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PRELIMINARY REGULATORY IMPACT ANALYSIS

Backover Crash Avoidance Technologies
NPRM
FMVSS No. 111

Office of Regulatory Analysis and Evaluation
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Executive Summary

Vehicles that are backing up have a potential to create a danger to pedestrians and other nonoccupants. Because a number of these injuries and fatalities occur off the roadway or on private property, they have been historically difficult to catalogue, and hence, analyze. With the advent of the Not-in-Traffic System, NHTSA is able to estimate the number and circumstances of these crashes, allowing it to establish more accurate estimates of the benefits of potential countermeasures to combat these incidents. Backover crashes involving all vehicles account for an estimated 292 fatalities and about 18,000 injuries annually. Backover crashes involving light vehicles[1] account for an estimated 228 fatalities and 17,000 injuries annually.

Annual Target Population (Light Vehicles)
228 Fatalities
17,000 Injuries

The agency has conducted research on a variety of technologies to mitigate these types of crashes. This research has focused on determining the ability of the various technologies (camera systems, sensor systems, and mirrors) to detect pedestrians, investigating the circumstances of backover pedestrian crashes that have occurred, and how drivers would use the technologies. This regulatory impact analysis was generated with the information we have to date and a number of assumptions have been made to provide the public with additional information about the potential costs and benefits of this rulemaking action.

System Effectiveness

Some systems, like airbags, have binary states; that is to say that they are either activated or they are not. Analysis includes a probability of whether or not it was being used, followed by a calculation of benefits in cases where it was in use.

For rear visibility, the analytical challenge is more complicated, but not unmanageable. Three conditions must be met for a rear visibility technology to provide a benefit to the driver. First, the crash must be one that is “avoidable” through use of the device; i.e., the pedestrian must be within the target range for the sensor, or the viewable area of the camera or mirror. Second, once the pedestrian is within the system’s range, the device must “sense” that fact, i.e., provide the driver with information about the presence and location of the pedestrian. Third, there must be sufficient “driver response,” i.e., before impact with the pedestrian, the driver must receive this information and respond appropriately by confirming whether someone is or is not behind the vehicle before

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[1] Light vehicles includes those vehicles with a gross vehicle weight rating (GVWR) of 4,536 kg or less (10,000 pounds or less). The proposal would officially cover passenger cars, trucks, multipurpose passenger vehicles [MPVs] (which include sport utility vehicles [SUVs] and vans), and buses (excluding school buses) with a GVWR of 10,000 pounds or less. For the purposes of this analysis, light vehicles are broken into two groups, “passenger cars” and “light trucks”. The term “light trucks” is meant to cover all trucks, MPVs, and buses (excluding school buses) with a GVWR of 10,000 pounds or less. In some tables the shorter term “LT” (light trucks) is used.

proceeding. These factors are denoted as f_A, f_S, and f_{DR}, respectively, in this analysis. Below is a table showing these factors and their product, the final system effectiveness.

System	F_A	F_S	F_{DR}	**Final Effectiveness** $F_A x F_S x F_{DR}$**=FE**
180° Camera	90%	100%	55%	**49%**
130° Camera	76%	100%	55%	**42%**
Ultrasonic	49%	70%	7%	**2.5%**
Radar	54%	70%	7%	**2.7%**
Mirrors	33%*	100%	0%**	**0%**

*F_A for mirrors is taken from separate source due to lack of inclusion in the SCI case review that generated F_A for cameras and sensors.
** F_{DR} for mirrors is taken from a small sample size of 20 tests. It is 0% because throughout testing, drivers did not take advantage of either cross-view or look-down mirrors to avoid the obstacle in the test.

Costs

The most expensive technology option that the agency has evaluated is the rearview camera. When installed in a vehicle without any existing adequate display screen, rearview camera systems are estimated to cost consumers between $159 and $203 per vehicle. For a vehicle that already has an adequate display, such as one found in navigation units, their incremental cost is estimated at $58. The total incremental cost to equip a 16.6 million vehicle fleet with camera systems is estimated to be $1.9 to $2.7 billion.

Rear object sensor systems are estimated to cost between $52 and $92 per vehicle. The total incremental cost to equip a 16.6 million vehicle fleet with sensor systems is estimated to be $0.3 to $1.2 billion.

Several different types of mirrors were investigated. Interior look-down mirrors could be mounted on vans and SUVs, but not cars, and are estimated to cost $40 per vehicle.

We also estimated the net property damage effects to consumers from using a camera or sensor system to avoid backing into fixed objects, along with the additional cost when a vehicle is struck in the rear and the camera or sensor is destroyed.

Costs (2007 Economics)

Costs	
Per Vehicle	\$51.49 to \$202.94
Net Costs - Total Fleet Including Property Damage Effects	\$723M to \$2.4B

Benefits

As noted above, the agency has spent considerable effort trying to determine the final effectiveness of these systems in reducing crashes, injuries and fatalities. We have researched the capabilities of the systems, the crash circumstances, and the percent of drivers that would observe and react in time to avoid a collision with a pedestrian or pedalcyclist. The estimated injury and fatality benefits of the various systems, based on NHTSA research to date, are shown below.

	180^{o} camera view	130^{o} camera view	Ultrasonic	Radar	Look-down mirror
Fatalities Reduced	112	95	3	3	0
Injuries Reduced	8,374	7,072	233	257	0

Net Benefits

In addition to the one-time installation costs, and the benefits that occur over the life of the vehicle, there would also be maintenance costs as well as repair costs due to rear-end collisions and "property damage only crashes" (which, like the benefits, occur over time). Below is a table containing lifetime monetized benefits and lifetime costs, and their difference, the net benefit. In this case, the costs outweigh the benefits and therefore the final number is a cost. The primary estimate includes a 130 degree camera system with mirror display. The low estimate includes an ultrasonic system. The high estimate includes a 180 degree camera system with mirror display.

Summary Table of Benefits and Costs
Passenger Cars and Light Trucks (Millions 2007$)
MY 2015 and Thereafter

Benefits	Primary Estimate	Low Estimate	High Estimate	Discount Rate
Lifetime Monetized	$618.6	$37.1	$732.6	7%
Lifetime Monetized	$777.6	$46.7	$920.8	3%
Costs				
Lifetime Monetized	$1,933.3	$722.6	$2,362.4	7%
Lifetime Monetized	$1,861.3	$730.4	$2,296.9	3%
Net Benefits				
Lifetime Monetized	-$1,314.7	-$685.5	-$1,629.8	7%
Lifetime Monetized	-$1,083.7	-$683.7	-$1,376.1	3%

Cost Effectiveness

While we examine several application scenarios (all passenger cars and all light trucks, only light trucks, and some combinations) and discount rates of 3 and 7 percent, the net cost per equivalent life saved for camera systems ranged from $11.8 to $19.7 million. For sensors, it ranged from $95.5 to $192.3 million per life saved. According to our present model, none of the systems are cost effective based on our comprehensive cost estimate of the value of a statistical life of $6.1 million.

Cost per Equivalent Life Saved	
Sensors (Ultrasonic and Radar)	$95.5 to $192.3 mill.
Camera Systems	$11.8 to $19.7 mill.

The range presented is from a 3% to 7% discount rate.

The agency is proposing requirements that would likely be currently met by using cameras for both passenger cars and light trucks. We also seek comment on an alternative aimed at reducing net costs that could be met by requiring having cameras for light trucks and either cameras or ultrasonic sensors for passenger cars. We also request comment on the extent to which the effectiveness of sensors and the response of drivers to sensor warnings could be improved.

I. Introduction

On February 28, 2008, Congress signed into law the Cameron Gulbransen Kids Transportation Safety Act of 2007.[2] This Act contains five distinct, substantive subsections that require NHTSA to issue regulations to reduce the incidence of child injury and death occurring inside or outside of light motor vehicles by: (a) considering automatic-reversal systems for power windows; (b) conducting rulemaking to expand the required field of view to prevent backover incidents; (c) a requirement for brake transmission shift interlock (BTSI) systems for vehicles with automatic transmissions; (d) a requirement that NHTSA shall establish and maintain a database on nontraffic, noncrash injuries and fatalities; and (e) providing information on vehicle-related hazards to children through a consumer information program. This Preliminary Regulatory Impact Analysis specifically addresses section (b). With regards to timing, the Cameron Gulbransen Kids Transportation Safety Act of 2007 specifies an initiation date within 12 months of the Act (February 28, 2009) signage and a final rule within 36 months of the passage of the Act (February 28, 2011).

The agency has published an Advanced Notice of Proposed Rulemaking (ANPRM)[3] to address subsection (b), which directs the Secretary of Transportation to amend Federal Motor Vehicle Safety Standard (FMVSS) No. 111, Rearview Mirrors, to develop a rearward visibility standard that expands the required field of view to enable the driver of a motor vehicle to detect areas behind the motor vehicle to reduce death and injury resulting from backing incidents. For purposes of this law, “vehicle backover injuries and deaths occur when a person is positioned behind a vehicle without a driver's knowledge as the driver backs up.”[4] This analysis accompanies the Notice of Proposed Rulemaking (NPRM).

With regard to the scope of vehicles covered by the mandate, the statute refers to all motor vehicles less than 10,000 pounds (except motorcycles and trailers).

A. Prior Agency Action on Rear Visibility

On November 27, 2000, NHTSA published an ANPRM (65 FR 70681)[5] soliciting comments on subjects related to rear visibility including, the area to be covered by rear detection devices; the effectiveness of mirrors, cameras, and sensor systems; potential display requirements; audible backup alarms; equipment damage; test procedures; costs and benefits; and the potential preemptive effect of the rulemaking. Based on its own research and the comments received, the agency published a notice of proposed rulemaking (NPRM) on September 12, 2005 (70 FR 53753)[6] proposing to require rear object detection systems on straight trucks with a gross vehicle weight rating (GVWR) of

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[2] Appendix A.

[3] The ANPRM was published in the Federal Register on March 4, 2009 (74 FR 9480) with the accompanying “Preliminary Regulatory Impact Analysis, Backover Crash Avoidance Technologies, FMVSS No. 111,” February 2009, (Docket No. 2009-0041-4).

[4] S. REP. 110-275, S. Rep. No. 275, March 13, 2008.

[5] Docket No. NHTSA-2000-7967-1.

[6] Docket No. NHTSA-2004-19239-1.

between 4,536 kilograms (10,000 pounds) and 11,793 kilograms (26,000 pounds). At the time of the notice, NHTSA did not believe that data indicated that lighter vehicles posed as great a risk for backover incidents as did trucks, although the agency noted that research on the subject was ongoing.

The purpose of the proposed requirement was to alert drivers of medium straight trucks to the presence of persons and objects directly behind the vehicle, thereby reducing backing-related deaths and injuries. This notice specified that manufacturers could choose one of two compliance options, either rear cross-view mirrors or rear video systems. The regulation also set minimum specifications for video monitors, if a video system was used to comply with the requirement. However, it did not permit sensor systems, such as radar or ultrasonic technology, to meet the standard because NHTSA did not believe that those systems provided reliable rear visibility data; but, the proposed regulation would not have prohibited vehicle manufacturers from installing these systems as a supplement to the requirement.

On July 21, 2008, NHTSA issued a notice withdrawing the rulemaking on rear visibility for medium straight trucks.[7] The reason for this withdrawal was that further research on the subject had shown that the problem posed by the types of vehicles addressed in the rulemaking was not as broad as originally believed, and that the proposed countermeasures would not result in as large a safety benefit as originally anticipated.

Ultimately, in February 2009, NHTSA issued its first Preliminary Regulatory Impact Analysis (PRIA) for Backover Crash Avoidance Technologies FMVSS 111. In this second PRIA, sales distribution, system effectiveness, and several summary tables were updated to reflect the proposal for rulemaking in the NPRM.

B. Possible Technologies for Mitigating Backovers

While there are a number of parking assistance systems deployed in the fleet, our research indicates that only a few may aid in the mitigation of backover incidents. At this time, the three technological solutions which the agency has evaluated to assist in mitigating backovers, are rearview video (RV) systems, sensor-based object detection systems (including radar, infrared, or ultrasonic sensors), and mirrors (rear convex and look-down mirrors). Current research has provided some guidance on which technologies may best mitigate backover crashes, and while none are cost-effective according to this analysis, camera systems are the most promising at approaching that status.

Rear Convex Mirrors

Rear-mounted convex mirrors are means to view areas behind a vehicle. When used as a single convex mirror with the reflective surface pointing at the ground, these mirrors are sometimes referred to as backing mirrors, under mirrors, or look-down mirrors. When provided as a pair of convex mirrors mounted vertically at the rear of the vehicle, they are referred to as rear cross-view mirrors. Rear cross-view mirrors are intended to aid a driver when backing into a right-of-way by showing objects approaching on a

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[7] Docket No. NHTSA-2006-25017.

perpendicular path behind the vehicle. Rear “cross-view” mirrors have been sold in the U.S. as original equipment,[8] and are also available as aftermarket products (mounted to the inside surface of the rear window).

Rearview Video Systems

For model year (MY) 2008, 5% of light truck vehicles sold were equipped with a RV system.[9] These systems permit a driver to see the area behind the vehicle via a video display showing the image from a video camera mounted on the rear of the vehicle. The images may be presented to the driver using a dedicated video display screen, or an existing screen in the vehicle, such as a navigation system, multifunction display screen, or a display embedded in the interior rearview mirror.

Sensor-Based Rear Object Detection Systems

Sensor-based object detection systems have been available for over 15 years as aftermarket products and for a lesser period as original equipment. Original equipment systems have been marketed as a convenience feature or “parking aid” for which the vehicle owner’s manuals and advertisements sometimes contain language denoting sensor performance limitations with respect to detecting children or small moving objects. Aftermarket systems, however, are frequently presented as safety devices for warning drivers of the presence of small children behind the vehicle. Object detection systems use electronic sensors that transmit a signal which, if an obstacle is present in a sensor’s detection field, bounces the signal back to the sensor producing a positive “detection” of the obstacle. These sensors detect objects in the vicinity of a vehicle at varying ranges depending on the technology. To date, commercially-available object detection systems have been based on short-range ultrasonic technology or longer range radar technology, although advanced infrared (IR) sensors are under development as well.

Future Technologies

NHTSA is aware of two additional sensor technologies being considered for implementation in rear object detection applications: infrared technology-based systems and video-based object recognition. As with other sensor systems, IR-based systems emit a signal, which if an object is within its detection range, will bounce back and be detected by a receiver. Rear object detection via video camera with real-time image processing capability is also being investigated for this application. While these technology applications may prove helpful in mitigating backover incidents, because of their early stages of development, it is not possible at this time to assess a cost benefit scenario using them.

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[8] Some Toyota 4-Runner base model vehicles have cross-view mirrors since at least Model Year 2003. They are mounted on the interior face of the rearmost structural pillars.

[9] Wards 2008 Automotive Yearbook.

II. Research Performed

A. Research on Current Technologies for Mitigating Backovers

Rear Convex Mirrors

Analysis

Rear convex mirrors have a low cost and last the life of the vehicle; however, they pose potential disadvantages. Convex mirrors present a wider field of view of unit magnification than flat mirrors by compressing the image of reflected objects in their field of view. This compression causes both image distortion and image minification, making objects and small-statured pedestrians difficult to discern and identify.

Given that cross-view mirrors are positioned to show an area to the side and rear of the vehicle, we also believe they would not provide a significant view of the area directly behind the vehicle. Additionally, NHTSA has learned that rear convex look-down mirrors are commonly found on SUVs and vans in Korea and Japan. However, despite their prevalence in those countries, NHTSA testing has not shown any positive effectiveness of these mirrors in mitigating backover crashes. Even if the mirrors provide an improvement to visibility, agency testing showed not a single participant actually used a rear-mounted mirror to survey behind the vehicle and to avoid a collision under test conditions.

Passenger Vehicle Research

In response to Section 10304 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), NHTSA conducted a study to evaluate methods to reduce the incidence of injury, death, and property damage caused by backing collisions of passenger vehicles. Available backover avoidance technologies were identified and eleven were chosen for examination including two auxiliary convex mirror systems designed to augment rear visibility. The study included assessment of their field of view and their potential to provide drivers with information concerning obstacles behind the vehicle.

The examination of rearview auxiliary mirror systems revealed that neither system provided full rear visibility, for pedestrians and objects were not visible in substantial areas directly behind the vehicle. Additionally, drivers were challenged to detect a 28-inch object behind the vehicle while using rearview auxiliary mirrors. The convexity of the mirrors caused significant image distortion, and reflected objects were difficult to discern. As such, concentrated glances were necessary to identify the nature of rear obstacles, and a driver making quick glances prior to initiating a backing maneuver may not allocate sufficient time to allow recognition of an obstacle presented in the mirror.

Rearview Video Systems

Analysis

RV systems offer the most comprehensive visual coverage of the area behind a vehicle. NHTSA has found that RV systems can display areas on the ground almost directly adjacent to the bumper of the vehicle. Furthermore, RV systems offer the possibility of an extremely wide field of view, with some systems able to show a 360-degree view around the vehicle. As with mirrors, a concern of RV systems to effectively mitigate backover crashes is their passive mode of operation which requires the driver to look at the display to assess whether a rear obstacle is present and to take an appropriate action in a timely manner.

Testing in Support of SAFETEA-LU Report to Congress

In response to Section 10304 of SAFETEA-LU, NHTSA examined three rearview video systems: One in combination with original equipment rear parking sensors, one aftermarket system combining RV and parking sensor technologies, and one original equipment RV-only system. This examination of rearview video systems included assessment of their field of view and potential to provide drivers with information about obstacles behind the vehicle.

Through this study, the agency made the following observations. Rearview video systems provided a clear image of the area behind the vehicle in daylight and indoor lighting conditions. RV systems revealed pedestrians or obstacles behind the vehicle within approximately 15 feet except for an area within 8-12 inches of the rear bumper at ground level. The rearview video systems also displayed wider visibility areas than the sensor-based systems tested in this study. The range and height of the visibility areas differed significantly between the two original equipment systems examined. In addition to limited field of view, limited height seemed to affect rear visibility.

In order for rearview video 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 RV systems cannot be known without assessing drivers' use of the systems and how they incorporate the information into their visual scanning patterns. As a result, NHTSA initiated research to investigate how drivers use RV systems.

GM Experimental Research on Systems for Reduction of Backing Incidents

GM conducted research to develop systems intended to assist drivers in recognizing people or objects behind their vehicle while performing backing maneuvers.[10] One study compared parking behaviors for rear camera and ultrasonic rear parking assist (URPA) systems together, separately, and under traditional parking conditions (i.e., neither system). Additionally, an obstacle was placed unexpectedly behind a driver's vehicle

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[10] ***Driver Performance Research into Systems for the Reduction of Backing Incidents at General Motors (SAE 2006).***

prior to the start of a backing maneuver to assess the driver's performance in obstacle detection and avoidance.[11] Twenty-four participants hit the obstacle, while five participants avoided the obstacle. Of those participants who hit the obstacle, three saw the obstacle while looking at the RV display,[12] one saw the obstacle in their mirror (URPA and RV system), and one participant noticed the obstacle out of the back window (RV system). These results suggested that participants with an RV system were significantly less likely to be involved in a backing incident.

GM also sponsored a second external research study to evaluate driver performance and rear camera systems.[13] In this study, each participant parked their vehicle using a rear camera and URPA system more than 30 times including practice trials. During one scenario, participants, unaware that an experimenter placed an obstacle behind the vehicle, were asked to perform a backing maneuver to engage the URPA and the rear camera system. In some cases, a flashing symbol was employed in the approximate location of the ruse object. While there were no statistically significant effects of either the symbol or the location of the ruse object, 65% of participants avoided the obstacle. Greater experience with the camera system and increased sample size may have attributed to a higher object avoidance rate in this study than compared to the first study.

Overall, GM's research on rearview video systems suggested that RV may provide limited benefit in some backing scenarios. Subsequent research is being undertaken to investigate overcoming driver expectancy issues, integration of obstacle warnings with video displays, and automated braking.

Research

NHTSA Experimental Research: On-Road Study of Drivers' Use of Rearview Video Systems

(see below, under "Multi-technology (sensor + camera) Systems" – this research project included observations from both combined systems that included cameras and sensor systems, and camera-only systems)

Sensor-Based Rear Object Detection Systems

Analysis

Ultrasonic sensors have detection performance that varies as a function of the degree of sonic reflectivity of the surface of the obstacle. For example, objects with a smooth surface such as plastic or metal reflect well, whereas objects with a textured surface, such as clothing, may not reflect as well. Radar sensors, which are able to detect the water in a human's body, are better able to detect pedestrians, but still demonstrate inconsistent detection performance, especially with regard to small children. It may be possible that sensor-based object detection system algorithms could be improved to allow for better

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[11] McLaughlin, Hankey, Green and Kiefer, 2003.

[12] Two participants were equipped with RV-only system and one with the combined URPA and RV system

[13] Lee, Hankey, Green, 2004.

detection of children; however, this modification may result in other less favorable aspects of system performance, such as increased false alarms. While sensor-based systems can detect children, NHTSA's research indicates that their performance is both "poor and inconsistent." Given these limitations, the agency is concerned whether sensor-based systems can serve as a reliable and effective safety countermeasure to mitigate backovers.

