 2003; Clifton, Burnier, and Akar 2009)

Vehicle Factors

- A paucity of studies have examined the impact of **vehicle design** and **motorcycle** type on pedestrian safety in particular.
- **Heavy vehicles**, such as Trucks, vans, and buses, are associated with more fatalities than sedan type vehicles (Kawato et al. 2013).
- Vehicles' **frontal geometry** and **impact speed** during collision were the contributing factors in pedestrian safety in general (Retting and Knipling 2010; Lefler and Gabler 2004). However, the design was not a significant factors related to child pedestrian collisions (Hitosugi et al. 2013b).
- Although the **crash avoidance technologies** (e.g., alcohol detection and interlock, night vision enhancement system) of current vehicles can reduce pedestrian involved crashes, more studies should examine driver interactions with such technologies to develop effective driver instructions on how to control or react to warnings, for instance.

Neighborhood Level Factors

- Risk of collision and severe injury are related to neighborhoods with **different characteristics** (i.e., lower-income, higher-density, more mixed-uses).
- Studies have found **combined effects** of built environmental factors on pedestrian-vehicle collision at a neighborhood-wide (e.g., census tract) level.
- In **suburban or rural areas**, even though the frequency of pedestrian collisions are lower, the severity of pedestrian injuries are higher than the injuries occur in urban areas due to the higher vehicle speeds in suburban or rural areas (Lee and Abdel-Aty 2005).
- To reduce pedestrian fatality rates more effectively, **employment density** in low income areas should be considered as an important factor that affects pedestrian collisions.
- The characteristics of **transit supply and demand** in neighborhoods are major determinants of pedestrian activity, which consequently increases pedestrian exposure risk.
- The residents in neighborhoods with **diverse land use types** (land use mix) were more likely to perceive the environment as safer than their counterparts living in neighborhoods dominated by monotonous land use pattern (Cho, Rodríguez, and Khattak 2009). The researchers found higher actual collision risks in areas with diverse land uses.
- There is a need to examine specific uses, such as **restaurants and liquor stores**, to identify the precise impact of commercial areas on pedestrian safety (Moudon et al. 2011; Clifton and Kreamer-Fults 2007). Moreover, examinations of current residential designs and types may help planners develop safety tools.
- A **school location** is often associated with higher pedestrian collision risks. More attention on diverse areas where school-age children walk and play will help reduce crash occurrence and injury severity.

Road Level Factors

- **Wider roads**, which allow higher vehicle speeds lead to more severe injuries (Zajac and Ivan 2003).
- Pedestrians are more likely to suffer from fatal injury on higher speed roads (Lee and Abdel-Aty 2005).
- Few studies have examined collision risks among older and younger pedestrian groups in **parking spaces** (Kim et al. 2010; Clifton and Kreamer-Fults 2007).
- Near **intersections**, the crash frequencies were prevalent because of the high volume of vehicles; however, the pedestrian injuries were less severe (Ewing and Dumbaugh 2009).
- **Darkness** may lead to more severe crashes by reducing drivers' and pedestrians' ability to notice each other. **Streetlights** reduce the probability of fatal pedestrian injuries (Kim et al. 2008), however, the effect of streetlights is smaller than the effect of daylight on reducing pedestrian crashes (Siddiqui, Chu, and Guttenplan 2003).
- The presence of **traffic signals** lowers the risk of collisions. It is not a sole factor that influences pedestrian safety (Spainhour et al. 2006). The characteristics of collision site, crosswalk location, and pedestrian and driver behaviors may also be associated.
- Generally, **bus stops** generate larger pedestrian volumes and thus, expect to generate higher risks of pedestrian collisions, however, one study that conducted at lower speed areas shows the counter results (Clifton, Burnier, and Akar 2009).
- Road condition (i.e., surface condition, material, markings) has little impact on pedestrian crashes (DiMaggio and Durkin 2002; Zajac and Ivan 2003)

Other Environmental Factors

- While **weather conditions** may affect road condition, some researchers found that adverse weather conditions (e.g., rain, snow, or fog) do not have a significant effect on pedestrian-vehicle crashes (DiMaggio and Durkin 2002; Gårder 2004).
- **Daylight** is an important environmental factor that affects pedestrian collisions indirectly. Road users should be aware and walk and drive more cautiously during nighttime.

Laws/Regulations/Education Programs

- To date, only a few studies have examined the impact of **regulations** (e.g., Blood Alcohol Concentration laws, speed limits) **on pedestrian-involved collisions**.
- Regulatory strategies on **reducing alcohol consumption** of **all road users**, including pedestrians, should be emphasized.
- It is urgent to regulate **drivers' speeding behavior** more stringently to reduce pedestrian severe injuries and fatalities on the road.
- Safety campaigns improved urban senior pedestrian behaviors (Reed and Sen 2005). Further effort to implement **campaign strategies** that are appropriate for different racial groups is needed.
- Evidence-based interventions to develop effective **safety education programs** for the non-motorized youth population is needed (Twisk et al. 2014).

2.3 Conclusion

The literature review points towards several findings in pedestrian safety research: more investigations and proactive actions are needed for seven categories—driver factors, pedestrian factors, vehicle factors, neighborhood level factors, road level factors, other environmental factors, and laws, regulations and education factors—that have potential impacts on pedestrian-vehicle collisions.

The findings of the literature review are presented in the following by each factor category:

Driver Factors

- Only a limited number of studies examined driver factors, compared to the studies that tested pedestrian factors on pedestrian-vehicle collisions.
- *Age:* given the complexity of current study results, more studies should be conducted to identify the impact of older and younger drivers on pedestrian crashes and to test the factors that are related to more frequent and severe pedestrian collisions in order to develop safety driving skills for both age groups.
- *Distraction:* as noted by various researchers (Caird et al. 2008; Atchley, Atwood, and Boulton 2011), many drivers are unwilling to modify their multi-tasking behavior, even though they consider the behavior as a significant safety problem. Therefore, more basic changes in social norms (e.g., considering phone use while driving as a socially unacceptable behavior) are required to reduce possible crashes.
- *Driver Inebriation:* based on the selected literature, more research on alcohol-induced pedestrian collisions was found than on drug-induced collisions, even though driving under the influence of drugs (for both illegal and prescription drugs) may result in higher pedestrian crash rates. Also, the impacts of alcohol- and drug-impaired driving on vehicle-pedestrian collisions are complicated. More studies examining the combined effects of impaired driving should thus be conducted. For instance, it is important to understand how multiple driver actions, such as inebriated driving and drowsy driving, interact and affect pedestrian safety.
- *Speeding:* it is imperative to conduct further studies focused on changing and improving driver awareness in order to develop both short- and long-term strategies for pedestrian safety.

Pedestrian Factors

- *Age*: since the average age of pedestrians is increasing, it is important to study the very old (85+) pedestrian group.

- *Pedestrian Ethnicity:* the immigrant population in the United States is growing, and there will likely be a noticeable change in travel patterns (e.g., more walking and higher demand of public transit service). According to the U.S. Census Bureau report (2012), Asians were the nation's fastest growing ethnic group (2.6 percent growth per year), followed by the Hispanics (2.2 percent growth per year). Moreover, the number of elementary school-aged children of these racial groups is also increasing rapidly. Therefore, studies that examine the racial differences in attitudes toward transportation safety and age-specific safety interventions are imperative.

- *Pedestrian distraction*: it is important to improve the safety behavior of young pedestrians with such devices since they limit their ability to react to change in dangerous situations (Walker et al. 2012).

- *Pedestrian inebriation:* further study should be conducted with multiple street classes to test the impact of pedestrian inebriety in different road settings.

Vehicle Factors

- *Vehicle design*: none of the studies showed a direct correlation between vehicle design and a level of pedestrian collision severity. Rather, all reviewed studies showed a potential increase in pedestrian protection by modifying vehicle design.

Neighborhood Level Factors

- *Neighborhood wealth:* to reduce the injury disparities among low-income young pedestrians, greater focus on diverse strategies such as improving environmental inequalities in lower-income areas is needed.

- *Crashes in Suburban or Rural Areas:* findings indicate that various speed-reducing interventions, such as narrowing road width or improving driver awareness, should be implemented in rural areas to decrease the rate of severe pedestrian injuries.

- *Employment Density:* in order to more effectively reduce pedestrian fatality rates, future research should consider employment density in low-income areas as an important factor that affects pedestrian-involved collisions.

- *Commuting Behaviors:* previous studies have found that transit supply and demand in neighborhoods are major determinants of pedestrian activity, which consequently affects pedestrian exposure risk (Ukkusuri et al. 2012). Given that current transportation plans encourage walking as a healthy travel mode, employer-based safety walking programs can help reduce road injuries and fatalities.

- *Development Patterns:* more populated and more mixed areas need more attention to reduce pedestrian-vehicle crashes. Specifically, previous studies indicate that different pedestrian safety interventions (e.g., increasing safety awareness for more dense neighborhoods) should be developed for neighborhoods with different characteristics.
- *Residential use:* future work should focus on closer examinations of residential land-use (e.g., residential designs and types) to help develop safety tools for planners.
- *School:* a school location is often associated with higher concentration of vulnerable child pedestrians than other land uses. Devoting more attention to diverse areas, where school-age children and youth live, walk, and play, will help reduce crash occurrence and injury severity. This is because while school zones have speed limits, other areas, such as recreational facilities, do not have particular regulations on reducing vehicle speeds.

Road Level Factors

- *Road type*: rather than testing current available road types, more investigation on creating innovative road types (e.g., 2+1 lane roads with median) that effectively reduce vehicle speeds may lead to greater opportunities for professionals to create safer road environments.
- *Road Design:* more research on street trees or safety-focused roadside designs will help reduce pedestrian collisions more effectively.
- *Presence of Parking Spaces:* both on-street and off-street parking spaces are located mostly within commercial or residential areas. However, no studies have evaluated the combined effect of land use type and parking on pedestrian safety.

Laws, Regulations, and Education Factors

- *Alcohol Enforcement:* not only drivers but also pedestrian alcohol impairment can also contribute to pedestrian collisions. Thus, regulatory strategies for reducing alcohol consumption of all road users should be emphasized.
- *Regulations:* more stringent regulations on turning maneuvers and road signs may help reduce severe injuries on the road.
- *Safety Education:* safety education or safety program should focus more on male drivers' driving behavior to reduce pedestrian collision more effectively.

Based on the findings from the literature review, four main areas that will focus on case studies are identified.

First, only a few studies have identified how to improve driver behavior and the effectiveness of altering driver attitudes (especially young and old male drivers) to reduce pedestrian-involved vehicle crashes. Interestingly, it is not indicated how the driver-related crash factors (e.g., speeding and drunk-driving) can be ameliorated by imposing more stringent enforcement.

Secondly, based on the previous findings, pedestrian behaviors (e.g., distracted walking, impaired walking) were often thought to be the primary factors that contributed to the pedestrian collisions. It appears that more research is needed on how to allocate responsibilities on road safety among motorists, non-motorists, and policy-makers to reduce pedestrian-vehicle crashes more effectively.

Moreover, many studies have identified the effects of built environment (i.e. infrastructure, neighborhood and road level environment) on pedestrian injuries. However, most of the findings do not fully discuss how the professionals (i.e. transportation planners, road engineers, and managers) incorporate built environment factors in road safety program to prevent pedestrian collisions more effectively.

Last, there was minimal exploration of the impact of policies and safety education programs on reducing pedestrian-vehicle crashes. Thus, efforts to evaluate and implement strategies for pedestrian safety in real world settings seem urgent.

The next chapter will review case studies to learn how countries in Europe have implemented national strategies, set timeline and targets, monitored progress, and managed challenges to reduce pedestrian collisions. Also more in-depth case studies will be followed.

CHAPTER 3 | Case Studies: Pedestrian Safety

This chapter offers case studies from France and Sweden that illustrate national road safety strategies based on the findings of the literature review in the previous chapter and secondary data obtained from official resources.

3.1 Efforts to Reduce Pedestrian Collisions in European Union

During the last several decades, a number of pedestrian safety measures have been implemented worldwide, largely in developed countries. The European Union (EU), for example, reduced the death rate by 39 percent from 2001 to 2010 (Figure 3), partly as a result of national policies (i.e., speed limits, drunk-driving enforcements), public education, and campaigns to make roads safer (Pace et al. 2012). Still, the vulnerable road users, including pedestrians, account for significant proportion of severe traffic injuries (39 percent) and fatalities (37 percent) in EU countries (WHO Regional Office for Europe 2009).

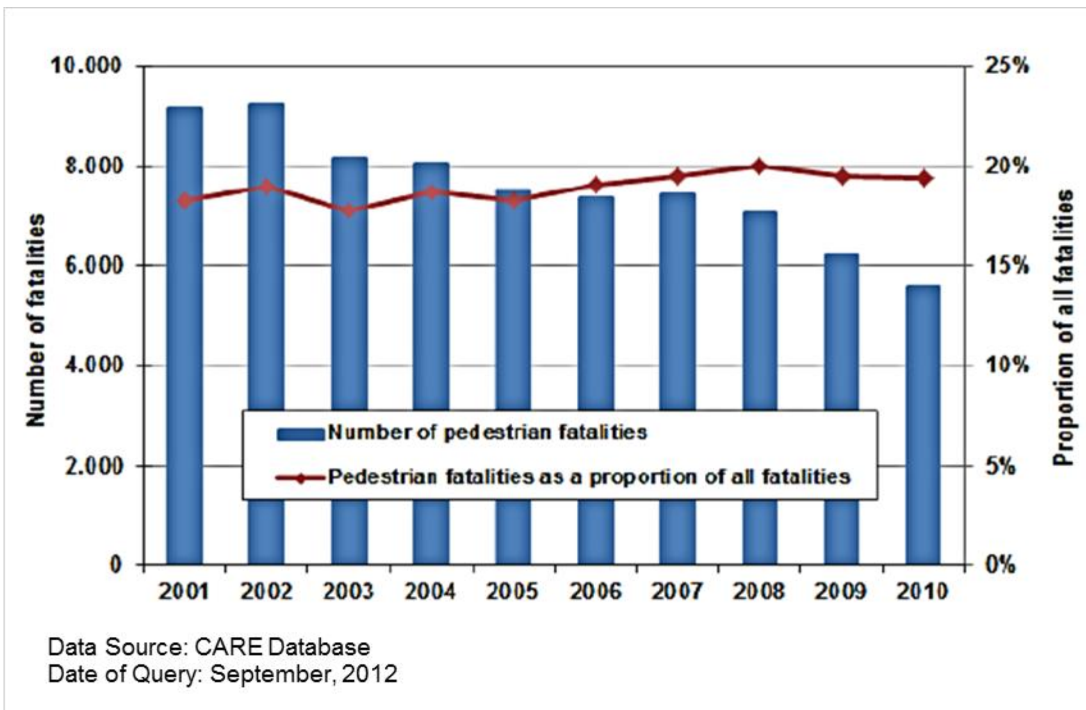


Figure 3 Number of pedestrian fatalities and proportion of total fatalities in EU-19, 2001-2010 (Figure Source: Pace et al. 2011, 2)

(Note: EU-19 includes Belgium, Czech Republic, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Finland, Sweden, and United Kingdom)

Only since the 1980s, there has been an understanding about the need for road planning for pedestrian safety and long term planning for sustainable safety policies were implemented in the mid-1990s (OECD 2001). The efforts have been led by cooperative parties, including politicians, professionals, the publics, and diverse transportation-related institutions, working toward zero death on the roads. Some of the leading European countries have achieved high reductions in pedestrian deaths. In 1994, Sweden launched its Vision Zero program and the Netherlands adopted Sustainable Safety strategy around the same time. Similarly, Norway, France, and the United Kingdom have continued their road safety interventions (Hauer and Brustlin 2010a). These countries are known for effective long-term preventive strategies that help reduce the considerable costs of pedestrian injuries (e.g., costs for care) and save the lives of pedestrians on the roads (Figure 4).

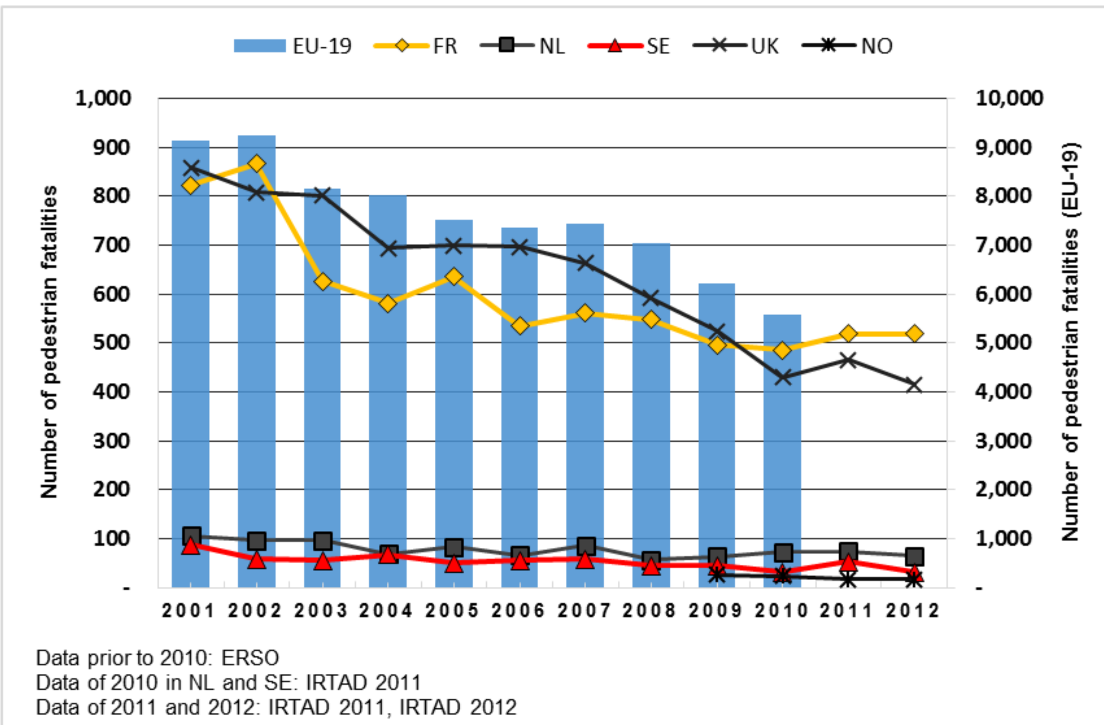


Figure 4 Pedestrian fatalities per million inhabitants by EU-24 country in 2010 (Data source: Pace et al. 2011, 4)
(Note: EU-19 includes Belgium, Czech Republic, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Finland, Sweden, and United Kingdom)

Pedestrian safety is also a primary concern in the United States. From 2001 to 2010, the pedestrian death rate was reduced by 12.6 percent, while total road deaths were reduced by 22 percent (National Highway Traffic Safety Administration 2012). Compared to the death reduction rate of the EU nations in the same period (39 percent), the U.S. figures still lag behind.

Therefore, there is a potential to reduce pedestrian crashes by applying the lessons of effective cases. A good starting point for this would be to understand the backgrounds, policy strategies, and results of the safety policies in selected countries. Each country's safety program strategies are described below.

France: Le Contrôle Sanction Automatisé (CSA)

Since the 1970s, France has imposed speed limits and seat-belt laws to reduce traffic fatalities. In 1997, the French inter-ministerial Road Safety Committee set a quantitative target to reduce the number of fatalities, but there was no remarkable decline in road users. Also, the level of enforcement in France was one of the lowest in Europe (Muhlrad 2006). Interestingly, in 2002, there was a considerable change in public attitudes to improve road safety due to the media campaign originating from President Chirac's election, in which the president had stressed on the importance of road safety. Consequently, more stringent safety regulations on speeding (e.g., exceeding 5 km/h over legal speed limits became a violation) and drunk-driving were implemented after his election. Serious speed enforcement, strong political commitment, and active public support in France have showed successful improvements in pedestrian safety, especially in drivers' behavioral adaptation, without rigorous infrastructure-oriented development (Hauer and Brustlin 2010b).

