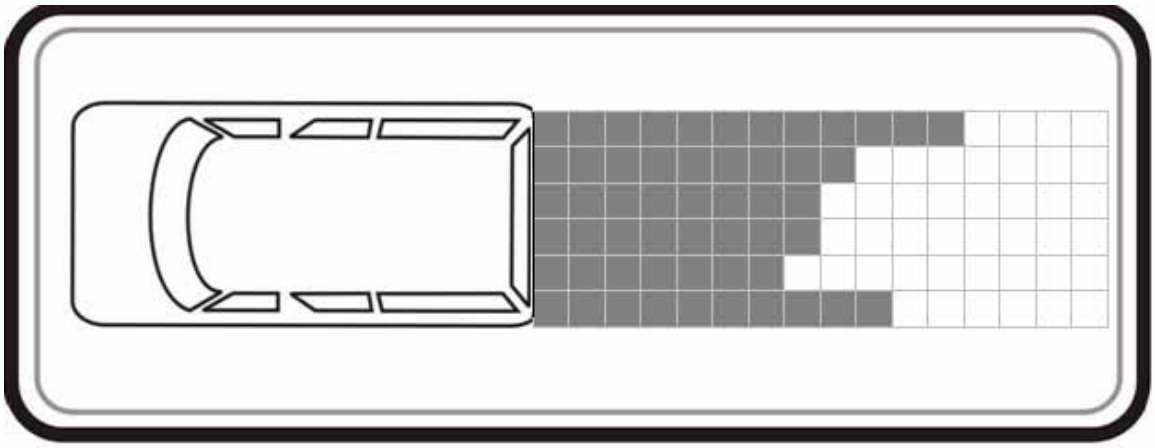
Vehicle Backover Avoidance Technology Study



November 2006

REPORT TO CONGRESS

National Highway Traffic Safety Administration
U.S. Department of Transportation
Washington, DC 20590

Executive Summary

This report responds to congressional interest and requirements to examine the safety problem of motor vehicle backover crashes involving pedestrians and the evaluation of available technologies that might help to reduce them. Special interest was expressed regarding the involvement of small children in these types of crashes.

The size of the safety problem can only be roughly estimated because many of the backover crashes that occur on private property are not recorded in State or Federal crash databases, which focus on crashes occurring in traffic-ways. Supplementing NHTSA crash records with death certificate reports, backover crashes involving all vehicle types are estimated to cause at least 183 fatalities annually. In addition, between 6,700 and 7,419 injuries result from backover crashes per year. A significant portion of these injuries are minor.

NHTSA tested several systems currently available as original equipment on vehicles and aftermarket products to evaluate their performance and potential effectiveness in mitigating backover crashes. The backover prevention technologies that are currently offered by vehicle manufacturers are marketed as"parking aids," which are designed to assist attentive drivers in performing low speed parking maneuvers. Some aftermarket systems using similar technologies are being marketed as safety devices.

Testing showed that the performance of sensor-based (ultrasonic and radar) parking aids in detecting child pedestrians behind the vehicle was typically poor, sporadic and limited in range. Based on calculations of the distance required to stop from a typical backing speed, detection ranges exhibited by the systems tested were not sufficient to prevent collisions with pedestrians or other objects.

Of the technologies tested for their potential to reduce backover incidents, the camera based systems may have the greatest potential to provide drivers with reliable assistance in identifying people in the path of the vehicle when backing.

However, the Agency cautions readers of this report about relying on the results of our testing or other published test results to promote such systems as an effective means to address the backover crash risk. In order to reduce the number of backover incidents, it is very important to obtain a better understanding of the environmental factors that limit the camera's effectiveness and the limits of driver performance using such systems.

One particular concern is that camera performance can change from vehicle to vehicle and from situation to situation. For example, rain, fog or other inclement weather can significantly reduce their ability to show drivers a clear view of objects in the danger zone in back of the vehicle. Even in clear daytime conditions, objects in the camera display may be difficult to see due to sun glare. A fuller understanding of these limitations is needed.

Further, the ability of drivers to become accustomed to such systems and then to use them effectively when backing needs to be better understood. Even if cameras allow the driver to identify an object in the back of a vehicle, the driver must look at the display and have the capability to identify an object or person in the path when backing up, and to react and brake quickly enough to prevent the incident. The speed being traveled, the level of driver attention and reaction time all play significant roles in estimating the systems' effectiveness.

Because of the potential that camera-based systems appear to offer in addressing the risk of backover, NHTSA plans to conduct additional work to estimate the effectiveness of such systems and to develop specifications of performance for any technology that could be developed to address this risk. Further, the Agency plans to encourage vehicle manufacturers to continue to develop systems that can be effective in addressing this risk at a reasonable cost to the consumer.

Future Research Plans

Because of NHTSA's concern about the serious safety problem presented by vehicle backing crashes, the agency intends to continue its work to address this hazard by conducting research in analyzing the safety problem more thoroughly and understanding the various scenarios under which such crashes occur. Additionally, the research will be aimed at technology-based countermeasures to make them more effective. These research activities are listed as either ongoing activities or those that are planned for the future.

Ongoing Research Activities

- Obtain more detailed information of the circumstances of the backover incidents and to provide accurate annual estimates of the number of deaths and injuries resulting from these crashes.

- The AAA Foundation is surveying thousands of AAA members who have purchased vehicles equipped with these technologies. NHTSA will be analyzing their responses to learn about the potential benefits and problems drivers are experiencing.

- Provide information to consumers regarding the hazard due to backover incidents and resulting injuries.

New Planned Activities

- Conduct additional research to estimate the potential effectiveness of camera-based systems.

- Develop in consultation with the industry and others, specifications for the performance of systems intended to prevent backover crashes.

- Sponsor meetings and discussions with stakeholders to share research findings, identify advances in technology and identify additional research needs relating to backover.

- Encourage the industry to continue research and development of vehicle-based systems that can address the backover hazard.

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CHAPTER 1: LEGISLATIVE RESPONSE SUMMARY

Congress required the National Highway Traffic Safety Administration (NHTSA) to conduct a "Vehicle Backover Avoidance Technology Study" of methods for reducing crashes involving passenger vehicles backing over pedestrians. Section 10304 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users SAFETEA-LU (Public Law No. 109-59) states:

(a) In General- The Administrator of the National Highway Traffic Safety Administration shall conduct a study of effective methods for reducing the incidence of injury and death outside of parked passenger motor vehicles with a gross vehicle weight rating of not more than 10,000 pounds attributable to movement of such vehicles. The Administrator shall complete the study within 1 year after the date of enactment of this Act and report its findings to the Senate Committee on Commerce, Science, and Transportation and the House of Representatives Committee on Energy and Commerce not later than 15 months after the date of enactment of this Act.

(b) Specific Issues to Be Covered- The study required by subsection shall--

(1) include an analysis of backover prevention technology;

(2) identify, evaluate, and compare the available technologies for detecting people or objects behind a motor vehicle with a gross vehicle weight rating of not more than 10,000 pounds for their accuracy, effectiveness, cost, and feasibility for installation; and

(3) provide an estimate of cost savings that would result from widespread use of backover prevention devices and technologies in motor vehicles with a gross vehicle weight rating of not more than 10,000 pounds, including savings attributable to the prevention of--

(A) injuries and fatalities; and

(B) damage to bumpers and other motor vehicle parts and damage to other objects.

The Senate Appropriations Report No. 109 -109 requested a similar report with additional requirements to identify educational and consumer information and to identify methods to quantify the backover safety problem. The report states:

Backover Incidents.--The Committee has become aware of possible increases in backover incidents, especially involving impacts between small children and the rear of reversing motor vehicles. The Committee directs NHTSA to evaluate means to reduce this incidence, including educational efforts undertaken by State agencies--such as the Utah Department of Transportation's Spot the Tot program--and by various organizations, as well as technological means provided by original equipment manufacturers and the aftermarket. In addition, NHTSA should explore the value of promptly providing relevant information to consumers on effective means to reduce or avoid backover incidents. NHTSA shall report to the House and Senate Committees on Appropriations within 1 year of enactment of this Act on its assessment of the magnitude of backover incidents and the means of mitigating

such incidents. If the Agency is unable to quantify the extent of the issue, then it should include possible means by which a better quantification of backover incidents may be obtained.

The following is a summary of NHTSA's response to the above congressional requests:

Section 10304 of SAFETEA-LU

> *"identify, evaluate, and compare the available technologies for detecting people or objects behind a motor vehicle with a gross vehicle weight rating of not more than 10,000 pounds for their accuracy, effectiveness, cost, and feasibility for installation"*

Identify technologies

Many vehicle manufacturers currently offer 'parking aid' technologies, which are designed to assist attentive drivers to back as they park. Vehicle manufacturers do not market these technologies as safety systems for preventing drivers from inadvertently backing into pedestrians. Parking aids are mainly intended to help drivers determine the distance to known objects at close distances rather than to prevent drivers from colliding with unforeseen hazards. However, some aftermarket systems using similar technology are advertised as safety devices.

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There are two major technology concepts which may help drivers detect objects behind a vehicle: visual-only systems and sensor-based warning systems. Some systems also integrate both visual and sensor-based warning systems.

<u>Visual-only systems:</u>

The visual-only system which provides drivers with the largest rearward field of view incorporates a camera that shows an image on a display that is usually integrated into the instrument panel as part of the navigation system. Aftermarket systems exist which offer a range of camera and display mounting options. Typically, the camera systems can provide drivers with a clear image of most of the rear blind zone. The blind zone is the area behind a vehicle that drivers cannot see when looking through their mirrors or windows.

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Less expensive visual-only technologies such as Fresnel lenses and interior rear-mounted convex mirrors (or cross view mirrors) can increase the view behind a

vehicle. A Fresnel lens is a wide angle, flat, plastic lens which is affixed to a vertical rear window. Currently Fresnel lenses are only offered as aftermarket systems. For SUV-type passenger vehicles, an interior rear-mounted, convex mirror is typically mounted inside the vehicle near or on the rear pillars. This type of visual-only system is offered by at least one vehicle manufacturer as well as in the aftermarket.

Sensor-based warning technologies:

The current generation of sensor-based warning technologies uses ultrasonic or radar sensors to detect the distance to nearby objects. This information is presented to the driver by way of auditory tones, a visual display, or both. These types of systems are more popular and less costly than camera systems. They are offered by both vehicle manufacturers and by aftermarket companies.

The current generation of warning technologies use ultrasonic or radar sensors to detect the distance to objects to the rear of a vehicle.

System accuracy

System accuracy in this report is defined as the ability of a system to allow an attentive driver to correctly and consistently detect people or objects behind a vehicle.

The rearview camera systems tested by NHTSA were able to display nearly the entire rear blind zone. Under ideal environmental conditions, the image quality is also clear enough to allow drivers to recognize an object or person. However, image quality can be diminished if the camera lens is obstructed (e.g., snow, rain, etc.) or sun glare falls on the lens or on the instrument panel display. Compared to rearview camera systems, the Fresnel lens and rear-mounted convex mirror provided a much smaller view of the blind zone and presented distorted images.

None of the sensor-based warning systems tested were able to consistently detect all objects or people in all locations in the blind zone behind a vehicle. All of the sensor-based systems' detection ranges contained "holes" where children were not detected. The radar-based systems tended to have a longer range than the ultrasonic systems. Certain objects were detected better than others. In general, the taller and larger the object, the more accurately it was detected. The majority of sensor-based warning systems tested were unable to detect objects below 18 inches in height. The maximum distance behind a vehicle in which a 3-year-old child could be detected ranged from 4 to11 feet. In many vehicles, drivers would not be able to see objects at these distances by looking through the windows or mirrors.

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System effectiveness

The effectiveness of a backover prevention technology is defined here as its ability to help drivers prevent backover crashes. Ideally, this would be determined by comparing backover injuries and fatalities occurring in vehicles with and without a system. However, determining this effectiveness number from real world crash data is not currently feasible for several reasons. Backover crashes are not consistently reported. If they occur on private property, they would not be reported as a traffic crash in State records or NHTSA databases. Death certificates include deaths occurring from motor vehicles on private property but do not always contain sufficient information to identify them as backover cases. In addition, the installation of parking aids is not recorded in police reports or coded in Vehicle Identification Numbers (VIN). Further complicating such evaluations is the low frequency of occurrence of backover crashes, which make statistical comparisons difficult.

Insights regarding potential effectiveness of backover prevention technologies can be gained through testing the performance of these technologies and the response of drivers using these technologies. NHTSA tests of ultrasonic and radar parking aids found that their detection range was insufficient, and they were not reliable in detecting children, especially moving children, even within the sensor's object detection range. Compared to sensor-based warning systems, rearview camera systems displayed a larger area of the blind zone in which pedestrians and other objects could be seen.

NHTSA conducted tests of ultrasonic and radar parking aids. It was found that their detection range was insufficient, and they were not reliable in detecting children, especially moving children, even within the sensor's detection range as determined by other static objects.

In addition to the requirement that systems detect objects and people reliably and at sufficient distance to stop before striking an object, effective systems must elicit appropriate driver responses. Several experimental studies of electronic backing aids were reviewed which found that when drivers were not expecting objects behind their vehicle, a large percent of them did not brake quickly enough or hard enough to stop before colliding with the object after receiving an auditory alert. For systems that produce false alarms, human factors research suggests that drivers may eventually respond by not braking as quickly as necessary to a real threat. One study suggested that rearview camera systems may lead to more effective driver responses than sensor-based warning systems, but the sample size was too small for the results to be conclusive.

Backing aid effectiveness also depends on the situational factors that lead up to a crash. For example, in some incidents no current backing aid would be able to provide a benefit (e.g., unattended children accidentally shifting the vehicle into reverse, "roll-a-ways" caused by transmission failure, people hidden underneath a vehicle, etc.). Many factors can influence effectiveness, including: the distance of the pedestrian from the backing vehicle, whether the pedestrian darts into the path

of the vehicle after the vehicle starts moving, whether the vehicle is turning or going straight when in reverse, how fast the vehicle is traveling, whether the driver is attentive, whether the driver scans the camera display, whether the driver is expecting someone to be near the rear of the vehicle, etc. Unfortunately, such information is not available and may be difficult to obtain even by trained crash investigators.

While the current generation of backing aids may result in some safety benefits, they are primarily designed to help drivers judge distances when parking at slow speeds. The findings from performance testing and available human factors experiments suggest that current sensor-based warning systems would not be effective countermeasures for preventing backover crashes. Rearview camera systems may be more effective for drivers that actively scan the display and back cautiously. Mirror systems for passenger vehicles do not provide as clear and as wide a rearward view as camera systems. Without further research on behavior of drivers using backing aids and a better understanding of crash scenarios, an accurate estimate of the likely effectiveness for different countermeasures is extremely difficult.

While the current generation of backing aids may result in some safety benefits, they are primarily designed to help drivers judge distances when parking at slow speeds.

Cost

The following are estimated consumer costs for potential backover prevention technologies if these systems were installed throughout the U.S. light vehicle fleet. These numbers do not represent the current retail costs of these systems.

Sensor-based Warning Systems:

The consumer cost for a new vehicle to be equipped with an ultrasonic or radar warning system is estimated to be between $41 and $100 per vehicle.

Visual-only Systems:

The consumer cost for a new truck to be equipped with a camera system was estimated at $325 in a recent Notice of Proposed Rulemaking (NHTSA, 2005). A large part of the cost of a rearview camera system is the display, which was a black and white Cathode Ray Tube (CRT) display, rather than a color Liquid Crystal Display (LCD) display, which is more common in the passenger car segment. It should be noted that the incremental cost for vehicles which already have an in-dash display screen (e.g. for a navigation system) would be smaller.

The consumer cost for a new vehicle to be equipped with a Fresnel lens is estimated to be between $8 and $13 per vehicle. Interior mirror systems are estimated to cost $13 per vehicle.

Feasibility for installation

In NHTSA's 2006 inventory of vehicles with advanced technologies, there were 100 vehicle models offered with factory equipped parking aid systems either as standard equipment, or as an option. Ultrasonic parking aids are the most common systems to be offered. There are also a number of aftermarket suppliers of parking aid systems capable of being installed on most vehicles. Since parking aid systems are already available in the market, it is clearly feasible to install them. However, these systems are not designed explicitly for use as safety systems.

"provide an estimate of cost savings that would result from widespread use of backover prevention devices and technologies in motor vehicles with a gross vehicle weight rating of not more than 10,000 pounds, including savings attributable to the prevention of--

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Cost savings from injuries and fatalities

The effectiveness of parking aid systems for preventing backover crashes is considered to be low. Precise system effectiveness cannot be determined without real world data. Experimental data will also have to be generated from extensive human factors research before quantitative estimates of effectiveness can be determined. Therefore, the number of injuries and fatalities that these systems could prevent is unknown. Effective systems specifically designed as backover prevention devices do not currently exist. As a result, the cost of these systems and any possible cost savings from reducing injuries and fatalities could not be estimated.

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Cost savings for vehicle damage

The NHTSA's National Center for Statistics and Analysis developed a model to estimate the benefits and costs, excluding injuries and fatality benefits, for parking aids (ultrasonic, camera, and a combination of both). Benefits are defined as the property damage costs eliminated by these systems (to the subject vehicle and the vehicle it strikes) if these were able to prevent backover incidents that would otherwise occur. Costs are defined as the incremental costs to the vehicle for these systems and the increase in property damage costs to repair these sensors in rear impact crashes (which include both when the vehicle is struck in the rear and backover crashes in which the sensors are not effective).

Based on the assumptions and estimates developed, none of the systems appear to be cost effective. The incremental repair costs to sensor-equipped bumpers in rear-end crashes is estimated to be greater than any reduction in property damage costs that result from backing crashes prevented.

The Senate Appropriations Report No. 109 -109

"evaluate means to reduce this incidence, including educational efforts undertaken by State agencies--such as the Utah Department of Transportation's Spot the Tot program--and by various organizations" as well as technological means provided by original equipment manufacturers and the aftermarket".

Educational efforts

The most extensive educational effort in the United States is Utah's *Spot the Tot* program. Primary Children's Medical Center developed the *Spot the Tot* program to encourage greater driver recognition of the potential danger of backing over a child. It has been promoted via radio public service announcements, press coverage, Internet websites, television coverage, and in safety fairs. The program's sponsors continue to publicize the program with poster and brochure distributions that include a "SPOT" vehicle window sticker to remind drivers to look around the vehicle for children before driving.

Other groups have produced brochures and posted web information that are not as well established as the *Spot the Tot* program. All of these educational programs have been designed based on specific backover incidents rather than on a data-driven, research-based backover strategy with evaluation components.

"In addition, NHTSA should explore the value of promptly providing relevant information to consumers on effective means to reduce or avoid backover incidents".