Research

NHTSA Research in Support of SAFETEA-LU 2006 Report to Congress

NHTSA examined eight sensor-based original equipment and aftermarket rear parking systems in response to Section 10304 of the SAFETEA-LU mandate.[14] NHTSA conducted testing to measure the object detection performance of short range sensor-based systems. Measurements included static field of view, static field of view repeatability, and dynamic detection range for different test objects. The agency assessed the system's ability to detect an adult male walking in various directions to the rear of the vehicle. Detection performance was also evaluated in a series of static and dynamic tests with 1-year-old and 3-year-old children. An examination of rear video and auxiliary mirror systems was also conducted by measuring field of view and image quality.

Sensor-based systems generally exhibited poor effectiveness (inconsistency and unreliability) to detect pedestrians, particularly children, located behind the vehicle. Testing showed that, in most cases, pedestrian size affected detection performance, as adults elicited better detection response than 1 or 3-year-old children. Specifically, each system could generally detect a moving adult pedestrian (or other objects) behind a stationary vehicle; however, each system exhibited some difficulty in detecting moving children. The reliability of the sensor-based systems 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.

While examining the consistency of system detection performance, the agency observed that each sensor-based system exhibited some degree of day-to-day variability in their detection patterns. Specifically, detection inconsistencies were generally noticed at the periphery of the detection zones and typically for no more than 1 foot in magnitude. On average, these sensor-based systems had detection zones which generally covered an area directly behind the vehicle. The sensor with the longest detection range could detect a 3-year-old child up to 11 feet (along a 3-5 ft wide strip). The majority of systems were unable to detect test objects less than 28 inches in height.

With regards to system response times, ISO 17386 recommends a maximum system response time of 0.35 seconds; three of the seven systems tested met this limit. Overall, the response times for this test ranged from 0.18 to 1.01 seconds. As such, in order for sensor-based backover avoidance systems to assist in preventing collisions, warnings must be generated by the system and the driver must perceive the warning within sufficient time to respond appropriately to avoid a crash. Based on the response times exhibited by these systems there appeared insufficient time for a driver to bring the

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[14] One of each of the original equipment and aftermarket sensor systems included rearview video.

vehicle to a stop to avoid possible collisions with pedestrians (assuming typical backing speeds).

Paine, Macbeth & Henderson Proximity Sensor Research

Paine, Macbeth & Henderson tested the performance of proximity sensor backing aids.[15] Their testing found that proximity sensors exhibited limited effectiveness for vehicles traveling at 5 km/h (3.1 mph) or more. Proximity sensors were prone to produce "nuisance alarms" in some driving situations and were deemed an unviable option to reduce backing incidents. This research suggested that a more effective system to mitigate backing incidents would incorporate sensors and wide-angle video camera technology; however, no data was provided to support this statement.

GM Sensor-Based Research

GM found that drivers do not always respond to a sensor's warning to alert them that an object is in the vicinity of the rear of the vehicle.[16] Often, sensor-based systems, as currently designed, do not provide the driver with a visual depiction of the presence of an obstacle located to the rear of a vehicle, thereby limiting their effectiveness in mitigating backovers incidents. This seems to imply that drivers are less likely to interrupt their actions without visual confirmation of a valid visual cue. However, GM is also investigating automatic vehicle braking and haptic warning strategies for long-range backing warning systems.

GM defined parking aid systems to include side-view mirrors which rotate downward when the vehicle is placed in the reverse gear position, RV camera systems, and ultrasonic rear parking assist systems. Each of these systems are designed to provide supplemental information to the driver to aid in locating and avoiding known fixed objects behind the vehicle and near the bumper. However, GM emphasized that these systems are not intended to function as collision warning or avoidance systems.

Unlike parking assistance systems, GM believes that backing warning systems are intended to alert drivers to the presence of unexpected or unseen objects behind their vehicles. To be more effective, GM believes that these systems should include a warning designed to capture the driver's attention with sufficient advance notice to allow the driver to stop or otherwise avoid the object.

GM sponsored a study on the effectiveness of backing warnings which indicated surprisingly low effectiveness.[17] The study found that only 13 percent of drivers avoided hitting an unexpected obstacle, and over 87 percent of the drivers collided with the obstacle following the warning. Sixty-eight percent of drivers provided with the warning demonstrated precautionary behaviors in response to the warning including, covering the brake, tapping the brake, or braking completely. While 44 percent braked, these braking levels were generally insufficient to avoid a collision. Although data provides some

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[15] Paine, Macbeth & Henderson (2003).

[16] SAE Paper 2006-01-1982.

[17] Llaneras, Green, Chundrlik, Altan, and Singer, 2004.

evidence that warnings influenced driver behavior, warnings were unreliable to induce drivers to immediately brake to stop the vehicle completely.

This study further suggests that knowledge and experience with the backing warning system may not significantly improve immediate driver response to a backing warning. While specific training on the warning system was provided to eight drivers, only one driver avoided the obstacle. In each case, drivers reported that they did not expect to encounter an obstacle in their backing path. Many drivers also reported that they searched for an obstacle following the warning, but “didn’t see anything” and continued their backing maneuver. These perceptions suggest that driver expectancy is a powerful determinant influencing driver behavior.

Although warnings in this study appeared to orient some drivers to search for an obstacle and/or take precautionary action (reduce speed, etc.), warnings did not necessarily lead drivers to brake sufficiently hard in response to the warning. Many drivers appeared to expect direct sensory confirmation of the existence of an object before initiating immediate avoidance behaviors. Similar behavioral results were observed in response to warnings from a rear-end collision avoidance system.[18] This study found that the primary effect of warning systems was redirecting a driver’s attention, rather than triggering an immediate driver response. However, unlike a forward collision warning situation, where drivers can simply look out the forward view and quickly detect an in-path threat, detecting rear obstacles presents a difficult challenge.

Research

NHTSA Experimental Research: On-Road Study of Drivers’ Use of Rearview Video Systems

(See below, under “Multi-technology (sensor + camera) Systems” – this research project included observations from both combined systems that included cameras and sensor systems)

Multi-technology (sensor + camera) systems

Description

Beginning in MY 2008, vehicles were equipped with backing aid systems which incorporated multiple technologies, namely RV systems augmented by rear parking sensors, where warning information is integrated with the RV visual display.

Research

NHTSA Experimental Research: On-Road Study of Drivers’ Use of Rearview Video Systems

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[18] Lee et al. (2002).

Drivers' use of rearview video systems was observed during staged and naturalistic backing maneuvers to determine whether drivers look at the RV display during backing and whether use of the system affects backing behavior. Thirty-seven test participants aged 25 to 60 years were comprised of twelve drivers of RV-equipped vehicles, thirteen drivers of vehicles equipped with an RV system and a rear parking sensor system (RPS), and twelve drivers of vehicles with no backing aid. All participants had driven and owned a 2007 Honda Odyssey minivan as their primary vehicle for at least 6 months, and participants were told that the purpose of the study was to assess how drivers learn to use the features and functions of a new vehicle.

Participants visited the sponsor's research lab to have unobtrusive video and other data recording equipment installed in their personal vehicles and for a brief test drive. Participants then drove their vehicles for a period of four weeks in their normal daily activities while backing maneuvers were recorded. At the end of four weeks, participants returned to the research lab to have the recording equipment removed. Then, participants took a second test drive, identical to the first, except that when backing out of the garage bay, an unexpected obstacle appeared behind the vehicle. The results of the naturalistic driving and unexpected obstacle scenario are provided below.

Results for naturalistic driving

- Thirty-seven participants made 6,145 backing maneuvers (at an average backing speed of 2.26 miles per hour), none of which resulted in a significant collision; however, some minor collisions (i.e., with trash receptacles and other vehicles) occurred during routine backing.
- In real-world backing situations, drivers equipped with RV systems spent 8 to 12 percent of the time looking at the RV display during backing maneuvers.
- On average, drivers made 2.17 glances per backing maneuver with the RV-only system, and 1.65 glances per maneuver with the RV and RPS system.
- Overall, drivers looked at least once at the RV display on approximately 65 percent of backing events. Drivers looked more than once at the RV display on only 40 percent of backing events.

Results for unexpected obstacle maneuver

- Drivers with an RV system made 13 to 14 percent of glances at the RV video display during the initial phase of backing in the staged maneuvers, independent of system presence.
- Drivers spent over 25 percent of backing time looking over their right shoulder in the staged backing maneuvers.
- Only participants who looked at the RV display more than once during the maneuver avoided a crash during the staged crash-imminent event.
- Results indicated that the RV system was associated with a statistically significant (28%) reduction in crashes with the unexpected obstacle as compared to participants without an RV system. (Data from these tests were combined with later tests and appear in Table V-3.) All participants in the "no system" condition crashed, since the staged obstacle event scenario was designed such that drivers without an RV system could not see the obstacle.

- The addition of RPS provided no additional benefit. Although statistically not significant, more participants equipped with both RV and RPS technologies crashed (85%) than did those equipped with the RV-only system (58%).
- The RPS system only detected the obstacle in 38% of obstacle event trials. Only 5 of 13 participants equipped with the combination RV and RPS system received an RPS warning indicating the presence of a rear obstacle; of those 5 participants, 4 crashed.
- It is possible that as sensor-based rear object detection systems are improved to detect children, their effectiveness would also improve; however, no data to support this assumption yet exists.

Possible reasons why the RV systems did not produce greater benefits during the obstacle event trials include delay associated with the appearance of the image in the RV display and drivers' inappropriate timing in determining when to look at the RV display. Furthermore, drivers' expectations to not encounter an obstacle in the research setting could have contributed to drivers exhibiting less vigilance than when performing real-world backing maneuvers.

Results of this study revealed that drivers looked at the RV display in approximately 14 percent of glances in baseline and obstacle events and 10 percent of glances in naturalistic backing maneuvers. The agency recognized that the timing and frequency of drivers' glances at the RV display has a noticeable impact on the likelihood of rear obstacle detection. However, making single or multiple glances at the RV display at the start of the maneuver does not ensure that the path behind the vehicle will remain clear for the entire backing maneuver. While RV systems offer the driver a useful tool for detecting rear obstacles, some guidance may be necessary to educate drivers as to the most effective way to incorporate this new visual information source into their glance behavior during backing maneuvers so as to increase the benefits attainable with these systems.

Future Technologies

Research

<u>*Additional NHTSA Backing Crash Countermeasure Research*</u>

NHTSA is currently engaged in cooperative research with GM on Advanced Collision Avoidance Technology relating to backing incidents. The ACAT backing systems project will assess the ability of advanced technologies to mitigate backing crashes and refine a tool to assess the potential safety benefit of these technologies. The focus of the ACAT Backing Crash Countermeasure Program is to characterize backing crashes in the U.S. and investigate a set of integrated countermeasures to mitigate them at appropriate points along the crash timeline (prior to entering the vehicle and continuing throughout the backing sequence). The objective of this research is to estimate potential safety benefits or harm reduction that these countermeasures might provide. A Safety Impact Methodology (SIM), consisting of a software-based simulation model together with a set of objective tests for evaluating backing crash countermeasures, will be developed to estimate the harm reduction potential of specific countermeasures. Included in the SIM's methods for estimating potential safety benefits will be a consideration of assessing and modeling unintentional potential disbenefits that might arise from a countermeasure.

While NHTSA anticipates the results of this advanced research will provide valuable information, the completion of this effort will not occur prior to the Congressional deadline for this mandate.

III. Target Population

Drivers tend to reverse their vehicle when parking or exiting a parking space, and as such many of these events can occur off the roadway. Thus, a number of these cases occur off the trafficway and outside the realm of data typically collected by NHTSA. (For example, the Fatality Analysis Reporting System (FARS) does not include fatal backing crashes occurring off the trafficway.).

Information on injuries and fatalities in backing crashes occurring on nonpublic roads and in most parts of driveways and parking lots is obtained through the Agency's Not-in-Traffic Surveillance (NiTS) system. The nontraffic crash component of that system was designed by using our existing crash data collection infrastructures. To collect information about injuries in nontraffic crashes, NHTSA requested that beginning in 2007 the NASS researchers, who visit the police jurisdictions that contribute crash reports to the NASS-GES sample, send all injury cases that did not qualify for NASS-GES to a NHTSA contractor for tracking and cataloguing. The injury crashes that did not qualify for the NASS-GES system because they were off of the trafficway (nontraffic) were then entered into NiTS. To collect information on nontraffic crash fatalities, NHTSA requested that beginning in 2007 the FARS analysts, who collect and enter the fatal traffic crash information into the FARS system for each State, send all cases that did not qualify for FARS to the NHTSA contractor. Similar to the nontraffic injuries, the crash fatalities that did not qualify for the FARS system because they were off of the trafficway were then entered into NiTS. NHTSA also supplemented the nontraffic crash fatality reports in NiTS with reports of nontraffic crash fatalities submitted by the NASS researchers. While NHTSA did not receive all possible reports through this system, NHTSA received a large enough sample to derive a national estimate of the total number of nontraffic backover crash fatalities and injuries and to describe the circumstances surrounding these crashes. These estimates were then added to the backing crash fatalities from FARS and the backing crash injuries from NASS-GES to produce an estimate of the total number of backover fatalities and injuries. These totals are presented in the following tables [19]

Due to a limitation in the data available, a breakdown of backover crashes by state is not available. Later investigation of SCI crashes found that an estimated 40 percent (35 of 85) of the victims were related to the driver, and that 95% of SCI backover crashes occurred in daylight conditions.

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[19] Data produced by the NiTS project can be found in "FATALITIES AND INJURIES IN MOTOR VEHICLE BACKING CRASHES" DOT HS 811 144.

Table III-1: Fatalities and Injuries in All Backing Crashes For All Vehicles

Injury Severity	*Total*		*Backovers*		*Other Backing Crashes*	
	Estimated Total	Sample Count	Estimated Total	Sample Count	Estimated Total	Sample Count
Fatalities	*463*	*929*	*292*	*179*	*171*	*750*
Incapacitating Injury	6,000	304	3,000	131	3,000	173
Non-incapacitating Injury	12,000	813	7,000	372	5,000	441
Possible Injury	27,000	929	7,000	179	20,000	750
Injured Severity Unknown	2,000	48	1,000	23	2,000	25
Total Injuries	*48,000*	*2,094*	*18,000*	*705*	*30,000*	*1,389*

Source: FARS 2002-2006, NASS-GES 2002-2006, NiTS 2007

Note: Estimates may not add up to totals due to independent rounding.

Vehicle Type Involvement in Backing Incidents

The following table summarizes the estimated fatalities and injuries in backing crashes for all vehicles as well as passenger vehicles (passenger cars and light trucks). Note that backover crashes differ from the greater category of backing crashes.

Table III-2: Injuries and Fatalities and Injuries For All Vehicles

Backing Crash Scenarios	*All Vehicles*		*Passenger Vehicles*	
	Fatalities	Injuries	Fatalities	Injuries
Backovers: Striking Nonoccupant	292	18,000	228	17,000
Backing: Striking Fixed Object	33	2,000	33	2,000
Backing: Noncollision	62	1,000	53	1,000
Backing: Striking/Struck by Other Vehicle	68	24,000	39	20,000
Backing: Other	8	3,000	8	3,000
Total Backing	*463*	*48,000*	*361*	*43,000*

Among cases where the type of striking vehicle is known, 78 percent of the backover fatalities and 95 percent of the backover injuries involved passenger vehicles. Table 3 indicates that all major passenger vehicle types (cars, utility vehicles, pickups, and vans) are involved in backover fatalities and injuries. However, understanding the association between vehicle type and backover crashes may indicate the vehicle types most likely to benefit from rear visibility enhancement countermeasures. In particular, some vehicles may have a greater risk of being in backing crashes than other vehicles. Table III-3 illustrates that pickup trucks and utility vehicles are overrepresented in backover fatalities and injuries when compared to all non-backing traffic injury crashes and to their proportion of the vehicle fleet. For example, utility vehicles make up 16 percent of the on-road fleet, but were involved in 20 percent of the backing injuries and 30 percent of the backing fatalities.

Table III-3: Passenger Vehicle Backover Fatalities and Injuries by Vehicle Type

Backing Vehicle Type	*Fatalities*	*Percent of Fatalities*	*Estimated Injuries*	*Estimated Percent of Injuries*	*Percent of Vehicles in Non-Backing Traffic Injury Crashes*	*Percent of Fleet*
Car	59	26%	9,000	54%	62%	58%
Utility Vehicle	68	30%	3,000	20%	14%	16%
Van	29	13%	1,000	6%	8%	8%
Pickup	72	31%	3,000	18%	15%	17%
Other Light Vehicle	0	0%	*	2%	1%	<1%
Passenger Vehicles	*228*	*100%*	*17,000*	*100%*	*100%*	*100%*

Source: FARS 2002-2006, NASS-GES 2002-2006, NiTS 2007, Polk 2006

Note: * indicates estimate less than 500, estimates may not add up to totals due to independent rounding.

The search criteria when compiling the target population should take into account a large number of vehicle types, not just the typical passenger cars and light trucks, but also an “other light vehicles” category which includes Low Speed Vehicles (LSVs). These include vehicles with a maximum speed of up to 25 mph, such as community vehicles, security carts, and golf carts. However, no Low Speed Vehicles were shown to have had any backover crashes.

The agency requests comments on why there appears to be a higher fatality rate for light trucks than for passenger cars (that is, the percent of fatalities for light trucks is higher than the percent of the fleet for light trucks and lower for passenger cars). And we also request comments on why the injury rates for passenger cars and light trucks are relatively close. These data indicate that passenger cars and light trucks have similar rates of incidences of backing up into people, but the fatality risk in light trucks is much higher than in passenger cars. The agency would like to know if anyone can determine a reason for the dichotomy.

Table III-4: Breakdown of Backover Fatalities and Injuries Involving Passenger Vehicles for Victims Under Age 5 Years (in %)

Age of Victim (years)	*Number of Fatalities*
0	<1
1	59
2	23
3	14
4	3
Total	*100*

Note: Estimates may not add to totals due to independent rounding.
Source: US Census Bureau, Population Estimates Program, 2007 Population Estimates;
FARS 2002-2006, NASS-GES 2002-2006, NiTS 2007

Table III-5. All Backover Fatalities and Injuries by Age of Victim

Age of Victim	*Fatalities*	*Percent of Fatalities*	*Estimated Injuries*	*Estimated Percent of Injuries*	*Sample Count of Injuries*	*Percent of Population*
All Vehicles						
Under 5	103	35%	2,000	8%	37	7%
5-10	13	4%	*	3%	33	7%
10-19	4	1%	2,000	12%	75	14%
20-59	69	24%	9,000	48%	383	55%
60-69	28	9%	2,000	8%	54	8%
70+	76	26%	3,000	18%	107	9%
Unknown			*	2%	16	
Total	*292*	*100%*	*18,000*	*100%*	*705*	*100%*
Passenger Vehicles						
Under 5	100	44%	2,000	9%	35	7%
5-10	10	4%	1,000	3%	30	7%
10-19	1	1%	2,000	12%	71	14%
20-59	29	13%	8,000	46%	319	55%
60-69	15	6%	1,000	8%	46	8%
70+	74	33%	3,000	19%	95	9%
Unknown			*	2%	12	
Total	*228*	*100%*	*17,000*	*100%*	*608*	*100%*

Source: US Census Bureau, Population Estimates Program, 2007 Population Estimates;
FARS 2002-2006, NASS-GES 2002-2006, NiTS 2007

IV. Rear Visibility Data

While the agency has not determined specific alternatives, one possibility for compliance testing (as is done in FMVSS No. 111 right now) would be for the agency to develop a test grid that includes an object that must be directly visible or indirectly visible with whatever countermeasure is developed by a manufacturer. Tests of current vehicles have been performed to provide information using a generic test grid. In essence this could be a performance test, such that when a driver in a vehicle could see a test grid of objects either through direct visibility by the driver, or through a countermeasure.

Rear Visibility of Current Vehicles

NHTSA found that the area around a vehicle that a driver can directly see without the aid of non-required mirrors or other devices (i.e., direct –view rear visibility) can be affected by the exterior, structural design of the vehicle.[20] These structural elements included the width of a vehicle's structural pillars and the size of its window openings. Additionally, vehicles with greater height and length are likely to have larger blind zone areas than vehicles with smaller dimensions. NHTSA has also found that head restraints can affect the direct rear visibility.

In 2007, NHTSA observed the rear visibility characteristics of 44 recent-model light vehicles[21] to assess the range of visible areas in the current fleet and provide information that can be used to determine whether a link exists between the rear blind zone area and the risk of a backover crash incidence. The visibility of a visual target was determined over a 6300-square-foot area stretching 35 feet to either side of the vehicle's centerline and 90 feet back from the vehicle's rear bumper. The agency selected a 29.4-inch-tall (approximately the height of a 1-year-old child) visual target. Rear visibility was measured for both a 50th percentile adult male driver (69.1 inches tall) and a 5th percentile adult female driver (59.8 inches tall). The areas, over which the visual target was visually discernible using direct glances (i.e., looking out vehicle windows) and indirect glances (i.e., looking into side or center rearview mirrors), were determined.