Norway: Vision Zero

The Norwegian 10-year Vision Zero road safety policy (2002-2011) has largely taken place within its national (Ministry of Transport) transportation plan (Elvik 2009). This enabled short term updates (every 4 years) with a strong integration between land use, transportation, and road safety plans. However, the lack of clear quantitative targets in its National Transport plan (e.g., reduce the number of road injuries by one third of the 2005-2008 result by 2020) seems to have impeded more active public participation in reducing road fatalities.

United Kingdom

Like other EU countries, road safety has been a traditional subject in the United Kingdom (UK). It established its first road safety target in 1987 (reduce one third of casualties by 2000), and the number of fatalities was already reduced by 39 percent in 1998 (Broughton 2000). Afterwards, the only pressure on UK safety programs was the reduction in death rate (Hauer and Brustlin 2010b). Finally, the Department of Transport established a vision (making UK's roads the safest in the world) and tried to minimize road deaths more effectively. However, setting a vision was not a significant tool for the safety programs. Moreover, the ongoing conflicts between economic developments (e.g., effectiveness of mobility) and climate change (e.g., reducing CO_2 emissions) in UK transportation planning strategies have hindered the successful implementation of pedestrian safety plans: pedestrian deaths still account for 22 percent among the total road deaths, which is about 10 to 12 percent higher than the average of other case countries (World Health Organization 2013).

Sweden: Vision Zero

The Swedish Road Administration (SRA) launched the Vision Zero program in the early 1990s. This program is still known for its radical policy principles which aim to eliminate any severe injuries or fatalities on the road (Belin, Tillgren, and Vedung 2012a). Also, its new responsibility allocation strategy, a shift from "blame road users" to "producer (e.g., road designer) is responsible for safety", has reduced road injuries by 2-3 percent annually (Johansson 2009). Above all, innovative traffic management principles, such as limiting vehicular speed to 30km/h (18 mi/h), a speed which does not exceed human tolerance and prevents fatal pedestrian injuries, as well as strict enforcement is one of the unique Swedish interventions to control speeding and ultimately reduce the pedestrian fatality rate. Similar innovative upgrades have been applied to mode-split (e.g., vehicles exceeding 70km/h or 44 mi/h must be separated by barriers) and intersection design.

The Netherlands: Sustainable Safety

One of the most densely populated countries in Northern Europe, the Netherlands has showed the greatest reductions in road fatalities: it experienced a 75 percent drop in road fatality between 1970 and 2005 (Wegman, Dijkstra, and Schermers 2005). Notably, the Netherlands' Start-up Sustainable Safety program, implemented between 1998 and 2002, shifted the approach from a reactive one to a proactive one: from "design a transportation system to accommodate human error" to "emphasis on behavioral and infrastructural improvements and education (SWOV 2005)." The residential speed limit program (called *Woonerf* where vulnerable road users have legal priority over motorists) and road re-classification have led to 9.7 percent reduction in road fatalities and 4.1 percent reduction in severe injury between 1997 and 2002 (Hauer and Brustlin 2010).

Different from other countries, the Netherlands' safety program has relied heavily on the work done by an individual research institute, the Institute for Road Safety Research (called *Stichting Wetenschappelijk Onderzoek Verkeersveiligheid,* SWOV). However, the safety program implementation process was stalled in the Netherlands because the decisions by politicians changed over time and decentralized governmental structure have resulted in unclear commitments (SWOV 2005). The Netherlands experience shows the importance of political structure and arrangement in effective safety program implementation.

Among the EU countries mentioned above, this paper will focus on the cases of France and Sweden in detail. The French CSA program provides strong enforcement and education for road safety while the Swedish Vision Zero program provides distinctive strategies for road and infrastructural improvements. Moreover, strong political commitments and numerous groups working for pedestrian safety in both countries add valuable lessons for future pedestrian safety programs.

3.2 Case Study

The following sections present backgrounds regarding pedestrian safety and safety programs in France and Sweden. The road injury and fatality data were gathered from the national reports prepared by International Road Traffic and Accident Database (IRTAD), European Road Safety Observatory (ERSO), the French Center for Studies on Networks, Transport, Urban Planning and Public Construction (CERTU), the Swedish National Road and Transport Research Institute (VTI).

3.2.1 France

Background

In France, strict road safety enforcements have produced considerable progress in road safety. France has achieved among the steepest declines in road fatality rate between 1997 and 2008 of all the OECD countries, reducing fatalities per vehicle kilometer travelled by 6.9 percent (Morris 2011). The 1997 and subsequent French road safety programs were effective in reducing pedestrian crashes in spite of the fact that those did not include specific pedestrian safety targets. Its main principle on altering drivers' behaviors by enforcement and education, significantly improved pedestrian safety.

Since 1970, as the number of vehicles increased in France, the number of deaths on the roads increased as well: in 1970, there were 16,455 road fatalities and 235,109 road injuries (Figure 5) (IRTAD 2009). In 1973, there was a major change in legislation: blanket speed limits and compulsory seatbelt-wearing were introduced, and a law on drunk-driving was established. Moreover, Prime Minister Jacques Chaban-Delmas implemented an extraordinary media campaign, promoting safe road behavior ("keep your speed down and don't drink and drive") and attracting public participation (Gerondeau 2006).

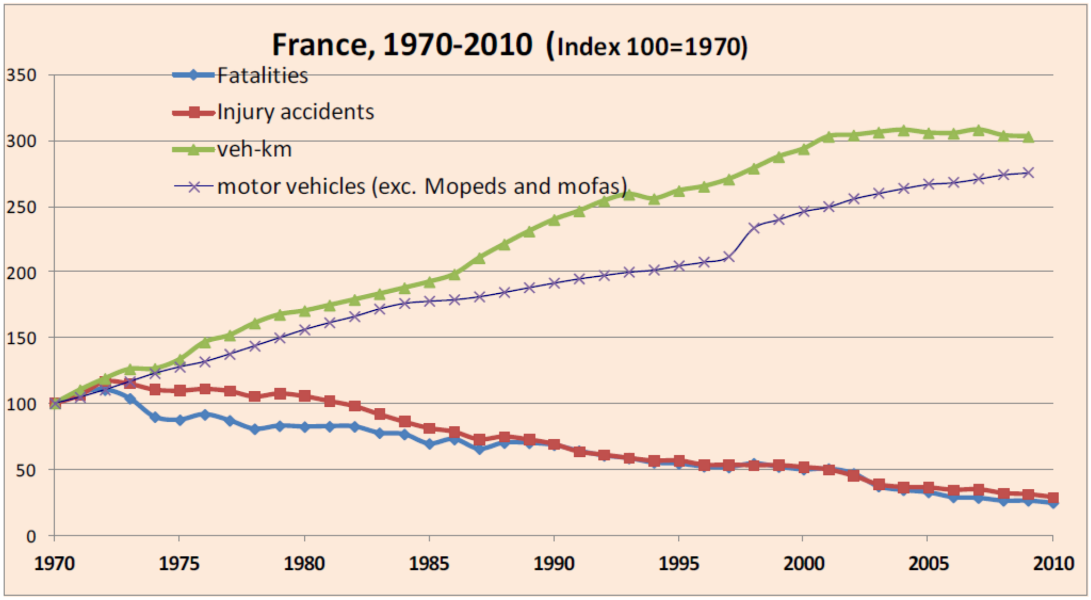


Figure 5 Reported road fatalities, injury crashes, motorized vehicles, and vehicle-kilometers in France, 1970-2010 (Source: IRTAD 2011, 133)

In 1997, the French government set the ambitious target to reduce road fatalities from about 8,000 (in 1996) to 4,000 by 2002 to achieve marked improvement in road safety for the first time (Muhlrad 2004). However, there were no pilot studies, new programs, or increases in funding sources, and campaign activities also remained the same from 1997 to 2002. Expectedly, there was no reduction in road safety during this period; thus the program target was not met in 2002. Consequently, road safety became a more serious issue in France.

In 2002, President Jacques Chirac's victory speech eventually initiated a new road safety program. He announced priorities for his upcoming five-year term of office (2002-2007), one of which was to improve road safety. He described his own horrifying crash experience during a speech in 1987. This deeply-felt commitment was effective at raising the public's and politicians' awareness of road safety: "everyone was surprised, since road crashes were generally considered as part of transport policy and not a serious health issue" (Gerondeau 2006).

Affected by the president's charismatic leadership, the Inter-ministerial Road Safety Committee (CISR) launched the 2002-2005 road safety program. The strategy included the following principles: (1) increase controls and sanctions to change behavior and ensure compliance with legislation, and (2) promote a road safety culture and involve all relevant parties. The changes in existing laws and regulations on drunk-driving and speeding, and in traffic education did not have specific quantitative targets. However, surprisingly, pedestrian fatalities dropped by 34.9 percent (from 822 to 535) between 2001 and 2006 (Figure 6) (Pace et al. 2012).

Finally, in 2010, France reached its lowest overall road fatality level since its crash data records had begun in the 1970s (IRTAD 2013). The most important lesson from the French safety program during the period 2002-2005 is the impact of strong political commitment on road safety.

Focusing on the 2002-2005 French road safety program, there was a remarkable reduction in the number of pedestrian fatalities. Based on the findings of the literature review, four countermeasures and their effects on pedestrian safety are reviewed in detail: (1) measures for improving driver behavior; (2) allocating level of responsibility on roads; (3) incorporating built environmental factors in road safety program; and (4) impact of campaigns and education programs.

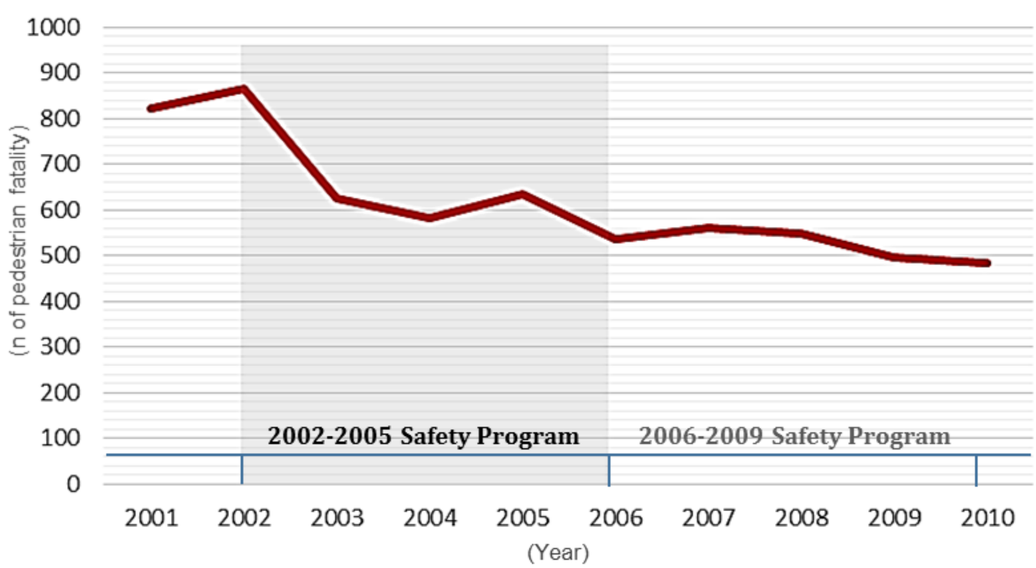


Figure 6 Pedestrian fatalities in France by year, 2001-2010 (Data source: CARE Database 2012)

Improving Driver Behaviors

Improvements in drivers' risky behaviors in France was largely achieved through policy and law enforcement changes. These actions were justified by the alarming situation in 2001: 60 percent of car drivers and 70 percent of motor-cyclists regularly exceeded posted speed limits; 31 percent of fatal crashes were caused by speeding and drunk drivers; and more than 50 percent of total mobile phone users used them while driving (Gerondeau 2006). Also, the increase in mobile phone use raised the perception in the need of mobile phone-related regulations.

Between 2002 and 2007, France achieved a 43 percent reduction in transportation-related mortality rates, after its robust road safety program initiative (Jost 2008). The efforts to reduce alcohol consumption before driving, speeding, and mobile phone use while driving profoundly helped improve traffic safety in France.

Driver inebriation

In 1992, France set a Point Demerit System for most road offences. The points out of total 12 were deducted from drivers' license based on the level of violence and made it possible to identify repeated offenders who had already lost points for similar offences (Gerondeau 2006). In 2002, the maximum permissible Blood Alcohol Content (BAC) level was lowered from 0.8 g/l to 0.5 g/l for general drivers and to 0.2 g/l for bus or coach drivers (IRTAD 2013). The drivers who exceeded the BAC level from 0.25 mg/l to 0.4 mg/l in their breath sample, or from 0.5 g/l to 0.8 g/l in their blood sample, were fined 135 euros (190 US dollars) and given a six penalty point deduction (out of 12) along with three years of license suspension. This was a significant change from previous laws, which allowed for a maximum three point deduction. Consequently, between 2003 and 2004, there was a 40 percent reduction in drunk-driving related fatalities (Gerondeau 2006). Interestingly, the French safety program officials not only implemented the strict enforcement systems, but they also developed communication programs (including trainings) with young drivers and people with addictions, as well as raised general awareness about the effects of alcohol use on traffic safety (Kwasniak and Kuzel 2009).

Speeding

The enforcement of speed limits was effective in reducing road fatalities in France. A general speed limit on roads (100-110 km/h or 62-68 mi/h) was implemented in 1973; however, the enforcement level in France remained low. Until 2002, 31 percent of total fatal crashes were caused by speeding motorists (Gerondeau 2006). In 2003, a new speed limit was enacted: 50 km/h (31 mi/h) in urban areas, 90 km/h (56 mi/h) on rural roads, and 130km/h (80 mi/h) on motorways. Also, lower general speed limits for bad weather conditions were implemented. The speed limit changes from 90 km/h to 80 km/h (50 mi/h) for rural roads and 130 km/h to 110 km/h for motorways in case of rain or snow (SafetyNet 2009). When road visibility was less than 50 m because of heavy fog, the speed limit on all roads changed to 50 km/h. On urban roads, the speed limit was unaffected by any weather conditions.

Later in 2003, 1,000 fixed radar units were installed throughout France, and an additional 500 mobile units were installed in the following year to enforce driver speeding behavior by automatic control system (Le Contrôle Sanction Automatisé, CSA) (Hauer and Brustlin 2010). The CSA was a fully automated system that caught any vehicles exceeding the legal speed limit by more than 5 km/h (3 mi/h).

This system involves five steps: (1) a violation is detected by cameras; (2) a photograph is taken; (3) the national treatment center receives the photo; (4) a computer automatically records the vehicle registration information; and (5) a penalty notice is sent out (Muhlrad 2006). The speed cameras enhanced the drivers' perceived probability of being punished and, therefore, improved the level of deterrence. This automatic system also allowed police officials to spend more time on alcohol and drug-impaired checking.

In order to make the CSA system more effective, the government decided to impose tougher penalty fines and adopt the point-demerit system (Muhlrad 2006). These were applied when drivers ignored stop signs or traffic lights and exceeded the speed limits. License suspension was re-introduced as a penalty for motorists who exceeded the speed limits or crossed a solid white line (Gerondeau 2006). For example, when the drivers exceeded speed limits over 40-49 km/h (25-30 mi/h), they were fined 135 euros (190 US dollars), given four penalty points, and sentenced to a three-year license suspension. Tougher sanctions were imposed on drivers exceeding speed limits over 50 km/h: a three-month imprisonment, a fine of 3,750 euros (5,200 US dollars), six (out of 12 points) penalty points, and a three-year license suspension (Gerondeau 2006).

Strong political action on road safety, along with the automatic speeding enforcement system, had substantial impacts on public attitudes toward altering driving behaviors. The French Annual Road Safety Report found significant improvements in the year 2003 compared to 2001 in terms of: (1) progress on drunk-driving (17.4 percent reduction in the drunk-driving rate); (2) fewer speeding offenders (10 percent reduction in exceeding the legal speed limit by 10 km/h or 6 mi/h); and (3) reduced average private vehicle speeds (average speed reductions in daytime by 2-3 km/h and night time by 4-7 km/h on rural roads) (Année 2005).

Then, a survey of public attitudes was released in 2005. According to the report, the rate of speeding violations had decreased 30 percent compared to 2001. While road fatality rates dropped by more than 30 percent between 2001 and 2005, the effect of the CSA system accounted for 75 percent of the reduction (Année 2005; Hauer and Brustlin 2010a). In other words, 75 percent of the total driver respondents said that automatic speed cameras positively impacted their driving behaviors (Muhlrad 2006).

When it comes to comparing the numbers over a longer period, the moving violations cited increased by 166 percent, license suspensions by 137 percent, and alcohol tests by 29 percent between 1998 and 2007 (Table 3). During the same period, total fatalities on French roads decreased by 49 percent, which is substantial. These results indicate that the new laws that aim to change road user behavior succeeded in reducing deaths on the roads.

	Number (thousands)		Percent Change,	Number per 1,000 Drivers,
	1998	2007	1998–2007	2007
Total moving violations cited	4,884	12,972	+166	322
Speed limit violations	1,084	8,098	+647	201
Failure to wear seat belt	635	407	–36	10
Driver's license suspensions for impaired driving, speeding, or points	110	261	+137	6
Alcohol tests	8,178	11,230	+29	279
Preventive test (i.e., not subsequent to crash or violation)	6,836	8,941	+31	222
Positive tests	167	376	+125	9
Fatalities	8.49	4.62	–49	
Licensed drivers		40,322		

NOTE: Citations include those issued by the two national police forces, which have jurisdiction on all roads and streets and account for most enforcement activity. Citations by municipal police are not included.

Data source: ONISR, 2008, 14, 165-168, 172

Table 3 Enforcement of road safety laws and related rates of road fatalities in France between 1998 and 2007 (Source: Transportation Research Board, 2011, 82)

Mobile phone use while driving

In 2002, traffic law enforcement was enhanced with an increased crackdown on road violations (Constant 2009). In 2003, driving with either a hand-held or hands-free mobile phone was forbidden (WHO 2011). In particular, drivers caught using a mobile phone while driving were fined 135 euros (190 US dollars) and given a three penalty point deduction (out of 12).

Compared to the number in 2001, the prevalence of mobile phone use while driving decreased by 52.1 percent between 2003 and 2004, right after the new legislation was enacted in 2003 (Constant 2009).

Responsibility Share

"At the heart of the commitment to road safety there is a fundamental struggle for a society that is more humane, one with greater solidarity and respect for others. We share the highway. *Road Safety is something we provide for each other*".

-Excerpt from speech by President Chirac at launch of World Health Day 2004

When it comes to road safety, there are two levels of responsibility: the level of (1) road users and (2) authorities. Namely, while each individual on the road is responsible for his or her own walking or driving behavior, authorities who are not on the road are also responsible for their policy implementation and monitoring. In the French road safety program from 2002 to 2005, the primary responsibility for road crashes was on "everyone" (Gerondeau 2006). This included road users, nationwide policy makers, and the rest of the population. In particular, the French government had taken on the main responsibilities for safe road standards, such as driver training, media campaigns, changing highway codes, and enforcing laws and regulations, rather than blaming road users for the road collisions (Gerondeau 2006). This principle of responsibility helped alter individuals' attitudes toward road safety. However, no public report indicates what proportion of decreased road fatalities was due to this principle during the 2002-2005 road safety program period.

Strategies to Incorporate Built Environmental Factors in Road Safety Program

While strong political will and public participation took place between 2002 and 2005 in France, far less attention was given to the effect of improvements in built environments (e.g., neighborhood design, road facilities) on reducing pedestrian crashes. Even though one of the most effective interventions to reduce pedestrian fatality is improving built environments as noted in the literature review chapter.

In the mid-1980s, the French government started to give priority to pedestrians on roads and made physical improvements. In 1984, the French Interministerial City Committee launched a safety program called "Safer City, Accident-free District" ("*Ville plus sûre, quartiers sans accidents-programme*"). The main purposes of this program were to reorganize the coexistence of pedestrians and motor vehicles, to alter driver behavior, and to increase the public's awareness (Faure and Neuville 1992).