Consumer information

NHTSA produced several print articles regarding the seriousness of backover crashes to inform drivers about the problem and provide common-sense safety tips for drivers to avoid potential fatalities. One article has been published on NHTSA's website, www.NHTSA.dot.gov. This article has been designed in such a manner that organizations can download it for inclusion in their newsletters. This article is also is being translated into Spanish to facilitate wider distribution.

A second article has been provided to the North American Precis Syndicate (NAPS), a news distributor that is in the process of distributing the article to more than 10,000 newspapers nationwide, with a total circulation of 2.25 million. This article, too, is currently being translated into Spanish for wider distribution. A similar article was

provided to the American Automobile Association (AAA) for inclusion in its membership newsletters.

The magnitude of the backover crash problem

NHTSA's national estimate is that there are at least 183 fatalities and between 6,700 and 7,419 injuries per year as a result of pedestrian backovers occurring both on and off traffic-ways. The magnitude of the backover problem has been estimated based on available data. Much of the difficulty in determining an exact count of backover crashes is due to the fact that NHTSA databases mainly cover traffic crashes, which excludes backover crashes that occur outside of the traffic-way (e.g., on private property).

In response to Sections 2012 and 10305 of SAFETEA-LU, NHTSA is currently in the process of exploring alternate ways of developing a system to improve the collection of non-traffic vehicle-related incidents. Information on the development is contained in the section on "Plans to improve data collection in the United States" of this report.

The trend in backover incidents

Backover crashes are not a new phenomenon, nor are they unique to the United States. Although the number of registered vehicles on the road has been consistently increasing in the United States, the available data provide little evidence to support the idea that pedestrian backover cases have been increasing. While media sources tend to suggest that the increasing number of larger vehicles, like SUVs and minivans, are contributing to the problem due to their large blind zones, many sedans have equally poor rear visibility. NHTSA is unable to conclude from available data that there is an increasing trend in backover crashes in the United States.

Summary

While there may be some mitigating effect on backover crashes with current parking aids, their effectiveness is expected to be low. The findings from performance testing and available human factors experiments suggest that parking aids would not be effective countermeasures for preventing backover crashes. Educational efforts are underway with programs like *Spot the Tot* and consumer information to increase driver sensitivity about the backover problem. However, effectiveness of educational programs is difficult to estimate.

CHAPTER 2: THE EXTENT AND NATURE OF THE BACKOVER SAFETY PROBLEM

Data sources with information on backover crashes

The term "backover" crash is used frequently in this report referring to backing crashes in which a vehicle moving in reverse strikes a person. This term is intended to distinguish all backing crashes (vehicle-vehicle, vehicle-property) from backing specifically into a person (pedestrian/bicyclist). While some "backovers" involve a person actually being run over by a vehicle, the term used here is also meant to include all cases in which a person was struck, but not necessarily backed over by a motor vehicle.

The term "backover" crash is used frequently in this report referring to backing crashes involving a person being backed into.

There is no U.S. Government data system designed specifically for collecting data on backover crashes. This is primarily true because many backover crashes occur on private parking areas, and these are not subject to current government reporting systems. However, some relevant information can be acquired through the NHTSA crash databases, hospital emergency department records, death certificates and by monitoring media sources.

The true extent and nature of backover crashes are difficult to determine because many crashes are not reported in currently available crash databases. Some cases are not included in the State and Federal databases due to the criteria used for defining traffic crashes. To be included, the crash must involve "a motor vehicle in transport, and occur on a traffic-way, or has an unstabilized situation[1] originating on the traffic-way." Thus, if the incident occurs entirely on a private driveway or in a parking lot, it is not considered a traffic crash and therefore may not be included in the statistics on crashes, even though it is vehicle-related. For backover crashes which involve only minor injuries, drivers may not report the incident to the police. Thus, the current sources of data on traffic crashes very likely underestimate the true extent of the backover crash problem.

The two current sources of data used to provide national estimates are:

> The Fatality Analysis Reporting System (FARS). This NHTSA database provides information on all motor vehicle traffic crashes in the United States involving at least one motor vehicle in transport on a traffic-way in which one or more people involved die of their injuries within 30 days of the crash.

[1] An "unstabilized situation" is a set of events not under human control. It originates when control is lost and terminates when control is regained

The National Automotive Sampling System General Estimates System (GES) is a nationally representative sample of all police-reported motor vehicle traffic crashes throughout the United States. Data are obtained from police crash reports.

Several studies have estimated the number of crashes, fatalities and injuries that may go unreported in the national crash databases. Hospital emergency room records compiled in the National Electronic Injury Surveillance System (NEISS) estimate that 61 percent of child backover crashes occurred off of a public roadway (CDC, 2005b). A study which compared hospital records to police reporting of pedestrian crashes (all types) estimated that 20 percent of pedestrian crashes are not reported to the police (Agran, Castillo & Winn, 1990). Estimates from a study of death certificates, which included both traffic and non-traffic backover crashes, indicated that only 14 percent of all backover fatalities occurred on the "Road/Street"[2] (NHTSA, 2004).

To overcome these limitations, other data sources have been examined to try to better understand the full extent and nature of the backover crash problem. These sources have included death certificates, hospital records, and newspaper articles. These sources can be used to identify backover crashes occurring on private driveways and parking lots. However, each has limitations affecting the usefulness of the information they can provide. Death certificates provide a limited amount of information about crash circumstances. Hospital records do not always provide a nationally representative sample and also do not usually describe the circumstances of the crash in detail. Newspaper reports offer the least confidence in their accuracy and do not provide a statistically valid sample on which an assessment of the national scope of the problem can be based. Some crashes are reported in newspapers, and not all newspapers are included in available databases, such as LexisNexis. Multiple newspapers may also report the same accident but describe it differently leading to the double counting of cases. Despite these limitations, a wide variety of data sources on backover crashes have been examined in this report to gain as much insight as possible on the extent of the backover problem. Given the current data limitations, the size of the backover crash problem can only be roughly estimated at this time.

The extent of the backover problem in the United States

A look into NHTSA's FARS data between 1991 and 2004 determined on average there are 76 backover fatalities per year. Of these, 55 involved light passenger vehicles (i.e., passenger cars, pickups, and sport utility vehicles). A backover case for the FARS analysis was defined as a crash where the vehicle struck a pedestrian/ pedacyclist with the rear of the vehicle and a driver was present. Using this same definition the GES was also analyzed. GES estimates that between the years 1994

[2] This percentage is based on the death certificates study location code of "Road/Street." This number does not directly imply the percentage of cases occurring on the traffic-way. See more on this under the "Circumstances of backover crashes" section of this report.

and 2004 there were an average of 1,377 people injured or killed in backover crashes per year[3]. Of these 1,264 crashes involved light passenger vehicles.

In 2004 NHTSA collected and reviewed death certificates from the year 1998 to determine the number of fatal backover crashes including non-traffic cases (NHTSA, 2004). This study estimated that 123 backover fatalities occurred for that year. In the process of writing this report it was found that there were a number of cases which had been identified by FARS but were not included in the total fatalities under the death certificate study. To provide the most accurate national estimate, cases were reviewed from both of these data sources to produce a refined national estimate of 183 backover fatalities per year. This estimate excludes driverless backover crashes and includes vehicles of all weight classes. More details on this determination of the national backover fatality rate can be found in the document "Estimation of Backover Crash Fatalities" in Docket No. NHTSA-2006-25579. An earlier Notice of Proposed Rulemaking (NHTSA, 2005) also presented a national fatality estimate, however the methodology used in this estimate lacks the precision of NHTSA's most recent estimate and thus, the refined estimate is provided in this report.

Hospital emergency records have also been used to gain insights into the problem size via the National Electronic Injury Surveillance System (NEISS). NEISS is a national probability sample of Emergency Rooms and Trauma Centers in the United States and its territories. Patient information is collected from each NEISS center for every emergency visit involving an injury associated with consumer products. NEISS data from the year 2000-2001 estimates that there are between 6,700 (NHTSA, 2004) and 7,419 (NHTSA, 2005) backover injuries per year. In 85 percent of these NEISS cases, the victims were treated and released (NHTSA, 2004). This number may underreport the problem, as many less severe injuries may be treated outside of an emergency room (e.g., personal physicians, household treatments).

A summary of the existing data on backover crashes is provided in Table 1.

[3] Since GES is a sampled database and the number of backover cases is limited it was determined that providing separate estimates of deaths and injuries could not be accomplished with confidence.

Table 1: Summary United States Estimates of Average Annual Backover Deaths and Injuries

Data Source	Yearly National Estimate	Years Surveyed	Details	Reference Source
Deaths				
FARS	76(all vehicles) 53(passenger vehicles)	1991-2004	Fatalities in backover traffic incidents	Analysis performed for this report
FARS & Death Certificates	183	1998	Backover deaths determined by adding the number of FARS cases which were not included by the death certificate study to the death certificate study estimate.	Analysis performed for this report
Death Certificates	123	1998	Estimated backover fatalities determined by reviewing death certificates	NHTSA, 2004
Injuries				
NEISS	6,700-7,419	2000-2001	Estimate of the number of people admitted to an emergency room due to a backover injury	NHTSA, 2004; NHTSA, 2005
Death and Injuries				
GES	1,377(all vehicles) 1,264(passenger vehicles)	1994-2004	People injured or killed in backover traffic incidents	Analysis performed for this report

Demographics in backover crashes

Summary: While people of all ages are the victims of backover crashes, children under 5 years old have the highest involvement in these crashes. More specifically toddlers (0-2 years old) are the highest risk group. Older pedestrians also have an elevated risk. Males in their 20s and 30s have the greatest chance of being the driver in a backover crash. The victim is typically known by the driver (family, friends or neighbors).

Victims: Children, and to a lesser extent older pedestrians, are overrepresented in backover incidents. Of the 183 backover fatalities estimated by the combination of death certificate and FARS cases that occur in the United States; 69 were children under 5 years old, 76 were children under 15 years old and 49 were over 70 years of age. When compared to the general United States population, the frequency distribution of backover fatalities (FARS 1991-2004, and Death Certificates) shows two groups are overrepresented: children under 5 years old and older adults (over 70). To represent these trends, Figure 1 presents the ratio of normalized backover crashes / the normalized United States population for each age group, each as a percent.

Based on NEISS data from 2001-2003, the CDC provides an estimate of 2,492 non-fatal injuries for children backed over by a motor vehicle (CDC, 2005b). Kids and Cars (an organization devoted to preventing vehicle-related child deaths) also

maintains a database of backover incidents. These are compiled by LexisNexis searches of newspapers, Internet keywords, and information from a network of personal and professional contacts. The data on their website (kidsandcars.org) indicate that there were 101 non-traffic backover fatalities among children under 15 years of age in the year 2004.

The age group under 5 years of age has been studied in depth by other researchers. Using data from an Orange County, CA, hospital-based monitoring system, different patterns of involvement were discovered between toddlers (0-2) and preschoolers (3-4) (Winn, 1991). Approximately 71 percent of the backover crash victims among children under 5 years old were toddlers. Using data from police reports, Walker (1993) also found that a similar 74 percent of backover crash victims under 5 years old were toddlers.

The victims are male in 56 percent of cases in the FARS (1991-2004) database and in 57 percent of the cases in GES (1994-2004).

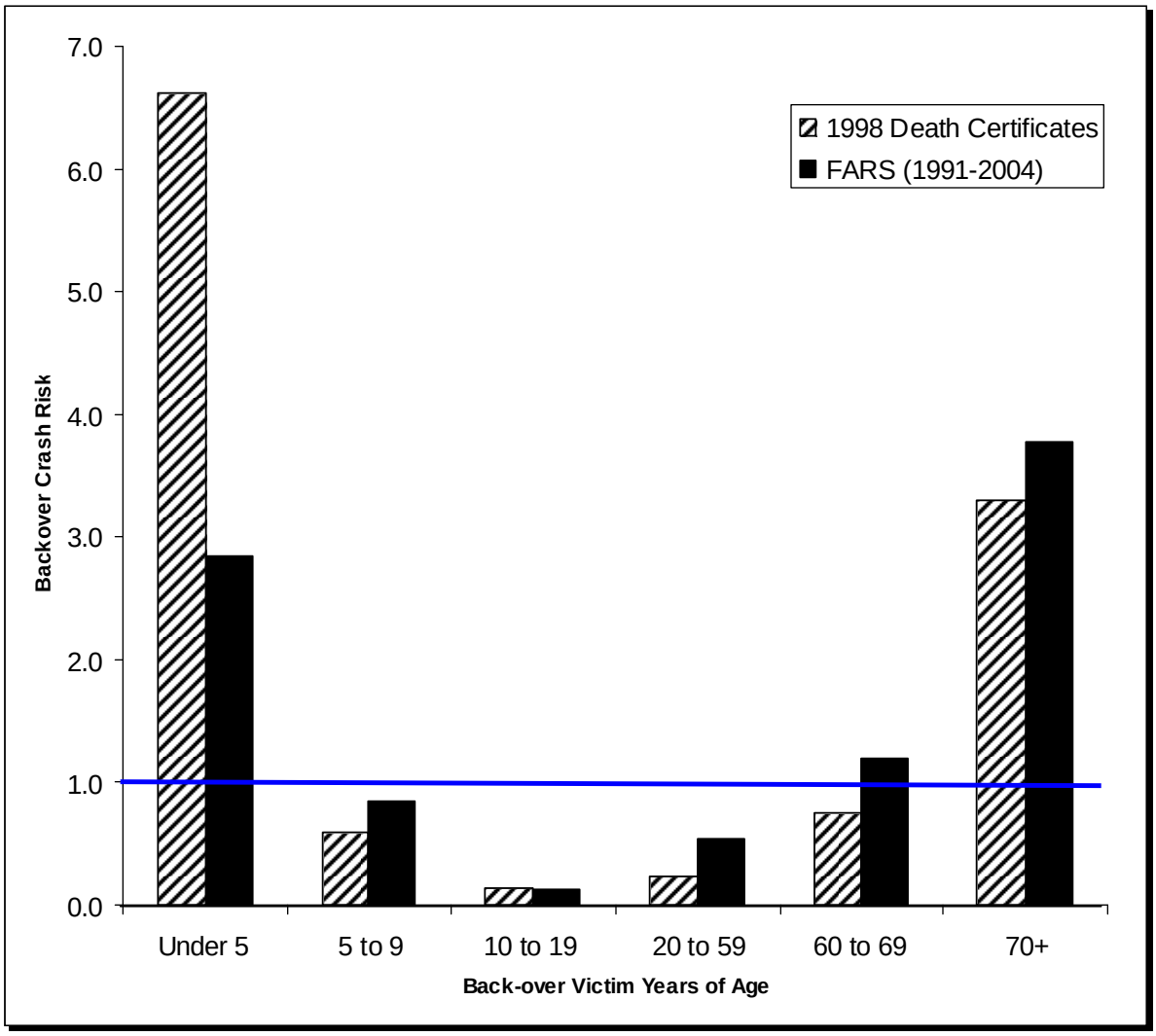

Figure 1: Backover Crash Risk by Age Group

Drivers: An analysis of pedestrian crashes examined the demographics of drivers involved in backover crashes using FARS (1991-2004) data. The driver was male in 77 percent of cases according to FARS. When compared to the population of United States Licensed Drivers (FHWA, 2000) it was found that drivers 20-39 years of age and those 70 years and older were overrepresented in backover crashes (Figure 2). However, drivers from 20-39 can be viewed as a larger societal problem as this group accounts for 41 percent of the licensed drivers, whereas drivers 70 and over only account for 6 percent of the licensed drivers.

Males in their 20s and 30s have the greatest chance of being the driver in a backover crash. The victim is typically known by the driver (family, friends or neighbors).

The increased risk for these drivers in their 20s and 30s may be due to the fact that this demographic is the most likely to have young children. Parents of young children would have a greater exposure to backing situations with pedestrian traffic and locations where other kids congregate (e.g., birthday parties, soccer practice, etc.).

Driver-victim relationship: According to a CDC analysis of the KIDS 'N CARS™ database from 2000-2001, in 57.7 percent of child pedestrian crash related injuries (not just backovers) the driver was a parent of the victim (CDC, 2002). A review of 1996-1998 Australian cases in which child pedestrians were killed in driveway crashes found that in 86 percent of the cases, the driver of the vehicle was a member of the child's family or a family friend (Neeman, 2002). A study of Utah emergency room records and police reports of pediatric (<10 years old) driveway backover cases found that the driver was a family member in 48 percent of cases or a neighbor in 24 percent of cases (Pinkney et al., 2006). These findings are not surprising given the high likelihood that vehicles in driveways are more likely to be driven by family and friends of the victims.

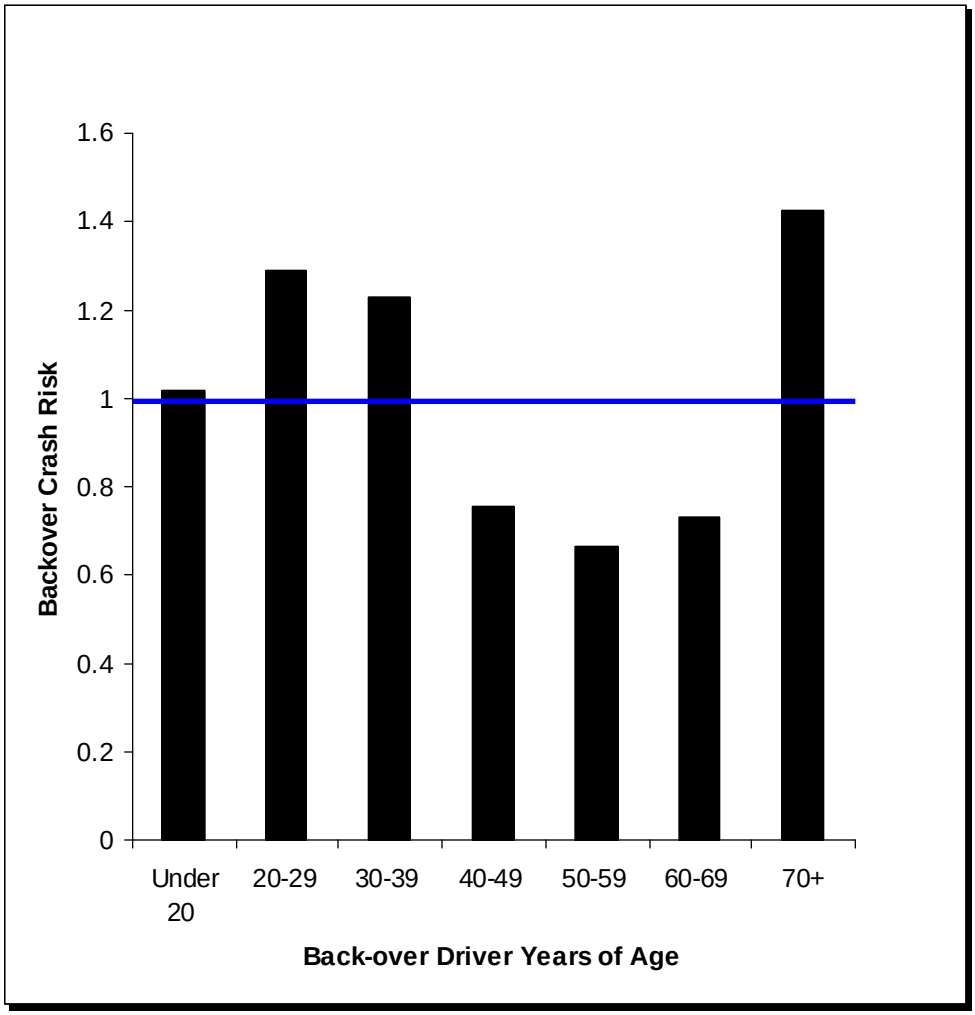

Figure 2: Backover Driving Performance by age group

Plans to improve data collection in the United States

Provisions in the recent NHTSA appropriation and authorization bills have directed the Agency to develop a method to collect data on non-traffic incidents and crashes that occur on non-public traffic-ways with special emphasis on backover incidents.