Since all passenger vehicles have side mirrors and center rearview mirrors that are essentially the same (excluding slight overall size differences), NHTSA determined that a key source of variability affecting rear visibility is a vehicle's body structure and interior components (e.g., rear head restraints). As such, the direct-view rear visibility metric focused on the impact of a vehicle's structural characteristics on rear visibility.

Through this study, NHTSA observed that rear blind zones for individual vehicles ranged in value from 100 to 1,440 square feet. When summarized by vehicle category and curb weight (as a surrogate indicator for vehicle size), as illustrated in Figure 1, the data shows that average direct-view rear blind zone areas varied within these groups. The greatest range of direct-view rear blind zone area size was seen for the 4,000-5,000 lb SUV group. Figure 2 illustrates that SUVs (as a whole) were associated with the largest average

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[20] Light Vehicle Rear Visibility Assessment, DOT HS 810 909, September 2008.

[21] Measured vehicles included the ten top-selling passenger cars and light trucks for calendar year 2006.

direct-view rear blind zone area as well as the largest range of values for the four body types examined. Overall, light trucks (segregated here into vans, pickups, and SUVs) as a vehicle class were observed to have larger rear blind zone areas than passenger cars, as indicated in Figure 2. While small light pickup trucks had relatively small direct-view rear blind zone areas, light trucks were generally overrepresented in backover incidents.

Figure IV-1. Direct-View Rear Blind Zone Area by Vehicle Category for a Measurement Field of 50-Foot Long by 60-Foot Wide.

Source: Light Vehicle Rear Visibility Assessment, DOT HS 810 909.

Note: Error bars show the range of values for each vehicle category.

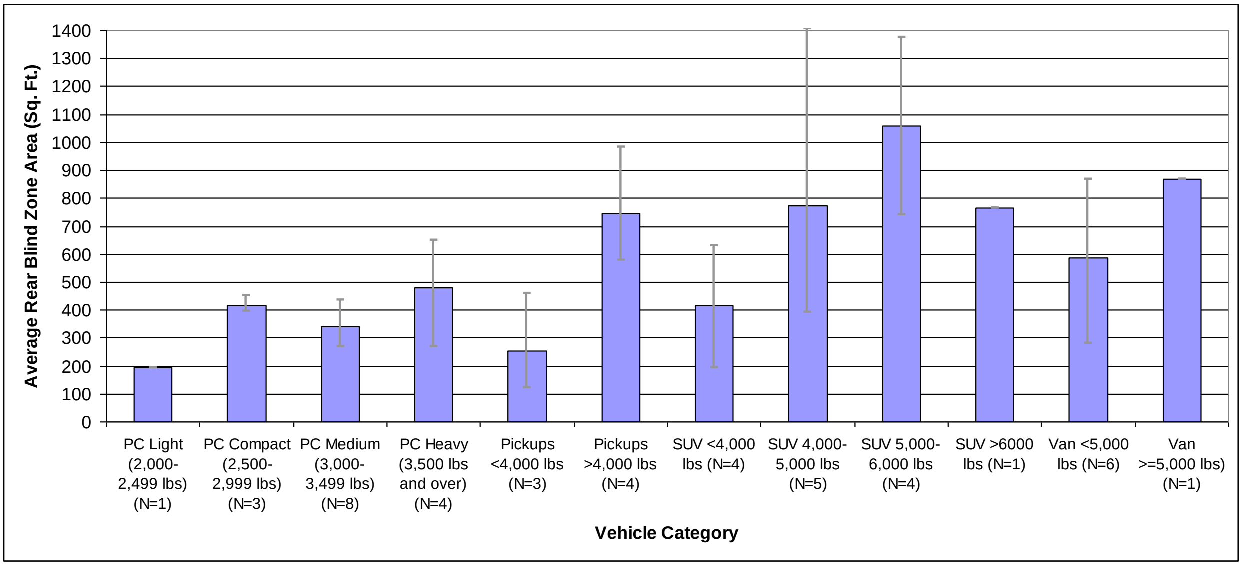
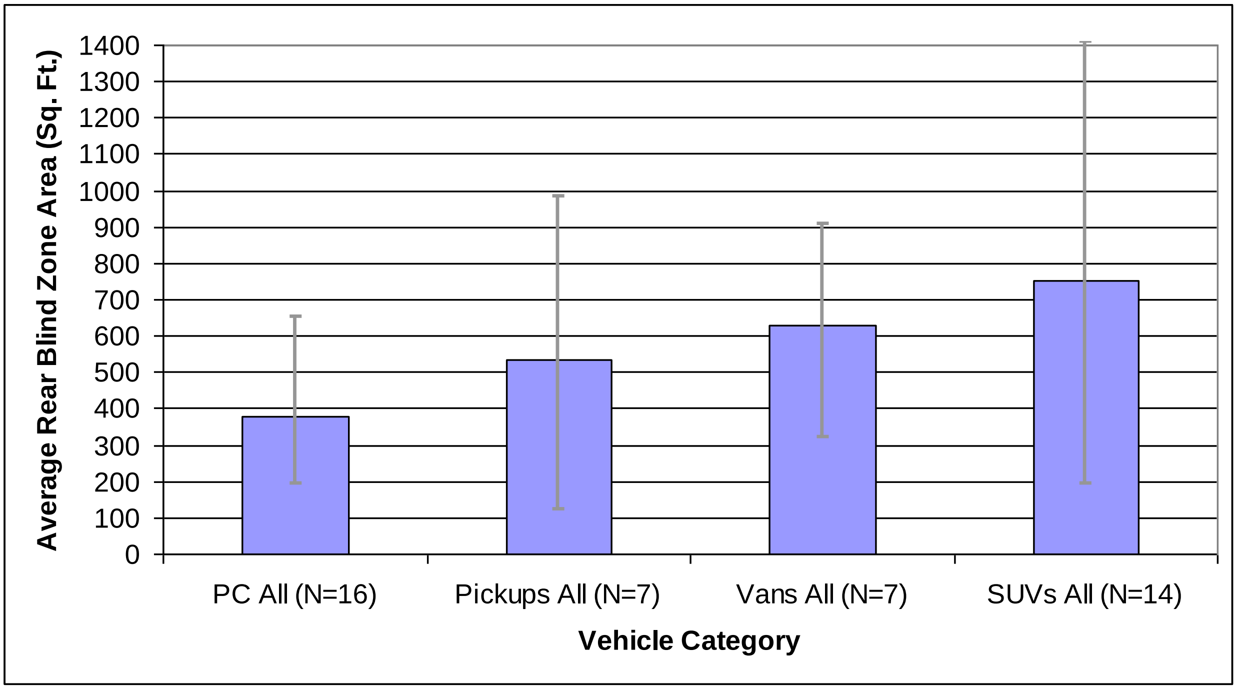


Figure IV-2. Direct-View Rear Blind Zone Area by Vehicle Category for a Measurement Field of 50-Foot Long by 60-Foot Wide.

Source: Light Vehicle Rear Visibility Assessment, DOT HS 810 909.

Note: Error bars show the range of values for each vehicle category.



Average direct-view rear longitudinal sight distances were acquired by mathematically averaging eight longitudinal sight distance measurements taken in 1-foot increments across the rear of each vehicle. As illustrated in Figure 3, generally light trucks had longer rear longitudinal sight distances than passenger cars. Exceptions to this trend included a few small pickup trucks for which average direct-view rear sight distance values were in the vicinity of those measured for smaller passenger cars, as shown in Figure 4. Average direct-view rear sight distance values were longest for a full-size van, SUVs and pickup trucks with a curb weight of 4,000 lbs or greater. Overall, our rear visibility measurements revealed that light trucks exhibited poor rear visibility when compared with passenger cars.

Figure IV-3. Direct-View Average Rear Longitudinal Sight Distance by Vehicle Category.

Source: Light Vehicle Rear Visibility Assessment, DOT HS 810 909

Note: Error bars show the range of values for each vehicle category.

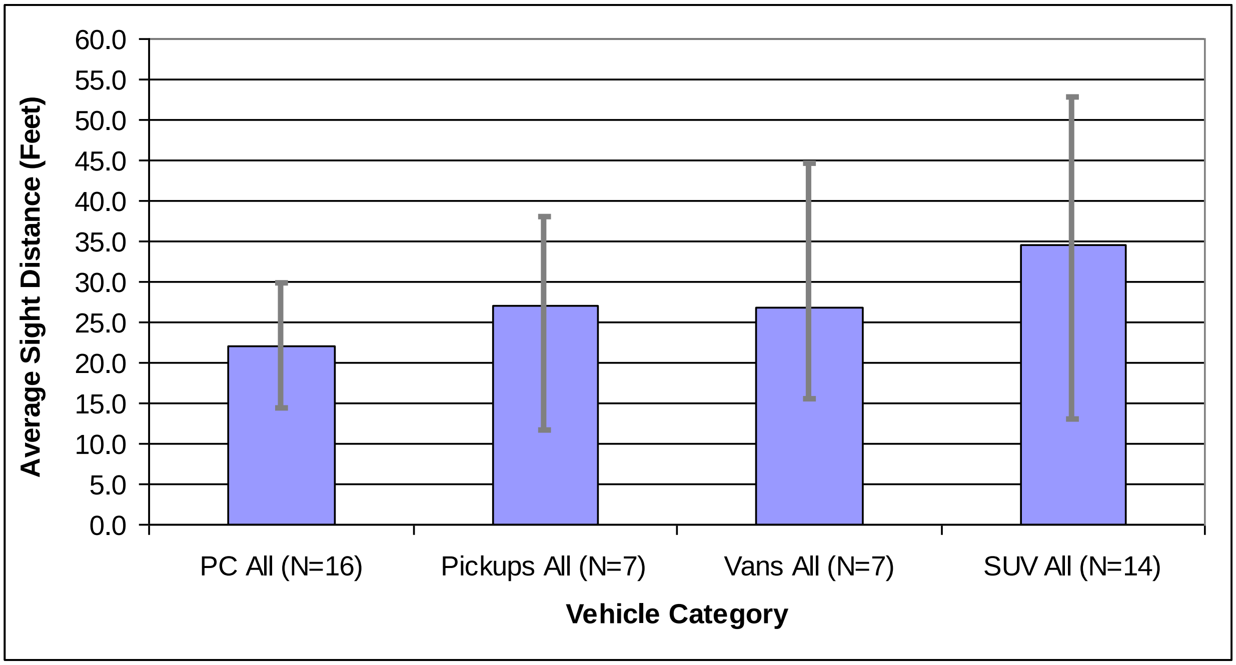
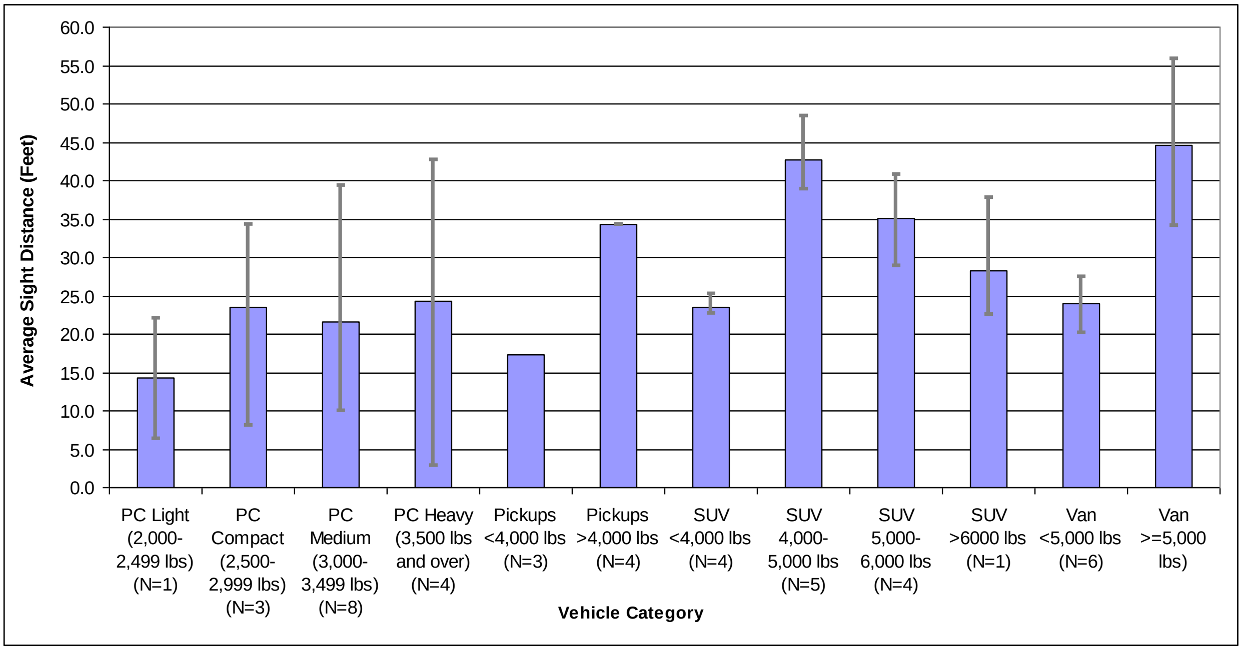


Figure IV-4. Direct-View Average Rear Longitudinal Sight Distance by Vehicle Category and Curb Weight.

Source: Light Vehicle Rear Visibility Assessment, DOT HS 810 909

Note: Error bars show the range of values for each vehicle category.



Relationship Between Rear Visibility and Backing/Backover Crashes

Using the rear visibility measurements discussed in the prior section, NHTSA investigated whether a statistical relationship could be identified between rear visibility and backing crashes and between rear visibility and backover crashes. For clarification, a backover is a specifically-defined type of incident, in which a non-occupant of a vehicle (i.e., a pedestrian or cyclist) is struck by a vehicle moving in reverse. Backing crashes include the set of all backover crashes, and involve all crashes when the vehicle is moving in reverse. The implication is if one solves the set of all backing crashes, that means they have solved the subset of backing crashes that are backovers. Rear visibility data were used to compute rear visibility metrics which could have a statistical relationship with backing and/or backover crashes. NHTSA assessed the relationship between real world backing/backover crashes and rear visibility based on three metrics: average rear longitudinal sight distance, direct-view rear visibility measurements for a 50 feet long by 60 feet wide test area, and direct-view rear visibility for a 50 feet long by 20 feet wide test area.[22]

Backing risk was estimated from police-reported crashes in the State Data System. Backing rates were calculated for 21 vehicle groups with vehicles that had at least 25 backing crashes to account for statistical variability. Backing rate data were provided by the following states for the specified calendar years:

- Alabama (2000-2003)
- Georgia (2000-2005)
- Kansas (2001-2006)
- Maryland (2000-2005)
- Missouri (2000-2005)
- New Mexico (2001-2006)
- North Carolina (2000-2005)
- Utah (2000-2004)
- Wisconsin (2000-2005)
- Florida (2000-2005)
- Illinois (2000-2005)
- Kentucky (2000-2005)
- Michigan (2004-2006)
- Nebraska (2000-2004)
- New York (2000)
- Pennsylvania (2000-2001, 2003-2005)
- Washington (2002-2005)
- Wyoming (2000-2005)

Simple correlation analysis revealed an association between the two direct-view rear blind zone areas and backing crash risk. Specifically, larger blind zone areas generally posed a greater risk of being involved in a backing crash. A statistically significant relationship[23] between backing crash risk and direct-view rear blind zone area was discovered for both test areas. However, in this analysis, an association between average rear longitudinal sight distance and backing risk was found to be weaker and not statistically significant.[24]

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[22] Light Vehicle Rear Visibility Assessment, DOT HS 810 909, September 2008 and an unpublished report by NHTSA's Mathematical Analysis Division "Rear Visibility and Backing Risk in Crashes," December 2008.

[23] r=0.51, p=0.02.

[24] r=0.26.

A multivariate logistic analysis to control for potentially confounding factors produced a statistically significant[25] relationship between backing crash risk and direct-view rear blind zone area was established for the 50-feet long by 60-feet wide area but not for the 50 feet long by 20 feet wide test area. These calculations suggest that larger blind zone areas as measured by the wide area are associated with a higher backing crash risk. Estimated results for the risk of backover crashes using rear longitudinal sight distance were not statistically significant. Based on the results of the logistic analysis, NHTSA believes that rear blind zone area measured over a test area 50-feet long by 60-feet wide, would provide some indication of a vehicle's backing crash risk, but may be larger than needed for a backover rulemaking. This makes some logical sense, since some of the backing crashes include backing out of a driveway into traffic, and the wider view available of traffic at speed, the better chance of seeing traffic and not backing into the street.

In this analysis, the agency examines the costs and benefits of two camera systems - 130 degree and 180 degree cameras. In essence a wider zone would require a 180 degree camera, rather than a 130 degree camera. While it is enticing to mandate the widest lens camera and largest display, the SCI data shows that most (85 percent) backovers occur within a length of 20ft of the starting position, and NHTSA's Monte Carlo analysis suggests a 10 foot wide area. This strongly suggests that a good test requirement for backover would examine the visibility provided to the driver covering specifically the 10 foot wide by 20 foot long area behind the vehicle. Both the 130 and 180 degree cameras cover this same space, so either would be appropriate. For perspective, the average blind zone area for vehicles with no countermeasures extends from the rear of the vehicle, back over 30 feet.

When examining all backing crashes (including backing into traffic from a driveway), a wider view of the area behind the vehicle is useful. The length of the view of the distance directly behind the vehicle is not statistically significantly different between vehicles. Our theory is that to reduce pedestrian crashes, one needs to see or be able to sense areas relatively close to the vehicle. For most vehicles we tested, a young child could not be seen within 12 feet of any of the vehicles, with most having sight distances beyond 20 feet. We could not find a statistically significant difference in crashes with vehicles with sight distances 20 to 50 feet back, since most of the need to see is in areas smaller than that, close to the rear of the vehicle. There were too few vehicles with sight distance less than 20 feet to determine whether there was a statistically significant difference between vehicles with a 12 to 20 foot sight distance. Rear visibility data for over seventy models is available in Appendix B.

For comparison, the following table provides a simplified detection range and the applicable countermeasures from those examined. It should be noted that the sight distances in the above tables denote how many feet from the vehicle's rear until vision begins, whereas the numbers below are the distances from the vehicle's rear up to the edge of the vehicle's visible range or system detection range. Note that the difference in

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[25] Chi-square=127, P=<0.001; chi-square=15, P=0.001 respectively.

range between 20 feet and 35 feet is not in the camera itself, but in the size of the display to allow image clarity.

Table IV-1 – Technologies Evaluated, with their Coverage Range

Coverage Range	Technologies that Could Meet this Range
6 ft range	Rear-mounted convex mirror, ultrasonic or radar sensors, rearview video system with in-rearview-mirror or in-dash display
16 ft range	Radar sensor(s), rearview video system with in-rearview-mirror or in-dash display
20 ft range	Rearview video system with in-rearview-mirror or in-dash display
35 ft range	Rearview video system with in-dash display

V. Benefits

A. Probability of a fatal backover being avoided

SCI Case Report Review Background

While a current annual estimate of backover crash fatalities and injuries can be pieced together from databases such as NiTS, FARS, and NASS-GES, the effectiveness of these backover methods needs to be created from a source with much more detailed information. In order to closely examine backover cases, Special Crash Investigations (SCI) were initiated. By collecting and analyzing a set of in-depth SCI cases, an estimate of the portion of backover crashes that are avoidable can be made. Test data from a study about backing aid usage, provides an estimate how many of those avoidable cases could be avoided. In short the fatalities calculation uses four parts; the target population of fatalities, F, the percentage of cases found to be “avoidable,” avoidability (factor f_A), the percentage of cases in which the system performs and provides the needed information (factor f_S), and the percentage of cases where drivers will recognize the information from the system and act appropriately to actually avoid a crash (factor f_{DR}), and calculate ($F * f_A * f_S * f_{DR}$), to estimate the potential benefits of different backover crash countermeasures. Injuries will be calculated similarly.

In order to better understand how avoidable these situations are, a few NHTSA analysts reviewed 50 available SCI case reports. The Special Crash Investigations are a collection of in-depth reports made soon after a crash and are not nationally representative, but they were chosen due to their detail and immediate availability. These are also cases where investigators had a chance to record volunteered reports and testimonies from police and those involved in the crash. A team of NHTSA analysts read the case reports, and based upon that information, decided whether or not the victim was moving at the time of the backing maneuver, if the victim was detectable given vision, mirrors, cameras, or sensor systems, and created an estimated, qualitative view of how avoidable the crash was with the given technologies. Some of the decisions from the team conflict with the coding from the SCI report, but these differences are mainly regarding whether or not the victim was moving, and are a product of the team trying to deduce the situation regarding the crash, rather than to code with certainty what precisely happened.