While the first phase (1984-1986) of the program focused on improving safety awareness, more attention on infrastructure development was given in the second phase of the program in 1987. At this time, the goal was to increase the visibility of the road (e.g., change road material and improve lighting to increase visibility) and reorganize urban space in favor of pedestrians (e.g., modify the layouts of crossroads and mixed spaces). As a result of this new improvement in the late 1980s and early 1990s, the average number of vehicle crashes dropped over 60 percent (Faure and Neuville 1992). Compared to pre-1984, safer urban roads and renovated street designs attracted more walkers on streets and pedestrian crash deaths in France decreased slowly at a fairly even rate (Faure and Neuville 1992).

Between1997 and 2001, there was a total stagnation in road safety numbers (Gerondeau 2006), thus the French government decided to focus more again on improving road behavior than investigating safe infrastructure construction.

Measures for Neighborhood Level Factors

Between 2002 and 2005, measures to improve neighborhood level environments heavily focused on improving road safety in urban areas. In 2001, the majority of pedestrian-involved vehicle crashes in France occurred on urban roads, where walking was a more common mode of travel compared to rural roads (Bax et al. 2001)

On rural roads, although the frequency was low, pedestrian crashes resulted in more severe injuries. In order to reduce road fatality rates, a new speed limit was introduced in both urban and rural areas in 2003: 50 km/h (31 mi/h) on urban roads, 90 km/h (56 mi/h) on rural roads, and 130km/h (81 mi/h) on motorways. Also, more attention on improving pedestrian safety in particular urban areas was needed. About 50 percent of pedestrian crashes were linked with leisure and shopping trips in urban areas, however, no specific speed-reducing strategies were implemented in commercial areas between 2002 and 2005 (SWOV 2001).

During the 2006 and 2009 safety program period, France decided to adopt the street use code (*code de la rue*) from Belgium and enacted it as a national legislation in 2008 (Heydecker and Robertson 2009; CERTU 2008). The main strategy was to improve pedestrian safety in residential, business, and commercial environments and the code included a legal redefinition of specific traffic zones (i.e. pedestrian area, pedestrian priority zone, and 30km/h zone) in urban areas. The scheme of user's priority, speed limits, rules of access for motorized vehicles, and specific measures and signage were different in each designated area (CERTU 2008) (Figure 7).

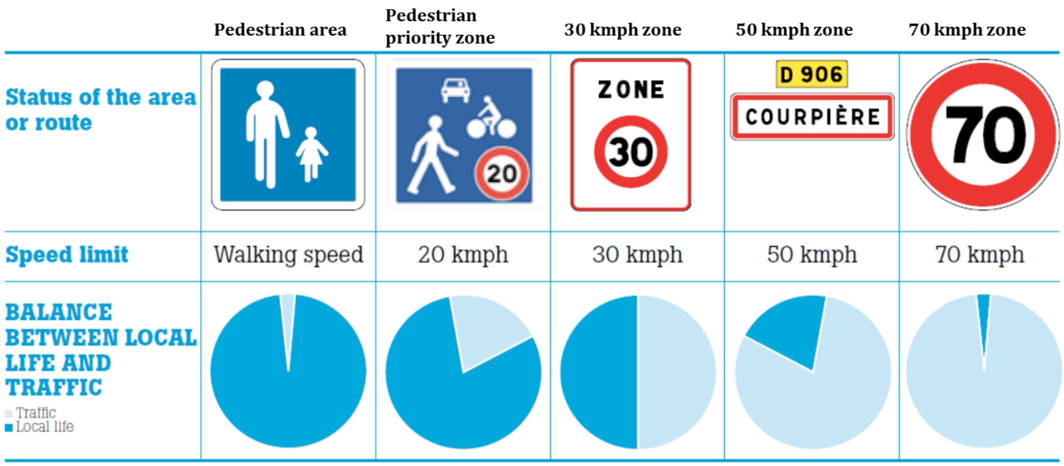


Figure 7 **Signs and speed limits for five different traffic zones in France (Source: CERTU 2008)**

The "pedestrian area", where pedestrians had priority over all vehicles, was introduced in 2008. Vehicles were only allowed to use this zone on special occasions and parking was not permitted in the area. The "pedestrian priority zone" was open to all road-users, but pedestrians had priority over other travel modes, such as motorcycles and cars (Murard 2009) (Figure 8). In this zone, motorized vehicles were limited to 20 km/h, whereas pedestrians could move around with complete freedom across the entire width of the road (Blanchard 2010). Moreover, motorized vehicles could only stop and park in designated areas in pedestrian priority zone. In"30 km/h zone", all vehicles had to be driven under 30 km/h and all residential neighborhoods were designated as 30 km/h zones (Figure 9). Also, crosswalks and pavement markings were not necessary, since pedestrian could cross anywhere in 30km/h zone. The "50 km/h zone" and "70km/h zone" were where vehicles were limited to a speed of 50 km/h and 70km/h respectively which had traffic calming effects (Murard 2009).

Figure 8 **Pedestrian priority zone in France (Source: CERTU 2008)**

Figure 9 **30 km/h zone in France (Source: CERTU 2008)**

In 2010, pedestrian fatalities accounted for 31 percent and 5 percent of all road fatalities in urban and rural areas respectively (Pace et al. 2012). To further reduce pedestrian fatalities in urban areas, a new safety provision required all drivers to yield, by stopping if necessary, to pedestrians who clearly intended to cross a street (CERTU 2012): if a pedestrian was more than 50 meters away from a crosswalk, drivers should yield to pedestrians. However, the pedestrian zones were mostly built near busy town centers in urban areas. Considering that about 80 percent of the French road network is located in rural areas, more investigation into reducing road fatalities might have been effective at reducing severe pedestrian crashes (IRTAD 2013).

Measures for Road Level Factors

There were few technical solutions for improving roads in France during the 2002 to 2005 safety program period. However, the crash rate revealed that simple solutions could have reduced French road fatalities. For example, in 2003, 1,180 preventable fatalities occurred in France: 630 killed by driving into trees, 406 into rock walls, 345 into bridge pillars, and 232 into lamp-posts (Gerondeau 2006). An installation of safety barrier between roads and sidewalks might have been effective in reducing these fatalities. Moreover, visibility problems caused by plants and darkness were usually examined in France between 2002 and 2005 (SWOV 2001). As of 2009, 21 percent of pedestrian fatalities, among 485 deaths, still happened under dark conditions without street lights (Pace et al. 2012).

Today, the main approach of French road level safety measurements is to "integrate motor vehicles and pedestrians" (CERTU 2013). In 2013, the national "Streets for All" ("*Une Voirie pour Tous*") program was launched to secure vulnerable road users, including pedestrians and cyclists, more effectively (CERTU 2013). This new program aims to disseminate information about design practices that integrate active modes of transportation, and to help change the lifestyles, travel habits, and transport practices of all road users to promote safe and attractive public space. Not only road managers and engineers, but also various scientific and technical experts work closely to develop and monitor the *Streets for All* program (CERTU 2013).

Compared to the strong policy-oriented safety strategies (e.g., stringent speed limits) in the last decade, the more recent French safety program focuses on improving road level factors to reduce pedestrian fatalities. However, the impact of this approach on pedestrian safety has not been proved. One researcher argues that the approach of integrating pedestrians and vehicles is still in its infancy and that there remain barriers to overcome, evaluations to be conducted, and experience to be gained (Hamilton-Baillie 2008).

Impact of Campaigns and Education Programs

Public attitudes and public communication were major factors in road safety improvements in France (Transportation Research Board 2008). The French government has been very active in carrying out informative campaigns to educate and alter road user behavior more effectively. It is important to note that both information campaigns and education programs can be effective when used in combination with other policy measures, such as speed limit regulations. They will only have a minimal effect if applied as stand-alone measures (IRTAD 2011).

Safety campaigns

The overall French experience shows how information campaigns integrated with strict regulations and speed-reducing techniques were successful in preventing pedestrian crashes.

Prior to the 1990s, the French media gave mass coverage to road safety issues in relation to specific events: new speed limits and a seatbelt-wearing regulation announcement in 1973, drunk-driving law legislation in 1978 and 1987, and the introduction of a point-demerit system and new speed limits in 1992. In contrast, over the period 1997-2001, campaigns were successful in reducing the number of road crashes, mostly due the limited resource allocation in national campaigns during this period (Gerondeau 2006). In 1997, the French government allocated only 7 million euros (out of a total 30 billion euros for the safe road program budget) to improve road users' behavior by advertising. Compared to the total advertisements spent by car manufacturers (1.5 billion euros a year), only a scant amount of public money was given to national safety campaigns.

At the end of 2002, however, media campaigns successfully improved driver behavior along with the new automatic control and sanction (CSA) system. Surprisingly, this change occurred before the legislative fully changes, since there was an active media campaign advertising the new safety systems. According to Gerondeau (2006), "so much television and radio aired the plans and interviews for the CSA system" that it immediately reduced road fatalities by 21 percent within a year, with 7,242 and 5,731 road deaths in 2002 and 2003, respectively (Pace et al. 2012). Indeed, pedestrian fatalities also decreased by 27.7 percent during the same period (Pace et al. 2012). As a result of the ongoing safety campaign in the media, the French has achieved significant short-term reduction in pedestrian fatalities and improvements in public awareness of road safety (Kwasniak and Kuzel 2009).

More recently, the road safety campaign has expanded to online media. The French Ministry of Interior (*Mnistere de Linterieur*) created a webpage (http://www.securite-routiere.gouv.fr) and uploads the campaign posters and video clips to mainly raise the safety awareness of young (age between 18 and 25) drivers and pedestrians (Figure 10).

Figure 10 Campaign posters that warns about the dangers of cell phone use while driving (Source: French Ministry of Interior, 2010)

Safety education

Between 2002 and 2005, France also made a number of efforts in safety education in three priority areas: teaching road safety in schools, driving classes in driving schools, and post-license training (Lyons 2006). During this safety program period, the road safety education started from primary school (7-8 year olds) to prevent road injuries and fatalities throughout lifetime. The lifelong education program was implemented by French Ministers in charge of Youth, National Education, and Research (The Ministry of Ecology and Sustainable Planning and Development 2013).

Also, three levels of certificates were introduced to be awarded by 11-year-olds, 13-year-olds, and 15-year-olds, respectively: (1) Certificate for Initial Road Education (APER); (2) Level 1 Road Safety School Certificate (ASSR 1); and (3) Level 2 Safety School Certificate (ASSR 2). The training of road safety certificates was given by teachers who have access to such information from the Department of School Education (The Ministry of Ecology and Sustainable Planning and Development 2013). Along with the safety certificate program, the French Ministry of National Education refined road safety educational materials for universities. Contents to be taught in math, civil education, life sciences were standardized and inspected. For all novice, experienced, and elderly drivers, the government provided post-license courses to ensure sustainable road safety.

Moreover, in 2002, the French Road Safety and Traffic Department (*Délégation à la sécurité et à la circulation routières*, DSCR) began publishing a monthly Road Safety Barometer of road fatality report. This effort increased public awareness and influenced public opinion on road safety (Muhlrad 2004). By educating road users, the French government has achieved continuous reduction in the number of road fatalities since 2002.

3.2.2 Sweden

Background

Sweden is one of the leading countries that managed to substantially reduce pedestrian fatalities. As mentioned in the previous section, the main changes investigated by the Swedish Road Administration (SRA) were new ways of allocating responsibilities and designing infrastructures for road safety. Road safety in Sweden has been a priority since 1967, when the Swedish government decided to change its traffic system from moving on the left- to the right-hand side of the roadway (Koornstra et al. 2002). The government had to re-educate the public, re-construct the road networks, and create new vehicles for public transportation because of the reform (Koornstra et al. 2002). During the late 1960s and early 1970s, the Swedish Road Safety Office was established, and they tested various speed limits to ensure a safe road environment.

Since the late 1970s, Sweden's rate of traffic fatalities per vehicle kilometer travelled has been among the lowest of the OECD countries (Transportation Research Board 2011). Between 1970 and 2010, there were 40 years of decline in road fatalities and only a modest increase in injury crashes despite increases in the number of cars on the roads (Figure 11). In fact, Sweden has had specified quantitative targets for road safety since 1989 (Lie and Tingvall 2001).

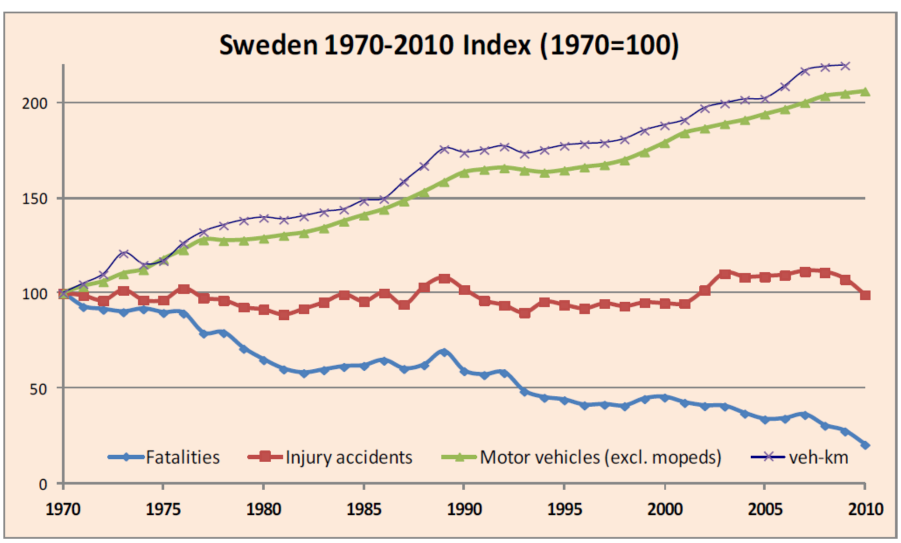


Figure 11 **Evolution in numbers of road fatalities, injury crashes, distance travelled, and vehicles-km in Sweden, 1970-2010 (Source: IRTAD 2011, 300)**

Overall, since 1970, most of the vulnerable road users, which include pedestrians, have benefited from the improvements in safety (Table 4). In the 1980s, most of the investments in pedestrian safety were focused on crossing facility improvements, such as zebra crossings, crossings at intersections, or refuges (Ekman and Draskoczy 1989). However, a lack of benefits of many road safety measures was recognized by scholars in the early 1990s. Thus, in 1993, the Swedish National Road Administration (called *Vägverket* or SRA) was established to replace the Road Safety Office.

In 1994, the new Swedish Minister for Transport declared that traffic safety would be one of its priorities (Johansson 2009). Much of the political debate on the new safety strategy between 1995 and 1997 was concentrated on the question of how many fatalities were acceptable. Finally, it was concluded that "a zero fatality target was the only justifiable goal" for Swedish road safety (Johansson 2009).

In 1997, the SRA developed the "Vision Zero" concept, and the Swedish Parliament introduced the new safety strategy to its safety program with the aim of eliminating any road fatalities and severe injuries by 2020 (Whitelegg and Haq 2009). The premise behind, and the wording of, Vision Zero was a game-changer. No one asked "what number of crashes should be reduced," but rather asked "what must be done to eliminate the risk of road injuries and deaths" (Hauer and Brustlin 2010b). Vision Zero built upon earlier work and involved an entirely new way of looking at road safety and a new set of principles for designing and managing road systems (Elvik 1999). Additionally, the Swedish parliament set an interim target to reduce deaths by 50 percent (of fatalities in 1996) by 2007 (Hauer and Brustlin 2010b).

									% change over		
	1970		2000		2007		2008		2007-2008	2000-2008	1970-2008
Passenger car occupants	634	49%	393	66%	276	59%	233	59%	-16%	-41%	-63%
Bicyclists	141	11%	47	8%	33	7%	30	8%	-9%	-36%	-79%
Mopeds	108	8%	10	2%	14	3%	11	3%	-21%	10%	-90%
Motorcycles and scooters	53	4%	39	7%	60	13%	51	13%	-15%	31%	-4%
Pedestrians	308	24%	73	12%	58	12%	45	11%	-22%	-38%	-85%
Other	63	5%	29	5%	30	6%	27	7%	-10%	-7%	-57%

Data Source: Road Safety Annual Report, IRTAD (2009)

Table 4 **Reported fatalities by road user group, 1970, 2000, 2007, and 2008 (Source: IRTAD 2009)**

In 1999, the Swedish government launched a short-term action plan containing eleven points aimed at strengthening road safety in accordance with the Vision Zero principles (Koornstra et al. 2002). This program clearly defined the priority areas for road safety strategy (e.g., emphasis on road user responsibility, special safety measures for the most dangerous roads, and better utilization of technology) (Lie and Tingvall 2001). Interestingly, one of the points targeted safer conditions for "cyclists," but none of them focused on "pedestrians," whose proportion of fatalities was about 4 percent higher than cyclists during the same period.

In 2003, the Swedish government established the Road Traffic Safety Inspectorate (within the Swedish Road Administration), which monitored whether road system designers and other stakeholders worked effectively for road safety (Belin and Tillgren 2012). In addition, this organization proposed an adequate interim target and solutions for Vision Zero.

In spite of the SRA's effort to reduce 50 percent of 1996 fatalities by 2007, the actual reduction was only 13 percent: though the target was 270 fatalities between 1997 and 2007, there were 471 fatalities in total (Lie and Tingvall 2009). An evaluation of the failure determined that the target for the 10-year period (1997-2007) had not been agreed upon among the stakeholders. Also, some researchers argued that "the target was not low enough to stimulate stakeholders to take action" and "it was not monitored as it should have been" (Lie and Tingvall 2009).

The failure to meet the 2007 target triggered a new target adoption in Sweden. In January 2009, the Government established a new authority in the transport sector, the Swedish Transport Agency, to expand the role of the Traffic Inspectorate organization. The Agency was formed by merging the Railway Board, the Civil Aviation Authority, the Maritime Administration, and parts of the County Administration Board and the Road Administration (Belin and Tillgren 2012).

In May 2009, the Swedish Parliament adopted a new interim target, aiming for a 50 percent reduction in fatalities and a 25 percent reduction in serious injuries between the base years 2006-2008 and 2020, and a 100 percent reduction by 2050 (Lie and Tingvall 2009).. Additional objectives have been identified in 16 designated Road Safety Performance

Indicators, including speed compliance, sober drivers, fatigued drivers, safe vehicles, safe roads, rescue, care and rehabilitation, seat-belt use, bike helmet use, and valuation of road safety (Luoma 2013). In contrast with the 1999 Eleven-Point program, one of the indicators, “share of safe pedestrian, cycle, and moped passages for the main municipal street network”, targeted pedestrian safety along with cyclists and moped users’ safety on roads. Also, the proposed safety indicators included driver behavior-related factors (i.e., speeding or drunk-driving).

More recently, in 2010, a new Road Safety Act (SFS 2010:1362) was adopted to stipulate the liabilities of the Swedish state road authorities (Belin and Tillgren 2012). However, still two-thirds of 57 pedestrian fatalities per year are associated with a motorized vehicle, a passenger car in particular (Larsson, Dekker, and Tingvall 2010).

Focusing on the 1997-2007 Swedish road safety program, the number of pedestrian fatalities was cyclical during the first ten years of the Vision Zero period (Figure 12). Based on the findings of the literature review, four countermeasures (i.e. measures for improving driver behavior, responsibility share, incorporating built environmental factors in road safety programs, and measures of safety campaigns and education programs) and their effects on pedestrian safety are reviewed in detail.