NHTSA data systems currently provide extensive information on motor vehicle crash incidents that occur on public traffic-ways. This information includes statistical data to provide national estimates and detailed reports on specific cases to support remedial actions.

Most of the NHTSA crash data systems rely on an existing State data system infrastructure. All of the 50 States crash data systems contain extensive data on motor vehicle traffic crashes that take place on public roads. However, these State

data systems do not routinely contain information on non-traffic incidents or crashes that occur on private property.

The primary issues facing NHTSA in the collection of data on non-traffic incidents and crashes are the collection of fatality and injury counts and the detailed data at the event level needed to understand in detail the circumstances surrounding the incidents.

Efforts to collect both the fatality data and detailed collision data are underway by NHTSA. The agency conducted a review of existing systems within NHTSA, surveillance systems in other Federal agencies, and non-Federal sources to determine the feasibility for collecting non-traffic fatality counts and detailed crash data. The review suggested possible expansion of NHTSA's existing crash databases and the use of other Federal agencies, especially the National Center for Health Statistics and the Consumer Product Safety Commission, which operate surveillance systems that may provide some useful information in arriving at a better estimate of the backover safety problem.

However, the review of the non-Federal sources including hospital systems, emergency medical services systems, insurance company data, and the news media databases found that they were generally incomplete or lacked the detail needed by NHTSA to understand the circumstances surrounding the incidents.

NHTSA is continuing to pursue the development of alternative ways to collect data on non-traffic incidents and crashes on non-public traffic ways. Research tasks include the exploration of ways to modify NHTSA's existing data systems (i.e., FARS, GES, and Special Crash Investigations), evaluation of other data sources such as death certificate data available from the National Center for Health Statistics, and collaboration with the Consumer Product Safety Commission on modifying their National Electronic Injury Surveillance System.

Data from other countries

Pedestrian backover is not a phenomenon unique to the United States. This crash problem has also been investigated by Canada, Australia and New Zealand.

Canada
According to Transport Canada (2004) approximately 17 pedestrians are killed and 1000 pedestrians are injured in Canada by backing vehicles each year. Transport Canada's crash data only record "Traffic" data and thus have similar problems with capturing all data related to backover crashes.

Australia
In Australia cases have been identified from the Bureau of Statistics via death summaries. It was found that there were 36 low speed child (under 7 years old) fatalities between 1996 and 1998 that resulted mostly from backing (Neeman, 2002).

New Zealand
Based on hospital records, 53 children (under 15 years old) were killed or hospitalized in a driveway related crash over a 2 year and 2 month period (Roberts, Norton & Jackson, 1995). The majority of these cases were backing situations.

There were similar trends reported from various other countries. Backover crashes tend to happen in off road scenarios (e.g., driveways), and they involve younger children (under 5 years old) at or near their homes.

Trends in backover incidents over time

One might expect that the number of backovers would be increasing due to increases in the number of vehicles in the fleet. There was a 14 percent increase in passenger vehicle registrations from 1997 to 2004 (NHTSA, 2006a). In addition, the size of vehicles has been increasing. With increasing vehicle size, one might expect that the corresponding increase in rearward blind zones would lead to a greater risk of backover incidents. SUVs, which are considered to have poor rear visibility, have had a 54 percent increase in registrations from 1997 to 2004. The percentage of SUVs in the passenger fleet increased from 7.6 percent to 14 percent over this same period.

Despite the above trends in the fleet with respect to vehicle registrations and increasing vehicle size, FARS backover fatalities analyzed for this report (1981-2004) do not show an increasing trend. In fact, there is a non-significant, yet decreasing trend. However, there are no accurate trend data specifically for the non-traffic incidents that may or may not follow the fatality trends seen in the traffic crash databases. A LexisNexis review of periodicals on backover incidents including non-traffic crashes from 1998 to 2002 was also not able to demonstrate a clear trend (NHTSA, 2004). The Kids and Cars data do show an increased number of cases for children from 1999 to 2005 (www.kidsandcars.org). However, it is possible that much of this increase can be attributed to improvements in the ability of this organization to identify such cases or due to the increasing attention that the news media may be giving to these problems rather than an actual increase in the number of backover cases.

Despite increasing vehicle registrations and increasing vehicle size, backover fatalities do not show an increasing trend.

Backover crashes involving pedestrians have been gaining more attention in recent years but the problem is not new. Studies of this crash type have appeared in the literature since at least 1971 when NHTSA (Snyder and Knoblauch, 1971) published research that identified more than 30 pedestrian crash types. Backover crashes were one of the types identified, comprising 2 percent of the pedestrian crashes in this 13 city analysis. Subsequently, NHTSA and the Federal Highway Administration conducted studies to further assess this crash type and identify possible behavioral countermeasures (Preusser et. al., 1985; Hunter et. al. 1995). In addition, a 1979 Canadian study examined child pedestrian fatalities and found that children between

1 and 4 years of age were overrepresented in collisions on or near private driveways. (Buhlman, 1979)

Circumstances surrounding backover crashes

Most backover crashes occur off of a road or street.

In the NHTSA analysis of death certificates, 14 percent of backover deaths were found that could be called the "Road/Street" occurrences (NHTSA, 2004). The specific locations of these crashes can be seen in Table 2. This table presents categories based on the limited details provided on the death certificates and in some cases supplementary information (e.g., newspaper reports). These data suggest that cases occur predominately away from streets and roads. A review of FARS cases from 2000 and 2001 by location also reveals that backover fatalities occur predominantly away from the roads or streets (Table 3).

Table 2: Backover deaths identified in 1998 Death Certificates by Location

Location	Frequency *	Percent
Driveway	21	23
Home	21	23
Parking Lot	21	23
Road/Street	13	14
Sidewalk	2	2
Other off road	13	14

Table 3: Backover deaths identified in FARS (2000-2001)

Location	Frequency	Percent
Driveway	44	43
Parking Lot	5	5
Road/Street	28	27
Other off road	25	25

* Table 2 data are from 35 States and the District of Columbia.

FARS cases by definition are traffic-way crashes. Details analysis (NHTSA 2004) shows these cases can occur in the driveway, parking lot, and other off road locations. For instance if a backing vehicle originates from a driveway, but a pedestrian impact occurred on the sidewalk, this would be considered a "traffic" crash.

The FARS (1991-2004) and GES (1994-2004) databases were analyzed to determine when backover crashes happen. It was hypothesized that backovers would be most likely during times when people would typically be outside. This might suggest that there would be an increase in backovers over the weekend as well as after school/work. However, no increase in weekend crashes was found. The breakdown by hour in the day found that there are more backovers during normal waking hours (9AM-9PM) but contrary to expectation, only a minor spike after typical school/work hours (3-6PM).

The weather did not appear to be a major factor in these backovers, as the weather was classified as "normal" in the majority of crashes (FARS = 94 percent; GES = 90 percent).

Vehicles involved in backover incidents

Several analyses have found that minivans, pickup trucks and SUVs have a higher involvement rate in backover crashes than passenger cars. A possible reason for this finding is the greater exposure of these vehicle types to the presence of children and other pedestrians around them when backing.

Understanding the association between vehicle type and backover crashes may indicate the vehicle types most likely to benefit from countermeasures capable of preventing these incidents. However, information about the involvement of vehicle types does not provide any direct evidence about the factors that contribute to crash risk and thus, what countermeasures might be helpful.

For example, a particular vehicle type, such as a minivan, may be involved in backover crashes because they have larger rear blind zones than other vehicles, because there are more of them on the road, they are exposed to more backing situations where children are present, because their design makes them more likely to cause severe injuries than other vehicles, or because drivers of those vehicles are more distracted.

Several analyses have found that minivans, pickup trucks and SUVs have a higher involvement rate than passenger cars. A possible reason for this finding is the greater exposure of these vehicle types to the presence of children and other pedestrians around them when backing.

Various measures can be used to compute rates of involvement. Using vehicle registration numbers provides a measure to adjust for the possibility that the number of incidents might be correlated with the number of vehicles on the road. In the case of backover crashes, the ideal exposure measure would be to divide the number of backover events by the number of times a vehicle is reversed under similar scenarios. However, these types of data are not available.

To investigate the role of vehicle type in backover crashes on driveways, an analysis was conducted by Pinkney et al. (2006). The backover incident and vehicle type data was compiled on children under 10 in the State of Utah, from 1998-2003. These data were based on police reports and emergency room records and thus, are more likely to include non-traffic incidents not captured in the FARS and GES databases. Their analysis used the number of vehicles registered in each type and calculated a backover crash rate per 100,000 vehicles per year. The results of their analysis found that trucks and minivans had significantly higher incident rates than passenger cars, while the difference in rates between SUVs and passenger cars was not statistically significant (Figure 3). This finding suggests that children are more likely to be struck by a reversing truck or minivan in driveways than by a

passenger car. However, this analysis does not provide the reasons for the disparity in backover rates among different vehicle types.

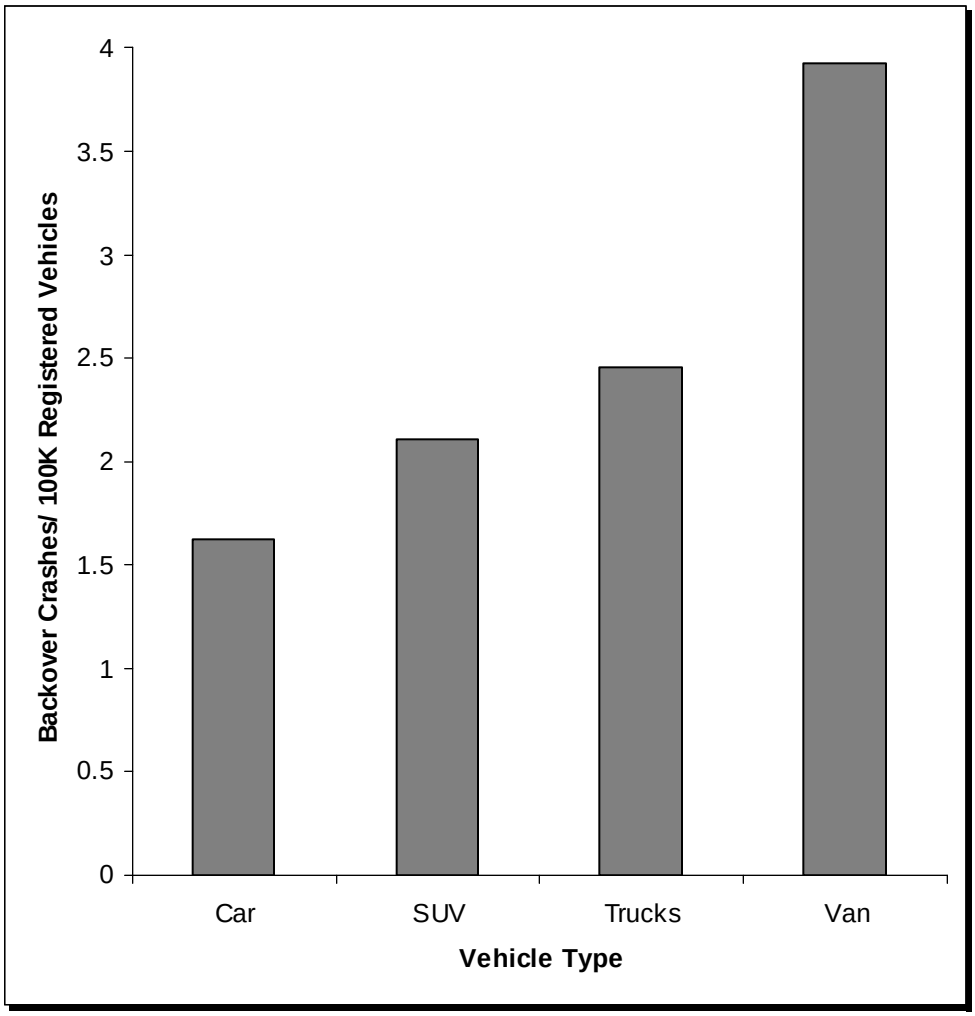

Figure 3: Backover Crash Rate in Utah by Vehicle Type (Pinkney et al., 2005)

For the current report, vehicle types were compared using the FARS database. The vehicle types as defined by FARS are likely to have used more rigid definitions than the Pinkney et al., study. For instance, the emergency room records used in the Pinkney et al., research may not have differentiated between a heavy truck and a pickup truck. Due to the relatively low number of backover incidents that are reported in the FARS databases, all backing crashes (not pedestrian exclusive) were compared for each vehicle type. The underlying assumption is that the results for all backing crashes would apply to pedestrian backover crashes. The pattern of the FARS data using vehicle registrations to determine backing crash rates (mean of 1997-2004; NHTSA, 2006a) matches the Utah data rather closely (See Figure 4).

Comparing crash rates per registered vehicle controls for the possibility that a vehicle type has more backing crashes simply because there are more of them on the road. To control for other possible factors (e.g., geography, miles driven) that

might affect the involvement rates of different vehicle types in backing crashes, forward crashes were used as an exposure measure. The proportion of backing crashes to forward crashes was computed for each vehicle type. These data can be seen in Figure 5. Similar to the registration data, this exposure measure shows that cars experienced a lower risk of backing crash involvement than the other vehicle types. However, unlike the registration data, trucks (in this case, pickups) have a lower risk than SUVs.

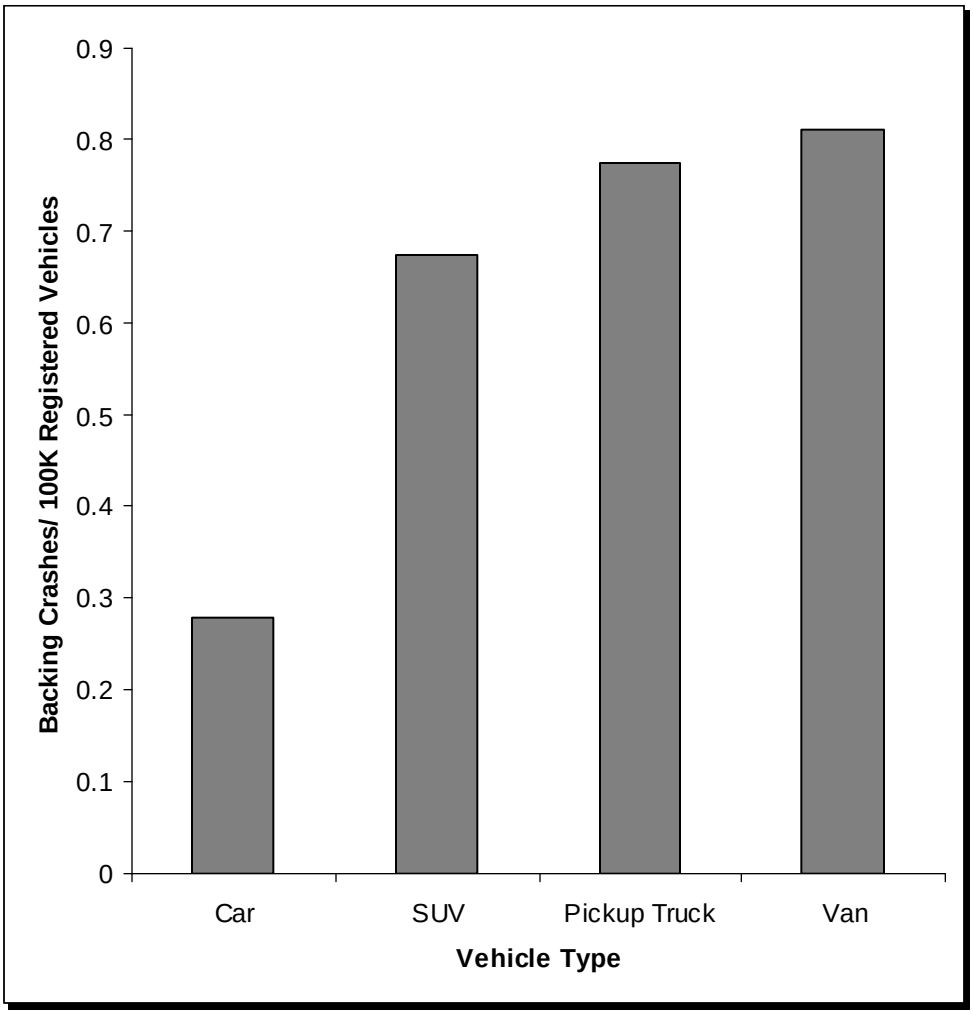

Figure 4: Backing Crash Rate by Vehicle Type Using Registration as Exposure (FARS 1994-2004).