Pedestrian movement

Before making judgments regarding the ability of the sensors and driver, one single determination was made that wound up pinning down the nature of the pedestrian case; was the pedestrian moving? Due to the nature of the SCI investigations, an exact location for the pedestrians was not available, but many times a description of what the pedestrian was doing before or during the backing maneuver was available. While determining pedestrian movement, the team formed one or more sets of scenarios for how the crash occurred, because precise locations for person and vehicle were not available. Thus, instead of the single presentation of a court-room style simulation, the team would sometimes consider multiple such re-enactments per case depending upon the inherent ambiguity of the SCI reports. If a pedestrian was moving during the crash, this has a negative impact on the sensor systems. Examples of phrases within the report that hinted whether the pedestrian was moving include “riding a bike” and “sitting and playing.” Also, “moving” is slightly a misnomer as it is a term used to specifically denote a case in which the pedestrian was not stationary at the beginning of the backing maneuver.

Driver visibility through line-of-sight

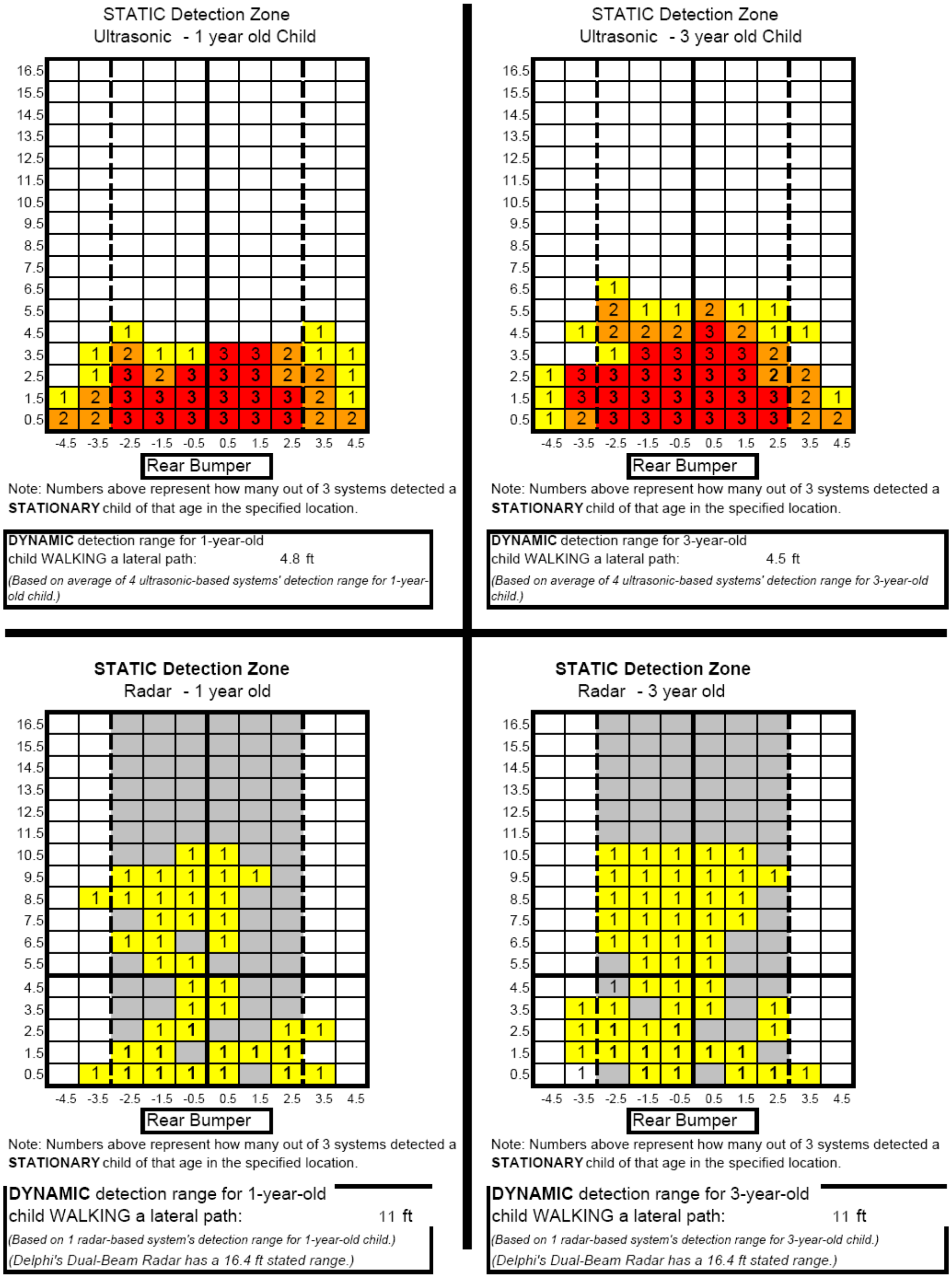
The driver’s visibility is the key to these cases, and despite the results of these cases, a determination was made based on the supposed pedestrian location (as determined by the narrative made by the SCI case author), and the visibility profile of the vehicle as laid out in the blind spot diagrams in the report. The two types of visibility catalogued in the evaluation were direct vision and visibility using mirrors. A pedestrian was visible using direct vision if they were visible by direct line-of-sight (no mirrors) to an average driver in the driver’s seat. This visual data is expected to be collected starting ten seconds prior to and throughout the backing motion. Thus, the pedestrian was “directly visible” if the driver would have seen them within or entering the upcoming backing trajectory of the vehicle, even before the vehicle was put into its rearward motion. This definition eliminates cases where a person is known to be within the vicinity of the vehicle, but the driver does not have recent or current line-of-sight to that person. With regard to “meaningful” amounts of data, the analysts attempted to assess the cases so that a “split second” view or obstructed view would not be coded as “visible,” as it would be too difficult to ascertain visually that there was a pedestrian in the way, nor would cases with insufficient reaction time given the circumstances be coded as “visible.” “Visible using mirrors” refers to the same constraints, excepting of course that the pedestrian had to be visible within the mirrors (any of the side and center rear view mirrors) rather than by direct line-of-sight.

Ability to Detect Pedestrians

A large part in the determination of whether a certain case could have been avoided was to determine in every case if the situation was one that could have been averted with the aid of certain technologies; in a word, whether the pedestrian was “detectable.” This is completely separate from the human factor of what the particular driver in the case was doing, as well as what an ideal driver would have been able to do. Simply put, would the countermeasure in question show or display any sign of the pedestrian whatsoever, regardless of how much time was left to the driver? After determining whether the technology would have detected the pedestrian, the next step is to ascertain if a prudent driver (as opposed to the driver of the case vehicle) *would have* been able to use such a technology in order to avoid the crash.

The driver’s ability to perceive objects behind the vehicle can be aided by various sensor technologies. The two considered were ultrasonic and radar systems, which can sense 1 year old children within these detection zones below as in Figure 5. These systems, especially ultrasonics, are known to be unreliable at picking up small objects, such as children, and have difficulty picking up objects that pass into the detection zone laterally. Stationary pedestrians that are larger in size or are as high as the bumper have an increased chance of being detected reliably. Sensor systems were assumed to cutoff above 3 mph. Radar systems perform better than ultrasonic systems in detecting distance to and recognition of people. Infra-red systems and composite systems used to differentiate human beings from their environment are available or theoretically possible, but were not considered in these case reviews.

Figure V-1 – Ultrasonic and Radar Sensor Detection Area



STATIC Detection Zone
Ultrasonic - 1 year old Child

	-4.5	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5	4.5
16.5										
15.5										
14.5										
13.5										
12.5										
11.5										
10.5										
9.5										
8.5										
7.5										
6.5										
5.5										
4.5			1						1	
3.5		1	2	1	1	3	3	2	1	1
2.5		1	3	2	3	3	3	2	2	1
1.5	1	2	3	3	3	3	3	3	2	1
0.5	2	2	3	3	3	3	3	3	2	2

Rear Bumper

Note: Numbers above represent how many out of 3 systems detected a **STATIONARY** child of that age in the specified location.

DYNAMIC detection range for 1-year-old child WALKING a lateral path: 4.8 ft

(Based on average of 4 ultrasonic-based systems' detection range for 1-year-old child.)

STATIC Detection Zone
Ultrasonic - 3 year old Child

	-4.5	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5	4.5
16.5										
15.5										
14.5										
13.5										
12.5										
11.5										
10.5										
9.5										
8.5										
7.5										
6.5			1							
5.5			2	1	1	2	1	1		
4.5		1	2	2	2	3	2	1	1	
3.5			1	3	3	3	3	2		
2.5	1	3	3	3	3	3	3	2	2	
1.5	1	3	3	3	3	3	3	3	2	1
0.5	1	2	3	3	3	3	3	3	2	2

Rear Bumper

Note: Numbers above represent how many out of 3 systems detected a **STATIONARY** child of that age in the specified location.

DYNAMIC detection range for 3-year-old child WALKING a lateral path: 4.5 ft

(Based on average of 4 ultrasonic-based systems' detection range for 3-year-old child.)

STATIC Detection Zone
Radar - 1 year old

	-4.5	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5	4.5
16.5										
15.5										
14.5										
13.5										
12.5										
11.5										
10.5					1	1				
9.5			1	1	1	1	1			
8.5		1	1	1	1	1				
7.5				1	1	1				
6.5			1	1		1				
5.5				1	1					
4.5					1	1				
3.5					1	1				
2.5				1	1			1	1	
1.5			1	1		1	1	1		
0.5		1	1	1	1	1		1	1	

Rear Bumper

Note: Numbers above represent how many out of 3 systems detected a **STATIONARY** child of that age in the specified location.

DYNAMIC detection range for 1-year-old child WALKING a lateral path: 11 ft

(Based on 1 radar-based system's detection range for 1-year-old child.)
(Delphi's Dual-Beam Radar has a 16.4 ft stated range.)

STATIC Detection Zone
Radar - 3 year old

	-4.5	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5	4.5
16.5										
15.5										
14.5										
13.5										
12.5										
11.5										
10.5			1	1	1	1	1			
9.5			1	1	1	1	1	1		
8.5			1	1	1	1	1			
7.5			1	1	1	1	1			
6.5			1	1	1	1				
5.5				1	1	1				
4.5			1	1	1	1				
3.5		1	1		1	1		1		
2.5		1	1	1	1			1		
1.5		1	1	1	1	1	1			
0.5		1		1	1		1	1	1	

Rear Bumper

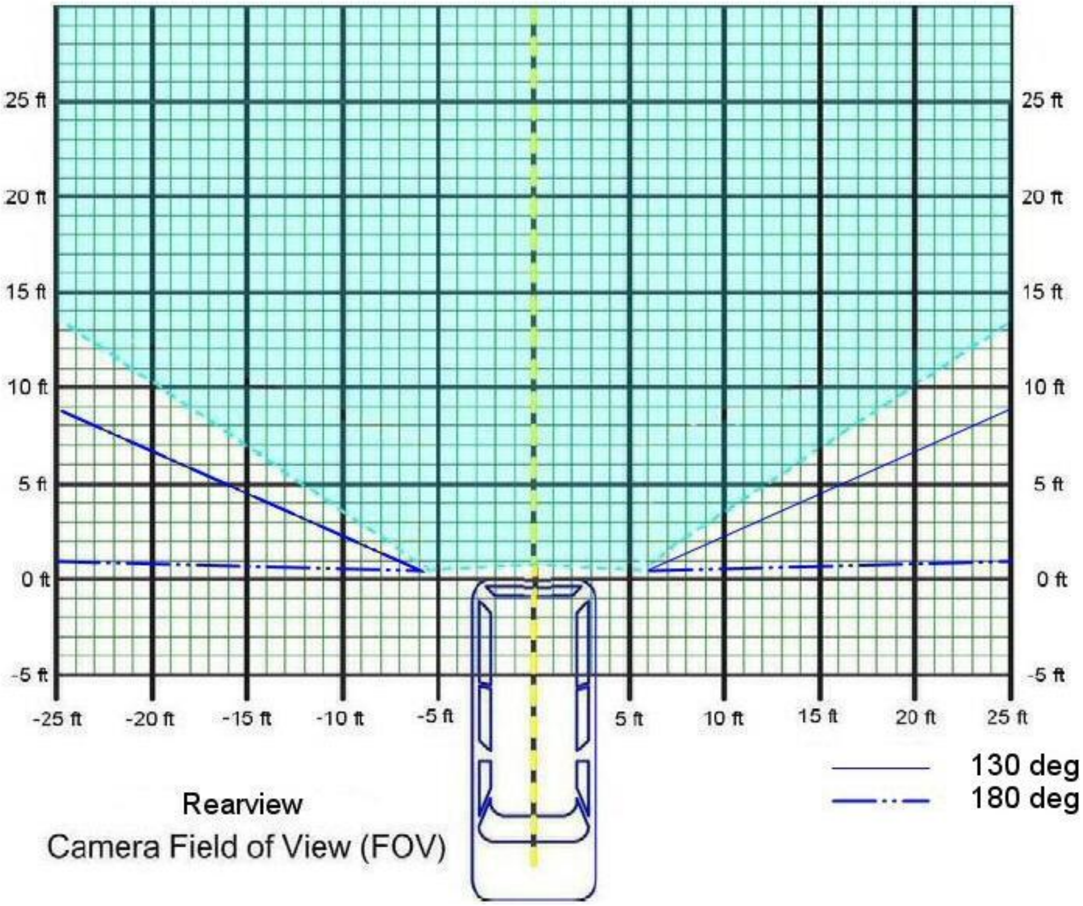
Note: Numbers above represent how many out of 3 systems detected a **STATIONARY** child of that age in the specified location.

DYNAMIC detection range for 3-year-old child WALKING a lateral path: 11 ft

(Based on 1 radar-based system's detection range for 3-year-old child.)
(Delphi's Dual-Beam Radar has a 16.4 ft stated range.)

Camera systems were also evaluated by the team. The display is assumed to be active immediately (a fraction of a second at most) after the vehicle is engaged in reverse (therefore, before and during the backing motion). However, the expectation is that a conscientious driver will look in the display before backing up, just as a conscientious driver is told to look behind them using mirrors or over their shoulder. Cameras have a single cone of visibility, and as such will not be able to see directly beneath the bumper, depending on practical placement and vehicle design. It was assumed that the camera would be placed aiming downward, and above the license plate, rendering it useless if a rear hatch (or other license fixture) was raised, or if the pedestrian was already fully underneath the car. Both 180 degree and 130 degree camera models were used in the evaluation. The 130 degree cameras were assumed to have slightly less ability at picking up pedestrians entering the viewing area laterally than the 180 degree camera. A good indication that a pedestrian was visible to the camera was if the report stated the pedestrian moved from one side of the vehicle and was struck by the rear of the vehicle on the other side. This does not necessarily mean that the crash was avoidable, merely that the pedestrian was visible (the wide angle of view assures that even a pedestrian running laterally towards the rear of the vehicle would be seen for a significant amount of time, barring viewing obstructions) Generally, if the pedestrian hit the center of the bumper it was assumed that the crash was visible from either type of camera. Figure 6 below shows the field of view for the two hypothetical camera systems used by the team.

Figure V-2 – Visible display area for camera systems



Crash Avoidability

It was estimated whether or not the pedestrian crash was "avoidable" using each of the different technologies by assuming a prudent driver is either looking at the technology and/or reacting to the technology at all of these times:

a) before putting the vehicle in reverse
b) after shifting into reverse, but before removing pressure to the brake
c) while moving the vehicle in reverse
d) at the time that the pedestrian enters into the space behind the vehicle and is threatened by its rearward motion.
e) at the time that the vehicle turned to put the pedestrian within a collision course

This means that the driver would not begin backing, or alternatively, stop backing immediately and fully, if they are given a sensor based warning or a camera based visual identification of a hazard. The goal of the analysts reading the SCI Reports was to establish an "avoidability" criterion, and this was done through a series of judgments regarding the crash situation. For example, was the victim moving? Was the victim visible using direct vision, mirrors, or cameras? Was the victim detectible using sensor systems? These questions were answered with yes, no, or unknown. All of these factors contributed to the final answers for the four final columns in Table 1 below, the avoidability for given technologies. However, there is no algorithm that translates from a case's disparate elements to its likelihood to be avoided. The possibility of avoidance was defined with the following statement: "Given your understanding of the circumstances presented in the case, would a prudent driver properly utilizing their vehicle and the backing technology in question be very likely, likely, unlikely, or very unlikely to avoid the pedestrian? Answer Yes, Probably Yes, Probably No, No respectively, or "unknown" if not enough information was available to make a judgment on the case. Cases in which there was a relative lack of knowledge, and cases which evoked weaker, less confident answers were marked as "probably." If the pedestrian was not "detectable" as determined earlier, no information gets passed onto the driver, which means the driver then has no reason to halt the backing maneuver. Below is by no means a comprehensive list of reasons for cases not being avoidable, but simply serve as a list of indicators guiding the reviewers' opinions. No single reason is ever given per case to describe why it was not avoidable, but rather the avoidability criterion is an inseparable amalgam of multiple factors.

1. Victim moving into path – If a pedestrian enters the path of the backing vehicle laterally, not giving enough time for the driver to react, that decreases the chance of avoidance.
2. Vehicle turning while backing – The team assumed that in most cases, when a vehicle was turning, their camera would continue to capture the majority of the event as it transpires as the image is captured from a wide-angle source, but would possibly suffer a small decrease in avoidance capability. As for sensors, this decrease in avoidance capability was greater, as the sensors would be sweeping out into a new area behind the vehicle, decreasing the time the pedestrian was detectable before impact.
3. If the pedestrian was low to the ground or was a small child, but the team decided it was still "detected" earlier in the case analysis, the avoidability would most likely be decreased slightly due to the fact that the sensor system would take longer to detect the pedestrian.
4. Increased relative vehicle speed – Faster vehicle backing speeds and faster pedestrian movement towards the vehicle both decrease the reaction time available for all systems.
5. Obfuscation and atmospheric conditions – Poor visibility (trees, shrubberies, snow, glare, fog, etc.) can impair the driver recognizing the pedestrian within the display. This was not a factor in most cases.
6. Incline of the road – Backing down a decline decreases the effectiveness of sensors the further away from the car the pedestrian is.
7. Pedestrian position – If it was difficult to determine where the pedestrian was, if they moved, or when they moved (in other words, if there were some level of uncertainty), that would negatively impact the likelihood that the crash could have been avoided, in order to keep our estimation of system performance a conservative one. This means that uncertainty regarding pedestrian position and movement affects both the visibility or detectability and the avoidability.

It is also worth noting that no effort was taken to account for recklessness, inebriation, or fatigue. All discussions of cases included a theoretical ‘perfect’ driver, and assumed that the technology was working as intended. No evidence was found within the cases to identify driver impairment as a significant cause of backover crashes. An estimation of the human part of the equation will be shown later on, and will be derived from human factors testing.

SCI Case Report Review Procedure and Results

Cases were reviewed individually, and the group met several times to reach a consensus that all members were satisfied best explained the situations. If no consensus could be made by the group, the results were averaged into one response. In the case of the “Possibility of Avoidance,” the group would consider the scenario, taking into consideration the factors above and any special factors unique to the case. In one report, the driver reported that their parking space existed on a hill that required a significant amount of throttle to be used while backing up. It was then assumed that a reasonable driver in such a situation would indeed be driving at such an increased speed. Although there was no strict formula as to how avoidability was determined, a general guideline was to look at the detection zone, blind spots, and visibility areas. If the pedestrian was detectable, then what followed was a cataloguing of all the impediments to a reasonable driver reacting in time after receiving a warning or recognizing a pedestrian on a display. The most sensitive part of the study was most likely the pedestrian’s position and actions during the event. When the team disagreed on nuances of the pedestrian’s role in the crash, the possibility of avoidance would most likely be arbitrated to an average value. The complete results of the evaluation are shown in Table 2.

Table V-1: Evaluation Team's Judgments regarding Movement, Detection, and Avoidability of 2007 SCI Backover Cases

	Victim moving? (Y/N/ Unk)	**Victim Visible?** (Y/N/Unk)				**Victim path passed through sensor detection zone?** (Y/N/Unk)		**Possibility of Avoidance** Y=Yes PY=Possibly Yes PN=Possibly NO N=No Unk = Unknown			
		Using direct vision	Using mirrors	in 180^{o} camera view	in 130^{o} camera view	Ultra-sonic	Radar	in 180^{o} camera view	in 130^{o} camera view	Ultra-sonic	Radar
Y	32	21	27	47	44	45	45	33	25	10	12
PY								12	13	14	15
PN								2	5	10	10
N	10	23	18	3	5	3	3	3	7	15	12
UNK	8	6	5	0	1	2	2	0	0	1	1
Y	64%	42%	54%	94%	88%	90%	90%	66%	50%	20%	24%
PY								24%	26%	28%	30%
PN								4%	10%	20%	20%
N	20%	46%	36%	6%	10%	6%	6%	6%	14%	30%	24%
UNK	16%	12%	10%	0%	2%	4%	4%	0%	0%	2%	2%
(Y) as % of Known	76%	48%	60%	94%	90%	94%	94%	66%	50%	20%	24%
(Y) or (PY) as % of Known								90%	76%	49%	54%

It should be restated that these results are the product of a team of analysts working to determine a clear vision of each SCI case, and as such are do not carry the precision found in the FARS files or even the very SCI cases from which they are gleaned. However, it represents our best estimate of the possibility of avoidance given the currently available data. The majority of cases involved moving pedestrians. Of the known cases, 76 percent (32/42) of the victims were moving. In just under half of the known cases (21/44), victims were visible using direct vision at some time slightly before or during the maneuver. However, in at least 90 percent of all known cases (44/48 to 47/50), for all four technologies considered, the pedestrian was at some point in a zone that was detectable by the sensors or visible by cameras. As for avoidability, 90 percent of cases were flagged as "yes" or "probably yes" for the 180 degree camera, compared with 76 percent for 130 degrees. The sensor systems did not fare as well as the camera systems, as they have a 49 and 54 percent avoidability estimate for ultrasonic and radar systems, respectively.