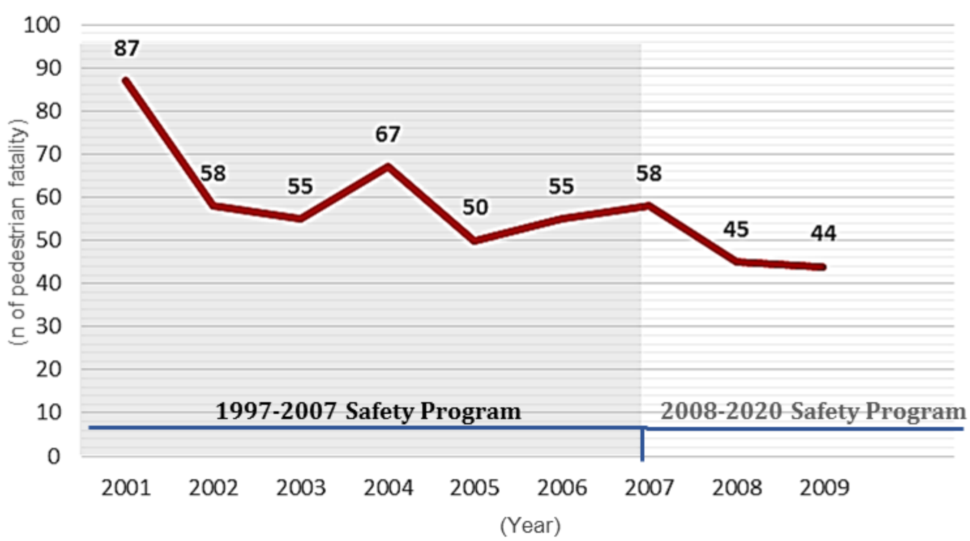


Figure 12 The number of Pedestrian Fatalities in Sweden by year, 2001-2010 (Source: Pace et al. 2012)

Improving Driver Behaviors

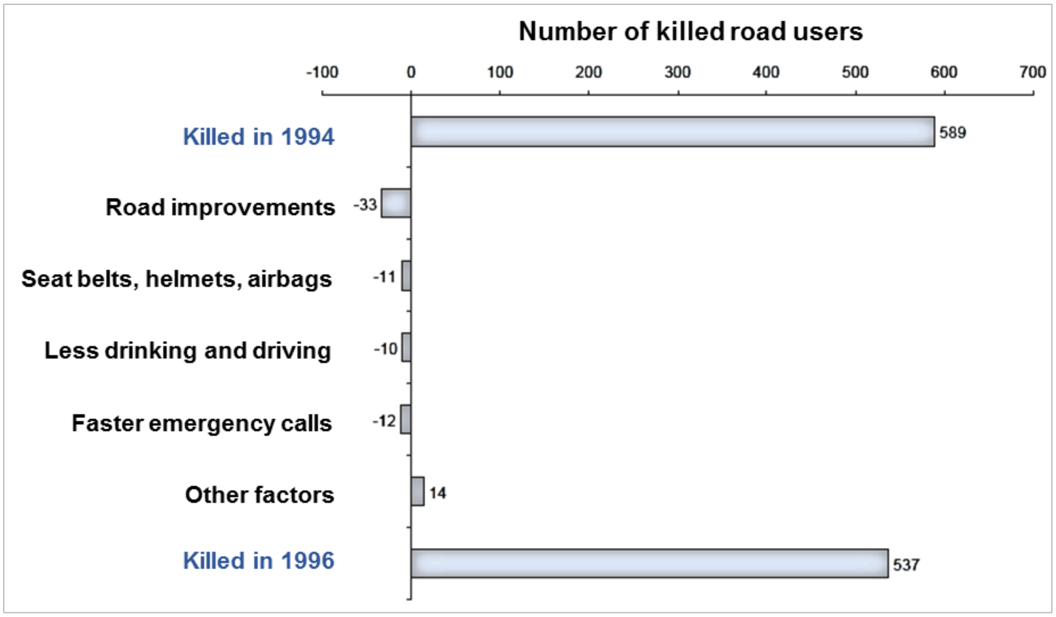
The Vision Zero program started with the idea that "we are human and we make mistakes" (Vision Zero Initiatives 2012). Based on this principle, the Swedish road authorities and traffic regulators aimed to provide a transportation system that was "forgiving [of] the errors of drivers" (Transportation Research Board 2011). Therefore, since 1997, the Swedish Government has focused on adapting the road system to the individual and his or her capacities rather than adapting individual behavior to the road system (Belin, Tillgren, and Vedung 2012b).

Sweden's 1997-2007 road safety program emphasized the control of drunk-driving and speeding (Transportation Research Board 2011). Much less attention, however, was drawn to enforcing mobile-phone use while driving. The regulations or policies that targeted improving driver behavior, including drunk driving, speeding, and mobile-phone use while driving, and their impact on pedestrian safety are described below.

Driver inebriation

Sweden introduced legal blood alcohol limits in 1951 (Koornstra et al. 2002). The lower limit was set at 0.5 g/l, and a second limit was set at 1.5 g/l with more strict sanctions. In 1995, Sweden became an EU member country, and its earlier restrictive regulations on importation of alcohol were changed (Lindgren 2008). Due to this change, Sweden liberalized its alcohol policy, and the flow of international alcohol increased substantially. At the same time, alcohol-impaired crashes significantly increased. In order to reduce drunk driving, the Swedish government set lower Blood Alcohol Concentration (BAC) and Breath Alcohol Concentration (BrAC) limits in 1994.

In 1994, the Swedish Government lowered its legal BAC limit to 0.2 g/l (from 0.5 g/l) and its BrAC limit to 0.1 mg/l (from 1.5 g/l), both of which are still the lowest in Europe (SWOV 2001). The administrative sanction for drunk-driving is suspension of the driving license for a period of up to three years depending on BAC level. The criminal sanctions are either high fines at the lower levels or prison at levels more than 1.0 g/l (Magnusson, Jakobsson, and Hultman 2011).



Original data source: Andersson et al. (1998)

Figure 13 Contributions of various factors to expected changes in the number of road accident fatalities in Sweden from 1994 to 1996 (Source: Elvik 2000).

In 1996, the Swedish National Road and Transport Research Institute (called *Väg- och TransportforskningsInstitut*, VTI) estimated the impacts of new Swedish road safety policy for the years 1994-1996. The report found that the number of nationwide road fatalities related to drunk driving had decreased by 10 fatalities out of 52 total fatality reduction (Figure 13). Also, the report estimated the expected reductions by the year 2000: a 22 fatality reduction related to drunk driving out of a total fatality reduction estimate of 190 (Elvik 2000).

Another effort in Sweden to reduce alcohol impaired driving was Random Breath Testing (RBT). RBT means that the police are allowed to test drivers' breath without having any suspicion (Luoma 2013). The proportion of injury crashes involving drunk drivers was reduced from 14 percent to 9 percent of all road collisions after the introduction of random breath testing in the 1970s (Luoma 2013). In 2006, the policy of High-frequency Alcohol Testing was introduced. The rate was increased to 380 tests per 1,000 licensed drivers (Breen et al. 2007).

In 2012, the Alcohol Ignition Interlock (Alcolock) system was implemented in all new cars, which was a new countermeasure to reduce alcohol-impaired driving: the device utilizes breath-alcohol sensors to confirm that a driver's BAC level was below a specified limit before the vehicle can be started (IRTAD 2011). Originally, in 1995, the Swedish National Road Authorities (SNRA) proposed pilot Alcolock programs: some of those drunk-driving offenders who would have their licenses revoked would be permitted to retain the possibility to drive on the condition that they had Alcolocks installed in their vehicles (SWOV 2001). As license revocation from drunk driving was a legal provision, it was necessary to create a new law in order to implement the pilot project. In 1998, the Swedish Parliament passed the new law, and a permanent system (for repeat offenders) was adopted in 2012 (IRTAD 2011).

In 2010, the Alcolock system was extended to include professional drivers (i.e. taxi or school bus drivers). In late 2012, more than 50 percent of all school buses implemented alcohol interlocks.

Speeding

In the Vision Zero approach, vehicle speed was the most important factor for improving pedestrian safety, not just something to be enforced: low vehicle speeds at every encounter between a vehicle and a pedestrian must be assured (FHWA 1999). Specifically, the "thresholds for the amount of biomechanical energy that can lead to serious injury" formed the basis for determining speed limits in Sweden (Elvik 2000).

In 1998, in order to not exceed the level of violence that the human body can tolerate, the Swedish government set new maximum vehicle speeds: (1) maximum 110 km/h (68 mi/h) on highways; (2) maximum 70 km/h (44 mi/h) for motorways, other divided highways, minor rural roads and major urban arterials; (3) maximum 50 km/h (31 mi/h) for junctions, urban main streets; (4) maximum 30 km/h (19 mi/h) for urban crossing facilities for pedestrians and cyclists, collectors, and mixed-use residential streets; and (5) speed limit only allowed at human walking speed, about 7 km/h (4 mi/h), for pure residential streets, where people meet and talk and children play (FHWA 1999; Elvik 2000).

In 1999, SRA tested different general speed limits in wintertime: the speed limits changed respectively from 110 km/h to 90 km/h (on highways) and from 70 km/h to 50 km/h (on motorways) during winter (Luoma 2013). This was because icy and snowy road conditions had played an important role in pedestrian crashes in Sweden (FHWA 2006). One study by the Swedish National Road and Transport Research Institute (VTI) found that the climate and icy road conditions in winter had a great impact on pedestrian-vehicle collisions in Sweden. Furthermore, in 2000, Elvik found that less daylight in winter exacerbates the risky road conditions in Sweden (Elvik 2000).

Despite the government's effort to reduce road fatalities caused by speeding, the percentage of drivers complying with the speeding law was still under 50 percent in 2000 (Elvik 2000). Thus, in 2008, the Swedish government decided to adopt a new speed limit system. The new system included tighter speed limits and introduced speed limits in 10 km/h steps, ranging from 30 km/h (urban local and collector streets) to 110 km/h (main highways) (IRTAD 2009). A maximum speed of 30 km/h in built-up areas was nothing new, but the work on turning Vision Zero into reality had emphasized that this must be the limit if "pedestrians and cyclists are to survive a collision" (IRTAD 2013). According to the VTI's Power Model analysis, based on Swedish Traffic Accident Data Acquisition (STRADA) data, more stringent speed limits prevented an average of 11 fatalities and 37 serious injuries among all road users per year between 2008 and 2012 (Vadeby et al. 2012).

In 2012, the SRA measured the average speed and compared the results with the average speed in 2004 (IRTAD 2013). The result showed that the average speed had decreased by 3.4 km/h between 2004 and 2012; thus the trend was positive from a pedestrian safety perspective.

Mobile phone use while driving

In Sweden, there is no law to ban or restrict the use of mobile phone use (whether hand-held or hands-free) while driving, but the government has focused on raising public awareness of the risk of distracted driving (WHO 2011). One Swedish study found that the increased use of mobile phones resulted in faster emergency calls in crashes, contributing to a reduction of 12 road fatalities out of 52 between 1994 and 1996 (Elvik 2000).

About 15 years later, in 2011, at the request of the government, VTI presented the results of a study on the use of mobile phones and other communication devices while driving: a major finding was that no actual safety impact in terms of crash frequency was found for the countries which already had restrictions for mobile phone use (Kircher and Patten 2011). The report suggests educating and informing the driver, while at the same time supporting him or her in the safe usage of mobile phone, rather than simply prohibiting the use of communication devices while driving (Vadeby et al. 2012).

*No data on the use of mobile phones while driving in Sweden is available.

Responsibility Share

In Sweden, similar to other European countries, the traditional transport system was designed for maximum vehicle capacity and mobility, not for pedestrian safety (FHWA 1999). This means that the road users hold the main responsibility for their own safety. The Vision Zero approach, however, placed the main burden for safety on system design by "recognizing humans' weaknesses and low tolerance to mechanical force" (Johansson 2009). According to Claes Tingvall, the Director of Road Safety, the difference between the old and the new safety approach is that "we used to say that 90 percent of all road accidents are caused by the individual whereas we now say that 90 percent of the injuries can be affected by the system designers" (Fahlquist 2006).

Specifically, in Sweden, the responsibility for road traffic safety has been introduced along three strategies (Johansson 2009): (1) the designers of the system are always ultimately responsible for the design, operations and use of the road transport system and are thereby responsible for the level of safety within the entire system; (2) road users are responsible for following the rules for using the road transport system set by the system designers; and (3) if road users fail to obey these rules due to a lack of knowledge, acceptance or ability, or if injuries do occur, the system designers are required to take the necessary further steps to counteract people being killed and seriously injured. Likewise, the Swedish government envisaged a chain of responsibility that both began and ended with the road system designers. Thus, system designers played an important role in reducing or eliminating fatalities and serious injuries on the roads (Belin and Tillgren 2012).

The impact of the new responsibility allocation on pedestrian safety, however, is still unclear. Between 1995 and 2008 (before and after the Vision Zero implementation), the number of Sweden's pedestrian fatalities dropped from 71 to 45 (FHWA 1999; IRTAD 2009), but the decline fluctuated and there were still 53 pedestrian fatalities (out of 319 total road fatalities) in 2011 (IRTAD 2013).

Strategies to Incorporate Built Environmental Factors in Road Safety Program

Prior to 1997, hardly any of the Swedish traffic safety programs explicitly included road engineering measures as a main part of their safety strategies. In 1997, the Vision Zero approach was implemented, and the Swedish government thus started to build roads with features that ensure low injury risk of pedestrians and safety considerations, which largely determined the opportunity of infrastructure project investments at that time (Transportation Research Board 2011).

Measures for Neighborhood Level Factors

In regard to neighborhood level infrastructure improvements, Swedish Road Authorities (SRA) mainly focused on urban areas, and a significant pedestrian fatality reduction was achieved through improving urban road conditions (IRTAD 2013). Safe transport system design entailed various traffic-calming strategies and rules to prevent crashes between vehicles and pedestrians in Sweden. More importantly, Swedish architects' and planners' combined interest in road safety and urban planning resulted in a new set of transportation planning guidelines focusing on road safety (Mcandrews 2010).

In urban areas, the construction of roads and land use planning followed the SCAFT (*Stadsbyggnad, Chalmers, Arbetsgruppenen för Forskning om Trafiksäkerhet,* Principles for Urban Planning with Respect to Road Safety) guidelines written by city planners, architects, and civil engineers and introduced in 1968. The ideas in SCAFT centered on four principles: (1) activities and land-uses should be located to minimize conflicts among cars and other modes of travel; (2) road space should be organized into a hierarchical network with priority on the local network given to pedestrians and bicyclists; (3) roads and the surrounding environment should be clearly visible for drivers to prevent confusion and distraction; and (4) safety should be a factor in the design of a development early in the planning process, and pedestrian infrastructure should be planned before roads for cars (McAndrews 2013). It is important to note that the SCAFT prioritized pedestrians' safety and separated pedestrians and cyclists from vehicle traffic by providing completely separated facilities on the road network. Also, the key point was that, for the first time, the Swedish government theorized that the interactions between the vehicle, driver, and road environment were what determined the safety of neighborhoods (McAndrews 2010).

The SCAFT strategy (e.g., separation of modes through separate networks) was implemented largely in urban residential areas. Housing developments had two separated grad networks: a pedestrian network (which connects housing and commercial activities) and a service road network for cars and parking spaces (Figure 14) (McAndrews 2010). Developments of single-family homes also used the same strategy of locating parking areas away from housing based on the SCAFT safety guidelines. In 1973, however, this approach was evaluated based on police-reported crashes and the opinions of road users and residents and revised, since the initial SCAFT design generated monotonous housing patterns and lack of use by pedestrians and cyclists (Koornstra et al. 2002). In SCAFT, livability was an important component for housing clusters and shopping plazas, but not for streets. Therefore, more attention on improving streets, where many pedestrians and cyclists spend their daily life, was raised by transportation planners.

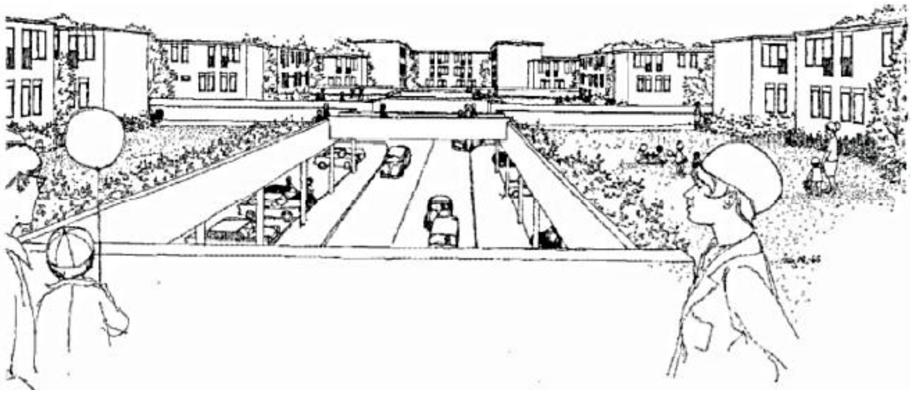


Figure 14 **Drawing of a SCAFT safe road environment design for a residential development (Source: McAndrews 2010, 67)**

Since the 1980s, traffic-calming strategies (e.g., 30 km/h zones) have been gradually introduced in residential, school, and hospital complex street designs in urban areas (Koornstra et al. 2002). In the mid-1990s, Vision Zero was implemented, and municipal authorities established a 30 km/h speed limit on urban streets (Vagverket 2009). Under this plan, vehicle speed should not exceed 30 km/h (19 mile/h) if there are pedestrians in the area. If there are no pedestrians or bicyclists, however, vehicles could travel up to 50 km/h (31 mi/h) at intersections and 70 km/h (43 mi/h) on the links (FHWA 1999). The theory behind this intervention was that collisions and conflicts between drivers and vulnerable road users cannot be eliminated, but their severity is minimized when vehicle speeds are slower. This strategy was implemented on a relatively large urban scale along with the "Calm Streets" ("Lugna gatan") guideline in 1998, and it aimed to minimize the conflicts between motorized and non-motorized traffic (Transportation Research Board 2001).

More recently, the concept of "Shared Space" was introduced in Sweden to mix road users and improve pedestrian and cyclist safety by ensuring very low vehicle speeds (around 15 km/h) within the area (Hydén 2011). Shared Space is an urban public space where drivers have to drive at a very slow pace and give full priority to pedestrians (Figure15). Due to the urban-focused safety improvements in Sweden, there was a 65 percent reduction in road fatalities in urban areas between 1980 and 2008, and a 39 percent reduction between 2000 and 2008 (IRTAD 2009).

Figure 15 **Before (top) and after (bottom) of Shared Space implementation in the Swedish City of Norrkoping (source: Hyden 2011, 9)**

Measures for Road Level Factors

In Sweden, the decrease in pedestrian fatalities over the last two decades has been achieved through improvement in the design of urban roads through the construction of roundabouts, traffic barriers, and other countermeasures in infrastructure during the 1997-2007 safety program period (IRTAD 2009). Vision Zero also entailed changes in the way of thinking and called for new solutions.

One example in particular can illustrate the difference that can be found in the choice between traffic lights or a roundabout at an intersection (Vagverket 2009). If the key objective is to reduce the number of crashes, then traffic lights are the best solution. However, though there will be fewer crashes, those that do happen often result in serious injury due to high vehicle speed. If the key objective is to avoid serious injuries, the roundabout will provide better results. The circulatory vehicle movements at roundabouts eliminate or reduce critical pedestrian injuries resulting from right-angle conflicts at corners or unexpected right or left-turning movements (Figure 16) (Stone et al. 2002). In other words, there may be more crashes, but the injuries will mostly be minor. One of the studies indicated that the expected number of road crashes at roundabouts would decrease by 53 percent and 89 percent for pedestrians (FHWA 1999). Moreover, the study showed that the interaction between vehicle drivers and pedestrians was significantly improved at roundabouts. In Sweden, there were around 150 roundabouts in 1980, and 1,500 were constructed during the 1997-2007 safety program period (Hydén 2011).