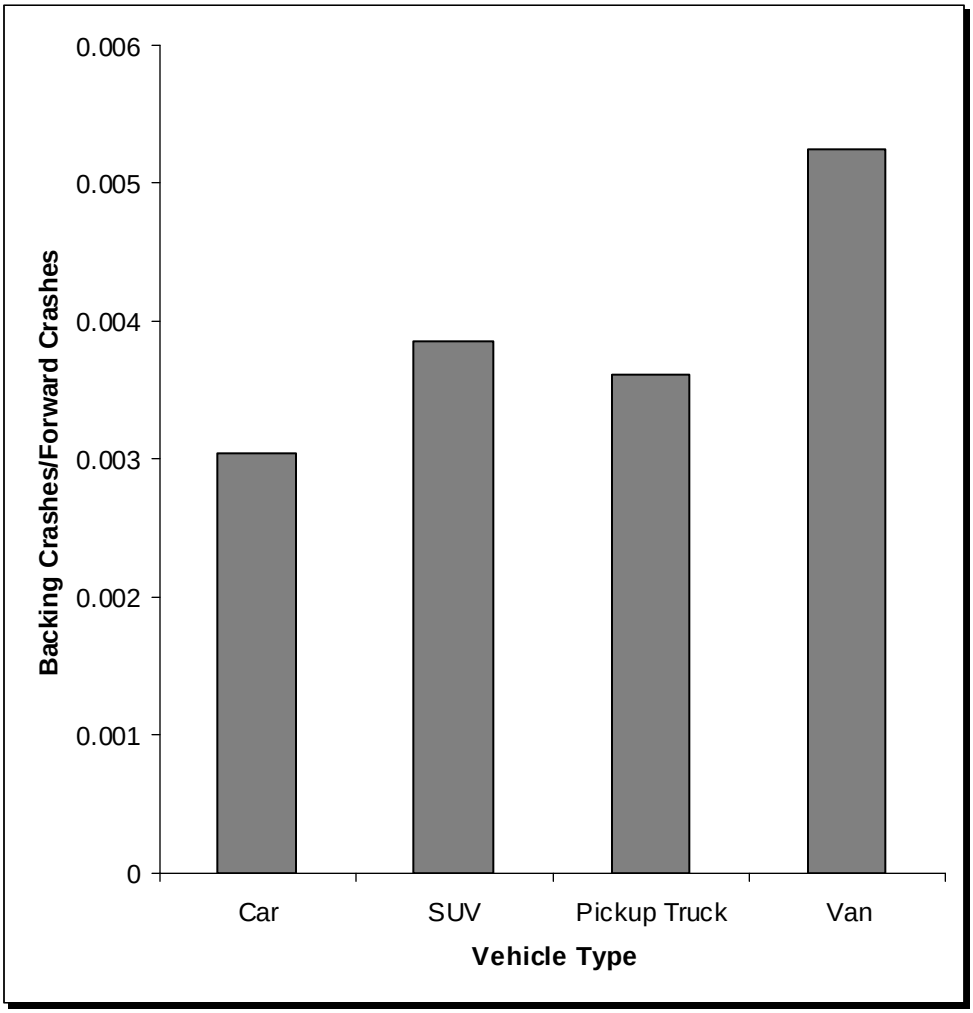

Figure 5: Backing Crashes by Vehicle Type Using Forward Crashes as Exposure (FARS 1995-2004)

Rearward visibility in different vehicles types

Almost all vehicles have a rear blind zone that could obscure the driver's visibility of small children.

A logical hypothesis about the pedestrian backover problem would be that the worse a vehicle's rear visibility, the larger the risk of backing over a pedestrian. The driver's rearward visibility of the roadway environment through the windows and mirrors varies from vehicle to vehicle. This is due to a combination of a vehicle's height, vehicle length, the driver's seating height, head restraint positions, and the rear window location/dimensions.

Behind a vehicle there is an area or zone in which a driver cannot see, not just a spot. This can be referred to as a "blind zone." The numbers discussed in this section are referred to as "blind spots" since they only represent a single testing point (or spot) behind the vehicle rather than the whole zone. Measurements of

vehicle “blind spots” have been computed by Paine, Macbeth & Henderson (2003) in Australia, as well as by Consumer Reports (2006) in the United States.

These numbers represent the closest distance at which an object of a specified height can be detected in a rearward view (Figure 6). Thus, a blind spot 12 feet long indicates that a driver would not be able to see a centrally located object within 12 feet behind the rear bumper.

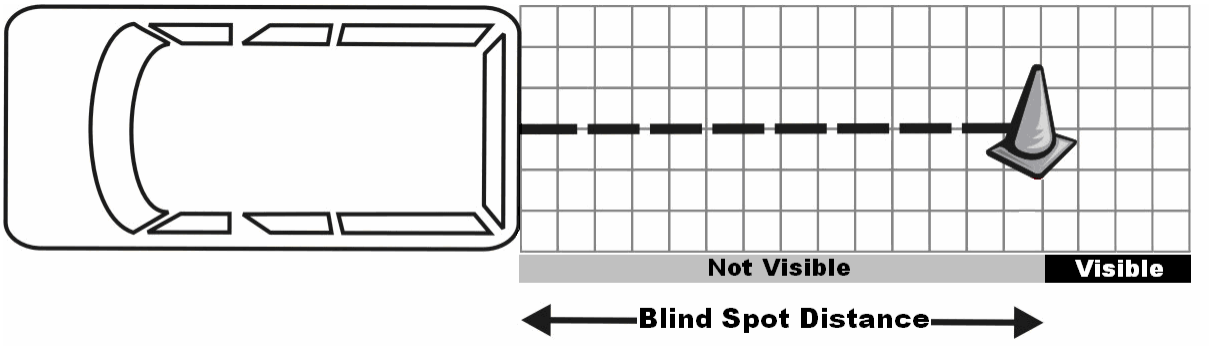

Figure 6: A vehicle blind spot

The two studies above generally used similar techniques. In the Australian study, a measuring device representing a 5’8” driver was used to detect a centrally located 24-inch-tall test cylinder. In the Consumer Reports work, actual drivers at 5’8” and 5’1” were seated in the vehicle and determined the distance from the rear bumper at which they could detect the top of a centrally located 28-inch-traffic cone. These objects approximate the height of a child less than one year old (CDC, 2005a).

The Consumer Reports data (Figure 7) show that the longest blind spots were found for pickup trucks, followed by minivans and SUVs. While the average blind spot tested for SUVs was higher than sedans, this does not imply that all SUVs have worse visibility than sedans.

The Consumer Reports data show several patterns. As expected, there is greater rear visibility for taller drivers than for shorter drivers. The average rear blind spot across all vehicles tested is 14 feet for a taller driver (5’8”) and 23 feet for a shorter driver (5’1”). With the smaller object and different vehicle configurations used in the Australian work, the blind spot averaged 23 feet.

To determine if certain vehicle types have a larger blind spot than others, the data were sorted by vehicle types. The Consumer Reports data (Figure 7) show that the longest blind spots were found for pickup trucks, followed by minivans and SUVs. While the average blind spot tested for SUVs was higher than sedans, this does not imply that all SUVs have worse visibility than sedans. The data indicate that sedans, on average, had a blind spot that was two feet smaller than SUVs (Sedans 21 feet, SUVs 23 feet). A large overlap exists in the blind spot range of the sedans (10-49 feet for the smaller driver) and SUVs (11-45 feet for the smaller driver). When the frequencies of the Consumer Reports blind spot distances for sedans and SUVs were compared; many sedans were found to have worse rearward visibility than some SUVs.

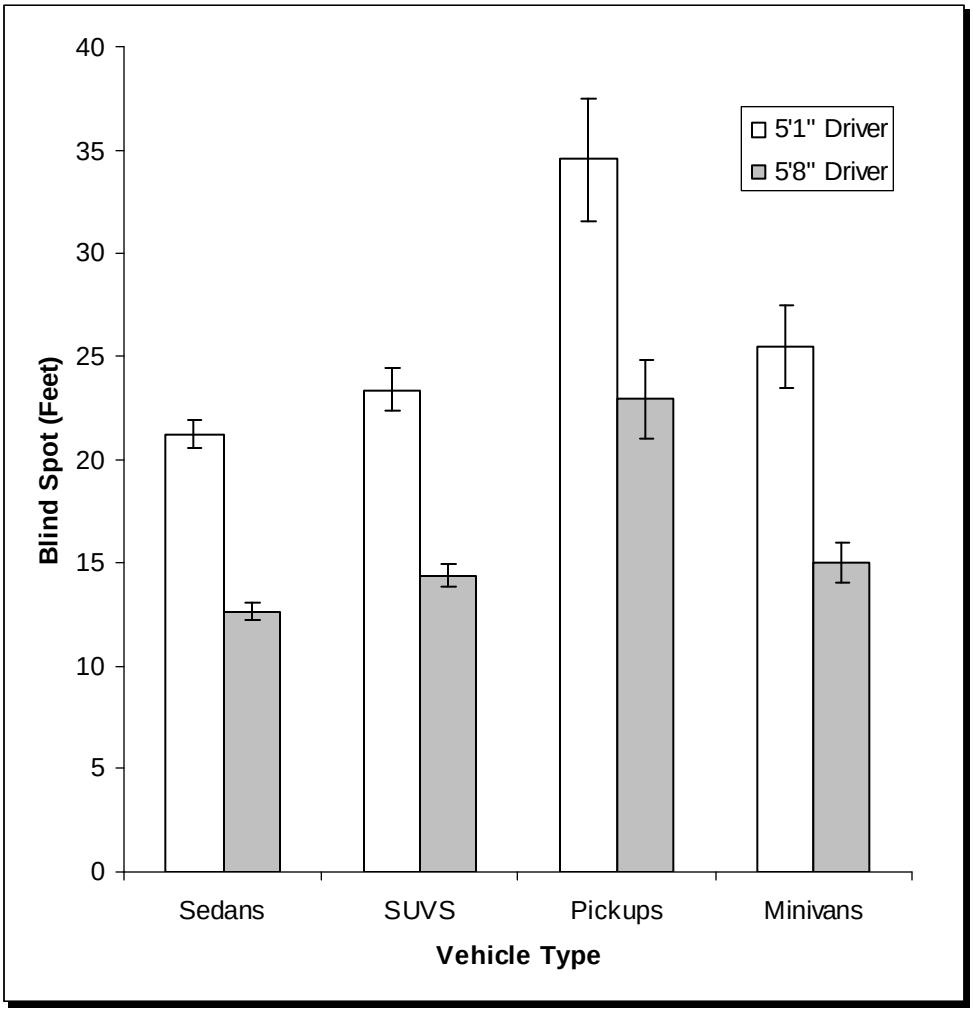

Figure 7: Consumer Reports Blind Spot Ratings by Vehicle Type (Y error bars representing Standard Error of the Mean)

In the Australian work, large cars had larger blind spots than SUVs (Categorized as "4WDs" in Australia), pickups (Utilities) and minivans (People Movers) (Figure 8). This finding may simply be an indication of the differences in vehicle styling in these different markets. For example, an SUV in Australia may be smaller than an SUV in the United States.

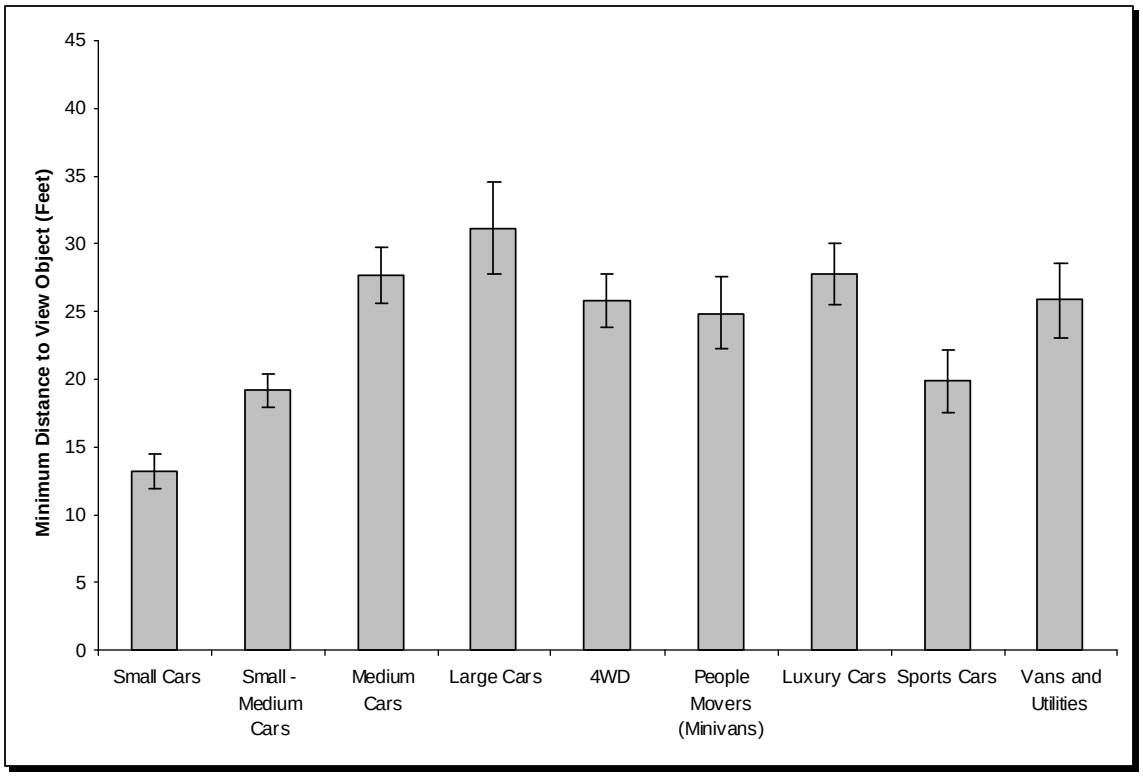

Figure 8: Visibility distances by Vehicle Type (Paine, Macbeth & Henderson, 2003, Australia Blind Spot Rating Y error bars representing Standard Error of the Mean)

The blind spots measured for different vehicles will also be affected by the measurement technique used. The blind spot numbers described above are determined from distances measured to objects positioned along the center line of the vehicle. As part of NHTSA's backover prevention technology review (NHTSA, 2006b) rear blind spots were measured with a similar procedure but with cones placed at various locations along the left and right of center as well as the center. The data, which are graphed in Figure 9, show that the rear visibility is typically worse on the left side of the vehicles tested compared to the centerline location. The figure also shows that the relative ranking of vehicles in terms of rear visibility will change as a function of the location of the object. Some vehicles have shorter blind spots than others along the centerline but longer blind spots at the left of center.

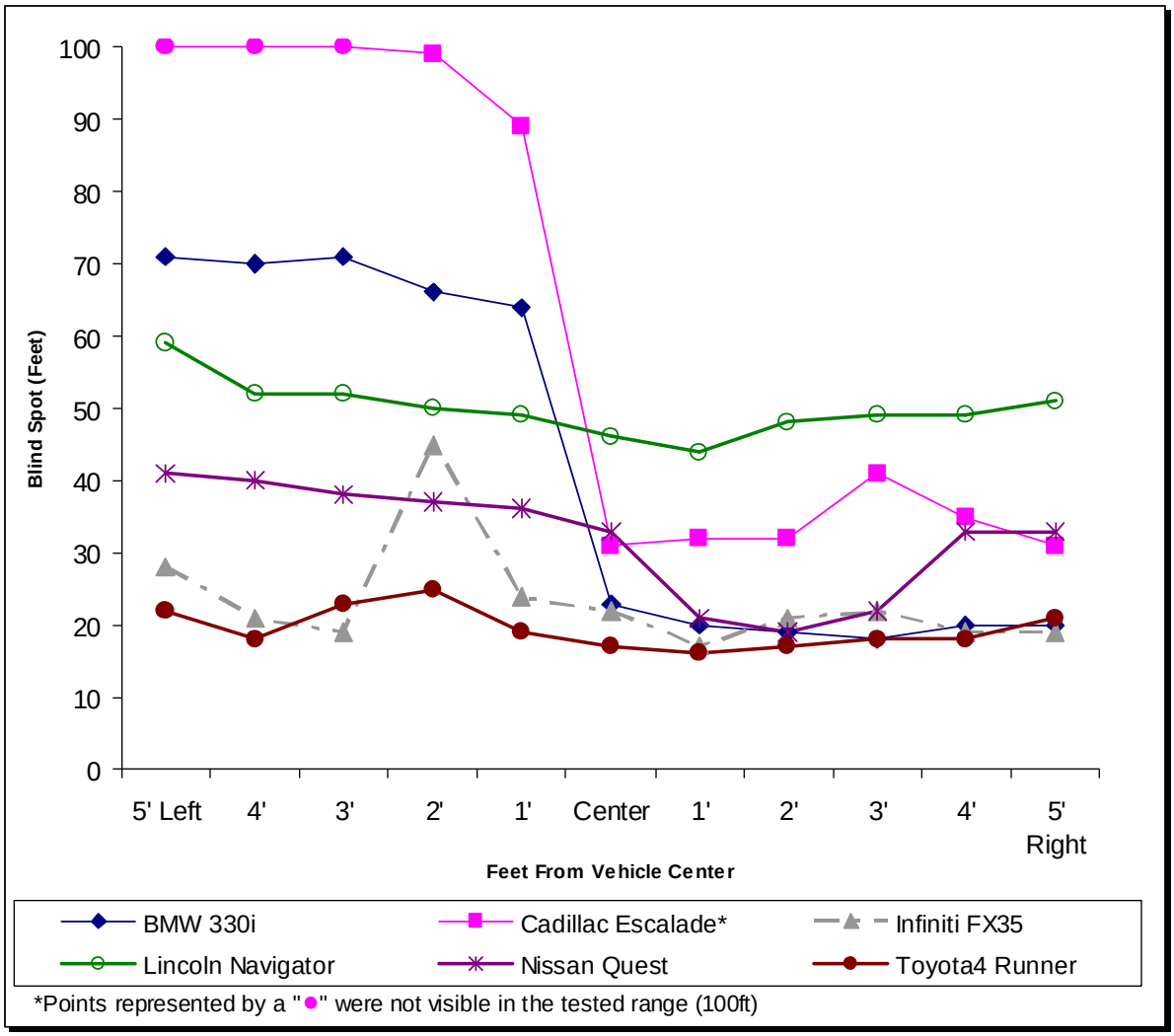

Figure 9: Driver Sight Distance (Using 28" Cone for a 5'10" driver)

These visibility ratings are not necessarily representative of the vehicle fleet, but they illustrate how rearward visibility can vary from vehicle to vehicle and location to location. Additionally, looking only at visibility in terms of a single location for a single target may not fully capture the visibility induced risk of a pedestrian backover involvement. These data do, however, present a general picture of the current state of rear visibility, and emphasize that most vehicles have large blind spots.

CHAPTER 3: EFFECTIVENESS OF POTENTIAL BACKOVER PREVENTION TECHNOLOGIES

A variety of technologies exist which have the potential to detect objects behind a vehicle including sensor-based and visual-only systems. This section outlines available technologies and describes the specific systems examined in this research. Additional details on this research are available in a NHTSA report titled, "Experimental Evaluation of Available Backover Prevention Technologies" (NHTSA, 2006b).

Currently available technologies for aiding drivers in detecting rear obstacles

Some vehicle manufacturers currently offer parking aid systems on a number of models. These systems are either sensor-based (ultrasonic or radar) warning systems or visual-only systems.

The sensor-based parking aids use sensors mounted in the rear bumper to detect obstacles. They are intended to aid drivers in performing low-speed backing and parking maneuvers by providing some form of signal (typically an auditory tone) to indicate the presence of, and distance to, obstacles behind the vehicle. At higher speeds (typically at or above 3 to 6 mph, per manufacturer's literature) sensor-based systems are inoperative.