Human Factors

NHTSA performed a number of research projects on drivers after they had been driving for a few months in vehicles with either:

1) No backup system
2) Camera systems (Rear Video = RV)
3) A Camera system (RV) and a Sensor System (Rear Parking Sensor System = RPS)

One of the aspects of this testing was a staged event, where a cardboard child size object with a picture of a child on it popped up from the ground directly behind the vehicle as they were backing up in a spot where they would have no notion or idea that a child could be anywhere in the vicinity. At that time, cameras recorded their head and eye movements to see how they backed up, whether they looked at the mirrors or video displays from the camera, whether they paid attention to warnings provided by the rear parking sensor system, and other related information.

Table 3 shows the results of that staged event. All of the drivers with no backup system hit the cardboard child, 58 percent with a camera system only hit the cardboard child and 85 percent of those with a camera and rear parking sensor system hit the cardboard child. The results of the staged event might be considered somewhat counter-intuitive – the camera systems (RV) and rear parking sensor systems Sensor Systems (RPS) together were less effective than just a camera system, although this distinction was not statistically significant. From that same report, driver glances at the camera display were fewer when the vehicle was equipped with both systems – however, it should be noted that the sensor was located in the instrument panel, not integrated with or near the camera display. Also, the camera in this study had a long delay (6 seconds) before turning on, but this delay was ignored within the constraints of the SCI case review.

In the PRIA accompanying the ANPRM, we made the following statements relating to the effectiveness of camera systems and driver response. These data and later collected data have been combined into Table V-3.

Table V-2: Staged Obstacle Event Outcomes[26]

System	N	Number that Crashed	Percent Crashed
No system	12	12	100%
RV only	12	7	58%
RV & RPS	13	11	85%
Total	37	30	81%

In that same event, 15 of the 25 drivers glanced at their mirrors at least once during the event, and 9 of those 15 looked multiple times. This data represents the human factor. Thus, it is assumed that 9/15 = 60 percent of cases involve drivers that are the hypothetical prudent drivers that are constantly aware while backing up, using the camera. All 7 of the drivers that avoided hitting the cardboard child looked multiple times. In the end, the number that counts is (5+2)/25 = 28 percent of cases with both RV only and RV & RPS in which the driver avoided the staged obstacle event. Since both systems had cameras, it was appropriate to try to estimate different effectiveness estimates for different countermeasures from this data. This represents the percentage of times that a driver will correctly respond in an avoidable situation.

This is a small experiment with 25 drivers. While it is likely that the camera's effectiveness estimate is somewhere in the area around 28 percent, there is uncertainty around that estimate and a reasonable range of effectiveness might be 15 to 40 percent.

In a similar fashion, we must estimate likely driver reaction to sensors. The ORSDURVS report provides a machine detection factor of 39 percent for the sensors (an ultrasonic system was used). This is an additional factor that must be considered when calculating benefits, as the system and the human driver need to both correctly respond to the pedestrian. After the system provides a warning, regardless of the driver's glance pattern their attention would be drawn to the threat of collision, providing an estimated 15 percent improvement in driver reaction over the camera system. Thus, it is likely that the effectiveness estimate is somewhere in the area around 43 percent, and a reasonable range of effectiveness might be 30 to 55 percent. Again, this was the logic presented in the February 2009 PRIA accompanying the ANPRM. For this PRIA, we combined the RV data with more recent testing, but decided against combining the RV & RPS system data with the RV only data (see Table V-3).

Human Factors 2009 Update

In 2009, VRTC performed additional testing with various backover avoidance technologies. This was done to improve the available knowledge of driver behavior. The new data was added to the previous set of Staged Obstacle Event Outcomes, and a combined table of both data sets follows.

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[26] Table 6 from On-Road Study of Drivers' Use of Rearview Video Systems (ORSDURVS) – Elizabeth Mazzae

Table V-3: Staged Obstacle Event Outcomes

	N	System Use	% Used	Number that Crashed	% Crashed	% Avoided	% Sensor Detections	Driver Braked in Response to Warning?
Look-down mirror	0	Used	0.0%					
	13	Didn't Use		13	100.0%	0.0%		
	13	**Total**		**13**	**100.0%**	**0.0%**		
Cross-view mirrors	0	Used	0.0%					
	7	Didn't Use		7	100.0%	0.0%		
	7	**Total**		**7**	**100.0%**	**0.0%**		
RPS only	14	Used	100.0%	13	92.9%	7.1%	100.0%	100.0%
	0	Didn't Use						
	14	**Total**		**13**	**92.9%**	**7.1%**		
RV in Mirror: 2.4"	8	Used	66.7%	4	50.0%	50.0%		
	4	Didn't Use		4	100.0%	0.0%		
	12	**Total**		**8**	**66.7%**	**33.3%**		
RV in Mirror: 3.5"	8	Used	80.0%	1	12.5%	87.5%		
	2	Didn't Use		2	100.0%	0.0%		
	10	**Total**		**3**	**30.0%**	**70.0%**		
RV in dash 7.8"	9	Used	75.0%	4	44.4%	55.6%		
	3	Didn't Use		3	100.0%	0.0%		
	12	**Total**		**7**	**58.3%**	**41.7%**		
RV & RPS	7	Used RV	58.3%	5	71.4%	28.6%	38.5%	
	6	Didn't Use RV		6	100.0%	0.0%		
	5	Sensor Warning	38.5%	4	80.0%	20.0%		
	8	No sensor warning		7	87.5%	12.5%		
	13	**Total**	**58.3%**	**11**	**85.0%**	**15.0%**		
No system	**12**	**N/A**	**N/A**	**12**	**100.0%**	**0.0%**		

Due to their lower driver factor, 2.4" mirrors are not being considered for this rulemaking, and the effectiveness for Rear Video will be combined from "RV in Mirror 3.5"" and "RV in Dash 7.8"" to form an f_{DR} of 55 percent (12/22). Likewise, the "RPS only" system had a driver factor of 7.1 percent. The system response factor (f_S) of RPS systems is assumed to be 19/27 = 70.4 percent, derived from both sets of RPS data.

Look-down mirrors and cross-view mirrors are assumed to have near 0% (f_{DR}) and are therefore excluded from inclusion in the list of appropriate countermeasures as there exists little evidence suggesting their ability to provide benefits in improving visibility in certain areas behind the vehicle. Some evidence exists to show that cross-view mirrors may produce a 33.4% potential backover crash reduction if a driver looks at a mirror once prior to the start of a backing maneuver.[27] Achieving this potential reduction is dependent upon drivers actually using the mirrors, but the above research summarized in Table 4 shows that even drivers familiar with the mirrors failed to use them.

It is worthwhile to mention that in all cases where the "RPS only" system provided an alert, all drivers reacted in some way, and no drivers were able to avoid a collision. The RPS systems used in these cases were both ultrasonic systems, and due to no similar available data regarding radar systems, the f_{DR} and f_S for radar systems will be assumed to be equal to that of ultrasonic systems, while the SCI case review accounted for the increased range of the radar, reflected in a higher f_A for radar. In general, drivers that received a warning from a sensor (RPS), sometimes stopped the vehicle and then looked out the rear window. When they were unable to visually see an obstruction, they continued on and ran over the cardboard child figure. Participants' comments following the conflict scenario were collected, confirming this progression of events. We assume that this same driver reaction would have taken place regardless of whether the sensor was ultrasonic or radar. That is to say that most drivers tend not to fully believe the information provided by sensor systems.

Before proceeding into the calculation of benefits, one final note must be made. In all 20 cases, using either cross-view mirrors or look-down mirrors, the driver failed to avoid the test object. The human factors testing provides our only information regarding the driver's willingness to use the technology available to them. While, as mentioned earlier in Chapter II, other sources may claim that "when drivers use them, mirrors provide benefits," there is no indication that even drivers familiar with the systems will decide to use them. Finally, by concluding that f_{DR} is 0% for mirrors, the overall effectiveness given by ($f_A * f_S * f_{DR}$) must also equal 0%. In other words, no matter how many backover cases are avoidable (f_A) using mirrors, and despite even an assumption that the system (f_S) performs perfectly 100% of the time, if nobody's looking carefully at the mirror while performing a backing maneuver, the system provides no benefits. For this reason only, analysis of mirrors has been set aside for the remainder of the document. If evidence of increased driver acceptance of this system is provided, mirrors will be reintroduced to the benefits discussion, but as of right now, there is no evidence that they will provide any benefits at all.

B. Benefits Calculations

Previous sections established the backover fatalities, F, which are comprised of an estimated 228 light vehicles, (59 passenger cars, 68 sport utility vehicles, 29 vans, and 72 pickups). Applied next is the 55 percent estimate for successful driver reaction with cameras and the 7 percent estimate for sensors, as f_{DR}. Sensors also apply the 70 percent detection rating for f_S whereas Cameras are assumed to have f_S = 100 percent. Finally,

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[27] Garrot, "The Ability of Rear-mounted Convex Mirrors to Improve Rear Visibility" http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0558.pdf

for the various systems, the avoidability percentages from the SCI case investigations are used, selecting the cases marked “Yes” or “Possibly Yes” from the total number of cases.

Table V-4: Avoidability and Potential Lives Saved by Technology after Successful Driver Reaction

Successful Driver Camera Reaction (f_{DR})		in 180° camera view	in 130° camera view	Ultra-sonic	**Radar**	Sensor Picks Up Pedestrian (Detection Rating)	Successful Driver Sensor Reaction (f_{DR})
	Avoidable (Y)	66%	50%	20%	24%		
	Avoidable (Y, PY)	90%	76%	49%	54%		
55%	Avoided (Y)	36%	27%	1%	1%	70%	7%
	Avoided (Y, PY)	49%	41%	1%	2%		
55%	Lives Saved (Y)	82	62	1	2	70%	7%
	Lives Saved (Y, PY)	112	95	3	3		

In the lower portion of the above table, ($F * f_A * f_S * f_{DR}$), has been calculated to estimate the potential benefits of the different backover crash countermeasures. Below, these numbers have been further broken down by using the same factors, but examining the distribution of passenger cars and light trucks found in the fatality target population.

Table V-5: Estimated Lives Saved by Vehicle Type

55% for camera OR 7%*for sensor	180° camera	130° camera	Ultrasonic	Radar
Pass Car (Y)	21	16	0	0
LT (Y)	61	46	1	1
Total (Y)	82	62	1	2
Pass Car (Y,PY)	29	25	1	1
LT (Y,PY)	83	70	2	3
Total (Y,PY)	112	95	3	3

Table 6: Estimated Injuries Avoided by Vehicle Type

55% for camera OR 7%*for sensor	180° camera	130° camera	Ultrasonic	Radar
Pass Car (Y)	3,290[28]	2,492	51	61
LT (Y)	2,852	2,160	44	53
Total (Y)	6,141	4,652	95	114
Pass Car (Y,PY)	4,486	3,788	125	137
LT (Y,PY)	3,888	3,284	108	119
Total (Y,PY)	8,374	7,072	233	257

*55% refers to successful driver reaction for cameras, 7% refers to successful driver reaction to ultrasonic or radar sensors. Note, some numbers are off by one, due to rounding

Thus, the total number of lives saved from camera systems could be between 62 and 112, and from sensor systems between 1 and 3. We assume the same effectiveness for injury cases as we do for fatalities. Injury reduction would be between 4,652 and 8,374 for cameras and between 95 and 257 for sensors.

C. Property Damage Only Crashes and Maintenance Costs

In a Preliminary Cost-Benefit Analysis of Ultrasonic and Camera Backup Systems[29], NHTSA modeled benefits and costs (excluding injuries and fatality benefits) from a societal perspective to determine cost effectiveness of such systems with regard to only installation, and maintenance and repair costs, and the benefits derived from backing avoidance. This model establishes that although benefits are generated when the driver successfully avoids a crash, unexpected costs arise when the system is damaged or destroyed in non-backing crashes, namely struck-from-the-rear collisions.

The findings of that analysis were that for a range of crash distributions (10 to 25 percent of rear-damaged vehicles were backing, as opposed to 75 to 90 percent of rear-damages vehicles were struck-from-the-rear), and for a range of driver factors (50% to 80% successful driver reaction), none of the systems were nearly cost-effective. Overall, the net costs with the old figures ranged from $45 to $468 per vehicle.

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[28] Calculated for example: 9138 Injuries * 54.54% driver factor * 66% camera avoidance factor

[29] See NHTSA docket 2006-25579-2.

For purposes of this analysis, the Property Damage & Repair (PDR) model was updated in the following ways: Initial system cost is not included as it is considered elsewhere in this report. Repair costs for the camera were updated to reflect the $58 and $88 camera costs, while the original labor costs remained the same. Repair costs in the model used assume that the a new bumper and fascia would be required with the replacement of a destroyed camera, but the further adoption of camera systems has shown us these can easily be added without requiring the camera to be built into the bumper. The Driver Reaction ratio of 80% was replaced with the ORSDURVS value of 55%. All other values, including distribution of crash severity and effectiveness of any camera system on detecting large stationary objects were kept constant. Sensors were similarly updated to include a 7% driver reaction factor. Additionally, to simplify inclusion in this report, the range of 10% to 25% rear-end collisions propagating through backing crashes as opposed to struck-from-the-rear collisions was simplified to 17.5%.

Table V-6: Net Impacts per Vehicle from Property Damage and Repair and Maintenance Costs ($2006)

	55% f_{DR}	
17.5% Backing	130 Camera	180 Camera
3% discount	-$31.43	-$28.56
7% discount	-$25.96	-$23.59
	43% f_{DR}	
17.5% Backing	Ultrasonic	Radar
3% discount	$3.35	$5.50
7% discount	$2.76	$4.54

These values are benefits and costs for the combination of property damage only crashes and rear-end collisions. They detail the net discounted impact due to crashes avoided, after incremental repair costs. These numbers will be applied later to the cost-benefit evaluation in this report. In cases where the values are negative, the result is a benefit discounted over the life of the vehicle. Thus, property damage only crashes have a relatively large positive effect on the cost effectiveness of cameras, and a relatively small negative effect on sensors. So, cameras are estimated to reduce the net present value of lifetime property damage costs by $23.59 to $31.43, while sensors are anticipated to increase lifetime property damage costs by $2.76 to $5.50.

D. Non-quantified Benefits

The following segment is only concerned with benefits that are extremely difficult or impossible to quantify. The primary discussion of benefits concerns itself with familiar components of cost-benefit analysis: injuries, fatalities, and property damage. However, the introduction of both detection systems and display systems leads to changes that might not be suited to inclusion in formal benefits conversation, but are worth mentioning in an abstract, qualitative manner.

For example, there exists a certain convenience/comfort factor in being able to see directly behind the vehicle while backing up. There is the *additional* convenience distinct from and beyond the potential fatalities, injuries, and property damage. This convenience/comfort factor is a reduction in anxiety or apprehension while backing up. Similarly, the improved ability to parallel park (whose property damage benefits are already discussed) may provide a decreased delay in traffic while a driver cautiously parallel parks in one attempt rather than in multiple attempts.

If a display is used in the dash, other information could be provided, not only navigation, but potentially safety warnings. It seems that the first rulemaking to introduce a display suffers the installation cost, and subsequent rulemakings piggyback on the mandated display to provide context-sensitive safety benefits. The display for a camera system has the additional "benefit" of facilitating the introduction of other safety systems. The incremental cost of installing those "other" systems will not take into account the cost of the display, because they were already accounted for via the rear visibility rulemaking. In this way, the non-quantifiable impact of mandating displays leads to the possibility of the introduction of other safety mechanisms, or decreased costs in deploying said mechanisms. All the preceding conversation regarding possible consequences is not typical of cost-benefit analysis, is completely qualitative, and merely should be taken as a simple reminder. The display unit in question will doubtless have purposes other than to provide a display when the vehicle is in reverse and remain dormant and inactive otherwise, and any other safety technology to use the display will not include display cost in its analysis.

The comprehensive cost of an injury/fatality includes time lost on the job, and time lost at home, but only for the case of the injured. The emotional well-being of the extended family members, friends, and other associates of the injured is not included in cost-benefit analysis. Even non-injured drivers in pedestrian crashes are not given injury costs. Above and beyond the physical injuries sustained by the pedestrian victim, it can be argued that the emotional distress of the driver should be counted, especially in cases where the driver injures a child, and even more so when the child is their own. Cost data for driver distress due to such "perceived guilt" or "shock" is not available for crashes, let alone for crashes involving family member fatalities. More information would be required for rigorous inclusion in a formal analysis, but this emotional response is potentially one of the results of a backover crash, and its personal nature may place more emotional weight behind it than an accident involving a total stranger to the driver.

The agency requests comments on these non-quantified benefits.

VI. Costs

The costs for improving rear visibility are found in both the installation and maintenance/repair of the various parts for a variety of technological options. Systems are comprised of some sort of sensing apparatus almost exclusively found in the rear of the vehicle, usually located in the bumper or directly above the license plate. This is important because some rear-end collisions (when the vehicle is struck in the rear by another vehicle) will impact the backover avoidance system, possibly requiring recalibration, repair, or replacement. In the report "Preliminary Cost-Benefit Analysis of Ultrasonic and Camera Backup Systems" these costs were detailed, based upon a methodology of "lifetime crashes." The repair costs for cameras, when combined with their benefits from avoiding property damage only crashes are evaluated in the previous section, as they provide a net benefit.

The cost of installing one of these systems varies greatly with the type of system being installed. Initial vehicle part costs (or manufacturer costs) were multiplied by 1.51 to find the cost to consumers on a per-vehicle basis. The sensor systems (including a warning buzzer) are less expensive than a camera system. We estimate the cost of an ultrasonic system at $51-$89, an infrared system at $47, and a radar system at $92. For camera systems, the display method is the primary discerning factor; a system with a camera and a dashboard display may cost up to $189, but a vehicle that's already equipped with a navigational device already has a screen and the total cost comes to $88.18.[30] The incremental cost for installing any system (sensor or camera) is decreased if the sensor's warning or the camera's image is routed through an already present display or speaker system. Thus, if a vehicle is already equipped with an in-dash navigation unit, no extra display would be required, eliminating the cost of the display. Because estimated prices for these systems have decreased over time, further comments for the proposed installation rate, current availability, and cost of these systems will continue to be welcomed, as are comments regarding alternative systems that would cost less and meet the proposed statutory requirement.

Each camera system cost was estimated based on a collection of confidential industry estimates and internal NHTSA estimates for small parts and the assembly process. Camera prices (for the lens and light sensing apparatus) are estimated to average $30 for 130 degree cameras and $50 for 180 degree cameras. Wiring for dash display systems was set to $8, but $11 for rear mirror display systems due to the wire navigating the A pillar and climbing forward to the rear view mirror. Assembly labor was estimated at $23.69/hr, and applied to a 3 minute installation time for a dash display system and camera for an assembly cost of $1.20. Alternatively, the 3.5 minute installation time for a mirror system, including the time to run the wire up the A pillar and around the windshield, comes to $1.40. Supposing the vehicle was already equipped with a display unit from a navigation system, the labor to simply install the camera would be 1 minute, or $0.40. Estimates from various manufacturers and parts suppliers were submitted,

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[30] All cost numbers for these systems are comprised of confidential data from vehicle manufacturers, data from dealerships, and data from system manufacturers. Teardown analysis of backover avoidance technologies is forthcoming as of November 2010.

however the costs for these systems seemed inflated to the price of large retail display units and were therefore brought back to a manufacturer costs by division by a factor of 1.51. From this we estimate mirror displays cost at $73, and dash displays at $66. A camera system with a rear-view mirror display costs between $173 and $203.

Table VI-1
Estimated Consumer Costs ($2007)

	130 Mirror	180 Mirror	130 Dash	180 Dash
Entire Camera System Required	$172.74	$202.94	$158.85	$189.05
Nav Unit Present, Cam & Wires needed			$57.98	$88.18

	Ultrasonic	Radar
Sensor System	$51.49	$92.26

For the purpose of this analysis, the number of vehicles equipped with cameras needed to be compiled from a variety of sources. The 2008 Wards Automotive Yearbook provides detailed sales for certain equipment for all 2007 cars. This, combined with comments from the industry, led us to assume the following current distribution of cars sold. We assumed that the distribution of the 22% of light trucks equipped with "rear object detection" are 5% camera, 18% sensor, and 1% combined systems. We also assumed that all camera-equipped systems already were equipped with a navigational unit in the dash.