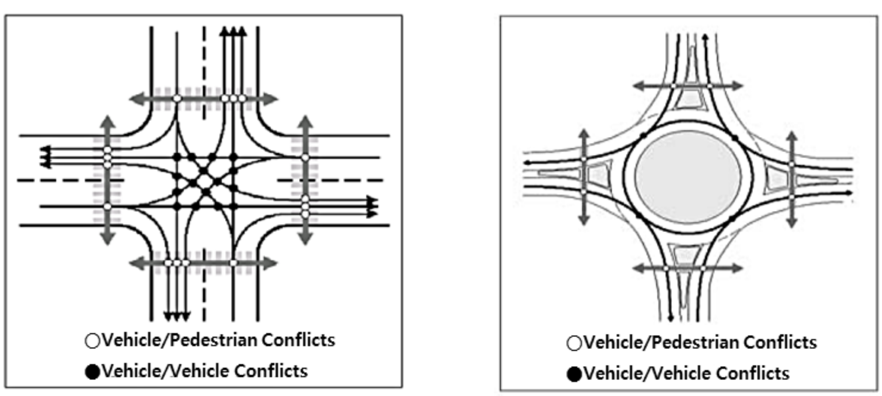


Figure 16 Pedestrian-vehicle and vehicle-vehicle conflict points at a right-angle intersection with traffic lights (left) and roundabouts (right) (Source: Stone, Chae, and Pillalamarri 2002, p 10)

In order to minimize pedestrian fatalities and severe injuries due to high speed vehicles, the Swedish government has constructed "barriers to manage kinetic energy by separating incompatible transportation modes (e.g., pedestrian and motor vehicles) on 30+ km/h roads" since the mid-1990s (Johansson 2009). One of the main principles of Vision Zero was that vulnerable road users should not be exposed to motor vehicles at speeds exceeding 30 km/h, and if this could not be satisfied, the vehicles should be separated (Johansson 2009). For roads with speeds higher than 50 km/h, barriers were installed both to the right and left of vehicles (Johansson 2009).

Moreover, opposing vehicle lanes were also divided by barriers. In 1995, steel wire barriers were implemented in the medians of motorways (Koornstra et al. 2002). Since 1998, "2+1 lanes" with median barriers have been built in rural areas (Johansson 2007). Traditional two-lane (43 ft.) rural roads were converted to the innovative 2+1 design, which is a 3-lane road on which opposing directions have access to the center lane in alternation (Figure 17) (Hauer and Brustlin 2010b). Since most of the 2+1 roadways have been constructed by re-striping existing roads and narrowing the shoulders, it has been associated with low-cost reform.

At the end of 2008, around 2,000 km of rural roads had median barriers on the 2+1 road system. Accordingly, the risk of fatal or severe crashes on these roads has dropped by 75-80 percent, which was a higher reduction than expected (IRTAD 2009). Some researchers have stated that road improvements reduced the number of road fatalities most effectively (Elvik 2000). However, the actual impacts of 2+1 roads with median barriers on pedestrian fatalities or severe injuries have not been proved. Median barriers can be effective at reducing the number of mid-block crossings, but only one study has shown that 48 percent of pedestrian indicated median barriers affected their crossing behaviors (Campbell et al. 2004).

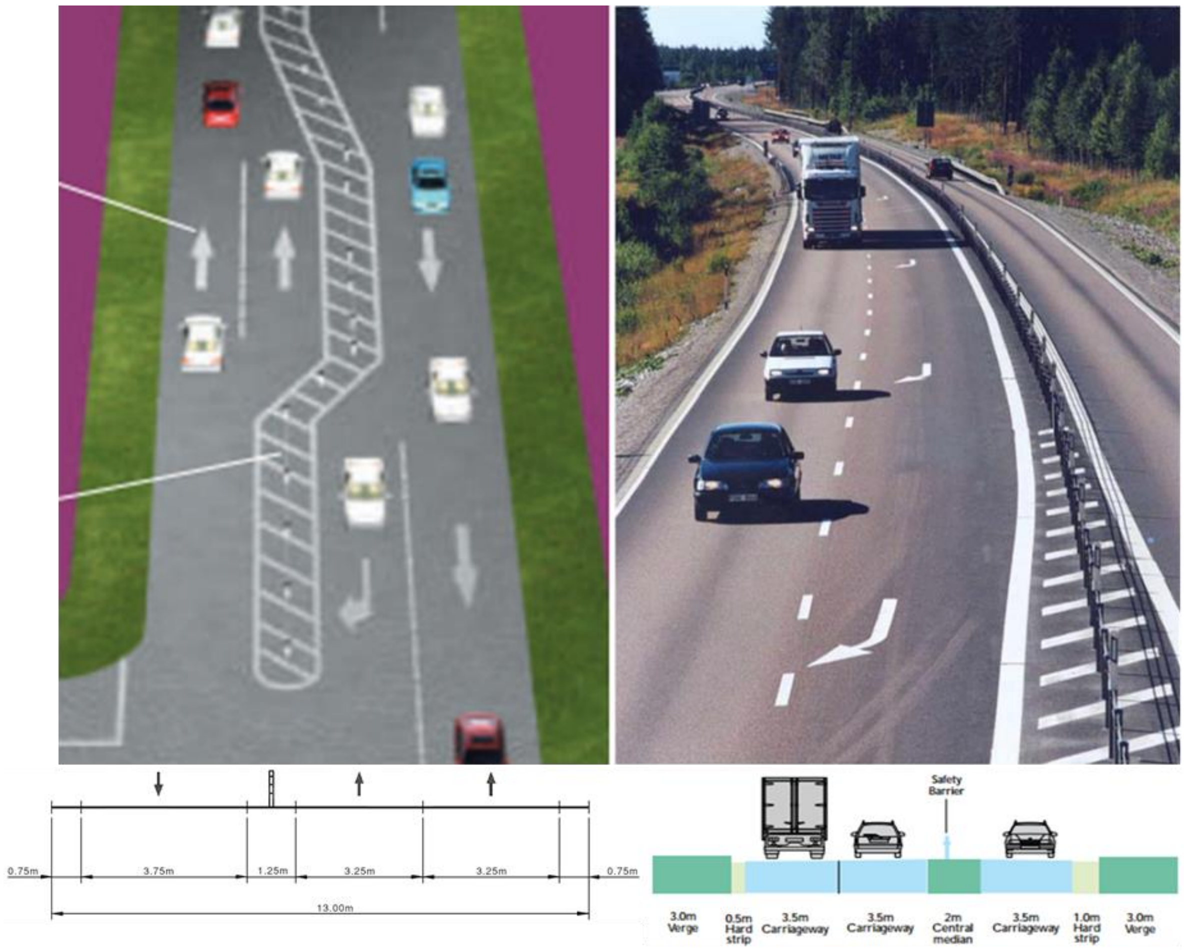


Figure 17 **Typical 2+1 roadway design with center cable barrier in Sweden (Source: Derr. 2003, 13)**

The Swedish Government encouraged not only new construction, but also monitoring and maintenance during the 1997-2007 safety program period. The SRA conducted in-depth studies of all fatal collisions since 1997 to provide quality road management (Belin and Tillgren 2012). In order to ensure that the conclusions drawn from the in-depth research is well-implemented, "OLA" ("*Objektiva fynd, Lösningar och Avsikter*", "Objective data, List of solutions, and Addressed action plans") process was conducted by relevant system designers (Vagverket 2009). Representatives from a multi-disciplinary group analyzed the crash data together to examine all traffic-related injuries and learn what can be done to prevent similar crashes from happening again (McAndrews 2013).

Impact of Campaigns and Education Programs

Generally, public campaigns and education are important, especially when new laws or road infrastructures are introduced, in order to inform the road users (IRTAD 2011). In Sweden, campaigns and education are usually customized for different age groups (e.g., children or young drivers).

Safety campaigns

In 1998, the National Board of Road Safety in Sweden launched communication campaigns that aimed at reducing inebriated driving behavior among 16-24 year old road users (Delaney et al. 2004). The major component of the campaign consisted of three television productions with different approaches of drunk-driving themes aired on television during peak time hours (Delaney et al. 2004). In 2000, an evaluation of this initiative was conducted with 1,360 respondents. The results indicate that the drunk-driving campaign (Do not Drink and Drive, DDD) was effective at increasing awareness regarding the BAC limits and their impact on road fatalities (Delaney et al. 2004). In contrast, one study has shown that the campaigns to reduce drunk-driving had no significant effect on reducing the number of fatal road collisions, whereas, the campaigns regarding speeding behavior were found to have significant positive effects on the number of fatalities (Elvik 1999).

In regard to campaigns that focus on child pedestrians, active media campaigns began during the 1980s (e.g., "Children in Traffic" in 1981, "Soft Children, Hard Cars" in 1982, and "School and Traffic" in 1985) (Koornstra et al. 2002). Currently, however, there are no national media campaigns targeting young pedestrian safety in Sweden (EuroSafe 2012).

Safety education

Since the 1960s, as mentioned in the previous chapter, the Swedish government has educated and informed pedestrians to control their behavior. The most typical examples are the efforts to teach children pedestrians how to behave in traffic (Hydén 2011). Road safety education (e.g., teaching crossing skills) is part of the official school curriculum, but it is not mandatory: each school decides on its extent. For pre-school children, the Swedish National Society for Road Safety organized voluntary “Children’s Traffic Clubs” which were arranged in co-operation with instructors or parents (Dragutinovic and Twisk 2006). During the early 1970s, the casualty rates for 4-6 year olds were reduced by 77 percent. However, in 1994, one Swedish study indicated that the effect of voluntary children’s traffic clubs on collision risk is not clear: the results show that the club member pedestrians do not have a lower crash risk than non-members (Gregersen and Nolen 1994).

Since the mid-1990s, there have been reforms in the driver training system for adolescents and younger drivers. Until 1989, when a new driving test was introduced, Swedish driver training was based on a theoretical test, which only had the objective of teaching candidates in the principles of driving (Schagen 2003). The SRA realized the needs of self-evident training and tests. In 1993, the minimum age for learning how to drive was reduced from 17 to 16 years old while the licensing age remained 18 (Braun et al. 2010).The purpose of lowering the age limit was to give opportunities to young or novice drivers to acquire more experience, through “accompanied practice”, before their actual driving test. Whereas accompanied driving increases the exposure of young drivers, the experiences showed that the number of road crashes during the accompanied driving phase are small and thus may have positive effects on reducing pedestrian-vehicle crashes (Braun et al. 2010).

Road safety campaign and education are always pre-crash actions and not stand-alone solutions for pedestrian safety. In Sweden, campaigns and education programs were conducted in combination with ongoing enforcement (i.e. new speed limits and lower BAC limit restrictions) and engineering (i.e. roundabout and barrier constructions) initiatives. However, the combined effect and the impact on reducing pedestrian fatalities or injuries have not been evaluated (Delaney et al. 2004).

3.3 Conclusion

In this chapter, four road safety countermeasures and their impacts on pedestrian safety are reviewed: (1) measures for improving driver behavior; (2) measures for allocating or sharing level of responsibility on roads; (3) measures for incorporating built environment factors in road safety programs; and (4) measures for safety campaigns and educational programs. Based on the available government documents, published studies, and data in European countries, this paper explored the French and Swedish approaches of improving general road safety and pedestrian safety over particular periods: between 2002 and 2005 for the French case, and between 1997 and 2006 for Swedish road safety programs. The key findings of the case studies are presented below.

Measures for Improving Driver Behaviors

- *France:* Among three different regulations (i.e. laws and sanctions for drunk-driving, speeding, and mobile-phone use while driving) to improve driver behaviors, strong enforcements on speeding behavior, including fixed penalty and point-demerit systems, and an automatic control system were effective in France. Between 2001 and 2005, speeding violations had decreased by 30 percent, and road fatality rates dropped by 30 percent during the same period.

- *Sweden:* The legal BAC limit (i.e. 0.02 percent) in Sweden is the lowest in Europe, and alcohol-related fatalities decreased by 10 out of 51 total road fatalities between 1994 and 1996. In regards to speeding, the Swedish speeding enforcement was based on its Vision Zero strategy, which took the view that vehicle speeds should not exceed the level of violence that the human body can tolerate. However, the compliance rate was still under 50 percent in 2000. Interestingly, Sweden has no regulations on mobile phone use while driving, since the government believes that such communication devices have strong positive effects, such as allowing for faster emergency calls, on saving lives on the roads.

Measures for Allocating Level of Responsibility on Roads

- *France:* In the French road safety program, the primary responsibility for road crashes was on "everyone", including road users, policy-makers, road designers, and other population groups. Less blame was put on road users, and the government took on the main responsibilities for road collisions. This principle of responsibility share helped alter individuals' attitudes toward road safety.

- *Sweden:* Based on the Vision Zero approach, the road system designers hold the main responsibility for traffic safety in Sweden. Therefore, if road users fail to obey traffic rules or if crashes occur, the system designers are required to take any necessary further steps.

Measures for Improving Built Environmental Factors

- *France:* While there was strong political will in France between 2002 and 2005, less attention was given to the environmental modifications. In regards to neighborhood level improvements, new speed limits were implemented on urban and rural roads: 50 km/h (31 mi/h) and 90 km/h (56 mi/h), respectively. However, the new speed limits were still fatal for pedestrians, and the French government decided to adopt a "30 km/h zone" for the 2006-2009 safety program period. There were few technical solutions for improving road level environments.

- *Sweden:* Swedish Road Authorities implemented various environmental modifications of separating or combining different travel modes for both neighborhood and road level interventions. Planners, engineers, and architects collaborated to ensure the safety of non-motorized traffic in urban areas based on the SCAFT and Calm Street guidelines and Vision Zero. Further efforts in improving road design were also based on Vision Zero: in order to reduce severe pedestrian injuries and fatalities due to the high vehicle speeds, construction of "roundabouts" was more popular than traffic lights, and these were effective at reducing deaths on urban roads. On rural roads, "2+1 road with a median barrier" design replaced conventional two-lane roads, which helped reduce severe crashes on rural roads by more than 75 percent.

Measures for Safety Campaigns and Educational Programs

- *France:* The French government has been very active in carrying out safety campaigns to educate and alter road user behavior since the 1970s. These efforts were even more effective along with new policy implementations (e.g., new speed limits) in 2002-2005. Road fatalities dropped by 21 percent and pedestrian fatalities decreased by 27.7 percent between 2002 and 2003. In terms of safety education, a life-long education program, starting from primary school, to prevent road crashes has enabled France to achieve continuous reduction in the number of fatalities since 2002. Safety certificate programs for young road users of different age groups also highlighted the successful educational measures in the French case.

- *Sweden:* Compared to France, the efforts to educate younger road user groups have been less active in Sweden, where most of the school training and education programs were voluntary. In 1993, the government lowered the minimum age for learning to drive (from 17 to 16 years old) to give more opportunities to young drivers to acquire more skills and experience thorough accompanied practice.

Overall, the French and Swedish road safety programs are examples of a process seeking to redefine experts' political responsibilities and improve physical environments to finally raise safety awareness among all road users.

Despite recent improvements in road safety in the United States, the current pedestrian safety level is far below the level of the best-performing European countries (OECD 2012). Compared to the pedestrian death reduction rate of France and Sweden between 1970 and 2011, the U.S. figures still lag behind. Figure 18 shows that from 1970 to 2011, total pedestrian fatalities declined by 85 percent in France and by 83 percent in Sweden. By contrast, there was only a 50 percent fall in pedestrian deaths in the U.S. over the same period.

In France and Sweden, as discussed above, public officials hold the main responsibility for road safety and undertake rigorous and innovative interventions to improve safety awareness and to reduce pedestrian deaths on roads. The gap between road safety progress in France/Sweden and the U.S. indicates that the U.S. may be missing important opportunities to reduce pedestrian injuries and fatalities.

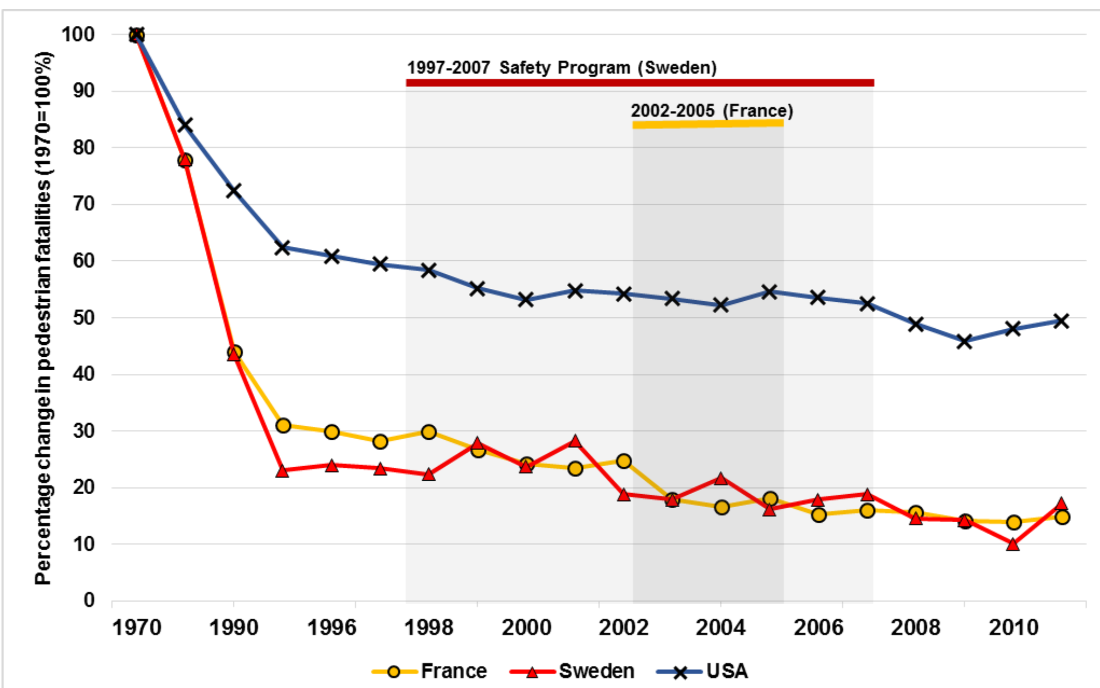


Figure 18 Trends in pedestrian fatalities in France, Sweden, and the US, 1970-2011 (1970=100%)
(Data source: IRTAD 2011, 2013 for France and Sweden and NHTSA 1990, 2001, 2009, 2010 for the US figures)

CHAPTER 4 Conclusion

As walking is highly encouraged as a mode of transport for active living today, it is becoming important to improve pedestrian-vehicle crash prevention strategies that consider both the physical and the social environment. This thesis focused on reviewing existing studies on pedestrian safety, identifying research gaps, and conducting case studies of France and Sweden to identify the factors that are associated with pedestrian-vehicle crashes and to examine how the best-performing European countries have improved pedestrian road safety by implementing national traffic safety programs.

In the first stage of the thesis, thirty-five studies on pedestrian road safety were reviewed, and the findings were classified into seven categories: (1) driver factors; (2) pedestrian factors; (3) vehicle factors; (4) neighborhood level environmental factors; (5) street level environmental factors; (6) other environmental factors; and (7) law/regulation/educational factors. These seven categories were further divided into several sub-categories for an extensive literature review. The findings suggested a need for more research on the strategies of regulating driver behavior, allocating responsibilities of pedestrian crashes, improving built environmental factors, and improving safety campaigns and educational programs to improve pedestrian traffic safety.

In the second stage, case studies of road safety programs in France and Sweden were reviewed to examine how pedestrian safety strategies were implemented and how their interventions had impacts on pedestrian safety. Both countries set a goal in their nation-wide road safety programs to improve pedestrian safety. A major similarity between the two nations' safety programs was the emphasis on improving the traffic safety culture of the society, particularly by modifying driver behaviors and shifting the responsibility of road safety from road-users to decision-makers. However, their implementation strategies showed differences. A four-year (2002-2005) road safety program in France focused on improving road behavior through government-organized campaigns and compulsory education programs that combined stricter driver behavior regulations (i.e. speeding, drunk-driving, and mobile phone use) and harsher penalties. In comparison, the ten-year (1997-2006) Vision Zero program in Sweden focused more on improving error-tolerant roadway design combined with stricter road enforcements (i.e. speeding and drunk-driving behavior) by heavily placing road safety responsibility on road system designers. Sweden has not achieved the rapid rate of decline in the pedestrian fatality rate that France has experienced during its safety program period, but both countries have seen a reduction of more than 80 percent since 1970. By contrast, the pedestrian fatality rate in the United States has decreased by less than 50 percent since 1970. The U.S. safety programs have underemphasized the significant need for measures to control unsafe road behavior, one of the major determinants of pedestrian-vehicle crash risk (Transportation Research Board 2011), and focused more on vehicle and infrastructure improvements.