The visual-only systems produced by the vehicle manufacturers include rearview camera systems and rear-mounted convex mirrors. Rearview camera systems display a video image of the area behind the vehicle on a display typically mounted in the instrument panel. For SUV-type passenger vehicles, interior rear-mounted convex mirrors are typically mounted inside the vehicle near or on the rear pillars.

Recently, a NHTSA-sponsored effort to document advanced technologies for passenger vehicles found that in 2006 there were thirty-one vehicle makes and 100 different model lines offering a parking aid system in the U.S. market (Llaneras, 2006). Twenty-six of the model lines offered a parking aid system as standard equipment. Most of the parking aid systems offered at the time of this inventory were sensor-based object detection systems.

Original equipment sensor detection systems are marketed as parking aids and do not purport to detect people. Typically, the vehicle owners' manuals contain cautionary warnings that tell drivers the limitations of the technology as a pedestrian detection system. Examples of these warnings are shown in the box below.

- "This system is not designed to prevent contact with small or moving objects. The system is designed to provide a warning to assist the driver in detecting objects to avoid damaging the vehicle. The system may not detect smaller objects, particularly those close to the ground." *2007 Lincoln Navigator*

- "Sensors have dead spaces in which objects cannot be detected. Be especially alert for small children and animals since they are not always detected by the sensors." *2004 Audi A8*

Although these systems are not designed or sold with the specific intention of detecting pedestrians, in some cases they will detect people behind a vehicle. Thus the performance of these systems for detecting people and objects was examined in this study.

Both the sensor-based and visual-only parking aid systems are also offered by aftermarket manufacturers. One visual-only system offered by aftermarket producers but not vehicle manufacturers is the Fresnel lens. A Fresnel lens is a wide angle, flat, plastic lens which is affixed to a vertical rear window. While the vehicle manufacturers claim that their technologies are parking aids some aftermarket producers market their products as safety devices.

Costs: Parking aids range in price based on the technologies that are used. Table 4 presents some estimates of consumer costs. The following are estimated consumer costs for potential backover prevention technologies if these systems were installed throughout the U.S. light vehicle fleet. These numbers are not based on the current consumer costs of these systems.

Sensor-based Warning Systems:

The consumer cost for a new vehicle to be equipped with an ultrasonic or radar warning system is estimated to be between $41 and $100 per vehicle.

Visual-only Systems:

The consumer cost for a new truck to be equipped with a camera system was estimated at $325 in a recent Notice of Proposed Rulemaking (NHTSA, 2005). A large part of the cost of a rearview camera system is the display, which was a black and white Cathode Ray Tube (CRT) display, rather than a color Liquid Crystal Display (LCD) display, which is more common in the passenger car segment. It should be noted that the incremental cost for vehicles which already have an in-dash display screen (e.g. for a navigation system) would be much smaller.

The consumer cost for a new vehicle to be equipped with a Fresnel lens is estimated to be between $8 and $13 per vehicle. Interior mirror systems are estimated to cost $13 per vehicle.

For details on these cost estimates see the cost benefit analysis for this report in Docket Number NHTSA-2006-25579 (http://DMS.DOT.GOV).

Table 4. Estimated Parking Aid Costs

Technology	New Vehicle Consumer Cost
Sensor-based	
Ultrasonic	$41
Radar	$41-$100
Visual-only	
Camera	$325
Fresnel lens	$8-$13
Mirror	$13

Effect of the potential backover prevention technologies on driving performance

There are a number of factors which can affect how a driver uses these systems. Even if a system detects objects accurately, this does not imply perfect driver performance.

Both sensor-based and visual backover prevention systems require the attention and the appropriate response of the driver in order to succeed in achieving crash avoidance.

Both sensor-based and visual-only backover prevention systems require the attention and the appropriate response of the driver in order to succeed in achieving crash avoidance. Systems that are purely visual (e.g., mirrors and rearview cameras) are passive, in that the driver has to look at the display, perceive the object(s) displayed in it, and then take action to avoid backing into the object. Sensor-based systems are somewhat active in that they draw the driver's attention to the presence of an object behind the vehicle that they might not have seen. Systems can be designed to be even more active using automatic braking to bring the vehicle to a stop if a rear obstacle is present. Thus, the different types of systems can require different levels of effort from the driver to avoid a crash. Figure 10 illustrates the sequence of steps involved in detecting and avoiding a rear obstacle, as a function of system type.

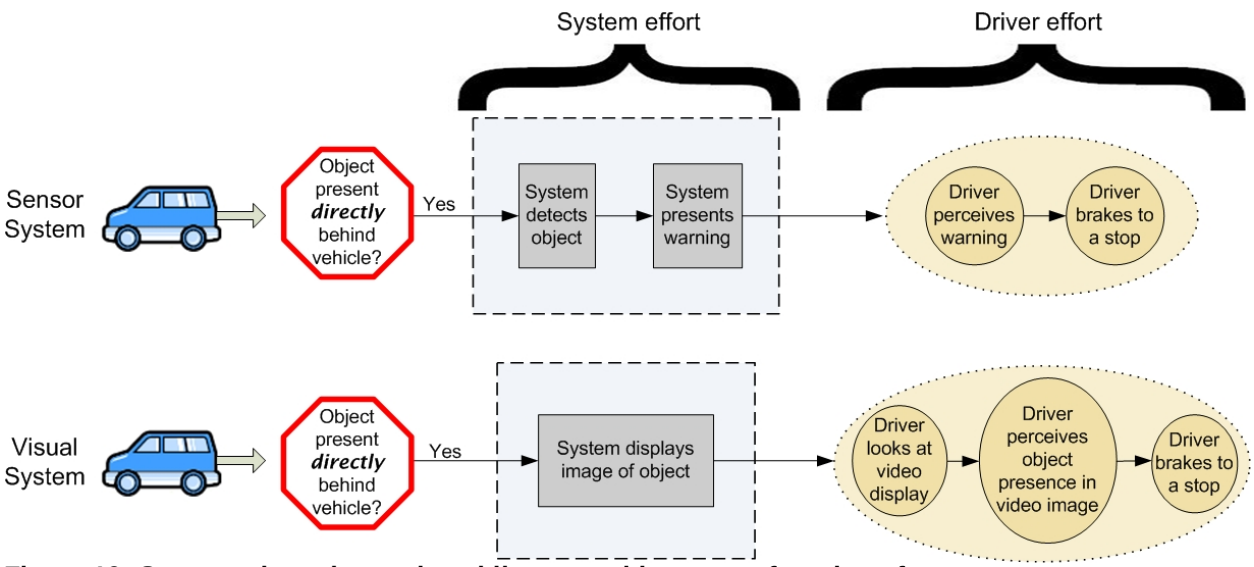

Figure 10: Steps to detecting and avoiding rear objects as a function of system type.

The above figure illustrates a simplified process of performing a backing maneuver with the aid of a backover prevention system. However, the process is actually somewhat complicated. A number of problems can occur in the process of performing a backing maneuver which can result in an unfavorable outcome (i.e., striking an object). The three main variables in the process of backing a vehicle include the system, the driver, and the physics of the situation (e.g., environmental conditions, timing of events). For a backover avoidance system to aid drivers in avoiding a collision with an obstacle present behind the vehicle, a number of steps involving these three variables must occur with favorable results:

- The system must:
  - *Sensor-based systems*: accurately detect the obstacle
  - *Visual-only systems*: clearly display the obstacle on an in-vehicle visual display
- The system must present the warning signal or obstacle presence information early enough that the vehicle can be braked to a stop before an obstacle is struck
- The driver's attention must be drawn to the warning or information the system is providing:
  - *Sensor-based systems*: presentation of an effective warning signal
  - *Visual-only systems*: driver chooses to look at the visual display
- The driver must perceive the warning, and

- The driver must make an appropriate crash avoidance response (The driver must apply the brakes hard and quickly to stop the vehicle before reaching the obstacle).

Figure 11 illustrates these steps and notes some additional factors that can impact the outcome of a backing situation. This following section outlines these aspects and presents research NHTSA has undertaken to better understand the performance of backover crash avoidance systems.

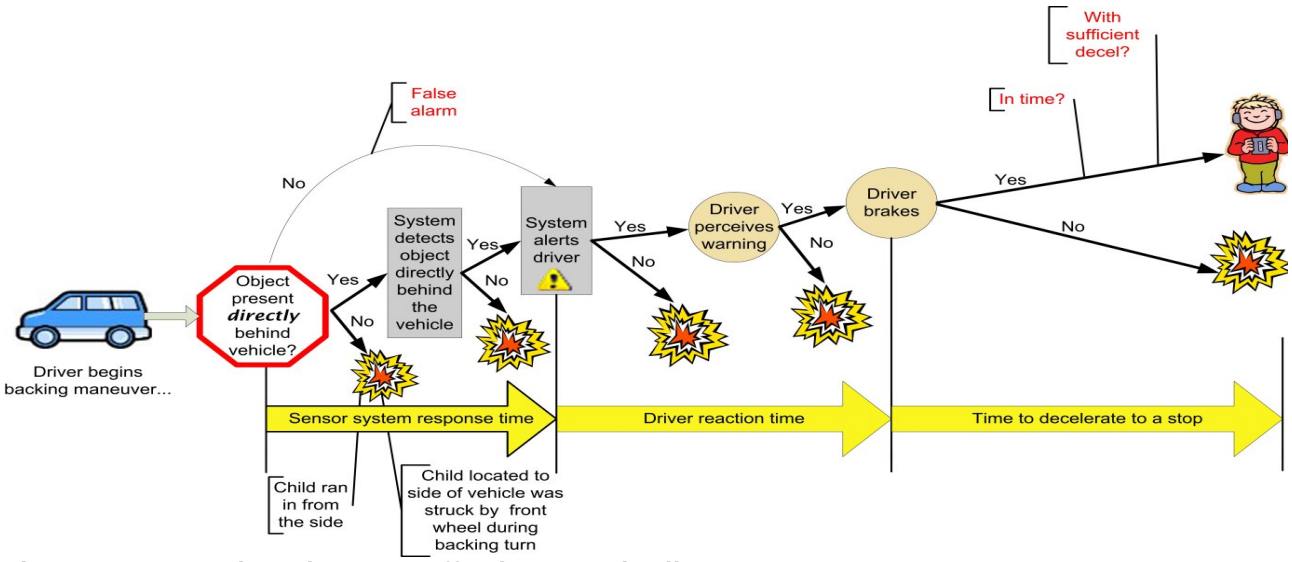

Figure 11: Sensor-based System Effectiveness Timeline

Previous testing of potential backover prevention technologies

Technologies for warning drivers of the presence of rear obstacles during backing maneuvers have been available for a number of years. As these technologies have emerged, NHTSA has taken the initiative to evaluate the performance of the technologies to assess their potential for reducing crashes, injuries, and deaths. During the 1990's, NHTSA performed two studies that examined the performance capabilities of commercially-available systems designed to reduce the incidence of injury and death outside of backing vehicles.

The first of these studies (NHTSA, 1994) examined systems designed for use with commercial motor vehicles (medium and heavy trucks). This study tested six commercially available backover avoidance systems (referred to as Rear Object Detection Systems during the study): five ultrasonic systems and one rearview camera system. Note that none of these systems were installed in the vehicle as original equipment; they were all aftermarket add-ons. The most significant and relevant result from that study was:

> "For rear object detection systems, the drivers were helped by the device when backing slowly to a loading dock and for warning of pedestrians. However, the low [adult] pedestrian detection rate found for some systems, the limited coverage area of all systems, and the

> variability of detection performance suggests that drivers cannot solely rely on these systems to back up safely under all situations."

A second study was conducted on systems intended for use with passenger vehicles and was performed as part of NHTSA's Intelligent Transportation Systems research (NHTSA, 1996). This study evaluated the performance of two commercially-available ultrasonic backover avoidance systems and two commercially- available rearview camera systems for passenger cars, along with side object detection sensors. As in the earlier NHTSA study, these were aftermarket add ons rather than vehicle original equipment. The following are the key findings of the latter NHTSA study.

Findings for ultrasonic backing systems:

> "With respect to the functional goals of a backing system, neither of these two systems meets any of the requirements. Even for near zone detection both systems have a maximum range of about 3m, not the 5m called for [in another report on this study.]"

> "[Ultrasonic backing systems] were found to be extremely sensitive and prone to false alarms. Backing systems suffer from orthogonal requirements. On the one hand one doesn't want the system to go off all the time, while on the other hand one would like to be sensitive to small targets, such as children, in an environment with a large amount of ground return."

Findings for rearview camera systems:

> "The two video systems tested appear to be quite capable of extending the drivers' field of regard. The contrast compression may obscure some targets under certain lighting conditions, but such a condition was not observed during these tests. The field of view of both systems provided adequate coverage toward the rear of the vehicle. These two systems are quite capable of satisfying the target detection functional goal. Obviously, they cannot satisfy the warning requirement."

Current testing of potential backover prevention technologies

The following section is a summary of NHTSA's recent testing of potential backover prevention technologies. More details can be found in the technical report titled "Experimental Evaluation of the Performance of Available Backover Prevention Technologies" (DOT HS 810 634).

System Selection: Systems were chosen for evaluation to provide a representative sample of each type of technology. To the extent possible, given time and available funding, systems from different automotive manufacturers were included to provide a balance of brands as well as to observe any differences that might be present in terms of how different manufacturers implement a particular sensor technology (e.g., ultrasonic). Similar vehicle types (namely, SUV and minivan) were sought to provide some consistency of platform allowing for isolation of system and sensor performance factors. A set of vehicles meeting these criteria was identified.

The resulting set of eleven systems selected for examination included:

- Eight ***sensor-based*** systems:
  - Four original equipment (OE) "parking aid" systems (one included rearview camera)
  - Four aftermarket systems (one included a rearview camera)
- Three ***visual-only*** systems:
  - One rearview video ("RearView Monitor") OE system
  - One OE auxiliary mirror system
  - One aftermarket auxiliary mirror system

Table 5 outlines the specific systems tested.

In surveying the various technologies available, and as discussed above, it was noted that all systems offered by original equipment (OE) manufacturers were advertised as "parking aids" rather than safety systems, while aftermarket systems were marketed as safety systems with the ability to warn drivers of children present behind backing vehicles. While the OE parking aid systems do not purport to detect pedestrians, they were still included in this testing to fully address the congressional directive that asked for an examination of "available technologies for detecting people or objects behind a motor vehicle." Furthermore, examining available parking aids allows NHTSA to inform consumers about their capabilities and permits comparison of their performance with aftermarket systems utilizing similar technology. All aftermarket systems were installed per the manufacturer's specifications.

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Table 5: Backover Avoidance Systems/Test Vehicles

	System Type	System Name	Technology	Number of Sensors / Camera Viewing Angle	Display Type	Manufacturer	Vehicle Year/Model
OEM	Single-Technology Sensor	Park Distance Control	Ultrasonic	4 sensors	LCD color graphical display, auditory alert	BMW	2006 330i
		Rear Sonar System	Ultrasonic	4 sensors	Auditory alert	Nissan	2005 Quest
	Multiple Technology	Extended Rear Park Assist	Ultrasonic/ Radar	2 ultrasonic, 1 radar	Auditory alert	Lincoln	2005 Navigator
		Ultrasonic Rear Parking Assist, Rear Vision Camera	Ultrasonic/ Video (integrated)	(Viewing angle not provided)	LCD color video, 3 LEDs, auditory alert	Cadillac	2007 Escalade
	Visual	RearView Monitor	Video	(Viewing angle not provided)	LCD color video	Infiniti	2005 FX35
			Convex mirrors	2 mirrors	Located at rearmost pillars	Toyota	2003 4Runner
After-market	Single-Technology Sensor	Mini3 LV Car Reversing Aid	Ultrasonic	3 sensors	LED distance display, auditory alert	Poron	(Aftermarket systems installed on a 2003 Toyota 4Runner)
		Guardian Alert	Doppler Radar, X-Band	1	LED, 3 colors	Sense Technologies	
		Guardian Alert	Doppler Radar, K-Band	2	LED, 3 colors	Sense Technologies	
	Multiple Technology	Reverse Sensing System, Rear Observation System	Ultrasonic, Mini-CCD camera	4 sensors; (Viewing angle not provided)	3 inch LCD display in rearview mirror	Audiovox	
	Visual	ScopeOut	Convex mirrors	2 mirrors	Mounted to inside of rear window	Sense Technologies	

Evaluation method**:** The object and person detection capabilities of sensor-based parking aid and backover crash avoidance systems were measured using a variety of "test objects". Objects included: 1-year-old and 3-year-old children, an adult male, 1 and 3-year-old crash test dummies (clothed like real children), a PVC pole specified by the International Organization for Standardization (ISO) in their standard ISO 17386, and various sizes of traffic cones.

Static object detection tests consisted of placing objects in various locations behind the vehicle and recording the response of the system. The area over which a system could detect objects is referred to as its "detection zone." Measurements included static detection zone, detection repeatability, dynamic detection range with a subset of test objects, and response time.

Dynamic object detection involved suspended test objects being moved laterally behind the vehicle and the system's response being recorded. Dynamic tests were also conducted with an adult walking in various directions behind the vehicle and with child subjects walking, running, and riding non-powered ride-on toys behind the vehicles.

Sensor-based warning system object detection response time was measured using a remote-controlled fixture containing an aluminum plate that would pop up from the ground. The height of the fixture when deployed was 36.5 inches. Testing was conducted indoors on a flat, level, concrete surface.

Findings for sensor-based systems

Sensor-based systems generally exhibited poor ability to detect child pedestrians, standing still or walking, behind the vehicle. Systems' detection performance for children was inconsistent, unreliable, and in nearly all cases quite limited in range. Testing showed that, in most cases, the detection zones of sensor-based systems contained a number of areas of uneven coverage in which a standing child was not detected.

All eight of the systems could generally detect a moving adult pedestrian (or other objects) within their detection zone area behind the vehicle when the vehicle was stationary. However, all of the sensor-based systems exhibited at least some difficulty in detecting moving children. A few of these test trials with children for which systems had problems detecting moving children are described here:

- 2005 Lincoln Navigator with 1-year-old subject: 1-year-old crawls behind the vehicle without being detected by the system, then gets up and walks back the other way and is detected after crossing most of the width of the vehicle.
- Audiovox aftermarket system with 1-year-old child. The child is detected when walking, but not when bending down to pick something up. She stands still momentarily and it stops detecting her.
- Audiovox aftermarket system test trials with a running 3-year-old child who is inconsistently detected within a range of 5 ft from the rear of the vehicle.
- 2007 Cadillac Escalade system test trials with a running 3-year-old child who is inconsistently detected within a range of 5 ft from the rear of the vehicle.
- 2006 BMW 330i system with a 3-year-old child detected while riding a ride-on toy and walking within 5 ft from the rear of the vehicle, but not detected when walking at a range of 7 ft from the rear bumper.