Table VI-2a
Estimated MY 2007 Backover Systems

Cars need display & Camera	93%
Cars w/ nav, no camera	7%
Cars fully equipped already	0%
Light Trucks need display & Camera*	82%
Light Trucks w/ nav, no camera*	13%
Light Trucks fully equipped already*	5%

*Assumes that the 22% trucks equipped with "rear object detection" are 5% camera, 18% sensor, and 1% overlap

*Assumes that all camera-equipped systems have navigation units in the dash

Regarding sensors, the installation rates were also taken from Wards, using the above assumption to arrive at 4 percent of passenger cars and 18 percent of light truck vehicles equipped with some sort of sensor system.

Table VI-2b
Projected MY 2010 Backover Systems

Distribution Estimate: 2010 Compliance Data		Cameras	Sensors
PC		**10.5%**	**9.1%**
LTs		**30.1%**	**29.7%**
	Truck	43.5%	35.7%
	Van	44.6%	44.3%
	SUV	18.3%	22.7%
Sum		19.8%	18.9%

Table IV-2b above contains the results of confidential compliance data NHTSA gathered in 2009. System availability was coded uniquely for each manufacturer, as was whether or not a system was optional or standard on certain models. This compliance data did not state the availability of navigation units, and for the purposes of this analysis, that number was assumed to be constant from the 2007 sales data. When a system was optional, the percentage of 2007 sales with cameras was used (5 percent). Even with this low percentage of vehicles to be equipped with optional cameras, the total number of cameras in the fleet will increase dramatically from 2007 to 2010. Sales Projections for the next 5 years, specifically regarding backover systems installation rates, are being requested from the manufacturers.

The following table shows the installation cost for a regulation requiring 100% of passenger cars and light trucks to have backover systems, assuming no vehicles were equipped with cameras, but accounting for those with navigational units. In other words, if all passenger cars and light trucks were suddenly equipped with 130 degree cameras, the total costs would be $2,868 million. Or if all passenger cars and light trucks were suddenly equipped with radar systems, the total costs would be $1,532 million.

Table VI-3
Total Installation Costs (in $M) for Backover systems, Assuming 0% install rate

		Mirror		Dash			
	Sales (in M)	130d camera	180d$ camera	130d camera	180d camera	Ultra-sonic	Radar
Passenger Car							
	8.0	$1,382	$1,624	$1,212	$1,454	$412	$738
Light Trucks							
	8.6	$1,486	$1,745	$1,252	$1,511	$443	$793
Total		$2,868	$3,369	$2,464	$2,965	$855	$1,532

The table below provides estimates for the cost of this regulation, taking into account the MY 2010 distribution of cameras and navigation units in sales.

Table VI-4
Total Incremental Installation Costs (in $M) for Backover systems

		Mirror		Dash			
	Sales (in M)	130d camera	180d$ camera	130d camera	180d camera	Ultra-sonic	Radar
Passenger Car	8.0	$1,237	$1,453	$1,078	$1,295	$375	$671
Light Trucks	8.6	$1,039	$1,220	$841	$1,022	$311	$558
Total		$2,275	$2,673	$1,919	$2,317	$686	$1,229

With a Pedestrian Detection add-on, camera systems can differentiate a human being from the rest of its environment. An estimated additional $75, including the price of the hardware and software is involved. These systems are in the prototype phase and not installed on many vehicles – they are a very new technology and extremely little data is available on them, but it is theoretically possible for such systems to have access to the vehicle's braking controls, eliminating the human element from backover avoidance. This could also be true of purely sensor-based systems.

These numbers are very different from the FMVSS No. 111 Preliminary Regulatory Evaluation[31] regarding rear detection systems on single-unit trucks, wherein a camera system used to cost $326 to install. The technology has matured to the point where some vehicles may be fully equipped with cameras for a little more than half that cost, or simply have a camera added when a navigational unit is present for nearly one fourth of that cost. Backover sensors have a much lower driver reaction factor than NHTSA previously anticipated. This has greatly reduced their effectiveness and will increase their cost/benefit ratio into triple digits.

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[31] Preliminary Regulatory Evaluation, FMVSS No. 111, NPRM to Require a Rear Detection System for Single-Unit Trucks, August 2005, (Docket No. 19239-2)

VII. Cost Effectiveness & Benefit-Cost Analyses

The intent of the final rulemaking is to mitigate pedestrian backover crashes. This section estimates the number of lives to be saved and injuries to be prevented per dollar spent for the reduction in equivalent lives lost due to backover crashes. It should be noted that the costs of the equipment needed to meet the requirements are incurred when the vehicles are purchased, but the injury benefits and the property damage impacts of rear visibility will accrue over the lifetime of the fleet. Therefore, discount factors are applied to estimate the present value of injury benefits and property damage for a meaningful comparison to costs.

Cost Effectiveness:

With respect to reduction in the number of fatalities and injuries, the agency estimates the number of "equivalent fatalities" that would be prevented, or "equivalent lives saved," a concept that incorporates a reduction in both the number of fatalities and injuries. The estimated equivalent lives saved and property damages prevented are discounted. The costs are reduced by the amount of discounted property damage prevented to derive "net costs." These "net costs" are then compared to the estimated equivalent lives saved.

There is general agreement within the economic community that the appropriate basis for determining discount rates is the marginal opportunity costs of lost or displaced funds. When these funds involve capital investment, the marginal, real rate of return on capital must be considered. However, when these funds represent lost consumption, the appropriate measure is the rate at which society is willing to trade-off future for current consumption. This is referred to as the "social rate of time preference," and it is generally assumed that the consumption rate of interest, i.e., the real, after-tax rate of return on widely available savings instruments or investment opportunities, is the appropriate measure of its value.

Estimates of the social rate of time preference have been made by a number of authors. Robert Lind[32] estimated that the social rate of time preference is between zero and six percent, reflecting the rates of return on Treasury bills and stock market portfolios. Kolb and Sheraga[33] put the rate at between one and five percent, based on returns to stocks and three-month Treasury bills. Moore and Viscusi[34] calculated a two percent real time rate of time preference for health, which they characterize as being consistent with financial market rates for the period covered by their study. Moore and Viscusi's estimate was

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[32] Lind, R.C., "A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options," in Discounting for Time and Risks in Energy Policy, 1982, (Washington, D.C., Resources for the Future, Inc.)

[33] J. Kolb and J.D. Sheraga, "A Suggested Approach for Discounting the Benefits and Costs of Environmental Regulations,: unpublished working papers.

[34] Moore, M.J. and Viscusi, W.K., "Discounting Environmental Health Risks: New Evidence and Policy Implications," Journal of Environmental Economics and Management, V. 18, No. 2, March 1990, part 2 of 2.

derived by estimating the implicit discount rate for deferred health benefits exhibited by workers in their choice of job risk.

OMB Circular A-4 recommends agencies use both three percent and seven percent as the “social rate of time preference”.

In the context of this particular regulatory evaluation of the efforts to improve rear visibility in light vehicles, safety benefits occur when there is a potential crash severe enough to result in occupant death or injury that would predictably be prevented by the required technology. The benefits could occur at any time over the vehicle’s lifetime. This analysis assumes that crashes over the vehicle fleet’s lifetime will occur in proportion to the number of miles a given year’s new vehicle fleet will be driven from year to year as it ages. Tables VI-1a and VI-1b contain the vehicle miles of traveled (VMT) by vehicle age and the survival probability schedules used in calculating age and survival factors. The values in the column indicating the percentage of fleet travel that would occur each year, i.e., weighted yearly travel, are used to distribute savings by year of vehicle operation. The vehicle miles traveled (VMT) by vehicle age distribution is used to determine the percentage of lifetime mileage that occurs each year that in turn is used to calculate the discount factors by year for the three and seven percent discount rates. The two right-hand columns show the weighted values for these discount factors. These values are derived by multiplying the yearly discount factors by the share of lifetime travel that occurs in the respective years and summing these factors over the 25 or 36 years. The values in the two columns are then summed to produce the following multipliers for the respective discount rates:

For passenger cars, 0.8304 for a three percent discount rate and 0.6700 for a seven percent discount rate, as shown in Table VII-1a.
For light trucks, 0.8022 for a three percent discount rate and 0.6303 for a seven percent discount rate, as shown in Table VII-1b.

Table VII-1a
Mid-Year Discount Factors, Passenger Cars

Age	VMT (a)	Survival (b)	(a) * (b)	% of VMT	3%	7%	Weighted 3%	Weighted 7%
1	14,231	0.99	14089	0.0926	0.9853	0.9667	0.0912	0.089518
2	13,961	0.9831	13725	0.0902	0.9566	0.9035	0.0863	0.0815
3	13,669	0.9731	13301	0.0874	0.9288	0.8444	0.0812	0.0738
4	13,357	0.9593	12813	0.0842	0.9017	0.7891	0.0759	0.0665
5	13,028	0.9413	12263	0.0806	0.8755	0.7375	0.0706	0.0594
6	12,683	0.9188	11653	0.0766	0.85	0.6893	0.0651	0.0528
7	12,325	0.8918	10991	0.0722	0.8252	0.6442	0.0596	0.0465
8	11,956	0.8604	10287	0.0676	0.8012	0.602	0.0542	0.0407
9	11,578	0.8252	9554	0.0628	0.7778	0.5626	0.0488	0.0353
10	11,193	0.7866	8804	0.0579	0.7552	0.5258	0.0437	0.0304
11	10,804	0.717	7746	0.0509	0.7332	0.4914	0.0373	0.0250
12	10,413	0.6125	6378	0.0419	0.7118	0.4593	0.0298	0.0193
13	10,022	0.5094	5105	0.0336	0.6911	0.4292	0.0232	0.0144
14	9,633	0.4142	3990	0.0262	0.671	0.4012	0.0176	0.0105
15	9,249	0.3308	3060	0.0201	0.6514	0.3749	0.0131	0.0075
16	8,871	0.2604	2310	0.0152	0.6324	0.3504	0.0096	0.0053
17	8,502	0.2028	1724	0.0113	0.614	0.3275	0.0070	0.0037
18	8,144	0.1565	1275	0.0084	0.5961	0.306	0.0050	0.0026
19	7,799	0.12	936	0.0062	0.5788	0.286	0.0036	0.0018
20	7,469	0.0916	684	0.0045	0.5619	0.2673	0.0025	0.0012
21	7,157	0.0696	498	0.0033	0.5456	0.2498	0.0018	0.0008
22	6,866	0.0527	362	0.0024	0.5297	0.2335	0.0013	0.0006
23	6,596	0.0399	263	0.0017	0.5142	0.2182	0.0009	0.0004
24	6,350	0.0301	191	0.0013	0.4993	0.2039	0.0006	0.0003
25	6,131	0.0227	139	0.0009	0.4847	0.1906	0.0004	0.0002
		Total	152143				0.8304	0.6700

Table VII-1b
Mid-Year Discount Factors, Light Trucks

Age	VMT (a)	Survival (b)	(a) * (b)	% of VMT	3%	7%	Weighted 3%	Weighted 7%
1	16,085	0.9741	15668	0.0871	0.9853	0.9667	0.0858	0.0842
2	15,782	0.9603	15155	0.0842	0.9566	0.9035	0.0806	0.0761
3	15,442	0.942	14546	0.0808	0.9288	0.8444	0.0751	0.0683
4	15,069	0.919	13848	0.0770	0.9017	0.7891	0.0694	0.0607
5	14,667	0.8913	13073	0.0726	0.8755	0.7375	0.0636	0.0536
6	14,239	0.859	12231	0.0680	0.85	0.6893	0.0578	0.0468
7	13,790	0.8226	11344	0.0630	0.8252	0.6442	0.0520	0.0406
8	13,323	0.7827	10428	0.0579	0.8012	0.602	0.0464	0.0349
9	12,844	0.7401	9506	0.0528	0.7778	0.5626	0.0411	0.0297
10	12,356	0.6956	8595	0.0478	0.7552	0.5258	0.0361	0.0251
11	11,863	0.6501	7712	0.0429	0.7332	0.4914	0.0314	0.0211
12	11,369	0.6042	6869	0.0382	0.7118	0.4593	0.0272	0.0175
13	10,879	0.5517	6002	0.0334	0.6911	0.4292	0.0230	0.0143
14	10,396	0.5009	5207	0.0289	0.671	0.4012	0.0194	0.0116
15	9,924	0.4522	4488	0.0249	0.6514	0.3749	0.0162	0.0093
16	9,468	0.4062	3846	0.0214	0.6324	0.3504	0.0135	0.0075
17	9,032	0.3633	3281	0.0182	0.614	0.3275	0.0112	0.0060
18	8,619	0.3236	2789	0.0155	0.5961	0.306	0.0092	0.0047
19	8,234	0.2873	2366	0.0131	0.5788	0.286	0.0076	0.0038
20	7,881	0.2542	2003	0.0111	0.5619	0.2673	0.0063	0.0030
21	7,565	0.2244	1698	0.0094	0.5456	0.2498	0.0051	0.0024
22	7,288	0.1975	1439	0.0080	0.5297	0.2335	0.0042	0.0019
23	7,055	0.1735	1224	0.0068	0.5142	0.2182	0.0035	0.0015
24	6,871	0.1522	1046	0.0058	0.4993	0.2039	0.0029	0.0012
25	6,739	0.1332	898	0.0050	0.4847	0.1906	0.0024	0.0010
26	6,663	0.1165	776	0.0043	0.4706	0.1781	0.0020	0.0008
27	6,648	0.1017	676	0.0038	0.4569	0.1665	0.0017	0.0006
28	6,648	0.0887	590	0.0033	0.4436	0.1556	0.0015	0.0005
29	6,648	0.0773	514	0.0029	0.4307	0.1454	0.0012	0.0004
30	6,648	0.0673	447	0.0025	0.4181	0.1359	0.0010	0.0003
31	6,648	0.0586	390	0.0022	0.4059	0.127	0.0009	0.0003
32	6,648	0.0509	338	0.0019	0.3941	0.1187	0.0007	0.0002
33	6,648	0.0443	295	0.0016	0.3826	0.1109	0.0006	0.0002
34	6,648	0.0385	256	0.0014	0.3715	0.1037	0.0005	0.0001

35	6,648	0.0334	222	0.0012	0.3607	0.0969	0.0004	0.0001
36	6,648	0.029	193	0.0011	0.3502	0.0905	0.0004	0.0001
		Total	179959				0.8022	0.6303

These multipliers are applied to the estimated number of equivalent fatalities prevented to give the present values of estimated safety benefits for the respective discount rates.

A. Fatality and Injury Prevented Benefits:

As a primary measure of the impact of the rear visibility standard, this analysis will measure the cost per equivalent life saved and also benefits in preventing property damage involved in the crashes. In order to calculate a cost per equivalent fatality, nonfatal injuries must be expressed in terms of fatalities. This is done by comparing the value of preventing nonfatal injuries to the value of preventing a fatality. Comprehensive values, which include both economic impacts and lost quality (or value) of life considerations will be used to determine the relative values of fatalities and nonfatal injuries. In the past, these values were taken from a study published by NHTSA when the estimated economic value of preventing a human fatality was $3.0 million.[35] In 2008, the Department of Transportation has determined that the best current estimate of the economic value of preventing a human fatality is $5.8 million in $2007. However, relative value coefficients for preventing injuries of different severity have not been developed. NHTSA is conducting research to revise the previously developed estimates. The revised estimates will be published when they become available. In the interim, we have adjusted the current estimates to reflect the revised $5.8 million statistical life for both crash avoidance and crashworthiness Federal motor vehicle safety standards (see Appendix A). Tables VII-2a and VII-2b show an example of how the comprehensive values are used for each injury severity level, as well as the relative incident-based weights for nonfatal injuries, AIS 1-5.

Table VII-2a
Process of Converting Nonfatal Injuries to Equivalent Fatalities
(Resulted from Rear Visibility Standard applied to Passenger Cars)

Injury Severity	No. of Fatalities and Injuries	Conversion Factor	Equivalent Fatalities (Undiscounted)
Fatalities	59	1.0000	59
AIS 5	29	0.6656	19
AIS 4	60	0.1998	12
AIS 3	420	0.0804	34
AIS 2	1162	0.0436	51
AIS 1	6,497	0.0028	18
Total			193

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[35] See Table A-1, The Economic Impact of Motor Vehicle Crashes 2000, DOT HS 809 446, NHTSA/DOT, L. Blincoe, A. Seay, E. Zaloshnja, T. Miller, E.Romano, S. Luchter, R. Spicer, May, 2002.

Table VII-2b
Process of Converting Nonfatal Injuries to Equivalent Fatalities
(Resulted from Rear Visibility Standard applied to Light Truck Vehicles)

Injury Severity	No. of Fatalities and Injuries	Conversion Factor	Equivalent Fatalities (Undiscounted)
Fatalities	169	1.0000	169
AIS 5	28	0.6656	19
AIS 4	57	0.1998	11
AIS 3	395	0.0804	32
AIS 2	1051	0.0436	46
AIS 1	5,589	0.0028	15
Total			292

The results in Tables VII-2a and -2b show that the installation of camera systems in passenger cars would apply to a target population of 193 equivalent fatalities, whereas in light truck vehicles it would apply to 292 equivalent fatalities.

In Table VII-3, the safety benefits from Tables VII-2 have been discounted at three and seven percent rates to express their present values over the lifetime of one model year's production. The discount factors and the discounted target population fatal equivalents are summarized in Table VII-3.

Table VII-3
Present Discounted Value of Fatalities within Target Population[36]
(For equipping light vehicles with camera systems)

Fatal Equivalent	Discount Rate	Discounted Fatal Equivalent
193 (Pass. Cars)	0.8304 at 3%	160
	0.6700 at 7%	129
292 (Light Trucks)	0.8022 at 3%	234
	0.6303 at 7%	184

The discounted fatal equivalents in Tables VII-3 show that passenger car target population is 129 equivalent lives discounted at seven percent and 160 equivalent lives discounted at three percent.

B. Property Damage Prevented Benefits

Table VII-4, identical to Table VI-4 from the Cost section, presents the discounted values of the estimated property damage prevented that the requirement would have on a per-vehicle basis at the respective discount rates. As in the case for discounting the equivalent fatality benefits, the numbers were derived by multiplying the estimated amount of property damage prevented by the discount factors that were shown in Table VII-3.

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[36] The discounted fatality numbers were rounded to the nearest integer.

Table VII-4
Net Impacts per Vehicle from Property Damage and
Repair and Maintenance Costs ($2006)

	55% f_{DR}	
17.5% Backing	130 Camera	180 Camera
3% discount	-$31.43	-$28.56
7% discount	-$25.96	-$23.59
	43% f_{DR}	
17.5% Backing	Ultrasonic	Radar
3% discount	$3.35	$5.50
7% discount	$2.76	$4.54

C. Net Cost Per Equivalent Life Saved

The costs per equivalent life saved for light vehicles are computed using the annual net cost figures (the sum of the installation costs from Chapter VI plus the discounted property damage impacts above) and the discounted equivalent lives saved. All of the calculations take into account the current installation rate, and thus benefits and costs are both reduced to those generated by the rulemaking itself. These installation rates were already produced for Table VI-2b, and the percentage of vehicles that need equipment are multiplied by the appropriate sales numbers, and then these products (in "number of cars") is multiplied by either the installation cost (per car) or the per-car impact from Property Damage to generate the corresponding values. Calculations have been made for the various technologies at the 3% and 7% discount factor. The following tables detail the equivalent lives saved, installation cost (the cost to implement the rulemaking by installing the devices), lifetime cost (installation costs plus the impacts from Property Damage and Repair and Maintenance, found in table VII-4 above), and cost per equivalent life saved for all considered.