The findings suggest that the strategies from the cases of France and Sweden can potentially be modified and implemented in the United States. It is true that the U.S. is a much larger country than France and Sweden, and most cities in the U.S. were designed to encourage auto-oriented development over the decades, while those two European countries were not. Also, land use patterns, traffic systems, planning, and the decision-making process among the countries are different. However, in general, the implementation of new safety interventions in the U.S. should involve raising awareness among the public and encouraging decision-makers to more effectively improve walking environments. Also, the strategies of combining different measures (e.g., implementing new speed limits and safety education at the same time) through active collaboration between experts from different fields will help increase pedestrian safety more effectively. All in all, legitimate road safety interventions must be consistent with the overall goals for the transportation planning system.

Along these lines, further research on how planners and professionals in other fields (i.e. architecture, public health, and public policy) can support pedestrian safety should be carried out. Currently, in the U.S., pedestrian safety is a transportation and public health problem, but as noted throughout this thesis, safety components should be recognized as a land-use, design, and policy problem too. Therefore, future research is needed that examines how planners, states' or cities' safety program (e.g., Complete Streets or Safe Route to School) coordinators, and other decision-makers can help raise the salience of pedestrian safety and shift the balance of road safety responsibility to reflect experts' roles in system risk.

Also, this thesis focused on measures for improving driver behaviors, allocating level of responsibility on roads, improving built environmental factors, and safety campaigns and educational programs of two European countries. Additional research on other measures, including measures of benchmarks in other countries will help in developing more robust pedestrian safety strategies in the United States. Moreover, a remaining task for pedestrian safety advocates is to adopt and adapt the strategies from benchmarking countries into the U.S by considering similar geographic (e.g., density or level of urbanization) or demographic characteristics (e.g., median age or income).

BIBLIOGRAPHY

AAA Foundation. 2014. “2013 Traffic Safety Culture Index”. Washington, DC.

Année, Bilan De L'. 2005. “La Sécurité Routière En France”. Securite Routiere. Paris.

Atchley, Paul, Stephanie Atwood, and Aaron Boulton. 2011. “The Choice to Text and Drive in Younger Drivers : Behavior May Shape Attitude.” *Accident Analysis and Prevention* 43 (1): 134–142. doi:10.1016/j.aap.2010.08.003. http://dx.doi.org/10.1016/j.aap.2010.08.003.

Bao, Shan, and Linda Ng Boyle. 2009. “Age-Related Differences in Visual Scanning at Median-Divided Highway Intersections in Rural Areas.” *Accident; Analysis and Prevention* 41 (1) (January): 146–52. doi:10.1016/j.aap.2008.10.007. http://www.ncbi.nlm.nih.gov/pubmed/19114149.

Bax, Charlotte, Claudia Evers, Inger Marie Bernhoft, and René Mathijssen. 2001. “Alcohol Interlock Implementation in the European Union; Feasibility Study”. Leidschendam, The Netherlands.

Belin, Matts-Åke, Per Tillgren, and Evert Vedung. 2012. “Vision Zero-A Road Safety Policy Innovation.” *International Journal of Injury Control and Safety Promotion* 19 (2) (January): 171–9. doi:10.1080/17457300.2011.635213. http://www.ncbi.nlm.nih.gov/pubmed/22166010.

Blanchard, Gilles. 2010. “Evaluation of Three New Pedestrian Priority Zones (‘Zone de Rencontre’) in France.” In *POLIS*, 20. Dresden: French Ministry of Ecology, Sustainable Development, Transport and Housing.

Braun, Eveline, Bernhard Schausberger, Karin Weber, and Martin Winkelbauer. 2010. *Best Practices in Road Safety: Handbook for Measures at the Country Level*. Luxembourg: Publications Office of the European Union.

Caird, Jeff K, Chelsea R Willness, Piers Steel, and Chip Scialfa. 2008. “A Meta-Analysis of the Effects of Cell Phones on Driver Performance.” *Accident; Analysis and Prevention* 40 (4) (July): 1282–93. doi:10.1016/j.aap.2008.01.009. http://www.ncbi.nlm.nih.gov/pubmed/18606257.

Campbell, B.J., Charles V. Zegeer, Herman H. Huang, and Michael J. Cynecki. 2004. “A Review of Pedestrian Safety Research in the United States and Abroad.”

CERTU. 2012. “Sharing the Street in Urban Areas: The Example of the ‘code de La Rue’ (Street Use Code) in France”. France.

———. 2013. “Certu Streets for All National ‘Streets for All’ Programme.”

Chang, Dow. 2008. “National Pedestrian Crash Report.”

Cho, Gihyoug, Daniel a Rodríguez, and Asad J Khattak. 2009. “The Role of the Built Environment in Explaining Relationships between Perceived and Actual Pedestrian and Bicyclist Safety.” *Accident; Analysis and Prevention* 41 (4) (July): 692–702. doi:10.1016/j.aap.2009.03.008. http://www.ncbi.nlm.nih.gov/pubmed/19540957.

Clifton, Kelly J, and Kandice Kreamer-Fults. 2007. “An Examination of the Environmental Attributes Associated with Pedestrian-Vehicular Crashes near Public Schools.” *Accident; Analysis and Prevention* 39 (4) (July): 708–15. doi:10.1016/j.aap.2006.11.003. http://www.ncbi.nlm.nih.gov/pubmed/17174259.

Clifton, Kelly J., Carolina V. Burnier, and Gulsah Akar. 2009. “Severity of Injury Resulting from Pedestrian–vehicle Crashes: What Can We Learn from Examining the Built Environment?” *Transportation Research Part D: Transport and Environment* 14 (6) (August): 425–436. doi:10.1016/j.trd.2009.01.001. http://linkinghub.elsevier.com/retrieve/pii/S1361920909000157.

Clifton, Kelly, and Andrea Livi. 2005. “Research on Women’s Issues in Transportation; Report of a Conference.” In *Research on Women’s Issues in Transportation: Report of a Conference*, Volume 2, 79–88. Washington, D.C.: Transportation Research Board.

Curry, Allison E, Jessica Hafetz, Michael J Kallan, Flaura K Winston, and Dennis R Durbin. 2011. “Prevalence of Teen Driver Errors Leading to Serious Motor Vehicle Crashes.” *Accident; Analysis and Prevention* 43 (4) (July): 1285–90. doi:10.1016/j.aap.2010.10.019. http://www.ncbi.nlm.nih.gov/pubmed/21545856.

De Craen, S, D a M Twisk, M P Hagenzieker, H Elffers, and K a Brookhuis. 2011. “Do Young Novice Drivers Overestimate Their Driving Skills More than Experienced Drivers? Different Methods Lead to Different Conclusions.” *Accident; Analysis and Prevention* 43 (5) (September): 1660–5. doi:10.1016/j.aap.2011.03.024. http://www.ncbi.nlm.nih.gov/pubmed/21658492.

Delaney, Amanda, Bella Lough, Michelle Cameron, and Whelan Max. 2004. “A Review Of Mass Media Campaigns in Road Safety.”

DiMaggio, Charles, and Maureen Durkin. 2002. “Child Pedestrian Injury in an Urban Setting: Descriptive Epidemiology.” *Academic Emergency Medicine : Official Journal of the Society for Academic Emergency Medicine* 9 (1) (January): 54–62. http://www.ncbi.nlm.nih.gov/pubmed/11772671.

Dragutinovic, Nina, and Divera Twisk. 2006. “The Effectiveness of Road Safety Education: A Literature Review”. Leidschendam, The Netherlands.

Dumbaugh, Eric. 2005. “Safe Streets, Livable Streets: A Positive Approach to Urban Roadside Design”. Georgia Institute of Technology.

Ehsani, J P, C R Bingham, J T Shope, T M Sunbury, and B Kweon. 2010. “Teen Driving Exposure in Michigan: Demographic and Behavioral Characteristics.” *Accident; Analysis and Prevention* 42 (4) (July): 1386–91. doi:10.1016/j.aap.2010.02.019. http://www.ncbi.nlm.nih.gov/pubmed/20441856.

Ekman, L., and M. Draskoczy. 1989. “Problems for Vulnerable Road Users in Sweden.”

Elvik, Rune. 1999. “Can Injury Prevention Efforts Go Too Far? Reflections on Some Possible Implications of Vision Zero for Road Accident Fatalities.” *Accident Analysis and Prevention* 31 (3) (May): 265–86. http://www.ncbi.nlm.nih.gov/pubmed/10196603.

———. 2009. “The Trade-off between Efficiency and Equity in Road Safety Policy.” *Safety Science* 47 (6) (July): 817–825. doi:10.1016/j.ssci.2008.10.012. http://linkinghub.elsevier.com/retrieve/pii/S0925753508001835.

“European Status Report on Road Safety: Towards Safer Roads and Healthier Transport Choices.” 2009. Copenhagen.

EuroSafe. 2012. “Child Safety Report Card 2012: Sweden”. Birmingham, UK.

Ewing, R., and E. Dumbaugh. 2009. “The Built Environment and Traffic Safety: A Review of Empirical Evidence.” *Journal of Planning Literature* 23 (4) (May 21): 347–367. doi:10.1177/0885412209335553. http://jpl.sagepub.com/cgi/doi/10.1177/0885412209335553.

Fahlquist, Jessica Nihlén. 2006. “Responsibility Ascriptions and Vision Zero.” *Accident; Analysis and Prevention* 38 (6) (November): 1113–8. doi:10.1016/j.aap.2006.04.020. http://www.ncbi.nlm.nih.gov/pubmed/16876759.

Faure, Anne, and Andre de Neuville. 1992. “Safety in Urban Areas: The French Program ‘Safer City, Accident-Free Districts.’” *Accident Analysis and Prevention* 24 (1): 39–44.

Fillmore, Mark T, Jaime S Blackburn, and Emily L R Harrison. 2008. “Acute Disinhibiting Effects of Alcohol as a Factor in Risky Driving Behavior.” *Drug and Alcohol Dependence* 95 (1-2) (May 1): 97–106.

doi:10.1016/j.drugalcdep.2007.12.018. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2376256&tool=pmcentrez&rendertype=abstract.

Forsyth, Ann, J. Michael Oakes, Kathryn H. Schmitz, and Mary Hearst. 2007. “Does Residential Density Increase Walking and Other Physical Activity?” *Urban Studies* 44 (4) (April): 679–697. doi:10.1080/00420980601184729. http://usj.sagepub.com/cgi/doi/10.1080/00420980601184729.

Gaines, Jean M, Kasey L Burke, Katherine a Marx, Mary Wagner, and John M Parrish. 2011. “Enhancing Older Driver Safety: A Driving Survey and Evaluation of the CarFit Program.” *Journal of Safety Research* 42 (5) (October): 351–8. doi:10.1016/j.jsr.2011.07.007. http://www.ncbi.nlm.nih.gov/pubmed/22093569.

Gårder, Per E. 2004. “The Impact of Speed and Other Variables on Pedestrian Safety in Maine.” *Accident; Analysis and Prevention* 36 (4) (July): 533–42. doi:10.1016/S0001-4575(03)00059-9. http://www.ncbi.nlm.nih.gov/pubmed/15094405.

Gerondeau, Christian. 2006. “Road Safety in France: Reflections on Three Decades of Road Safety Policy.”

Gregersen, Nils Petter, and Sixten Nolen. 1994. “Children’s Road Safety and the Strategy of Voluntary Traffic Safety Clubs.” *Accident Analysis and Prevention* 26 (4): 463–470.

Hamilton-Baillie, Ben. 2008. “Towards Shared Space.” *Urban Design International* 13 (2): 130–138. doi:10.1057/udi.2008.13. http://www.palgrave-journals.com/doifinder/10.1057/udi.2008.13.

Harrison, Emily L R, and Mark T Fillmore. 2005. “Are Bad Drivers More Impaired by Alcohol? Sober Driving Precision Predicts Impairment from Alcohol in a Simulated Driving Task.” *Accident; Analysis and Prevention* 37 (5) (September): 882–9. doi:10.1016/j.aap.2005.04.005. http://www.ncbi.nlm.nih.gov/pubmed/15907777.

Hatfield, Julie, and Susanne Murphy. 2007. “The Effects of Mobile Phone Use on Pedestrian Crossing Behaviour at Signalized and Unsignalized Intersections.” *Accident; Analysis and Prevention* 39 (1) (January): 197–205. doi:10.1016/j.aap.2006.07.001. http://www.ncbi.nlm.nih.gov/pubmed/16919588.

Hauer, Ezra, and Vanasse Hangen Brustlin. 2010a. “Lessons Learned from Other Countries” (9).

———. 2010b. “White Papers for ‘Toward Zero Deaths’, A National Strategy on Highway Safety: 9. Lessons Learned from Other Countries”. Washington, D.C.

Heydecker, B J, and S A Robertson. 2009. “Evaluation of Pedestrian Priority Zones in the European Area Report to the Korea Transport Institute KoTI”. London.

Hitosugi, Masahito, Hitoshi Kawato, Sayaka Gomei, Koji Mizuno, and Shogo Tokudome. 2013. “Severity of Child Pedestrian Injuries due to Bonnet-Type-Vehicle Collision.” *Pediatrics International : Official Journal of the Japan Pediatric Society* 55 (5) (October): 624–8. doi:10.1111/ped.12140. http://www.ncbi.nlm.nih.gov/pubmed/23701244.

Holland, Carol, and Roslyn Hill. 2007. “The Effect of Age, Gender and Driver Status on Pedestrians’ Intentions to Cross the Road in Risky Situations.” *Accident; Analysis and Prevention* 39 (2) (March): 224–37. doi:10.1016/j.aap.2006.07.003. http://www.ncbi.nlm.nih.gov/pubmed/16979132.

Hydén, Christer. 2011. “The Safety of Pedestrians”. Lund, Sweden.

IRTAD. 2009. “Road Safety Annual Report 2009.”

———. 2011. “Road Safety Annual Report 2011.”

———. 2013. “Road Safety Annual Report 2013.”

Johansson, Roger. 2009. “Vision Zero – Implementing a Policy for Traffic Safety.” *Safety Science* 47 (6) (July): 826–831. doi:10.1016/j.ssci.2008.10.023. http://linkinghub.elsevier.com/retrieve/pii/S0925753508001859.

Johnson, Emily, Judy A. Geyer, Nirmeet Rai, and David R. Ragland. 2004. “Low Income Childhood Pedestrian Injury: Understanding the Disparate Risk”. Berkeley.

Johnston, Lucy, and Victoria Peace. 2007. “Where Did That Car Come from?: Crossing the Road When the Traffic Comes from an Unfamiliar Direction.” *Accident Analysis and Prevention* 39 (5) (September): 886–93. doi:10.1016/j.aap.2006.12.010. http://www.ncbi.nlm.nih.gov/pubmed/17270134.

Kawato, Hitoshi, Masahito Hitosugi, Koji Mizuno, Yasuhiro Matsui, and Shogo Tokudome. 2013. “Analysis of Child-Vehicle Collision Injuries by Vehicle Type.” *Journal of Pediatric Surgery* 48 (7) (July): 1588–92. doi:10.1016/j.jpedsurg.2011.09.039. http://www.ncbi.nlm.nih.gov/pubmed/23895977.

Kim, Joon-Ki, Gudmundur F Ulfarsson, Venkataraman N Shankar, and Sungyop Kim. 2008. “Age and Pedestrian Injury Severity in Motor-Vehicle Crashes: A Heteroskedastic Logit Analysis.” *Accident; Analysis and Prevention* 40 (5) (September): 1695–702. doi:10.1016/j.aap.2008.06.005. http://www.ncbi.nlm.nih.gov/pubmed/18760098.

Kim, Joon-Ki, Gudmundur F Ulfarsson, Venkataraman N Shankar, and Fred L Mannering. 2010. “A Note on Modeling Pedestrian-Injury Severity in Motor-Vehicle Crashes with the Mixed Logit Model.” *Accident; Analysis and Prevention* 42 (6) (November): 1751–8. doi:10.1016/j.aap.2010.04.016. http://www.ncbi.nlm.nih.gov/pubmed/20728626.

Kircher, Katja, and Christopher Patten. 2011. “Mobile Telephones and Other Communication Devices and Their Impact on Traffic Safety A Review of the Literature.”

Koornstra, Matthijs, David Lynam, Göran Nilsson, Piet Noordzij, Hans-Erik Pettersson, Fred Wegman, Peter Wouters, and SWOV. 2002. “SUNflower: A Comparative Study of the Development of Road Safety in Sweden, the United Kingdom, and the Netherlands”. Leidschendam.

Korner-Bitensky, Nicol, Ailene Kua, Claudia von Zweck, and Kathy Van Benthem. 2009. “Older Driver Retraining: An Updated Systematic Review of Evidence of Effectiveness.” *Journal of Safety Research* 40 (2) (January): 105–11. doi:10.1016/j.jsr.2009.02.002. http://www.ncbi.nlm.nih.gov/pubmed/19433202.

Kwasniak, Andrew M., and Michael J. Kuzel. 2009. “French Lessons: A Review of an Effective Road Safety Program.” *ITE Journal* 79 (8): 32–39.

Larsson, Peter, Sidney W.a. Dekker, and Claes Tingvall. 2010. “The Need for a Systems Theory Approach to Road Safety.” *Safety Science* 48 (9) (November): 1167–1174. doi:10.1016/j.ssci.2009.10.006. http://linkinghub.elsevier.com/retrieve/pii/S0925753509001878.

LaScala, E a, F W Johnson, and P J Gruenewald. 2001. “Neighborhood Characteristics of Alcohol-Related Pedestrian Injury Collisions: A Geostatistical Analysis.” *Prevention Science : The Official Journal of the Society for Prevention Research* 2 (2) (June): 123–34. http://www.ncbi.nlm.nih.gov/pubmed/11523752.

LaScala, Elizabeth a, Paul J Gruenewald, and Fred W Johnson. 2004. “An Ecological Study of the Locations of Schools and Child Pedestrian Injury Collisions.” *Accident; Analysis and Prevention* 36 (4) (July): 569–76. doi:10.1016/S0001-4575(03)00063-0. http://www.ncbi.nlm.nih.gov/pubmed/15094409.

Lee, Chris, and Mohamed Abdel-Aty. 2005. “Comprehensive Analysis of Vehicle-Pedestrian Crashes at Intersections in Florida.” *Accident; Analysis and Prevention* 37 (4) (July): 775–86. doi:10.1016/j.aap.2005.03.019. http://www.ncbi.nlm.nih.gov/pubmed/15869737.

Lefler, Devon E., and Hampton C. Gabler. 2004. “The Fatality and Injury Risk of Light Truck Impacts with Pedestrians in the United States.” *Accident Analysis & Prevention* 36 (2) (March): 295–304. doi:10.1016/S0001-4575(03)00007-1. http://linkinghub.elsevier.com/retrieve/pii/S0001457503000071.

Lerner, Neil, Jeremiah Singer, and James Jenness. 2010. “White Papers for ‘Toward Zero Deaths’, A National Strategy on Highway Safety: 3. Safer Drivers”. Washington, D.C.

Lichenstein, Richard, Daniel Clarence Smith, Jordan Lynne Ambrose, and Laurel Anne Moody. 2012. “Headphone Use and Pedestrian Injury and Death in the United States: 2004-2011.” *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention* 18 (5) (October): 287–90. doi:10.1136/injuryprev-2011-040161. http://www.ncbi.nlm.nih.gov/pubmed/22248915.

Lie, Aners, and Claes Tingvall. 2001. “Governmental Status Report, Sweden”. Stockholm.

———. 2009. “Governmental Status Report, Sweden”. Stockholm.

Loeb, Peter D., and William a. Clarke. 2009. “The Cell Phone Effect on Pedestrian Fatalities.” *Transportation Research Part E: Logistics and Transportation Review* 45 (1) (January): 284–290. doi:10.1016/j.tre.2008.08.001. http://linkinghub.elsevier.com/retrieve/pii/S1366554508001130.