Video recordings of these scenarios are available in U.S. Department of Transportation Docket Management System, NHTSA-2006-25579.

Between test trials, several instances were captured on video of systems failing to detect children playing behind the vehicle within the systems' detection zones. A few of these "uncommanded test trials" with children are described here:

- 2005 Nissan Quest with two 3-year-old children playing: Two 3-year-old boys play behind the vehicle and are inconsistently detected.

- 2005 Nissan Quest with two 3-year-old children playing: Two 3-year-old boys play behind the vehicle. One boy rides by on a pedaled ride-on toy, the system detects him, and then he moves out of view leaving the second boy still standing behind the vehicle approximately 5 feet away without any response from the system.
- Poron aftermarket system with 1-year-old and 3-year-old children playing: The system initially detects a PVC pole the children are playing with, then it detects the 1-year-old, then it stops detecting altogether.

The size of the pedestrian had an effect on detection performance. Adults elicited better detection response from the sensor systems than did the 1- and 3-year-old children tested. Testing in which an adult walking parallel, perpendicular, and diagonal to the rear bumper showed that systems were able to detect the adult within their respective detection zone regardless of the orientation of the person's walking path. Detection zone patterns observed for a standing adult were typically similar in width and range to those obtained with a 36-inch-traffic cone. Sensor-based systems' performance in detecting an adult lying on the ground was poor, with all but one system detecting the person in only a few, sporadic locations.

Sensor-based systems were found to be generally unable to detect traffic cones of 18 inches in height or less. However, all systems tested were able to detect a 3 5/8 inch high, plastic parking curb centered behind the vehicle (parallel to the bumper) at one or more locations between 3 and 7 feet aft of the vehicle's rear bumper. The 40 inch PVC pole was well detected by OE sensor-based systems using ultrasonic technology.

While ultrasonic systems can detect stationary obstacles behind the vehicle when the vehicle is stationary, Doppler radar-based sensors, by design, cannot. Doppler radar-based sensors (e.g., the Guardian Alert systems) also cannot detect objects moving at the same speed and direction as the vehicle on which they are mounted. Some radar systems (frequency-modulated continuous wave radar) are capable of detecting stationary objects when a vehicle is stationary (e.g., Lincoln Navigator).

Sensor-based systems typically can only detect pedestrians or objects that are directly behind the vehicle. None of the systems tested had large enough detection zones to completely cover the blind spot behind the vehicle on which they were mounted. The sensor with the longest range of those tested could detect a 3-year-old child, moving or still, out to a range of 11 feet. The closest distance behind any of the six vehicles tested at which a child-height object could be seen by the driver, either by looking over their shoulder or in the center rearview mirror, was 16 feet.

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Figure 12 compares, for a 28-inch-tall traffic cone (approximately the height of an average 1-year-old child), the size of the rear blind zone area spot for one test

vehicle to the sensor system detection zone for that vehicle's parking aid system. It should be noted that the sensor system detection zone is much smaller than the area in which an object is not visible with mirrors or a direct view. Additional figures illustrating coverage for other systems are included in Appendix A. For some positions of the side rearview mirror a portion of the area behind the vehicle can be seen by the driver, however the figures do not consider any visibility seen by side rearview mirrors.

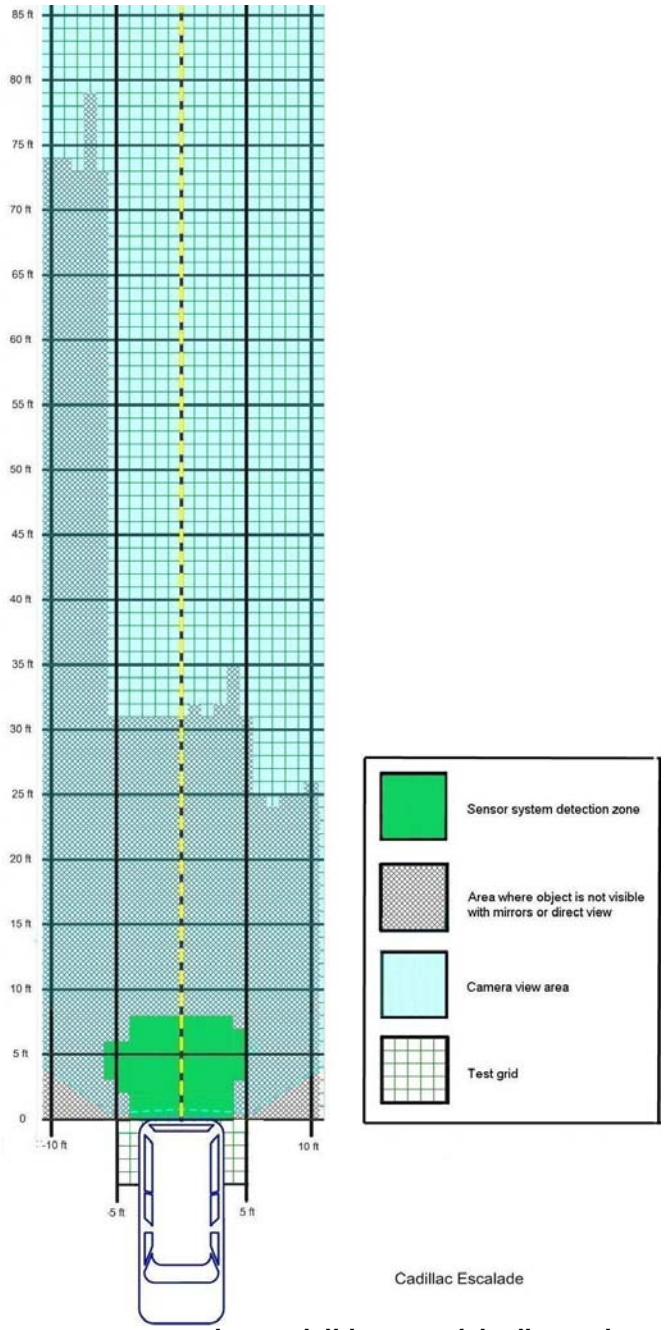

Figure 12. System coverage areas and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2007 Cadillac Escalade)

Response times of sensor-based systems to detect objects ranged from 0.18 to 1.01 seconds. The ISO has published a recommendation (ISO 17386) for parking aid

systems to have a maximum response time of 0.35 seconds (measured with an alternate procedure). Only three of the seven systems tested met the ISO limit.

For a sensor-based system warning to be effective, it must be provided early enough that the driver has time and sufficient physical space in which to stop the vehicle. Based on an analysis of naturalistic driving conducted by Huey, Harpster, & Learner (1995), a system should provide drivers with a warning that allows them to brake to a stop from at least 5 mph. Based on the data collected for this report, calculations were made to determine what conditions must be met in order for collision avoidance to be possible given the observed system response times and detection range for a 3 year-old-child. The speeds ranged from a low of 0.9 mph to a high of 4.2 mph, as shown in Table 6.

To provide a reference point helpful in understanding the implications of these values, natural backing speeds (i.e., speed at which a vehicle with an automatic transmission will travel in reverse gear without throttle application) were measured as part of this testing. While natural backing speeds provide a reference point, it should be noted that actual backing speeds can vary depending on the situation. Vehicles involved in this research had a natural tendency to back at speeds generally above the maximum backing speed for which a crash could be avoided (see Table 6). For all but one of the OE systems tested the natural backing speed of the vehicle was above the maximum speed for braking to a stop without striking a 3-year-old child (based on detection ranges observed during dynamic test trials).

Table 6: Maximum Speeds for Braking to a Stop and Natural Backing Speeds for Selected Vehicles

Vehicle	Max. Speed Vehicle Can Be Traveling for Crash Avoidance 3-yr-old Child (mph)	Natural Backing Speed - Steady State (mph)
Cadillac Escalade	1.7	4.0
Lincoln Navigator	4.2	4.0
Nissan Quest	0.9	4.3
BMW 330i	1.9	4.9
Guardian Alert (Toyota 4Runner)	1.2 X-Band / 2.6 K-band	7.0
Audiovox (Toyota 4Runner)	1.9	7.0

The combination of system response times and detection range values result in successful crash avoidance being unlikely except for fairly low vehicle backing speeds. For the ultrasonic sensor-based systems tested, the calculated median maximum speeds for braking to a stop for a 3-year-old child indicate that a crash might only be avoidable if the vehicle is traveling at speeds below 2.0 mph. This indicates that the maximum detection range for ultrasonic sensor-based systems tested was insufficient to prevent a backover situation in which the obstacle is a 3-year-old child. However, only about 50 percent of the vehicles

The combination of system response times and detection range values result in successful crash avoidance being unlikely except for fairly low vehicle backing speeds.

that back into pedestrians are traveling at speeds below 2.0 mph (based on analysis presented in NHTSA, 1995). The situation for the radar-based sensor systems is slightly better, but still one in which crash avoidance is unlikely. A system should have a maximum detection range that facilitates warning the driver in time for them to brake to a stop from at least 5 mph to avoid colliding with a 3-year-old child.

The reliability (i.e., ability of systems to work properly without an unreasonable failure rate) of sensor-based systems as observed during testing was good, with the exception of one aftermarket, ultrasonic system that malfunctioned after only a few weeks, rendering it unavailable for use in remaining tests. In examining consistency of system detection performance, it was noted that all of the sensor-based systems tested exhibited at least some degree day-to-day variability in their detection zone patterns. Results of static sensor-based system detection zone repeatability showed a range of performance quality. Inconsistency in detection was usually seen in the periphery of the detection zones and typically was not more than 1 foot in magnitude.

Overall, the consistency of detection performance and understandability of warning variations exhibited by sensor-based systems was not sufficient to permit a good assessment of the appropriateness of system warning levels.

Findings for visual-only systems (rearview cameras and auxiliary mirrors)

NHTSA also examined visual-only systems including rearview video camera systems and two auxiliary mirror systems designed to augment driver rearward visibility. The examination of these systems included assessment of their field of view and potential to provide drivers with information about obstacles behind the vehicle. Rearview camera systems provided a clear image of the area behind the vehicle in daylight and indoor lighted conditions.

The two auxiliary mirror systems tested had substantial areas behind the vehicle in which pedestrians or objects could not be seen. Visually detecting a 28-inch-tall traffic cone behind the car using the rearview auxiliary mirrors proved to be challenging for drivers. The combination of head restraint location, driver range of mobility (when belted), and rear window tinting contributed to the difficulty. The mirror convexity also caused significant distortion of displayed objects, making them more difficult to recognize. A hurried driver making quick glances prior to initiating a backing maneuver might not allocate sufficient time to allow the driver to recognize an obstacle presented in the mirror.

The rearview camera systems showed pedestrians or obstacles behind the vehicle and displayed a larger area than was covered by the detection zones of sensor-based systems tested in this study. The range and height of the viewable area differed significantly between the two OE systems examined. In addition to limiting the field of view, the limited view height of one system seemed to complicate the judgment of the distance to rear objects.

In order for rearview camera systems to assist in preventing backing collisions, the driver must look at the video display, perceive the pedestrian or object in the video screen, and respond quickly and with sufficient force applied to the brake pedal to bring the vehicle to a stop. The true efficacy of rearview camera systems cannot be known without assessing drivers' use of the systems and how they incorporate the information into their visual scanning patterns (i.e., looking behind over the shoulder and glancing at mirrors). However, these systems do have the potential of providing a good field of view of the objects including pedestrians behind the vehicle.

Summary of the testing of potential backover prevention technologies

In summary, results showed that the performance of ultrasonic and radar parking aid and aftermarket backing systems in detecting child pedestrians behind the vehicle was typically poor, sporadic (i.e., exhibiting many "holes" and variability), and limited in range. Based on calculations of the distance required to stop from a particular vehicle speed, detection ranges exhibited by the systems tested were not sufficient to prevent collisions with pedestrians or other objects given a vehicle backing at typical speed. The rearview camera systems examined had the ability to display pedestrians or obstacles behind the vehicle clearly in daylight and indoor lighted conditions. To estimate the effectiveness of these systems in reducing backing crashes research must be performed to assess drivers' use of the systems. The fields of view of auxiliary mirror systems examined covered a smaller area to the rear of the vehicle than the rearview camera systems did and the displayed image was subject to distortion due to mirror convexity and other factors (e.g., window tinting) making rear obstacles more difficult to recognize.

In summary, results showed that the performance of ultrasonic and radar parking aid and aftermarket backing systems in detecting child pedestrians behind the vehicle was typically poor, sporadic (i.e., exhibiting many "holes" and variability), and limited in range.

Driver opinions about parking aid usefulness and effectiveness

Almost 300 drivers who purchased recent model year vehicles (2000-2004) with parking aids for backing were interviewed by phone to assess their opinions and use of the devices (Llaneras, 2006). Most of the parking aids were electronic sensor systems that provided auditory or visual feedback on the distance to objects that are close to the rear bumper. Approximately 25 percent of the sample was also equipped with a rearview camera system. These parking aids are intended to assist attentive drivers to determine how close they are to nearby objects while backing in low speed situations.

Most drivers found their parking aids helpful in detecting obstacles when parking. At least 85 percent felt the systems are effective or very effective at providing warnings about objects sufficiently in advance. Only about 50 percent of drivers rated the system very effective in minimizing false alarms. As many as 80 percent thought the parking aid would lower their likelihood of being involved in a backing-related crash, but a few drivers (11 percent) believed that the system might increase the likelihood.

This may have resulted from their reported over reliance on the system and less reliance on using the vehicle's mirrors or direct glances when backing. Another possible concern from a safety point of view was the finding that 67 percent of owners believed that their parking aid system would provide warnings at any backing speed. However, most systems only operate at speeds less than 6 mph. Thus, while this small scale survey provides an indication that many drivers like the systems and find them helpful, some drivers described situations that might lead to decreased safety.

Human factors studies of driver performance using parking aids

Factors affecting driver performance and system effectiveness: Effectiveness of potential backover prevention technologies will not only depend on the detection capabilities of the sensors, but on the driver's ability to properly use the information to assist them while backing. Various factors can detract from the ability of drivers to use these devices effectively. Driver characteristics include their level of attentiveness, their visual search patterns, their ability to interpret the information presented, their time to decide what to do, and the appropriateness of their response. The characteristics of potential backover prevention technologies that can influence the driver's ability to prevent backover crashes include the clarity of the display, the location of the display, the timing of the warnings, and the rate of false warnings and/or nuisance warnings.

Although all of these factors are relevant to backing aid effectiveness, the number of research studies on driver's actual use of in-vehicle parking aids or of pedestrian detection devices used while backing, is sparse. A set of three studies sponsored by General Motors examined several types of backing aids to more directly measure their ability to help drivers avoid backing crashes.

Study 1 -*McLaughlin, Hankey, Green, & Kiefer (2003):*
This study evaluated three parking aid systems, including an ultrasonic rear parking aid (URPA, which has a display of chime and lights on the passenger side), a rear video (RV) with in-dash video display, and a combination of URPA with RV. These systems were compared to a control condition where only a mirror and back window view were available. These aids are primarily intended to aid parking rather than to warn drivers of unforeseen objects or pedestrians. Nevertheless, the study included an evaluation of the ability of parking aids to serve as crash countermeasures, using a special study procedure. After participants completed several standard parking and backing tasks, a one-time ruse was introduced whereby an obstacle was placed, unknown to the driver, about two to three feet behind the vehicle. The drivers were instructed to return the vehicle to the building, that required them to back again.

The findings showed that 23 percent of the 22 drivers with one of these parking aids avoided the obstacle. Of the five drivers who avoided the obstacle, three saw the object with the rear video system. These results suggest that when the presence of an object was unexpected, the effectiveness of the parking aids was very low. The presence of the RV benefited only a few drivers among the participants.

Study 2- *Details outlined in NHTSA Docket #19239-66:*
The intention of this study was to look at factors which may affect the design of rear video overlays which incorporate sensor data into the video image. This study involved a one-time ruse similar to that used in the first study. After parking 32 times drivers were told "We can head back to the building" with a curb blocking forward travel and an obstacle placed to the rear of the vehicle. During this backing maneuver 65% of drivers avoided the unexpected obstacle. The reason for this increased effectiveness is not clear but could be attributed to the integration of the sensor and video information on the same display, or due to the increased level of driver experience with the system by the time the study was conducted.

Study 3- *Llaneras, et al (2005):*
Vehicle equipped with a rear parking assist (RPA) and a longer range, rear object detection system (RODS).

The RPA provided staged signals starting at 10 feet away from the vehicle and progressed to a 5-beep signal with all LED lights flashing at 1 foot. The RODS cue incorporated similar auditory and visual signals that were activated either as an imminent collision warning or as a two-stage warning. After practicing backing toward a wall and a mannequin of a child, drivers were presented with an unexpected obstacle, by moving a child's toy using a remote control device. Although the RODS sounded a warning of the presence of the obstacle, only 13 percent of the participants avoided the toy car. In a second surprise trial at the end of 24 additional trials, drivers backed in a parking lot aisle during which RODS was manually triggered even though no obstacle was presented. Although drivers were now more familiar with RODS, 27 percent ignored the RODS signal and gave no discernable reaction.

Drivers who exhibited an inadequate braking response to RODS in a surprise trial indicated that they did not expect an obstacle to be behind them, that the signal must be a false alarm, and thus ignored the alert. Further, the authors' report concluded that "many drivers appeared to want direct sensory confirmation of the existence of an object before initiating immediate hard braking."

Driver Response Summary:
A summary of the findings from the human factors studies is shown in Figure 13. These results show that current technologies would not help many drivers avoid backing into unexpected objects.