Table VII-5a
Equivalent Lives Saved, Net Cost, and Cost per Equivalent Life Saved for Backover Systems at the 3% and 7% Discount Rate
Passenger Cars and Light Trucks

	Equivalent Lives Saved 3% discount rate	Installation Costs (in $M)	Lifetime Costs (incl. PDO crashes) (in $M) 3% discount rate	Net Cost/EQ Life Saved (in $M)
130 Mirror	127.4	$2,275.3	$1,861.3	**14.6**
130 Dash	127.4	$1,919.2	$1,505.1	**11.8**
180 Mirror	150.8	$2,673.1	$2,296.9	**15.2**
180 Dash	150.8	$2,316.9	$1,940.7	**12.9**
Ultrasonic	7.6	$685.8	$730.4	**95.5**
Radar	8.4	$1,228.8	$1,302.1	**154.5**

	Equivalent Lives Saved 7% discount rate	Installation Costs (in $M)	Lifetime Costs (incl. PDO crashes) (in $M) 7% discount rate	Net Cost/EQ Life Saved (in $M)
130 Mirror	101.3	$2,275.3	$1,933.3	**19.1**
130 Dash	101.3	$1,919.2	$1,577.2	**15.6**
180 Mirror	120.0	$2,673.1	$2,362.4	**19.7**
180 Dash	120.0	$2,316.9	$2,006.2	**16.7**
Ultrasonic	6.1	$685.8	$722.6	**118.8**
Radar	6.7	$1,228.8	$1,289.4	**192.3**

From all of these values, we find that the lowest estimated cost per equivalent life saved for cameras requires a 130 degree dash-display camera system, at the 3 percent discount level, and would cost an approximate $11.8 million per equivalent life saved. The highest camera estimate requires a 180 degree mirror-display camera system, at the 7 percent discount level, and would cost an approximate $19.7 million per equivalent life saved. The lowest cost per equivalent life saved for sensor systems was $86.7 per life saved, equipping ultrasonic systems at the 3 percent discount level. However, the highest cost per equivalent lives saved for sensors was the radar system at the 7% discount level, providing a cost of $211.9 million per life saved. For perspective, NHTSA estimates a cost of $6.1 million per statistical life when valuing a reduction in premature fatalities, so none of these systems are cost effective.

While a rulemaking that only requires light trucks to be equipped is within scope, NHTSA is not proposing at this time that the fleet be equipped based on vehicle type. Below are the costs and benefits for such an alternative.

Table VII-5b
Equivalent Lives Saved, Net Cost, and Cost per Equivalent Life Saved for Backover Systems at the 3% and 7% Discount Rate, by Vehicle Type

	Equivalent Lives Saved		Lifetime Costs, including PDO crashes (in $M)	
PC Only	3% discount rate	Installation Costs (in $M)	3% discount rate	Net Cost/EQ Life Saved (in $M)
130 Mirror	59.4	$1,236.6	$1,011.6	**$17.0**
130 Dash	59.4	$1,078.4	$853.4	**$14.4**
180 Mirror	70.3	$1,452.8	$1,248.3	**$17.7**
180 Dash	70.3	$1,294.6	$1,090.2	**$15.5**
Ultrasonic	3.6	374.5	398.9	**$111.2**
Radar	4.0	671.1	711.1	**$180.0**
LT Only				
130 Mirror	68.0	$1,038.7	$849.7	**$12.5**
130 Dash	68.0	$840.7	$651.7	**$9.6**
180 Mirror	80.5	$1,220.3	$1,048.6	**$13.0**
180 Dash	80.5	$1,022.3	$850.6	**$10.6**
Ultrasonic	4.1	$311.3	$331.5	**$81.6**
Radar	4.5	$557.8	$591.0	**$132.1**
	Equivalent Lives Saved		Lifetime Costs, including PDO crashes (in $M)	
PC Only	7% discount rate	Installation Costs (in $M)	7% discount rate	Net Cost/EQ Life Saved (in $M)
130 Mirror	47.9	$1,236.6	$1,050.8	**$21.9**
130 Dash	47.9	$1,078.4	$892.6	**$18.6**
180 Mirror	56.7	$1,452.8	$1,283.9	**$22.6**
180 Dash	56.7	$1,294.6	$1,125.8	**$19.8**
Ultrasonic	2.9	374.5	394.6	**$136.4**
Radar	3.2	671.1	704.1	**$220.9**
LT Only				
130 Mirror	53.4	$1,038.7	$882.6	**$16.5**
130 Dash	53.4	$840.7	$684.6	**$12.8**
180 Mirror	63.3	$1,220.3	$1,078.4	**$17.0**
180 Dash	63.3	$1,022.3	$880.5	**$13.9**
Ultrasonic	3.2	$311.3	$328.0	**$102.8**
Radar	3.5	$557.8	$585.2	**$166.4**

D. Benefit-Cost Analysis

Effective January 1, 2004, OMB Circular A-4 requires that analyses performed in support of final rules must include both cost effectiveness and benefit-cost analysis. Benefit-cost analysis differs from cost effectiveness analysis in that it requires that benefits be assigned a monetary value, and that this value be compared to the monetary values of costs to derive an estimate of net benefit. In valuing reductions in premature fatalities, we used a NHTSA value of $6.1 million based on a value of $5.8 million per statistical life from the most current DOT guidance on valuing fatalities[37]. This value represents an updated version of a meta-analysis of studies that were conducted prior to 1993.

When accounting for the benefits of safety measures, cost savings not included in value of life measurements must also be accounted for. Value of life measurements inherently include a value for lost quality of life, plus a valuation of lost material consumption that is represented by measuring consumer's after-tax lost productivity. In addition to these factors, preventing a motor vehicle fatality will reduce costs for medical care, emergency services, insurance administrative costs, workplace costs, and legal costs. If the countermeasure is one that also prevents a crash from occurring, property damage and travel delay would be prevented as well. The sum of both value of life and economic cost impacts is referred to as the comprehensive cost savings from reducing fatalities. For the analysis, as shown in Appendix A, we used $6.1 million comprehensive cost per statistical life.

Total costs were derived by multiplying the value of life by the equivalent lives saved, as shown in Tables VII-6.

Table VII-6
Monetized Benefits and Net Costs for Backover Systems at the 3% and 7% Discount Rates with a Value of $6.1M per Equivalent Life

	Equivalent Lives Saved 3% discount rate	Monetized Benefits (in $M) 3% discount rate	Installation Costs (in $M)	Lifetime Costs (incl. PDO crashes) (in $M) 3% discount rate	Net Costs (Lifetime Costs – Monetized Benefits) (in $M)
130 Mirror	127.4	$777.6	$2,275.3	$1,861.3	**$1,083.7**
130 Dash	127.4	$777.6	$1,919.2	$1,505.1	**$727.6**
180 Mirror	150.8	$920.8	$2,673.1	$2,296.9	**$1,376.1**
180 Dash	150.8	$920.8	$2,316.9	$1,940.7	**$1,019.9**
Ultrasonic	7.6	$46.7	$685.8	$730.4	**$683.7**
Radar	8.4	$51.4	$1,228.8	$1,302.1	**$1,250.7**

	Equivalent Lives Saved 7% discount rate	Monetized Benefits (in $M) 7% discount rate	Installation Costs (in $M)	Lifetime Costs (incl. PDO crashes) (in $M) 7% discount rate	Net Costs (Lifetime Costs – Monetized Benefits) (in $M)
130 Mirror	101.3	$618.6	$2,275.3	$1,933.3	**$1,314.7**
130 Dash	101.3	$618.6	$1,919.2	$1,577.2	**$958.6**
180 Mirror	120.0	$732.6	$2,673.1	$2,362.4	**$1,629.8**
180 Dash	120.0	$732.6	$2,316.9	$2,006.2	**$1,273.7**
Ultrasonic	6.1	$37.1	$685.8	$722.6	**$685.5**
Radar	6.7	$40.9	$1,228.8	$1,289.4	**$1,248.4**

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[37] "Revised Departmental Guidance, Treatment of Value of Preventing Fatalities and Injuries in Preparing Economic Analyses", Memorandum from D. J. Gribbin, General Counsel and Tyler D. Duval, Assistant Secretary for Transportation Policy, February 5, 2008.

Our analysis of rear visibility results in costs that outweigh the benefits given the current technology and our understanding of the target population and installation rates. A reduction in lives lost to and injuries caused by backover accidents, in addition to benefits from property damage only crashes, are expected, but the combination of the monetized benefits and the cost of implementation and maintenance are a net cost between $236 million and $1.6 billion.

E. Potential Alternatives

In order to explore fully other possible rulemaking options, a variety of combinations of technology were examined, specifically, ones in which light trucks were equipped with a camera system, and passenger cars were given no extra equipment, a similar camera, radar, or ultrasonic systems. The results of examining such combinations are available below. Note the camera/radar and camera/ultrasonic options have decreased costs compared to mandating cameras for both vehicle types, but have a higher cost per life saved. It would not fulfill the requirements of the statute to require cameras for light trucks and nothing for passenger cars; those numbers are provided only as a point of comparison. Also, the camera/radar option has a higher net cost associated with it than simply mandating cameras for both, and will most likely not be viable on those grounds. Comments on these alternatives and suggestions of others are welcome.

Rear Visibility Options
Discounted at 3%
($Millions of 2007)

	Installation Costs*	Monetized Benefits	Property Damage Costs	Net Costs	Net Cost per Equivalent Life Saved
LT Camera PC Camera	$1,919 to $2,275	$778	$ -414	$727 to $1,084	$11.8 to $14.6
LT Camera PC Radar	$1,512 to $1,710	$439	$ -149	$924 to $1,122	$18.9 to $21.7
LT Camera PC Ultrasonic	$1,215 to $1,413	$437	$ -165	$613 to $811	$14.7 to $17.4
LT Camera PC Nothing	$841 to $1,039	$415	$ -189	$237 to $435	$9.6 to $12.5

*The range of camera costs assumes 130 degree camera with the display in the dash (lower cost) to the display in the mirror (higher cost)

F. Sensitivity Analysis

To better understand the impact in choosing a value for a statistical life, a sensitivity analysis is helpful. A low and high range estimate of $3.5 and $8.7 million were substituted in place of $6.1 million as the value of a statistical life. In addition, adjusted relative cost numbers for injuries MAIS 1 to 5 were determined to remain consistent with the low and high values of a statistical life. A table with the pertinent information follows.

Table VII-7
Monetization of Injury Subtotals, with Comprehensive Relatives
for $3.5, $6.1, and $8.7 million per life saved

		MAIS1	MAIS2	MAIS3	MAIS4	MAIS5	Fatal
$3.5M	Injury Subtotal	$11,951	$166,759	$351,246	$802,496	$2,640,937	$3,504,610
	Comprehensive Relatives	0.0034	0.0476	0.1002	0.2290	0.7536	1.0000
$6.1M	Injury Subtotal	$16,799	$265,938	$490,657	$1,219,777	$4,063,088	$6,104,610
	Comprehensive Relatives	0.0028	0.0436	0.0804	0.1998	0.6656	1.0000
$8.7M	Injury Subtotal	$21,647	$365,117	$630,069	$1,637,059	$5,485,239	$8,704,610
	Comprehensive Relatives	0.0025	0.0419	0.0724	0.1881	0.6302	1.0000

The very same process used to generate Tables VII-5a and VII-6 was applied using these new fatality and injury costs. The range of values for cost per life saved and net cost (total costs minus monetized benefits) are provided in the table below.

Table VII-8
Range for Cost per Equivalent Life saved and Net Costs minus Monetized Benefits,
across 3% and 7% discount factors, by Value of a Statistical Life (in $M)

		$3.5M per life		$6.1M per life		$8.7M per life	
Cost per Equivalent Life Saved	Cameras	10.9	18.1	11.8	19.7	12.3	20.4
	Ultrasonic	87.7	109.1	95.5	118.8	99.1	123.2
	Radar	141.9	176.6	154.5	192.3	160.2	199.5
Net Cost	Cameras	$1,019.2	$1,904.4	$727.6	$1,629.8	$435.9	$1,355.2
	Ultrasonic	$699.4	$701.2	$683.7	$685.5	$666.2	$671.6
	Radar	$1,263.8	$1,270.0	$1,248.4	$1,250.7	$1,231.4	$1,233.1

VIII. Regulatory Flexibility Act and Unfunded Mandates Reform Act Analysis

A. Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small business, small organizations and small Government jurisdictions.

5 U.S.C §603 requires agencies to prepare and make available for public comments initial and final regulatory flexibility analysis (RFA) describing the impact of proposed and final rules on small entities. Section 603(b) of the Act specifies the content of a RFA. Each RFA must contain:

1. A description of the reasons why action by the agency is being considered;
2. A succinct statement of the objectives of, and legal basis for a final rule;
3. A description of and, where feasible, an estimate of the number of small entities to which the final rule will apply;
4. A description of the projected reporting, recording keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the final rule;
6. Each regulatory flexibility analysis shall also contain a description of any significant alternatives which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact on small entities.

1. Description of the reason why action by the agency is being considered

NHTSA is proposing this action to carry out the requirements of the Cameron Gulbransen Kids Transportation Safety Act of 2007.

2. Objectives of, and legal basis for, the final rule

The Act requires the agency to conduct rulemaking to expand the required field of view to prevent backover incidents.

3. Description and estimate of the number of small entities to which the final rule will apply

The final rule will affect motor vehicle manufacturers. There are no light truck manufacturers that are small businesses. However, there are six domestically owned small passenger car manufacturers.

Business entities are defined as small business using the North American Industry Classification System (NAICS) code, for the purpose of receiving Small Business Administration assistance. One of the criteria for determining size, as stated in 13 CFR 121.201, is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, light and heavy duty trucks, buses, motor homes, or motor vehicle body manufacturing, the firm must have less than 1,000 employees to be classified as a small business.

We believe that the rulemaking would not have a significant economic impact on the small vehicle manufacturers because the systems are not technically hard to develop or install and the cost of the systems ($160 to $200) is a small proportion (less than half of one percent) of the overall vehicle cost for most of these specialty cars. The exception is Standard Taxi ($200/$25,000 = 0.8 percent of the sales price). Since every manufacturer needs to meet the standard, the proposal would have no effect on competition. However, it does raise the overall cost, and could affect sales in a small way.

Currently, there are six small passenger car motor vehicle manufacturers in the United States. Table VIII-1 provides information about the 6 small domestic manufacturers in MY 2007. All are small manufacturers, having much less than 1,000 employees.

Table VIII-1
Small Vehicle Manufacturers

Manufacturer	Employees	Estimated Sales	Sale Price Range	Est. Revenues*
Fisker Automotive**	N/A	15,000 projected	$80,000	N/A
Mosler Automotive	25	20	$189,000	$2,000,000
Panoz Auto Development Company	50	150	$90,000 to $125,000	$16,125,000
Saleen Inc.	170	1,000#	$39,000 to $59,000	$49,000,000
Saleen Inc.	170	16##	$585,000	$9,000,000
Standard Taxi***	35	N/A	$25,000	$2,000,000
Tesla Motors, Inc.	250	2,000	$65,000 to $100,000	N/A

* Assuming an average sales price from the sales price range.
** Fisker Automotive is a joint venture of Quantum Fuel Systems Technologies Worldwide, Inc. and Fisker Coachbuild, LLC.
*** Standard Taxi is a subsidiary of the Vehicle Production Group LLC. 35 employees is the total for VPG LLC.
# Ford Mustang Conversions

The agency has not analyzed the impact of the proposal on these small manufacturers individually.

<u>4. A description of the projected reporting, record keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record.</u>

This proposal includes no new requirements for reporting, record keeping of other compliance requirements.

<u>5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the final rule</u>

We know of no Federal rules which duplicate, overlap, or conflict with the final rule.

6. A description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the proposal on small entities.

The agency is considering a variety of alternatives and knows of no other alternatives that can achieve the stated objectives and minimize the impacts on small entities.

B. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by States, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2007 results in $130 million (119.816/92.106 = 1.30). The assessment may be included in conjunction with other assessments, as it is here.

IX. Probabilistic Uncertainty Analysis

This chapter identifies and quantifies the major uncertainties in the cost-effectiveness and net benefit analyses and examines the impacts of these uncertainties. Throughout the course of these analyses, many assumptions were made, diverse data sources were used, and different statistical processes were applied. The variability of these assumptions, data sources, and statistical processes potentially would influence the estimated regulatory outcomes. Thus, all these assumptions, data sources, and derived statistics can be considered as uncertainty factors for the regulatory analysis. The purpose of this uncertainty analysis is to identify the uncertainty factors with appreciable variability, quantify these uncertainty factors by appropriate probability distributions, and induce the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process.

A Monte Carlo statistical simulation technique[38] is used to accomplish the process. The technique is to first randomly select values for those uncertainty factors from their pre-established probability distributions. The selected values then are fed back to the cost-effectiveness and net benefit analysis process to generate all possible outcomes. The process is run repeatedly. Each complete run is a trial. Crystal Ball®[39], a spreadsheet-based risk analysis and forecasting software package which includes the Monte Carlo simulation technique tool, was chosen to automate the process. In addition to simulation results, Crystal Ball® also provides the degree of certainty (or confidence, or credibility) that is associated with the simulated results. The degree of certainty provides the decision-makers an additional piece of important information to evaluate the outcomes.

The analysis starts by establishing mathematical models that imitate the actual processes in deriving cost-effectiveness and net benefits, as shown in previous chapters. The formulation of the models also allows analysts to conveniently identify and categorize uncertainty factors. In the mathematical model, each variable (e.g., cost of technology) represents an uncertainty factor that would potentially alter the model outcomes if its value were changed. Variations of these uncertainty factors are described by appropriate probability distribution functions. These probability distributions are established based on available data. If data are not sufficient or not available, professional judgments are used to estimate the distribution of these uncertainty factors.

After defining and quantifying the uncertainty factors, the next step is to simulate the model to obtain probabilistic results rather than single-value estimates. The simulation

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[38] See a: Robert, C.P. & Casella, G., *Monte Carlo Statistical Methods*, Springer-Verlag New York, Inc., 1999, and
b: Liu, J.S., *Monte Carlo Strategies in Scientific Computing*, Springer-Verlag New York, Inc., 2001
(Or any statistics books describing the Monte Carlo simulation theory are good references for understanding the technique).

[39] A registered trademark of Decisioneering, Inc. (now a unit of Oracle company)

repeats the trials until certain pre-defined criteria[40] are met and a probability distribution of results is generated. Note that the uncertainty analysis did not examine the technology "look-down mirrors" since the mean benefit estimated in the previous chapter is 0.

A. Simulation Models

Mathematical models were built to imitate the process used in deriving cost-effectiveness and net benefits as developed in previous chapters. Both the cost-effectiveness and net benefit models comprise three principal components: injury benefits, property damage savings/costs, and vehicle technology costs. These three components are discussed separately in the following sections.

A.1 Injury Benefit Component

In the cost-effectiveness model, injury benefits are represented by fatal equivalents (FEs) reduced. In the net benefit model, injury benefits are represented by their monetary value, which is the product of comprehensive cost per life saved and FEs. Since benefits (fatalities and injuries reduced) were already expressed as FEs in the cost-effectiveness model, the net benefit model is just one step removed from the cost-effectiveness model. Therefore, the FE model is discussed first.

FEs is derived through the following steps:

1. Establishing baseline fatal and injury populations
2. Deriving initial injury benefits (i.e., fatalities and MAIS 1-5 injuries eliminated by the proposal),
3. Adjusting the initial injury benefits to account for technology installation rate for MY 2010 fleet passenger vehicles (2010-based adjustment factor)
4. Deriving FEs by multiplying the injury benefits by their corresponding injury-to-fatality ratios, and
5. Discounting FEs to derive the discounted net benefits over the vehicle's life.

Therefore, FEs can be represented by the following mathematical formula for each of the technologies examined in the PRIA:

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[40] The pre-defined criteria may change with each uncertainty analysis. In this case, we require a 99 percent precision in mean for each simulated outcome such as total costs, cost-effectiveness, and net benefits as described later.

$$FEs = \sum_{i=1}^{2}[\sum_{j=1}^{6} T_{ij} * e * r_j] * a_i * d_i \text{ - - - - - } (1)$$

Where,

T_{ij} = target population, i=1 for PCs and i=2 for LTVs; j=1 as MAIS j injuries with j=6 as fatalities

e = effectiveness of the technology against the target population

r_j = MAIS j injury-to-fatality ratio with j=6 as fatalities

a_i = 2010-based adjustment factor

d_i = cumulative lifetime discount factor, either at 3 or 7 percent discount rate.

The effectiveness "e" defined here is essentially the product of three independent factors: (1) the percentage of cases that were found to be "avoidable", i.e., avoidability (f_A), the percentage of cases in which the system performs and provides the needed information (f_S), and the percentage of cases where drivers will recognize the information from the system and act appropriately to actually avoid a crash (f_{DR}). Therefore, e can be further expanded as:

$e = f_A * f_S * f_{DR}$

Also, a_i, the 2010-based adjustment factor is basically equal to 1 minus the technology installation rate in MY 2010 passenger vehicle fleet.

The product of the target population (T_{ij}) and the corresponding technology effectiveness rate (e) represents the initial injury severity j benefits for the ith vehicle type (= T_{ij}*e = T_{ij}* f_A * f_S * f_{DR}). Multiplying the injury severity j benefits by its corresponding injury-to-fatality ratio [= T_{ij}*e * r_i]) derives its FEs. Summed over the injury severity (index j) thus derives the total FEs for the ith vehicle type type (= $\sum_{j=1}^{6} T_{ij} * e * r_j$). The initial FEs then were adjusted to 2010 level to account for technology installation rate by multiplying it by the 2010-based adjustment factor a_i [= $\sum_{j=1}^{6} T_{ij} * e * r_j$ * a_i)]. Finally, the total FEs are discounted either at a 3 or 7 percent rate to reflect the net benefits of the rule over a vehicle's life.