Loukaitou-Sideris, a., R. Liggett, and H.-G. Sung. 2007. “Death on the Crosswalk: A Study of Pedestrian-Automobile Collisions in Los Angeles.” *Journal of Planning Education and Research* 26 (3) (March 1): 338–351. doi:10.1177/0739456X06297008. http://jpe.sagepub.com/cgi/doi/10.1177/0739456X06297008.

Lyons, Ronan. 2006. “Child Safety Good Practice Guide: Good Investments in Unintentional Child Injury Prevention and Safety Promotion”. Amsterdam. http://www.childsafetyeurope.org/publications/goodpracticeguide/.

Magnusson, Patrick, Lisa Jakobsson, and Sven Hultman. 2011. “Alcohol Interlock Systems in Sweden: 10 Years of Systematic Work.” *American Journal of Preventive Medicine* 40 (3) (March): 378–9. doi:10.1016/j.amepre.2010.11.015. http://www.ncbi.nlm.nih.gov/pubmed/21335272.

McAndrews, C. 2013. “Road Safety as a Shared Responsibility and a Public Problem in Swedish Road Safety Policy.” *Science, Technology & Human Values* 38 (6) (June 25): 749–772. doi:10.1177/0162243913493675. http://sth.sagepub.com/cgi/doi/10.1177/0162243913493675.

Mcandrews, Carolyn Ann. 2010. “Road Safety in the Context of Urban Development in Sweden and California”. University of California, Berkeley.

Miranda-Moreno, Luis F, Patrick Morency, and Ahmed M El-Geneidy. 2011. “The Link between Built Environment, Pedestrian Activity and Pedestrian-Vehicle Collision Occurrence at Signalized Intersections.” *Accident; Analysis and Prevention* 43 (5) (September): 1624–34. doi:10.1016/j.aap.2011.02.005. http://www.ncbi.nlm.nih.gov/pubmed/21658488.

Moudon, Anne Vernez, Lin Lin, Junfeng Jiao, Philip Hurvitz, and Paula Reeves. 2011. “The Risk of Pedestrian Injury and Fatality in Collisions with Motor Vehicles, a Social Ecological Study of State Routes and City Streets in King County, Washington.” *Accident; Analysis and Prevention* 43 (1) (January): 11–24. doi:10.1016/j.aap.2009.12.008. http://www.ncbi.nlm.nih.gov/pubmed/21094292.

Muhlrad, Nicole. 2006. “Speed Enforcement and Road Safety in France.” In *GAMBIT 2006*, 20.

Murard, Frédéric. 2009. “The « Code de La Rue » (Street Use Code) Program in France.”

Nasar, Jack, Peter Hecht, and Richard Wener. 2007. “‘Call If You Have Trouble’: Mobile Phones and Safety among College Students.” *International Journal of Urban and Regional Research* 31 (4) (December 13): 863–873. doi:10.1111/j.1468-2427.2007.00759.x. http://doi.wiley.com/10.1111/j.1468-2427.2007.00759.x.

———. 2008. “Mobile Telephones, Distracted Attention, and Pedestrian Safety.” *Accident; Analysis and Prevention* 40 (1) (January): 69–75. doi:10.1016/j.aap.2007.04.005. http://www.ncbi.nlm.nih.gov/pubmed/18215534.

Nasar, Jack L, and Derek Troyer. 2013. "Pedestrian Injuries due to Mobile Phone Use in Public Places." *Accident; Analysis and Prevention* 57 (August): 91–5. doi:10.1016/j.aap.2013.03.021. http://www.ncbi.nlm.nih.gov/pubmed/23644536.

National Highway Traffic Safety Administration. 2012. "Traffic Safety Facts: 2010 Data". Washington, D.C.

———. 2013. "Traffic Safety Facts 2011 Data: Pedestrians". Washington, D.C. www-nrd.nhtsa.dot.gov/CATS/index.aspx.

Neider, Mark B, Jason S McCarley, James a Crowell, Henry Kaczmarski, and Arthur F Kramer. 2010. "Pedestrians, Vehicles, and Cell Phones." *Accident; Analysis and Prevention* 42 (2) (March): 589–94. doi:10.1016/j.aap.2009.10.004. http://www.ncbi.nlm.nih.gov/pubmed/20159083.

Noland, Robert B, Nicholas J Klein, and Nicholas K Tulach. 2013. "Do Lower Income Areas Have More Pedestrian Casualties?" *Accident; Analysis and Prevention* 59 (October): 337–45. doi:10.1016/j.aap.2013.06.009. http://www.ncbi.nlm.nih.gov/pubmed/23856641.

Öström, M, and a Eriksson. 2001. "Pedestrian Fatalities and Alcohol." *Accident; Analysis and Prevention* 33 (2) (March): 173–80. http://www.ncbi.nlm.nih.gov/pubmed/11204887.

Oxley, Jennifer, Michael Lenné, and Bruce Corben. 2006. "The Effect of Alcohol Impairment on Road-Crossing Behaviour." *Transportation Research Part F: Traffic Psychology and Behaviour* 9 (4) (July): 258–268. doi:10.1016/j.trf.2006.01.004. http://linkinghub.elsevier.com/retrieve/pii/S1369847806000155.

Pace, Jean-François, María Teresa Tormo, Jaime Sanmartín, Pete Thomas, Alan Kirk, Laurie Brown, George Yannis, Petros Evgenikos, Panagiotis Papantoniou, Jeremy Broughton, et al. 2012. "Basic Fact Sheet 'Pedestrians'". D3.9. EC FP7 Project.

Pace, Jean-François, María Teresa Tormo, Jaime Sanmartín, Pete Thomas, Alan Kirk, Laurie Brown, George Yannis, Petros Evgenikos, Panagiotis Papantoniou, Jeremy Brandstaetter, et al. 2012. "Traffic Safety Basic Facts 2012 'Pedestrians.'" doi:Deliverable D3.9 of the EC FP7 project.

Perez, William A., Mary Anne Bertola, Jason F. Kennedy, and John A. Molino. 2011. "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)". Washington, D.C.

Reed, Randal, and Siddhartha Sen. 2005. "Racial Differences and Pedestrian Safety: Some Evidence from Maryland and Implications for Policy." *Journal of Public Transportation* 8 (2): 37–39.

Retting, Richard, and Ronald Knipling. 2010. "White Papers for: 'Toward Zero Deaths', A National Strategy on Highway Safety: 4. Safer Vehicles." *White Papers for"Toward Zero Deaths", A National Strategy on Highway Safety: 4. Safer Vehicles*. Washington, D.C.

Rosenbloom, Tova. 2009. "Crossing at a Red Light: Behaviour of Individuals and Groups." *Transportation Research Part F: Traffic Psychology and Behaviour* 12 (5) (September): 389–394. doi:10.1016/j.trf.2009.05.002. http://linkinghub.elsevier.com/retrieve/pii/S1369847809000278.

SafetyNet. 2009. "Pedestrians & Cyclists."

Schagen, Ingrid van. 2003. "Traffic Calming Schemes: Opportunities and Implementation Strategies". Leidschendam, The Netherlands.

Schroeder, Paul, Mikelyn Meyers, and Lidia Kostyniuk. 2013. "National Survey on Distracted Driving Attitudes and Behaviors (2012)". Washington, D.C.

Siddiqui, Naved A, Xuehao Chu, and Martin Guttenplan. 2003. "Crossing Locations, Light Conditions, and Pedestrian Injury Severity." *Journal of Transportation Research Board* (No. 1982): 141–149.

Southeastern, The, John R Stone, Kosok Chae, and Sirisha Pillalamarri. 2002. "The Effects of Roundabouts on Pedestrian Safety" (August).

Spainhour, Lisa, Isaac Wootton, John Sobanjo, and Patrick Brady. 2006. "Causative Factors and Trends in Florida Pedestrian Crashes." *Transportation Research Record* 1982/2006 (1) (January 1): 90–98. doi:10.3141/1982-13. http://trb.metapress.com/openurl.asp?genre=article&id=doi:10.3141/1982-13.

SWOV Institute for Road Safety Research. 2005. *Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020*. Edited by Fred Wegman and Letty Aarts. SWOV.

Tefft, Brian C. 2013. "Impact Speed and a Pedestrian's Risk of Severe Injury or Death." *Accident; Analysis and Prevention* 50 (January): 871–8. doi:10.1016/j.aap.2012.07.022. http://www.ncbi.nlm.nih.gov/pubmed/22935347.

The Ministry of Ecology and Sustainable Planning and Development. 2013. "Road Safety in France."

Twisk, Divera a.M., Willem P. Vlakveld, Jacques J.F. Commandeur, Jean T. Shope, and Gerjo Kok. 2014. "Five Road Safety Education Programmes for Young Adolescent Pedestrians and Cyclists: A Multi-Programme Evaluation in a Field Setting." *Accident Analysis & Prevention* 66 (May): 55–61. doi:10.1016/j.aap.2014.01.002. http://linkinghub.elsevier.com/retrieve/pii/S0001457514000050.

Ukkusuri, Satish, Luis F. Miranda-Moreno, Gitakrishnan Ramadurai, and Jhael Isa-Tavarez. 2012. "The Role of Built Environment on Pedestrian Crash Frequency." *Safety Science* 50 (4) (April): 1141–1151. doi:10.1016/j.ssci.2011.09.012. http://linkinghub.elsevier.com/retrieve/pii/S0925753511002578.

Vadeby, Anna, Åsa Forsman, Arne Carlsson, Urban Björketun, and Mohammad-Reza Yahya. 2012. "Evaluation of the New Speed Limits – Traffic Safety and Environmental Effects". Linköping, Sweden.

Vagverket. 2009. "SAFE TRAFFIC – Vision Zero on the Move". Borlänge, Sweden.

Walker, Esther J., Sophie N. Lanthier, Evan F. Risko, and Alan Kingstone. 2012. "The Effects of Personal Music Devices on Pedestrian Behaviour." *Safety Science* 50 (1) (January): 123–128. doi:10.1016/j.ssci.2011.07.011. http://linkinghub.elsevier.com/retrieve/pii/S0925753511001585.

Wegman, Fred, Atze Dijkstra, and Govert Schermers. 2005. "Sustainable Safety in the Netherlands : The Vision , the Implementation and the Safety Effects."

Whitelegg, John, and Gary Haq. 2006. "Vision Zero: Adopting a Target of Zero for Road Traffic Fatalities and Serious Injuries John Whitelegg and Gary Haq Vision Zero". Stockholm.

WHO. 2013. "Global Status Report on Road Safety 2013: Supporting a Decade of Action."

Wier, Megan, June Weintraub, Elizabeth H Humphreys, Edmund Seto, and Rajiv Bhatia. 2009. "An Area-Level Model of Vehicle-Pedestrian Injury Collisions with Implications for Land Use and Transportation Planning." *Accident; Analysis and Prevention* 41 (1) (January): 137–45. doi:10.1016/j.aap.2008.10.001. http://www.ncbi.nlm.nih.gov/pubmed/19114148.

Zajac, Sylvia S, and John N Ivan. 2003. "Factors Influencing Injury Severity of Motor Vehicle-Crossing Pedestrian Crashes in Rural Connecticut." *Accident; Analysis and Prevention* 35 (3) (May): 369–79. http://www.ncbi.nlm.nih.gov/pubmed/12643954.

Zegeer, Charles, Dan Nabors, Dan Gelinne, Nancy Lefler, and Max Bushell. 2010. "Pedestrian Safety Strategic Plan : Recommendations for Research and Product Development."

Zegeer, Charlie, William Hunter, Loren Staplin, Fran Bents, Richard Huey, and Janet Barlow. 2010. “White Papers for ‘Toward Zero Deaths’, A National Strategy on Highway Safety: 5. Safer Vulnerable Road Users : Pedestrians , Bicyclists , Motorcyclists , and Older Users”. Washington, D.C.

APPENDIX | Literature Review Matrix

Table 5 Pedestrian-Vehicle crash factors. Arranged by reviewed literature and factor categories.

No.			1	2	3		4	5	6				7	8	9	10	11		12	13	14	15	16
Primary Author			**Gårder**	**Holland**	**Lee**		**Oström**	**Tefft**	**Hatfield**				**Johnston**	**Kim**	**Lichenstein**	**Loeb**	**Nasar**		**Neider**	**Rosenbloom**	**Schwebel**	**Siddiqui**	**Spainhour**
Date			2004	2007	2005		2000	2013	2007				2007	2008	2012	2009	2013		2010	2009	2012	2003	2006
Study Area			Maine, United States	Birmingham, UK	Florida, United States		Northern Sweden (rural)	Austin, TX, United States	Sydney, Australia (suburbs)				New Zealand	North Carolina, United States	United States	United States	United States		Chicago, IL, United States	N/A (urban)	United States	Florida, United States	Florida, United States
Study Population			Pedestrian crashes (n=1,598)	17-92 years old (n=293)	Pedestrian crashes near 1563 intersections (n=7,000)		pedestrian fatalities autopsied (n=286)	Pedestrians struck by vehicles, older than age 15 (n=315)	(n=546)				Male pedestrians (n=12)	Ped over 18 years old (n=5,808)	Ped collisions involving headphone use (n=116)	Ped fatality data for the years 1975-2002	Ped involved crashes due to mobile phone use (n=1,506)		College students, 18-30 years old (n=36)	(n=1,392)	College students, aged 17-45 (n=138)	Pedestrian crashes reltaed to crossings (n=58,202)	Fatal pedestrian crashes (n=353)
Dependent variable (fatalities/severity/collision/risk)			collision	risk (behavior)	collision	severity	fatalities (peds)	fatalities & severe injuries	risk (cell phone use)				risk (crossing behavior)	severity	collision	fatality	collision	collision	risk (peds crossing behavior)	risk (behavior at intersection traffic lights)	risk (crossing behavior)	severity	collision
	Variables								signalized (female)	signalized (male)	unsignalized (female)	unsignalized (male)					driver	ped					
Driver Factor	age			o	o (mid-age)		o							o			o	o				o	
		young (17-24)			_		_							_									
		adult (25-64)		o	_		_							_									
		adult (16-64)		o	_		_							_									
		older (65+)		x	_		_							_									
		older (70+)		x	_									_									
	sex			o	o		o							o			o	o				o	
	physical disability																					o	
	ethnicity																					x	
	behavior/ action			o																			o
		driver making left/right turn												o									
		vehicle going straight																					
		vehicle backing /parking												o									
		vehicle merging												_									
		more than one vehicle involved																					
		speeding			x	o		o						o								o	o
	driver distraction																						
		cell phone use												o			o	o					
		inattention																					o
		fatigue-asleep																					x
	inebriety																						
		alcohol involved driving			o		o							o								o	o
		drug involved driving			o																		x
	poor pedestrian visibility																					o	o
	crash history record		x																				
	driver fault						x																
Pedestrian factors	age			o	o (mid-age)	o	o	o	o	x				o	o		o	o		x		o	
		child (<5)			_		_		_													_	
		child (<15)			_		_								_							_	
		youth			_		_	_	_						_								
		adult (16-64)			_		_	_	_					_	_					_			
		older (65+)			_		_	_	_					_	_					_		_	
		70+			_		_	_	_					_	_					_		_	
	sex			o	o	x	o	x						x	x		o	o		o		o	
	physical disability																					o	
	marital status																						
	ethnicity																					x	
		African American																				_	
		Hispanic																				_	
		Asian																					
		other																					
		country of origin											x										

Legend: **X** indicates an independent variable that is measured but *not significantly* associated with dependent variable

O indicates an independent variable that is *significantly* associated with dependent variable

_ indicates variable that *aggregated* into major factors

Table 5 continued (study no. 17-35)

	No.	17	18	19	20		21	22	23	24	25	26	27	28	29		30		31		32	33	34	35
	Primary Author	**Hitosugi**	**Kawato**	**Lefler**	**Cho**		**Clifton**	**Clifton**	**DiMaggio**	**Kim**	**LaScala**	**Li**	**Loukaitou-Sideris**	**Miranda-Moreno**	**Moudon**		**Noland**		**Ukkusuri**		**Wier**	**Zajac**	**Reed**	**Twisk**
	Date	2013	2013	2004	2009		2007	2009	2002	2010	2004	2010	2007	2011	2011		2013		2011		2009	2013	2005	2014
	Study Area	Tsukuba and Tsuchiura, Japan	Tsukuba and Tsuchiura, Japan	United States (6 major cities)	Montgomery County, MD, Washington D.C. (well-developed urban)		Baltimore City, Maryland (near public schools)	Baltimore City, Maryland	New York City (urban)	North Carolina, United States	California, United States	Canada, downtown Toronto (urban, 8-lane divided road strip)	Los Angeles, United States (urban)	City of Montreal, Canada	King County, WA, United States		New Jersey, United States		New York City, United States		San Francisco, United States (urban)	Connecticut, United States (rural)	Maryland, United States	United States
	Study Population	Injured child pedestrian (n=47)	Under 13 years old injured pedestrian (n=68)	5-years vehicle-pedestrian collision cases (n=31,260)	318 community analysis zones (n=249, survey participants), (n=1,559, total crashes)		163 public schools (n=1,513 pedestrian -vehicular crashes)	(n=4,695)	Injured individual under 20 years old (n=32,578)	police-reported ped crashes (n=5,808)		Crossing pedestrians (n=618)	Pedestrian involved crashes (n=25,683)	Signalized intersection (n=519)	Pedestrian who were involved in collisions (n=2,457)		(n=81,785)	(n=8,117)	N/A (census tract level)	N/A (zip-code level)	176 census tracts (n=4,039)	pedestrian crashes on the rural crossings (n=278)	Survey (n=809)	young adolescents (n=1,874)
	Dependent variable (fatalities/severity/collision/risk)	severity	severity	severity	risk (perceived)	collision	severity (high, all-ages)	severity	severity	severity	collision (child ped)	risk (signal compliance)	collision (per sq mile)	collision (ped crashes)	severity (state route)	severity (city streets)	fatality (drivers & occupants)	fatality (peds)	fatality	collision	collision	severity	risk (senior peds' safety attitude)	risk (safe behavior)
	Variables																							
Driver Factor	**age**									o														
	young (17-24)									_														
	adult (25-64)									_														
	adult (16-64)									_														
	older (65+)									_														
	older (70+)									_														
	sex									o														
	physical disability																							
	ethnicity																							
	behavior/ action								o														o	
	driver making left/right turn								_	o					x/o	x/o								
	vehicle going straight								_						o	o								
	vehicle backing /parking								_	o														
	vehicle merging																							
	more than one vehicle involved														x									
	speeding			o						o				x										
	driver distraction																							
	cell phone use																							
	inattention																							
	fatigue-asleep																							
	inebriety																							
	alcohol involved driving									o					x	o						o		
	drug involved driving																							
	poor pedestrian visibility																							
	crash history record																							
	driver fault																							
Pedestrian factors	**age**	x	x		x			o	o	o					o (age sq)							o		x
	child (<5)	_	_					o	_						_	o								
	child (<15)		_												_	x								
	youth								_						_	x								_
	adult (16-64)							_		_					_	x/o								
	older (65+)							o		_					_	o						_		
	70+									_					_	o								
	sex				o			o	o	x					x	x							o	o
	physical disability																							
	marital status				o																			
	ethnicity																						o	
	African American																						_	
	Hispanic																							
	Asian																						_	
	other																						_	
	country of origin																							

Table 5 continued (study no. 1-16)