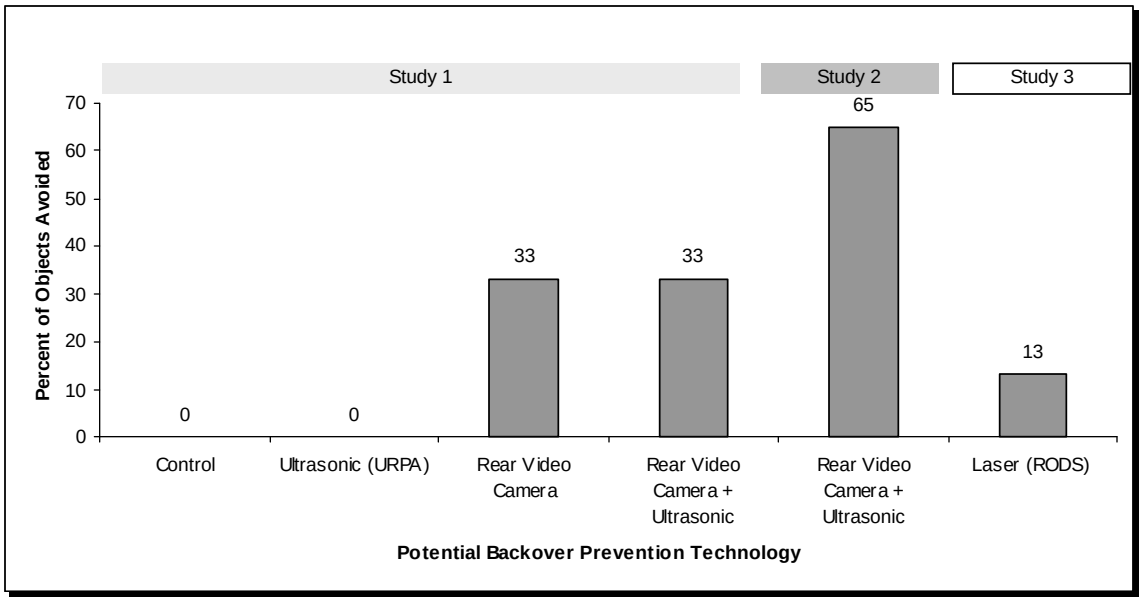

Figure 13: Percent of Unexpected Objects Avoided in GM Sponsored Work

False warnings: The reliability of a warning system should be considered when drivers are not making effective use of the warning. The general nature and context of false warnings have been characterized by Breznitz (1984) who modeled the false warning phenomenon around the shepherd who often cried "wolf" to obtain help from the villagers. After frequently responding and finding no wolf, the villagers stopped responding - to the eventual advantage of the wolf. A warning system is intended to warn a driver about an unexpected, unknown, often imminent conflict. From time to time, however, a warning system will emit a warning in the absence of a real threat, i.e., a false warning.

In the Early Adopter study, about 40 percent of the parking aid owners showed some concern about "false alarms" in their systems (Llaneras, 2006). In a field study of backing with a large truck, Ruff (2006) reported that only 41 percent of the warnings required immediate action or extra caution from the driver. The Llaneras et al. (2005) experiment indicated that some drivers did not brake when warned because they interpreted the signals in the surprise event as false warnings, even though they never experienced false warnings in the study.

While there are apparently no studies that quantified the effect of false warnings on effectiveness of sensor-based warning systems, the growing research on obstacle warnings for *forward* moving vehicles provides useful insights on the influence of false warnings. Yamada & Kuchar (2006) investigated effects of warning reliability (false warnings and misses) with a system that detects and warns drivers of pedestrians in a driving simulator. A comparison of a warning system issuing 100 percent true warnings was made with a system issuing 50 percent true warnings. It was observed that the latter group showed a slower accelerator release time and slower braking time. These results are also in agreement with those of Abe & Richardson (2004) who observed that brake response time after a single false warning was longer (but not significantly) than the response time before the false warning. Additionally, Lees, Lee, & Brown (In press) examined the effect of a history

of false warnings on driver response to a forward collision warning for a surprise event. The driver group that experienced a 71 percent false warning rate took more than twice as long (a full second longer than the group with no false warnings) to respond to the conflict. Half of the group with false warnings did not even use the brake.

These studies suggest that a history of false warnings can degrade the driver's response to an imminent conflict by either increasing response time or by omitting the response. Considering the effect of a partially or completely blocked view during backing on an attempt to verify a warning, the dampening effect of numerous false warnings on a true warning response may be *larger* than that for forward or lateral warnings in which warning confirmation is faster, more direct, or easier. This emphasizes the need for minimizing false alarms in backing warnings.

Summary of human factors research: The experimental studies showed that most drivers who are not expecting obstacles behind their vehicles will not be helped by rear object warning devices and will strike the object. In contrast, most of the drivers (81 percent) in the survey study said they would brake to an immediate stop for an unexpected alert while backing. However, behavior in an unexpected, time constrained situation is difficult to predict. When actually using a backing aid, it was observed that most drivers struck, or would have struck, an obstacle when they traveled in reverse even though they received information that an obstacle was in their travel path. When backing aids present false warnings as well, research suggests that drivers will brake even less effectively to a real threat.

When actually using a backing aid, it was observed that most drivers struck, or would have struck, an obstacle when they traveled in reverse even though they received information that an obstacle was in their travel path.

Camera-based visual systems are able to provide images of objects behind vehicles. Paying attention to the visual cues will very much depend upon how the feedback is provided to the driver and how well that information is processed. Drivers' responses could be enhanced as they gain familiarity with the system. Adding other aids such as chimes or other voice warnings and braking assistance could improve the performance of such systems.

CHAPTER 4: EDUCATIONAL EFFORTS ON PREVENTING BACKOVERS

NHTSA Education Research Programs

NHTSA has sponsored several studies which provided recommendations for educational programs and consumer messages. One study, conducted by Preusser, et. al. (1985), identified and developed public education messages for various pedestrian crash types, including backovers. Recommendations were given for behavioral advice that could be adopted by pedestrians, parents, and drivers. Prototype TV and radio scripts, pamphlets, and posters were produced. A study by Blomberg and Cleven (1998) focused on elderly pedestrians. They developed video, public service announcements, and flyers that included safety tips for older pedestrians to help avoid backover crashes. In 2006, NHTSA published a Bicycle and Pedestrian Resource Guide CD that includes a description of the backing crash type and countermeasures to reduce its occurrence (NHTSA, 2006c). It was prepared for the pedestrian/bicycle safety professional and others who are proactive in developing programs at the State or community level.

Current NHTSA Consumer Information

NHTSA has taken several steps to help expand consumer awareness about the problem of backover crashes and possible ways to prevent them.

NHTSA produced several print articles regarding the seriousness of backover crashes, to sensitize drivers to the problems and provide common-sense safety tips for drivers to avoid potential fatalities. The first article has been published on NHTSA's website, www.NHTSA.dot.gov. This article has been designed in such a manner than organizations can download it for inclusion in their newsletters. This article currently is being translated into Spanish to facilitate wider distribution.

A second article has been provided to the North American Precis Syndicate (NAPS), a news distributor that is in the process of distributing the article to more than 10,000 newspapers nationwide, with a total circulation of 2.25 million. This article, too, currently is being translated into Spanish for wider distribution. A similar article was provided to the AAA for inclusion in their membership newsletters. If published in each AAA Club's newsletter, the article will reach 44 million members.

In addition, NHTSA's National Standardized Child Passenger Safety Training Program includes information on the safety of children in and around cars focused on programs that conduct child safety seat inspection check points. This training program has produced over 25,000 certified technicians around the country who help share this information with parents and caregivers.

Identification of additional educational efforts

Identifying backover prevention educational efforts was accomplished through multiple sources, including the NHTSA Regional Offices, the Department of Health and Human Services, the Children's Safety Network (CSN) list serve, and the State and Territorial Injury Prevention Directors Association (STIPDA). Although many responses were received, very few backover specific educational programs were identified. The most extensive program is the *Spot the Tot* initiative based out of Utah's Primary Children's Medical Center. This program is funded from multiple private and government sources, including the Utah Highway Safety Office. The program was begun when the trauma department at the Primary Children's Medical Center noted numerous backover incidents and reached out to the leaders of the State's successful safety belt campaign to address the issue. A taskforce was established and developed a plan of action. The Primary Children's Medical Center developed the program with limited funds comprised mostly of donations.

Description of the educational efforts

This program was developed to increase awareness about the backover problem. While other groups have produced brochures and posted information on various internet websites, they are not as well promoted as the *Spot the Tot* program.

Spot the Tot was developed in early 2005 after a taskforce conducted a survey of citizens regarding backovers and methods of preventing them. Because most individuals surveyed did not recognize the danger of backovers, the Primary Children's Medical Center developed *Spot the Tot*. *Spot the Tot* is principally a program to encourage recognition of the potential threat of backing over a child. In addition it provides safety tips such as:

Spot the Tot is mainly focused within Utah where materials are distributed at the Primary Children's Medical Center, along with physician offices, hospitals, and daycares.

- Walk around the vehicle before driving
- Know where children are
- Roll down the window to hear what is happening near the vehicle
- Teach children to move away from vehicles that are starting
- Teach children not to play in, under, or around vehicles

These safety messages have been promoted via radio public service announcements, press coverage, television coverage, and safety fairs. The organizers continue to do print and website promotions, along with poster and brochure distribution that includes a "SPOT" vehicle window sticker to remind drivers to look around the vehicle for children before driving. In addition, the most recent initiative includes an interactive demonstration with a model SUV to show parents the extent of the blind zone and to help children learn to keep a safe distance from vehicles. *Spot the Tot* is primarily focused within Utah where materials are distributed at the Primary Children's Medical Center, along with physician offices,

hospitals, and daycares. This medical center serves a large region of the Northwest; therefore parts of Idaho, Montana, Nevada, and Wyoming have also been exposed to the program. Recently, Safe Kids Worldwide has arranged a licensing agreement with the Primary Children's Medical Center to allow Safe Kids to launch a nation-wide *Spot the Tot* educational program in the summer of 2006.

Other States that responded with information on backover education include California where the University Medical Center in Fresno, CA publishes a brochure titled "Where are your kids? Child Safety in your driveway" that addresses the risks and vehicle concerns associated with backovers. The Maryland State Highway Office has published a brochure "Kids and Trucks: A Dangerous Combination!" that addresses what drivers, employers, and parents can do to prevent backover incidents. The New York State Department of Health, Bureau of Injury Prevention, has developed a one-page brochure that was distributed to local health and traffic safety boards in New York to increase awareness and encourage prevention efforts for drivers and parents. In addition, the Children's Hospital of Pittsburgh has addressed the issue of driveway safety and on their website, http://www.chp.edu/besafe/adults/02driveway.php, and makes recommendations for preventing such tragedies, including:

- It is best if the driveway is not used as a playground.
- If you allow children to play in the driveway, block it off to prevent cars from pulling in.
- When backing out of driveway, know where every child is. Count heads to be sure.

The advocacy group Kids and Cars provides a variety of materials that can be ordered online at http://www.kidsandcars.org to educate and raise awareness of the public on the dangers of leaving children alone in and around cars, including specific recommendations on backover prevention.

All of the above educational programs have been developed in reaction to specific backover incidents rather than a data-driven, research-based backover prevention strategy with evaluation components. California is currently engaged in a collaborative effort among six trauma centers to collect information on backover injuries. It is a prospective, multi-center observational study to collect reliable data that reveals the prevalence of the problem, along with patterns of circumstances, risk factors, and strategies to mitigate the risks. The data will then provide the basis for the development of a community outreach and education campaign to prevent further backover incidents. The California Kids' Plates Program, funded by specialty license plates sold by the Department of Motor Vehicles, has sponsored the project through June, 2007.

CHAPTER 5: COST EFFECTIVENESS OF PARKING AIDS AS BACKOVER PREVENTION TECHNOLOGIES

Cost effectiveness of current parking aids in reducing property damage

The NHTSA's National Center of Statistical Analysis developed a model to estimate the benefits and costs, excluding injuries and fatality benefits, for parking aids. This analysis was performed for ultrasonic, rearview cameras, and a combination of the two. Further details on this model can be found in the document "Preliminary Cost-Benefit Analysis of Ultrasonic and Camera Backup Systems" under Docket No. NHTSA-2006-25579 (http://DMS.DOT.GOV).

Benefits are defined as the property damage costs eliminated by these systems (to the vehicle and what it strikes). Costs are defined as the incremental costs to the vehicle for these systems and the increase in property damage costs to repair the sensors in rear impact crashes (which include both when the vehicle is struck in the rear and in backing crashes in which the sensors are not effective). Since system effectiveness and the cost to repair depend so much on the speed before impact, crashes were examined in three speed ranges, resulting in Light, Medium, and Heavy damages.

There are a significant number of assumptions made in using this model, based on available information to arrive at the estimates. The assumptions regarding the crash distribution (the percent of rear impacts that are "struck in the rear" versus "backing up") and the human reaction to the system are the most sensitive variables in the model.

Based on these assumptions and estimates at this time, none of the systems appear to be cost effective. The incremental repair costs for the backup system affect all crashes involving the rear bumper. Vehicles experience a relatively large number of rear-end impacts that would damage and require the replacement of the parking aid sensors. The parking aids only mitigate the cost of the smaller number of minor backing crashes which tend to have smaller total costs.

Based on our assumptions and estimates at this time, none of the systems appear to be cost effective.

Benefits and cost savings of parking aid systems in terms of death and injury prevention

At this time, there is no way to accurately estimate how effective any parking aid would be at preventing deaths and injuries. As shown in this report, parking aids are not fully effective solutions to the pedestrian backover crash problem. The current ultrasonic and radar sensor systems are not very effective at detecting children located behind the vehicle at a distance at which a driver will likely respond in time to the system's information. The testing of rearview cameras showed better driver responses if the drivers looked at the display before backing. However, the research on driver's usage of rearview cameras tested only a small sample of drivers and limited number of backing scenarios. Furthermore research suggests that many systems will not prevent all backover crashes. The percent of crashes which could be prevented by these technologies is unclear. It would be expected that crashes such as: "roll-a-ways" (transmission/parking brake failures), children knocking the car into gear, pedestrians running and cyclists traveling at high speed across the rear of the vehicle, or people underneath a vehicle would not be prevented by these technologies. Without additional research on the specific details of these crashes and the development of a true backover crash countermeasure, rather than a parking aid, meaningful estimates of death and injury benefits and cost effectiveness cannot be calculated.

Based on the research and analysis we have done to date, we anticipate very low cost effectiveness, in terms of death and injury prevention, from current parking aids.

Based on the research and analysis conducted to date, the agency anticipates very low effectiveness, in terms of death and injury prevention, from current parking aids. In addition, since these systems themselves can be damaged in rear-end impacts, they do not appear to be particularly cost effective in reducing total property damage.

CHAPTER 6: SUMMARY AND CONCLUSIONS

Report Summary

Congress required NHTSA to conduct a study of the safety problem associated with crashes involving passenger vehicles backing over pedestrians and to evaluate available methods for reducing them, including backing aids and educational efforts. The agency addressed the congressional requirements through an analysis of crash data, discussions with vehicle and equipment manufacturers, testing of a representative sample of backing aids, review of human factors research, review of other available backing-related studies, and identification of existing educational programs.

The true extent of the problem is difficult to determine because of various limitations in the available data sources. NHTSA estimates that at least 183 fatalities occur annually due to backover crashes. The reasons for this problem are also not known but may include driver inattention, pedestrian inattention, poor vehicle visibility, or driving too fast.

This report documents the findings from testing of available parking aids as possible countermeasures for addressing the backover safety problem. The two primary types include sensor-based warning systems and visual-only systems. Results showed that the performance of ultrasonic and radar backing aids in detecting child pedestrians behind the vehicle was typically poor. The rearview camera systems typically provided drivers with the ability to see pedestrians in the majority of the rear blind zone areas.

Because countermeasure effectiveness also depends on the ability of drivers to use the technology, available human factors research was examined. This research found that most drivers who are not expecting objects to be behind their vehicles will not stop in time and will strike the object. Drivers were more likely to not brake at all, or quickly enough for warning technologies when drivers could not visually confirm the presence of rear objects. The testing of rearview cameras showed better driver responses if the drivers looked at the display before backing. Additional human factor research on these systems is needed to estimate the effectiveness of these systems in preventing backover crashes.

A number of educational efforts have been identified which may help to sensitize drivers toward the problem and provide common sense safety tips. NHTSA has initiated an effort to provide additional consumer information about the dangers of backover crashes.

The report also discusses existing education efforts aimed at preventing backover crashes. Utah's *Spot the Tot* program is detailed along with NHTSA's consumer information program.

Of the technologies tested for their potential to reduce backover incidents, the camera based systems may have the greatest potential to provide drivers with reliable assistance in identifying people in the path of the vehicle when backing.

However, the Agency cautions readers of this report about relying on the results of our testing or other published test results to promote such systems as an effective means to address the backover crash risk. In order to reduce the number of backover incidents, it is very important to obtain a better understanding of the environmental factors that limit the camera's effectiveness and the limits of driver performance using such systems.

One particular concern is that camera performance can change from vehicle to vehicle and from situation to situation. For example, rain, fog or other inclement weather can significantly reduce their ability to show drivers a clear view of objects in the danger zone in back of the vehicle. Even in clear daytime conditions, objects in the camera display may be difficult to see due to sun glare. A fuller understanding of these limitations is needed.

Further, the ability of drivers to become accustomed to such systems and then to use them effectively when backing needs to be better understood. Even if cameras allow the driver to identify an object in the back of a vehicle, the driver must look at the display and have the capability to identify an object or person in the path when backing up, and to react and brake quickly enough to prevent the incident. The speed being traveled, the level of driver attention and reaction time all play significant roles in estimating the systems' effectiveness.

Because of the potential that camera-based systems appear to offer in addressing the risk of backover, NHTSA plans to conduct additional work to estimate the effectiveness of such systems and to develop specifications of performance for any technology that could be developed to address this risk. Further, the Agency plans to encourage vehicle manufacturers to continue to develop systems that can be effective in addressing this risk at a reasonable cost to the consumer.

Future Research Plans

Because of NHTSA's concern about the serious safety problem presented by vehicle backing crashes, the agency intends to continue its work to address this hazard by conducting research in analyzing the safety problem more thoroughly and understanding the various scenarios under which such crashes occur. Additionally, the research will be aimed at technology-based countermeasures to make them more effective. These research activities are listed as either ongoing activities or those that are planned for the future.

Ongoing Research Activities

- Obtain more detailed information of the circumstances of the backover incidents and to provide accurate annual estimates of the number of deaths and injuries resulting from these crashes.

- The AAA Foundation is surveying thousands of its members who have purchased vehicles equipped with these technologies. NHTSA will be analyzing their responses to learn about the potential benefits and problems drivers are experiencing.

- Provide information to consumers regarding the hazard due to backover incidents and resulting injuries.

New Planned Activities

- Conduct additional research to estimate the potential effectiveness of camera-based systems.

- Develop in consultation with the industry and others, specifications for the performance of systems intended to prevent backover crashes.

- Sponsor meetings and discussions with stakeholders to share research findings, identify advances in technology and identify additional research needs relating to backover.

- Encourage the industry to continue research and development of vehicle-based systems that can address the backover hazard.