No.			1	2		3	4	5				6	7	8	9	10		11	12	13	14	15	16
Primary Author			Gårder	Holland	Lee		Oström	Tefft	Hatfield				Johnston	Kim	Lichenstein	Loeb	Nasar		Neider	Rosenbloom	Schwebel	Siddiqui	Spainhour
Date			2004	2007	2005		2000	2013	2007				2007	2008	2012	2009	2013		2010	2009	2012	2003	2006
Dependent variable (fatalities/severity/collision/risk)			collision	risk (behavior)	collision	severity	fatalities (peds)	fatalities & severe injuries	risk (cell phone use)				risk (crossing behavior)	severity	collision	fatality	collision	collision	risk (peds crossing behavior)	risk (behavior at intersection traffic lights)	risk (crossing behavior)	severity	collision
	Variables								signalized (female)	signalized (male)	unsignalized (female)	unsignalize d (male)					driver	ped					
	familiarity (environment)												o										
	physical stature							o															
		BMI						x															
	body region (chest/head/neck)						x																
	walking speed												x										
		crossing time							o	o (faster)	x	o											
	peds in group								o	x	o	o								o			
		walking with children/grandchildren																					
	distracted walking																						
	cell-phone use								o	o	o	o							o				
		texting							_	_	_	_							_		o		
		talking on the phone							_	_	_	_							_				
		hands-free phone							_	_	_	_											
		hand-held phone							_	_	_	_											
	portable music player																		o		o		
		head-phone use (phone/mp3)													o				_				
		listening to music																	_				
	medical conditions (mental)																						
	inebriety																						
		alcohol involved walking			o	o	o															o	o
		drug involved walking			o	o																	x
	crash history record																				o		
	pedestrian fault						x																
	pedestrian behavior/ avoidance																o	o					o
		signal obedience							_														
		looks for traffic before crossing							o	x	o	x											
		crossing at non-crosswalk																					o
		crossing at non-intersection																					
		off-roadway																					
		walking along the roadway												o									
		looks for traffic while crossing							o	x	o	x											
		looks left and right																	o		o		
		looks away																			o		
		waited for traffic to stop before crossing							o	x	o	x		x									
		missed opportunities to cross																			x		
		inattention																					o
		fatigue-asleep																					x
	ped in crosswalk													o									
	mobility								_														
		pushing cart/ stroller/ walking with pets																					
	clothing																						
		reflective clothing																				x	
		dark clothing																					
Vehicle Factors	vehicle year																						
	vehicle type		_		o	o	o	x						o	o (train)							x	
		SUV												o								_	
		one-box type vehicle																					
		light truck						_						_								_	
		trucks/vans/buses	_		_	_	_	_						o								_	
		car (sedan)	_		_	_	_	_						_									
		compact car																					
		motorcycles					_							_									
		public (police/ emergency)												_									
	vehicle design																						
		impact configuration (angle, height of vehicle)																				x	
		vehicle bumper height						x															
		vehicle curb weight						x															
	vehicle tech																						
	collision velocity																						

Table 5 continued (study no. 17-35)

	No.	17	18	19	20		21	22	23	24	25	26	27	28	29		30		31		32	33	34	35
	Primary Author	**Hitosugi**	**Kawato**	**Lefler**	**Cho**		**Clifton**	**Clifton**	**DiMaggio**	**Kim**	**LaScala**	**Li**	**Loukaitou-Sideris**	**Miranda-Moreno**	**Moudon**		**Noland**		**Ukkusuri**		**Wier**	**Zajac**	**Reed**	**Twisk**
	Date	2013	2013	2004	2009		2007	2009	2002	2010	2004	2010	2007	2011	2011		2013		2011		2009	2013	2005	2014
	Dependent variable (fatalities/severity/collision/risk)	severity	severity	severity	risk (perceived)	collision	severity (high, all-ages)	severity	severity	severity	collision (child ped)	risk (signal compliance)	collision (per sq mile)	collision (ped crashes)	severity (state route)	severity (city streets)	fatality (drivers & occupants)	fatality (peds)	fatality	collision	collision	severity	risk (senior peds' safety attitude)	risk (safe behavior)
	Variables																							
Pedestrian factors	familiarity (environment)																	o						
	physical stature	o	x																					
	BMI																							
	body region (chest/head/neck)	x	o	o																				
	walking speed											o												
	crossing time											o												
	peds in group											x			o	o								
	walking with children/grandchildren																						o	
	distracted walking																							
	cell-phone use																							
	texting																							
	talking on the phone																							
	hands-free phone																							
	hand-held phone																							
	portable music player																							
	head-phone use (phone/mp3)																							
	listening to music																							
	medical conditions (mental)																							
	inebriety																							
	alcohol involved walking							o							o	x						o		
	drug involved walking							o																
	crash history record																							
	pedestrian fault																							
	pedestrian behavior/ avoidance														o	o								
	signal obedience							o							o	x								
	looks for traffic before crossing																							
	crossing at non-crosswalk														x	x								
	crossing at non-intersection														x	x								
	off-roadway									_														
	walking along the roadway									_					x	o								
	looks for traffic while crossing																							
	looks left and right																							
	looks away																							
	waited for traffic to stop before crossing																							
	missed opportunities to cross																							
	inattention																							
	fatigue-asleep																							
	ped in crosswalk									_														
	mobility																							
	pushing cart/ stroller/ walking with pets											x												
	clothing																							
	reflective clothing																							
	dark clothing							o																
Vehicle Factors	vehicle year			x																				
	vehicle type	x	x	o				o		o												o		
	SUV	_	_ (head injuries)							o														
	one-box type vehicle	_	_	_						_														
	light truck			_						_														
	trucks/vans/buses	_		_				x		o														
	car (sedan)	_	_	_				_		_														
	compact car			_																				
	motorcycles							x		_														
	public (police/ emergency)							o		_														
	vehicle design			o (frontal geometry)																				
	impact configuration (angle, height of vehicle)	x																						
	vehicle bumper height																							
	vehicle curb weight																							
	vehicle tech																							
	collision velocity	x	x																					

Table 5 continued (study no. 1-16)

No.			1	2	3		4	5	6				7	8	9	10	11		12	13	14	15	16
Primary Author			Gårder	Holland	Lee		Oström	Tefft	Hatfield				Johnston	Kim	Lichenstein	Loeb	Nasar		Neider	Rosenbloom	Schwebel	Siddiqui	Spainhour
Date			2004	2007	2005		2000	2013	2007				2007	2008	2012	2009	2013		2010	2009	2012	2003	2006
Dependent variable (fatalities/severity/collision/risk)			collision	risk (behavior)	collision	severity	fatalities (peds)	fatalities & severe injuries	risk (cell phone use)				risk (crossing behavior)	severity	collision	fatality	collision	collision	risk (peds crossing behavior)	risk (behavior at intersection traffic lights)	risk (crossing behavior)	severity	collision
	Variables								signalized (female)	signalized (male)	unsignalized (female)	unsignalized (male)					driver	ped					
Neighbor-hood Level Environment	regional location (rural v. urban)		_		x	o									o	x							o
	transportation network (road length)																						
	road density																						
	area type		o																				
		downtown area																					
		downtown fringe																					
		compact residential																					
		low-density residential																					
		village																					
		med-density commercial																					
		low-density commercial																					
	population characteristics																						
		wealth (home value/ income)														x							
		ethanol consumption (pop.)														o							
		# of cell phone subscribers														o	o						
		marital status																					
		age (area)																					
		youth population (<15)																					
		children population (<5)																					
		senior population (65+)																					
		% transit or non-motorized users																					
		race (area)																					
		non-white pop. Ratio																					
		black pop. ratio																					
		hispanic pop. ratio																					
		no. of jobs																					
		education level (area)																					
		HH size																					
		vehicle-ownership																					
	development (residential/ pop density)																						
		neighborhood compactness																					
		residential density																					
		population density																					
		resident population																					
		employee population																					
		unemployment rate/density														o							
	commute behaviors																						
		workers commuting to work by walking																					
		workers commuting to work by public transportation																					
		pedestrian and bicycle commuting (%)																					
	transit access																						
	commercial access																						
	land area																						
	land use mix																						
		commercial												o									
		residential												x									
		higher density residential																					
		institutional												x									
		industrial												x									
		restaurants																					
		office																					
		farm												x									
		park/ open lands																					
		rec. facilities																					
		vacant																					
		school																					
	school characteristics																						
		rec. facilities near school																					
		school type (ele/mid/high)																					
		school set back																					
		road class near school																					
		school enrollment																					

Table 5 continued (study no. 17-35)

	No.	17	18	19	20		21	22	23	24	25	26	27	28	29		30		31		32	33	34	35
	Primary Author	Hitosugi	Kawato	Lefler	Cho		Clifton	Clifton	DiMaggio	Kim	LaScala	Li	Loukaitou-Sideris	Miranda-Moreno	Moudon		Noland		Ukkusuri		Wier	Zajac	Reed	Twisk
	Date	2013	2013	2004	2009		2007	2009	2002	2010	2004	2010	2007	2011	2011		2013		2011		2009	2013	2005	2014
	Dependent variable (fatalities/severity/collision/risk)	severity	severity	severity	risk (perceived)	collision	severity (high, all-ages)	severity	severity	severity	collision (child ped)	risk (signal compliance)	collision (per sq mile)	collision (ped crashes)	severity (state route)	severity (city streets)	fatality (drivers & occupants)	fatality (peds)	fatality	collision	collision	severity	risk (senior peds' safety attitude)	risk (safe behavior)
	Variables																							
Neighbor-hood Level Environ-ment	regional location (rural v. urban)																						o	
	transportation network (road length)													o										
	road density				_	_	x										o	o						
	area type																					x		
	downtown area																					_		
	downtown fringe																					_		
	compact residential																					_		
	low-density residential																					_		
	village																					_		
	med-density commercial																					_		
	low-density commercial																					_		
	population characteristics																							
	wealth (home value/ income)						x	x			o		o		x	o	o	o			o			
	ethanol consumption (pop.)																							
	# of cell phone subscribers																							
	marital status										x													
	age (area)										o		_											
	youth population (<15)						o				o													
	children population (<5)						x						_	x					x	o	x			
	senior population (65+)												_	_					o		o			
	% transit or non-motorized users				_	_													o	o				
	race (area)										x		_											
	non-white pop. Ratio						o																	
	black pop. ratio										_								_					
	hispanic pop. ratio										_		o						_					
	no. of jobs													_										
	education level (area)										x		x						_					
	HH size												x											
	vehicle-ownership						x						x				o	o						
	development (residential/ pop density)												o											
	neighborhood compactness				o	o																		
	residential density				_	_										o								
	population density				_	_	o	x					_			x	o	o	o	o				
	resident population													o							o			
	employee population										o			_							o			
	unemployment rate/density				_	_							o				o	o			x			
	commute behaviors																							
	workers commuting to work by walking																				x			
	workers commuting to work by public transportation																				x			
	pedestrian and bicycle commuting (%)				_	_																		
	transit access						o	o																
	commercial access						o																	
	land area																				o			
	land use mix				x	o	o	x																
	commercial							_		o			o	o	x				o	o	o			
	residential							_		_			x	_					x	o	o			
	higher density residential																				x			
	institutional									_			o	_										
	industrial									_			x	_					x	o	x			
	restaurants															o								
	office												o		x									
	farm									_														
	park/ open lands						x			_			x	_					x	o				
	rec. facilities													_										
	vacant												o											
	school							x						o					x	o				
	school characteristics						x																	
	rec. facilities near school						o																	
	school type (ele/mid/high)						x				o (middle school)													x
	school set back						x																	
	road class near school						o																	
	school enrollment						x																	

Table 5 continued (study no. 1-16)

	No.	1	2		3	4	5				6	7	8	9	10		11	12	13	14	15	16
	Primary Author	**Gårder**	**Holland**	**Lee**		**Oström**	**Tefft**	**Hatfield**				**Johnston**	**Kim**	**Lichenstein**	**Loeb**	**Nasar**		**Neider**	**Rosenbloom**	**Schwebel**	**Siddiqui**	**Spainhour**
	Date	2004	2007	2005		2000	2013	2007				2007	2008	2012	2009	2013		2010	2009	2012	2003	2006
	Dependent variable (fatalities/severity/collision/risk)	collision	risk (behavior)	collision	severity	fatalities (peds)	fatalities & severe injuries	risk (cell phone use)				risk (crossing behavior)	severity	collision	fatality	collision	collision	risk (peds crossing behavior)	risk (behavior at intersection traffic lights)	risk (crossing behavior)	severity	collision
	Variables							signalized (female)	signalized (male)	unsignalized (female)	unsignalized (male)					driver	ped					
Road Level Environment	**road class type**	_											o		x						o	
	freeway												o		_							
	US route												o								_	
	state route												o		_						_	
	local city street												x								_	
	portion of major roads																					
	road type			x	x								o									
	# of lanes			x	x																o	
	presence of driveways																					
	presence of arterial streets																					
	road design (curved)	_											o									x
	road width	o																				
	street connectivity																					
	freeway length																					
	roadway length																					
	local-rural road length																					
	(n)-lane length																					
	one parking lane length																					
	block length																					
	residential street length																					
	presence of sidewalks																					x
	sidewalk length																					
	sidewalk width																					
	sidewalk density																					
	presence of parking lot																					
	presence of off-street parking																					
	presence of on-street parking																					
	presence of freeway ramps																					
	collision location	_				o							o									
	location along highway												o									
	crosswalk location												o								o	
	mid-block location																				o	
	intersection location																					
	traffic signal location																					
	(n)-way intersection	_																				
	# of intersection																					
	# of cul-de-sacs																					
	# of crosswalks																					
	traffic control			x	o																	
	center refuge island																					
	junction																					
	presence of ped facilities																					x
	presence of barrell (cones)	x																				
	all way stop																					
	presence of signals	o											x									x
	presence of street light												o								o	o
	public transit																					
	arterial streets without public transportation																					
	bus transit																					
	bus lines length																					
	med. daily boardings																					
	bus stop density																					
	bus route density																					
	# of bus routes																					
	# of subway stations																					
	# of transit stop																					
	prox. to commuter rail																					
	prox. to subway station																					
	path condition																					x
	path maintenance																					
	path material																					
	visibility (shrubs)																					
	unmarked crosswalk	o																				
	traffic volume																		x			
	pedestrian volume																					
	AADT	_																				
	presence of other pedesetrian waiting																		o			
	red-light crossing of another pedestrian																		x			

Table 5 continued (study no. 17-35)

	No.		17	18	19	20		21	22	23	24	25	26	27	28	29		30		31		32	33	34	35
	Primary Author		Hitosugi	Kawato	Lefler	Cho		Clifton	Clifton	DiMaggio	Kim	LaScala	Li	Loukaitou-Sideris	Miranda-Moreno	Moudon		Noland		Ukkusuri		Wier	Zajac	Reed	Twisk
	Date		2013	2013	2004	2009		2007	2009	2002	2010	2004	2010	2007	2011	2011		2013		2011		2009	2013	2005	2014
	Dependent variable (fatalities/severity/collision/risk)		severity	severity	severity	risk (perceived)	collision	severity (high, all-ages)	severity	severity	severity	collision (child ped)	risk (signal compliance)	collision (per sq mile)	collision (ped crashes)	severity (state route)	severity (city streets)	fatality (drivers & occupants)	fatality (peds)	fatality	collision	collision	severity	risk (senior peds' safety attitude)	risk (safe behavior)
	Variables																								
Road Level Environment	road class type								x		o				o	x	x	x	x						
		freeway									_				_										
		US route									_				_			_	_						
		state route									_							_	_						
		local city street									_				_										
		portion of major roads													o										
	road type										o														
		# of lanes														x									
		presence of driveways						o																	
		presence of arterial streets																				o			
	road design (curved)										x														
		road width													x					x	o		o		
	street connectivity					_	_		x																
		freeway length																		o	o				
		roadway length										x			o					o	o				
		local-rural road length																		o	o				
		(n)-lane length																		x	o				
		one parking lane length																		x	o				
		block length												o											
		residential street length																				x			
	presence of sidewalks																								
		sidewalk length												x											
		sidewalk width				_	_																		
		sidewalk density				_	_																		
	presence of parking lot																								
		presence of off-street parking						x																	
		presence of on-street parking																					x		
	presence of freeway ramps																					o			
	collision location		x																						
		location along highway								x															
		crosswalk location							o						x									o	
		mid-block location																							
		intersection location												x		x									
		traffic signal location																							
		(n)-way intersection																		x	o				
	# of intersection								_						x							x			
	# of cul-de-sacs								_																
	# of crosswalks					_	_																		
	traffic control																								
		center refuge island											o (two-stage x-ing)												
		junction														x									
		presence of ped facilities																							
		presence of barrell (cones)																							
		all way stop																		x	o				
		presence of signals							x		x														
		presence of street light									o			x									x		
	public transit																								
		arterial streets without public transportation																				o			
		bus transit				_	_																		
		bus lines length												o	o										
		med. daily boardings																							
		bus stop density													_										
		bus route density				_	_																		
		# of bus routes				_	_																		
		# of subway stations													_					o	o				
		# of transit stop						o	o					o	o										
		prox. to commuter rail				_	_																		
		prox. to subway station				_	_																		
	path condition		o			x	x			x													x		
		path maintenance				_	_																		
		path material				_	_																		
		visibility (shrubs)												o											
		unmarked crosswalk																							
	traffic volume											o			x							o		o	
	pedestrian volume														o										
	AADT														o	o	o						x		
	presence of other pedesetrian waiting																								
	red-light crossing of another pedestrian																								

Table 5 continued (study no. 1-16)

	No.	1	2	3		4	5	6				7	8	9	10	11		12	13	14	15	16
	Primary Author	**Gårder**	**Holland**	**Lee**		**Oström**	**Tefft**	**Hatfield**				**Johnston**	**Kim**	**Lichenstein**	**Loeb**	**Nasar**		**Neider**	**Rosenbloom**	**Schwebel**	**Siddiqui**	**Spainhour**
	Date	2004	2007	2005		2000	2013	2007				2007	2008	2012	2009	2013		2010	2009	2012	2003	2006
	Dependent variable (fatalities/severity/collision/risk)	collision	risk (behavior)	collision	severity	fatalities (peds)	fatalities & severe injuries	risk (cell phone use)				risk (crossing behavior)	severity	collision	fatality	collision	collision	risk (peds crossing behavior)	risk (behavior at intersection traffic lights)	risk (crossing behavior)	severity	collision
	Variables							signalized (female)	signalized (male)	unsignalized (female)	unsignalized (male)					driver	ped					
Other factors	weather	x		x	o	x							x								x	
	clear												_									
	cloudy												_									
	fog												_								_	
	rain												_								_	
	snow												_									
	wind																					x
	daylight	x		o	o	x															o	
	temp.																					
	season					x								o								
	summer time																					
	in-school months																					
	walking trend (# of ped injuries)														x	o	o					
	driving trend (# of driver injuries)															o	o					
	day of the week	o				o																
	peak time	x				x							o									
Law/ Regulation/ Education	BAC law														o							
	turn restrictions																					
	speed limit	o													x						o	
	safety campaigns (TV)																					
	education																					

Table 5 continued (study no. 17-35)

No.		17	18	19	20		21	22	23	24	25	26	27	28	29		30		31		32	33	34	35
Primary Author		**Hitosugi**	**Kawato**	**Lefler**	**Cho**		**Clifton**	**Clifton**	**DiMaggio**	**Kim**	**LaScala**	**Li**	**Loukaitou-Sideris**	**Miranda-Moreno**	**Moudon**		**Noland**		**Ukkusuri**		**Wier**	**Zajac**	**Reed**	**Twisk**
Date		2013	2013	2004	2009		2007	2009	2002	2010	2004	2010	2007	2011	2011		2013		2011		2009	2013	2005	2014
Dependent variable (fatalities/severity/collision/risk)		severity	severity	severity	risk (perceived)	collision	severity (high, all-ages)	severity	severity	severity	collision (child ped)	risk (signal compliance)	collision (per sq mile)	collision (ped crashes)	severity (state route)	severity (city streets)	fatality (drivers & occupants)	fatality (peds)	fatality	collision	collision	severity	risk (senior peds' safety attitude)	risk (safe behavior)
	Variables																							
Other factors	**weather**							x	x	x		o										x		
	clear									_		_												
	cloudy									_														
	fog									_														
	rain									_														
	snow									_		_												
	wind																							
	daylight							o	o	o					x	o								
	temp.											o												
	season								x															
	summer time										o													
	in-school months										o													
	walking trend (# of ped injuries)								o															
	driving trend (# of driver injuries)																							
	day of the week								x															
	peak time							x		o		x			x									
Law/ Regulation/ Education	**BAC law**																							
	turn restrictions													x										
	speed limit																					x		
	safety campaigns (TV)																						o	
	education																							o