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APPENDIX A: Selected Backing System Test Results

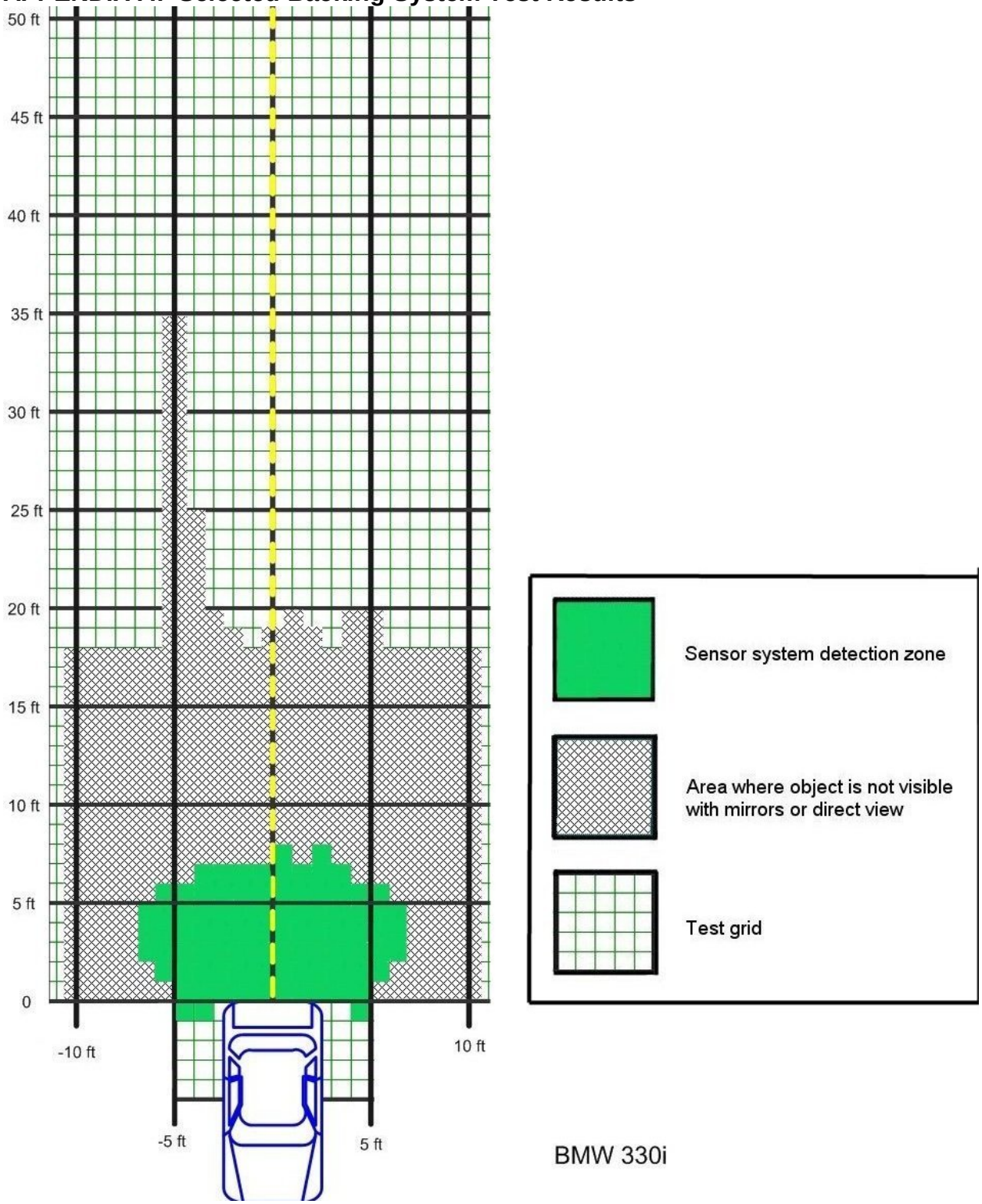

Figure A1. System coverage areas and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2006 BMW 330i)

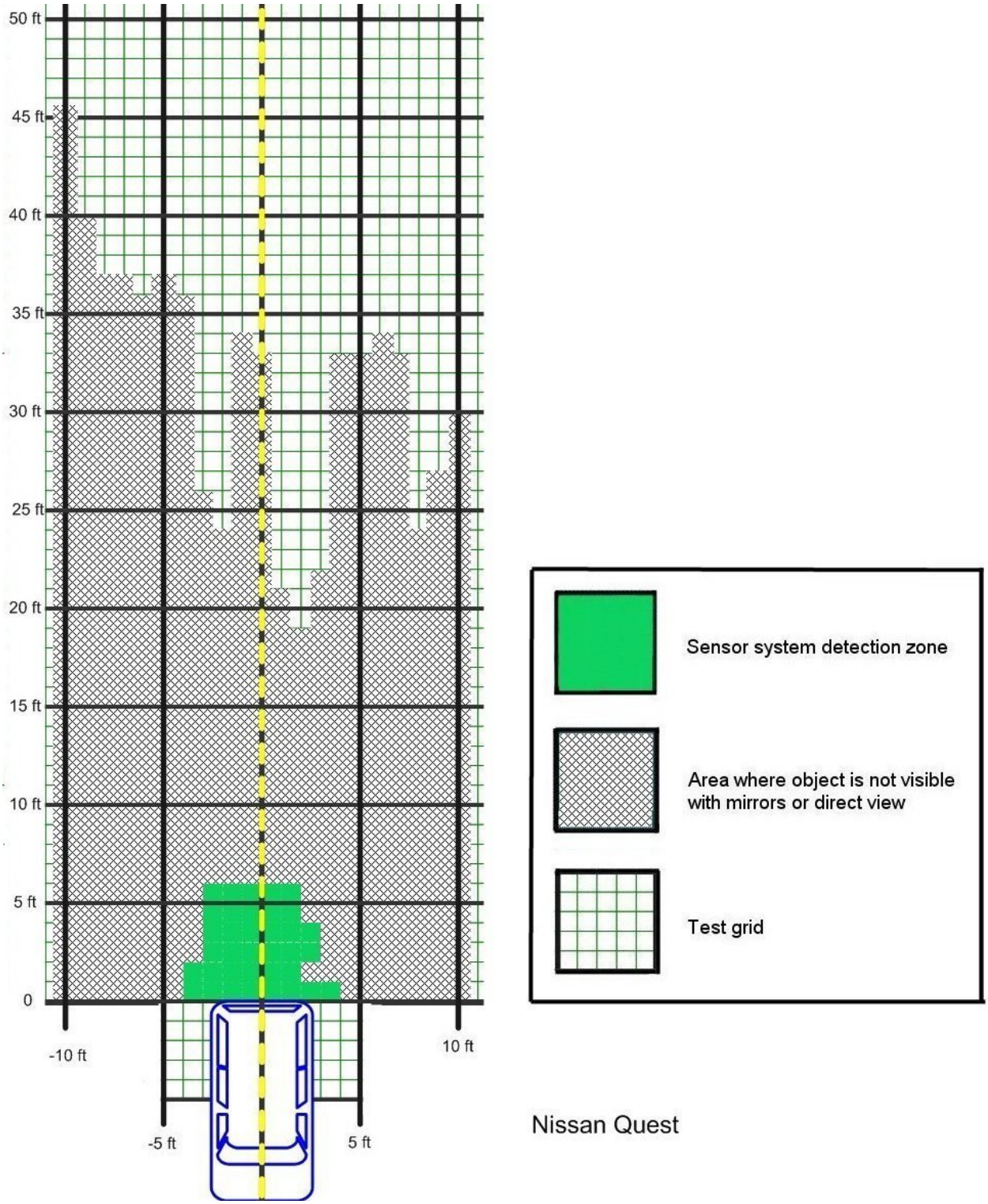

Figure A2. System coverage areas and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2005 Nissan Quest)

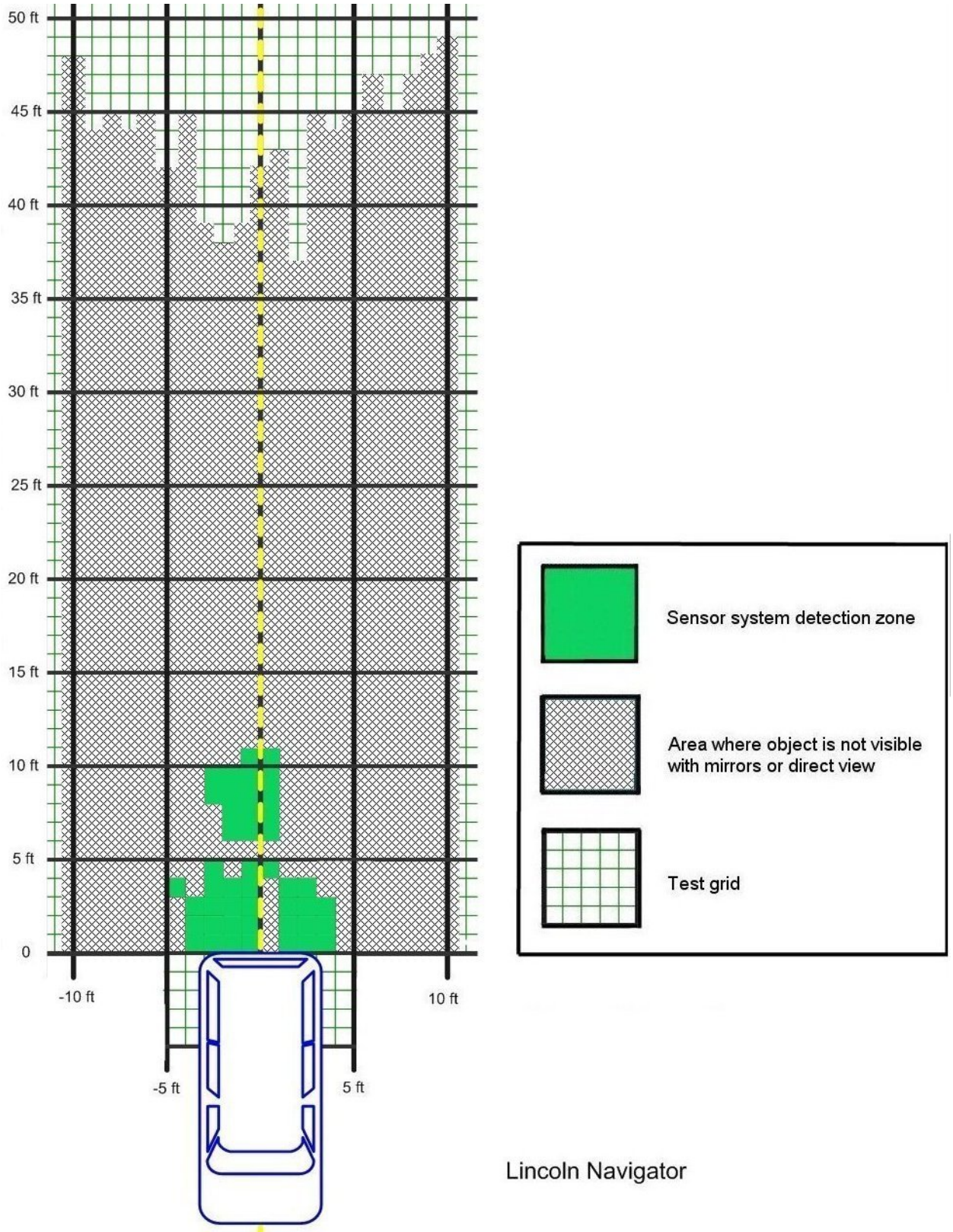

Figure A3. System coverage areas and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2005 Lincoln Navigator)

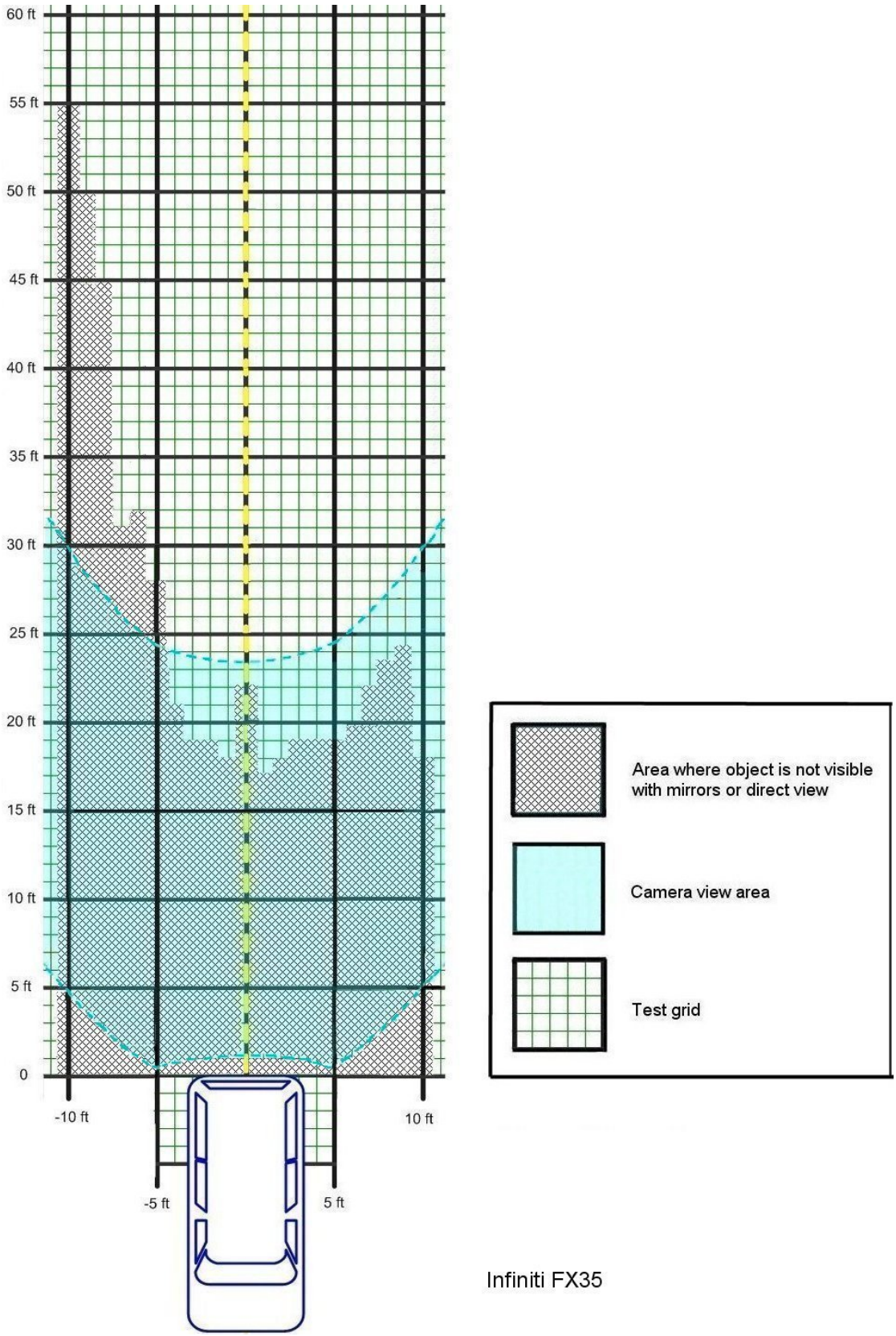

Figure A4. System coverage areas and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2005 Infiniti FX35)

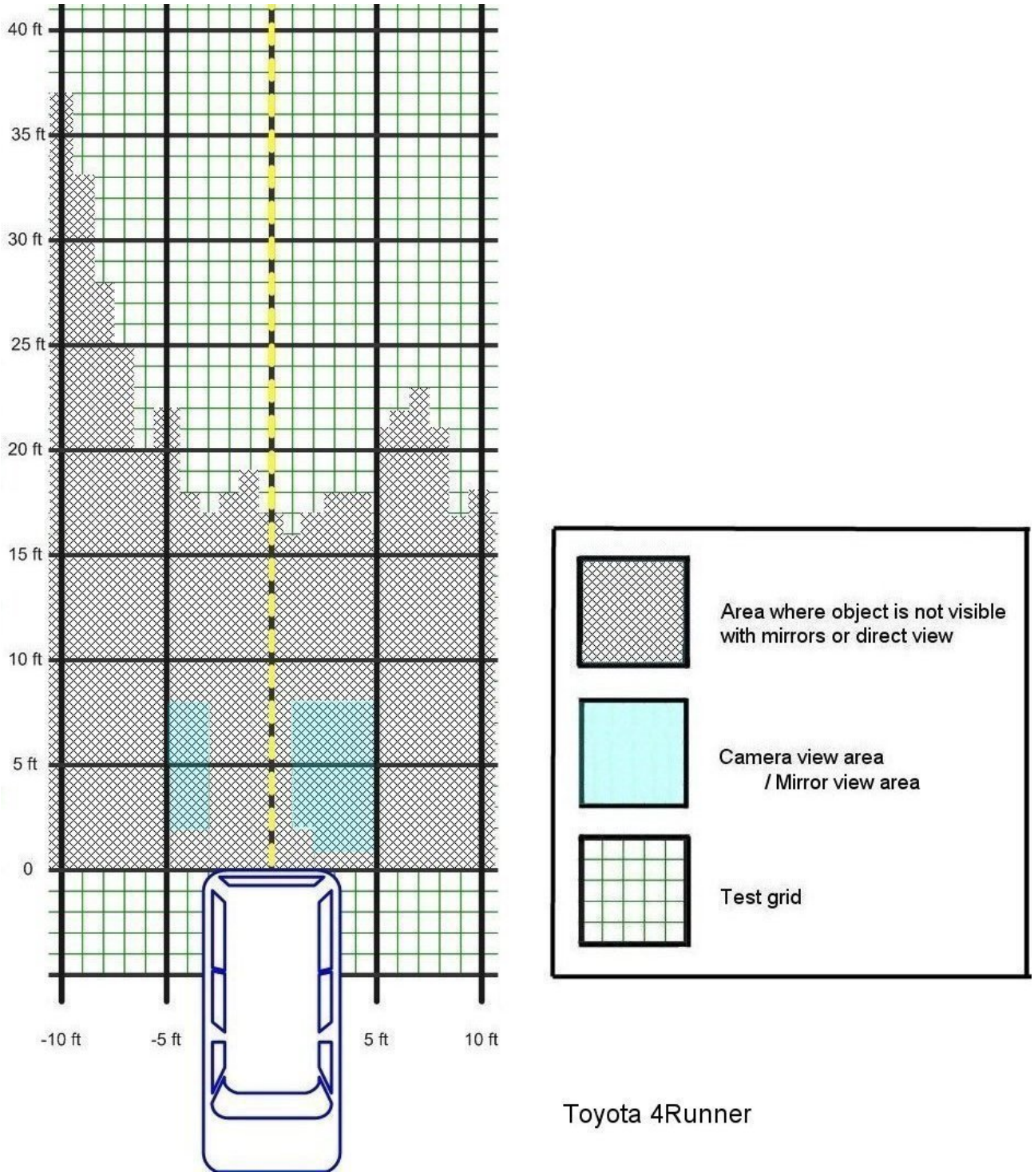

Figure A5. Cross-View mirror coverage areas (for 10 feet by 10 feet area behind vehicle) and non-visible areas (via direct glance or center rearview mirror) for 28-inch-tall traffic cone (2003 Toyota 4Runner)