FEs is the basic benefit measurement for estimating cost-effectiveness. For net benefits, FEs are translated into monetary value. If M denotes the cost per fatality, benefit in the net benefit calculation is equal to M*FEs. Hence, the benefit component for net benefits is:

$$M * FEs = M * \sum_{i=1}^{2}[\sum_{j=1}^{6} T_{ij} * e * r_j] * a_i * d_i$$

$$= M * \sum_{i=1}^{2}[\sum_{j=1}^{6} T_{ij} * f_A * f_S * f_{DR} * r_j] * a_i * d_i$$

A.2 Lifetime Property Damage Savings (S)

Property damage savings include the benefits of eliminating backing over crashes and the costs for technology repair/maintenance from property damage only and rear-end crashes. Property damage savings are realized over a vehicle's life and would be discounted at 3 and 7 percent. Therefore, S can be represented by the following mathematical formula:

$$S = \sum_{i=1}^{2} u_i * v_i * a_i$$

Where,

u_i = discounted (at 3 or 7 percent) unit lifetime property damage savings for affected

vehicles, with i=1 as PCs and j=2 as LTVs

v_i = number of new vehicles

a_i = 2010-based adjustment factor.

A.3 Vehicle Technology Cost Component

Vehicle technology cost (VC) is the product of technology cost per affected vehicle and the number of affected vehicles. The number of affected vehicles can be derived by multiplying the total number of new vehicles and the proportion of vehicles that need to install the technology (i.e., number of new vehicles * 2010-based adjustment factor). The 2010-based adjustment factor used in the cost component is further segregated by implementation options (full or partial system). The vehicle technology cost of the proposal can be represented as:

$$VC = \sum_{i=1}^{2} \sum_{j=1}^{2} c_{ij} * v_i * a_{ij}$$

Where, VC = vehicle technology cost

c_{ij} = technology cost per affected vehicle, i=1 for PCs and i=2 for LTVs;
j=1 for full system and j=2 for partial system

v_i = number of new vehicles

a_{ij} = 2010-based adjustment factor.

Note that, the 2010-based adjustment factor a_i used in the FE model is the sum of corresponding full (a_{i1}) and partial system adjustment factor (a_{i2}), i.e., $a_i = a_{i1} + a_{i2}$. The full and partial systems primarily are for camera systems. A full system includes a camera and a display system. A partial system only includes a camera. The partial system would be required for vehicles that already are equipped with an in-dash navigation unit.

A.4 Cost-Effectiveness Model and Net Benefit Model

After the fatal equivalents, property damage savings/costs, and vehicle technology cost were established, the cost-effectiveness model (CE) is calculated as the ratio of net costs

(NC) to fatal equivalents (FEs) where NC is equal to vehicle technology cost (VC) minus lifetime property damage savings (S). The cost-effectiveness model (CE) has the format:

$$\begin{aligned} CE &= \frac{NC}{FEs} \\ &= \frac{VC - S}{FEs} \end{aligned}$$

The net benefit is the difference between benefits expressed in monetary value and the net cost. Thus, the net benefit model (NB) has the format:

$$\begin{aligned} NB &= M * FEs - NC \\ &= M * FEs + S - VC \end{aligned}$$

Where, M is the cost per fatality.

B. Uncertainty Factors

Each parameter in the above cost-effectiveness and net benefit model represents a major category of uncertainty factors. Therefore, there are ten major categories of uncertainty factors that would impact the cost-effectiveness: (1) target crash population, T_{ij}, (2) avoidability, $f_{A,}$ (3) system performance factor, f_S, (4) driver factor, f_{DR}, (5) 2010-based adjustment factors a_{ij}, (6) injury-to-fatality ratios, r_i, (7) cumulative lifetime discount factors, d_i, (8) discounted unit lifetime property damage savings, u_i, (9) technology cost per affected vehicle, c_i, and (10) number of new vehicles, v_i. The net benefit model has one additional uncertainty factor (11) cost per life, M, in addition to ten for the cost-effectiveness model.

<u>Target population, T_{ij},</u> is important to benefit estimates because it defines the crash population of risk without the proposal. Fatal and injury target populations were derived from three data systems: FARS, GES, and NiTS. The major uncertainties in this factor arise from reporting errors in NiTS and survey errors in GES. The reporting errors in NiTS are not available due to the lack of an established off-roadway crash baseline to which NiTS can be compared. Consequently, the overall variation of the target population is unknown. However, given that NiTS has sufficient sample and that sampling systems including GES generally allow a 5 percent sampling error, a normal distribution with a standard error as 10 percent of the mean is considered sufficient to describe variations of the target populations.

Note that probability functions for target fatal and MAIS injury populations cannot be established independently because their relative ratios are expected to regress to the mean relative ratios as reported in the crash databases. To address this interdependency issue, the analysis first established the variation for the overall target population (i.e., all injury and fatalities). After establishing the variation (i.e., a normal distribution with 10 percent of the mean as one standard deviation), the overall target population was distributed into fatalities and MAIS injuries. The distribution was based on their mean proportions. These mean proportions are treated as constants.

Avoidability f_A, is significant since it would affect the effectiveness of the proposed technology. The sources of its uncertainty include the bias inherent in the expert judgments and the representativeness of cases where f_A were derived from. Since a team of reviewers first accessed the value of f_A independently for each of the selected cases and then they jointly resolved any discrepancies, the point estimate of f_A for each case is considered to be a fair assessment. Furthermore, the sample cases that were reviewed by the team are adequate to represent backing over crashes. Therefore, the agency believes that the range between the avoidable percentage and the combined percentage of "avoidable", "possibly avoidable", and "possibly not avoidable" is sufficient to capture the variation for f_A. In order words, for each technology examined by the PRIA, the value of f_A would fall between these two percentages.

Due to the range constraint, beta probability distributions are chosen to describe the variations for f_A for its flexibility and capability of setting distribution boundary. In addition to lower and higher bounds, a beta distribution has two more parameters, α and β, that determine the shape of the beta distribution. The values of α and β were established by setting the mean of the distribution as the combined percentage of "avoidable" and "possibly avoidable" cases.

System performance factor, f_S, addresses the limitation of the technologies and would also affect the effectiveness of technologies. However, this factor is primarily used in determining the reliability of sensor-based systems such as ultrasonic and radar systems. It would not affect the camera systems. Sources of uncertainty for f_S include experimental errors and production variation. Based on expert assessment and the agency's experience with manufacturers' production reliability of vehicle safety systems, a 10 percent performance variation is considered to be sufficient to account for the majority of the uncertainties associated with f_S. Any value within this range is expected to have an equal chance to be the true system performance. Thus, the analysis treats f_S as uniformly distributed for the ultrasonic and radar systems. It is treated as constant with value of 1 since it does not impact the camera systems.

Driver factor, f_{DR}, also affects the effectiveness of the technologies examined in the PRIA. The sources of its uncertainty include, but are not limited to, experimental errors, representativeness of drivers used for the experiment, driving environment, and driver conditions. Variations for these uncertainty sources are unknown. Nevertheless, the analysis treats the values of f_{DR} as normally distributed to account for the impact of this factor. One standard deviation is set to be 10 percent of the mean.

2010-based adjustment factors, a_{ij}, are used to adjust the initial benefits and costs to 2010 level. The source of its uncertainty primarily is from projection errors. Since, a_{ij} would impact both benefits and costs of the proposal in similar magnitude. Variations for these factors thus would not be expected to increase the uncertainty level for cost-effectiveness and net benefit measurements. Therefore, this factor is treated as a constant.

Injury-to-fatality ratios, r_j, reflect the relative economic impact of injuries compared to fatalities based on their estimated comprehensive unit costs. They were derived based on the 2007 update of the most current 2002 crash cost assessment[41]. The crash cost assessment itself is a complex analysis with an associated degree of uncertainty. At this time, these uncertainties are also unknowns. Thus, the variation in these ratios is unknown and the analysis treats these ratios as constants.

Cumulative lifetime discount factors, d_i, represent the present discount factor over the vehicle's life. These factors are derived based on the agency study on vehicle miles traveled and vehicle survivability[42]. Variation of these factors comes from vehicle mileage surveys, national vehicle population, and statistical process. These uncertainties cannot be quantified at this time. Thus, the analysis treats these factors as constants.

Discounted unit lifetime property damage savings, u_i, is expected to have certain level of variability. Its variations come from many sources: the probability that a vehicle over its lifespan would be involved in property damage only or rear-end crashes, the cost of repairing/replacing the proposed technology, annual vehicle miles traveled, survival probability of the vehicle, and the discount rate. Variations for these sources are unknown at this time. Given its impact on the overall cost of the proposal, the uncertainty analysis treats the distribution of u_i similar to that of the technology cost which is treated as uniformly distributed (see below). In other words, the value of u_i is treated as uniformly distributed with a 10 percent deviation from the mean, i.e., $0.9*\text{mean} \le u_i \le 1.1*\text{mean}$.

Technology cost per affected vehicle, c_i, is a concern. The sources of cost uncertainties arise from, but are not limited to, maturity of the technologies/countermeasures and potential fluctuation in labor and material costs (e.g., due to economics from production volume). According to professional judgments of NHTSA cost analysts and contractors, the cost generally will fall within 10 percent of the point estimate shown in the cost chapter. Any cost within this range would have equal chance to be the true cost. Thus, the analysis treats the cost as uniformly distributed.

Number of new vehicles, v_i, is an uncertainty factor that would impact the cost estimates. Although, vehicle sales have gradually increased over time, they are subject to annual variation due to changes in economic conditions, which are difficult to predict as evidenced in 2007-2009 recession. Thus, v_i is treated as a constant.

The ten factors discussed above would impact the cost-effectiveness outcome. The net benefit model has an additional factor, the cost of statistical life, M.

Cost per statistical life, M, is an uncertainty factor for net benefits. The cost is based on recent meta-analyses of the wage-risk value of statistical life (VSL). These meta-analyses deployed different statistical methodologies and assumptions. But, generally, these studies show that an individual's willingness-to-pay (WTP) for reduction in

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[41] The Economic Impact of Motor Vehicle Crashes 2000, NHTSA DOT HS 809 446, May 2002

[42] Vehicle Survivability and Travel Mileage Schedules, Technical Report, DOT HS 809 952, January 2006 (Docket No. 22223-2218)

premature fatalities is from $1 million to $10 million[43]. After adjusted to 2007 value, WTP is ranged from $1.6 to $10.6 million. The agency assumes the value of M is normally distributed with mean $6.1 million and its three standard deviations were between the mean and the updated range.

C. Quantifying the Uncertainty Factors

This section establishes the appropriate probability distributions for the uncertainty factors that come with appreciable variations (i.e., target crash population and effectiveness) and quantifies the constant values for other factors.

Target Crashes, T_{ij}. As previously described, probability distributions for fatal and MAIS injury target populations are not established independently due to interdependency of their relative size. A normal probability distribution for the overall target population was established first. The mean of the normal distribution is the overall mean population reported in the target population section. One standard deviation is set to be 10 percent of the mean. The established variations then were distributed to fatalities and injuries based on their relative mean ratios. Thus, probability distributions for fatal and individual MAIS injury population were actually generated through the simulation process.

The overall target population is 15,117 (non-fatal and fatal injuries combined). Therefore, the mean of the normal distribution is 15,117 and one standard deviation is 1,512. After the variation for the overall target population was established, T_{ij} for each i and j, was derived by applying their respective proportion to the overall target population. Basically, each T_{ij} is a product of the overall target population and a constant (i.e., its proportion). As a result, each T_{ij} also is normally distributed with 10 percent of its mean as one standard deviation. Figure IX-1 depicts the simulated probability distributions for fatal and MAIS injury target population. The proportions used to derive the fatal and MAIS injury target populations are treated as constants. They are represented by their respective mean proportions shown in the initial target population. Table IX-1 shows these proportions.

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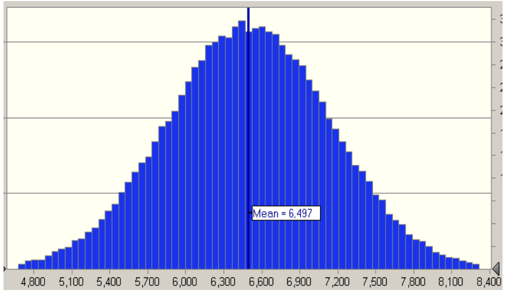
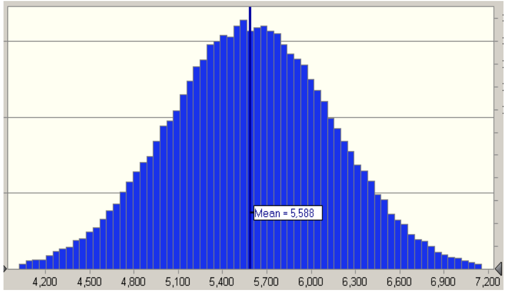
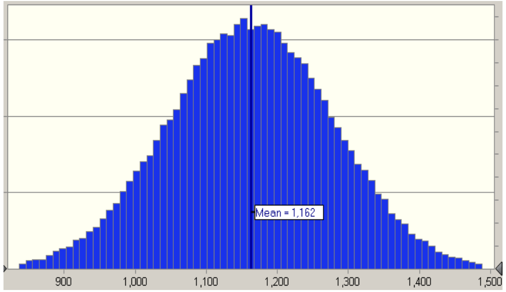
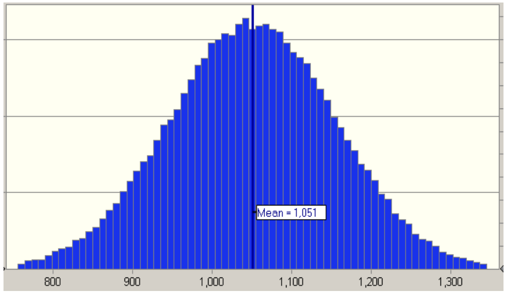
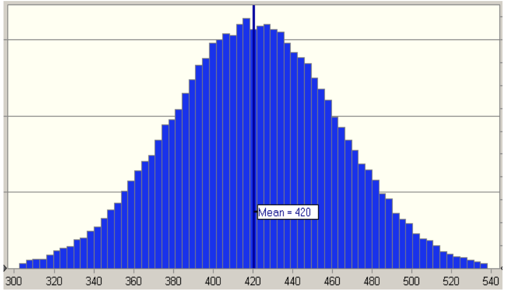
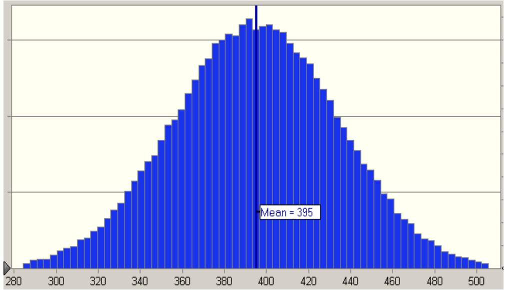
[43] See a: Mrozek, J.R. and L.O. Taylor, What determines the value of a life? A Meta Analysis, Journal of Policy Analysis and Management 21 (2), pp. 253-270,

b: Viscusi , W. K., The Value of Life: Estimates with Risks by Occupation and Industry, Economic Inquiry, Oxford University Press, vol. 42(1), pages 29-48, January, 2004, and

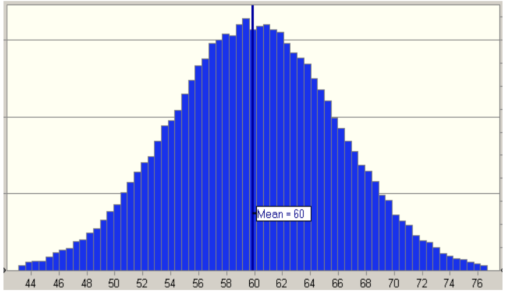
c: Viscusi, W. K. & Aldy, J.E., The Value of a Statistical Life: A Critical Review of Market Estimates through Out the World, Journal of Risk and Uncertainty, Kluwer Academic Publishers, vol. 27(1), pages 5-76, August, 2003.

Figure IX-1
Simulated Normal Probability Distributions for Target Population (T_{ij})

PCs	LTVs
 MAIS 1 Injuries (T_{11}) Mean: 6,497; SD: 650	 MAIS 1 Injuries (T_{21}) Mean: 5,588; SD: 559
 MAIS 2 Injuries (T_{12}) Mean: 1,162; SD: 116	 MAIS 2 Injuries (T_{22}) Mean: 1,051; SD: 105
 MAIS 3 Injuries (T_{13}) Mean: 420; SD: 42	 MAIS 3 Injuries (T_{23}) Mean: 395; SD:40

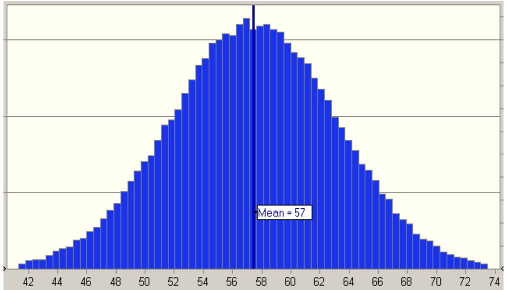
PCs: passenger cars, LTVs: light trucks/vans

Figure IX-1 - Continued
Simulated Normal Probability Distributions for Target Population (T_{ij})



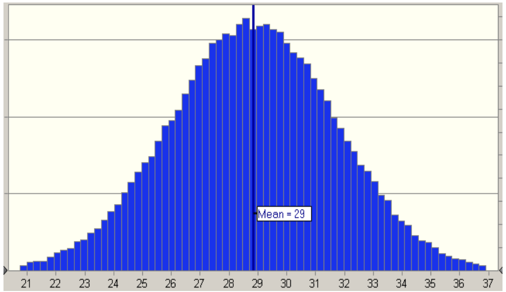
MAIS 4 Injuries (T_{14})

Mean: 60; SD: 6



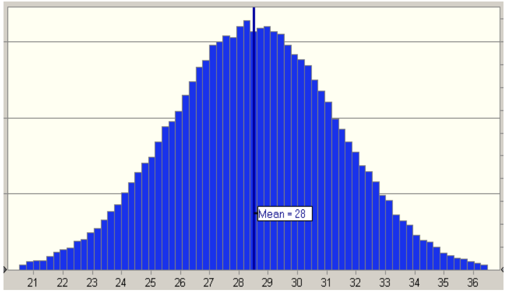
MAIS 4 Injuries (T_{24})

Mean: 57; SD: 6



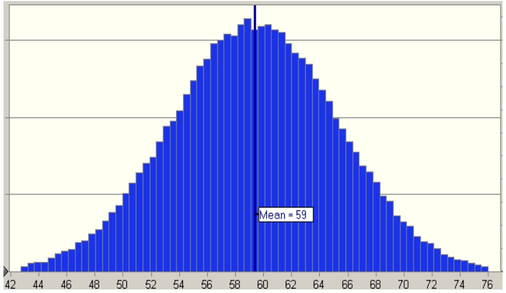
MAIS 5 Injuries (T_{15})

Mean: 29; SD: 3



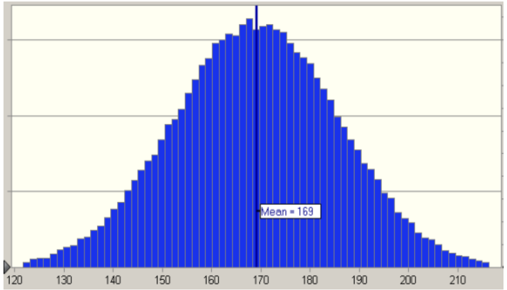
MAIS 5 Injuries (T_{25})

Mean: 28; SD: 3



Fatalities (T_{16})

Mean: 59; SD: 6



Fatalities (T_{26})

Mean: 169; SD: 17

PCs: passenger cars, LTVs: light trucks/vans

Table IX-1
Constant Values for Distributing Target Population

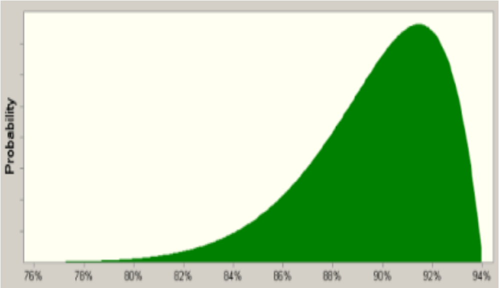
	PCs	LTVs
MAIS 1	0.4187	0.3602
MAIS 2	0.0749	0.0677
MAIS 3	0.0271	0.0255
MAIS 4	0.0039	0.0037
MAIS 5	0.0019	0.0018
Fatalities	0.0038	0.0109
Column Total	0.5302	0.4698

Avoidability f_A. Values of f_A are assumed to be beta distributed and bounded by the percentage of avoidable cases and the combined percentage of "avoidable", "possibly avoidable", and "possibly not avoidable" cases. The shape parameters α and β of the beta distribution function were determined by ensuring that the mean of the distribution is equal to the percentage of avoidable and possible avoidable cases. Figure IX-2 depicts the beta distribution for each of the technologies examined in the PRIA. Due to the range and mean constraints, as shown, these distributions tend to be negatively skewed, i.e., a distribution with a relatively longer tail towards the lower end of values.

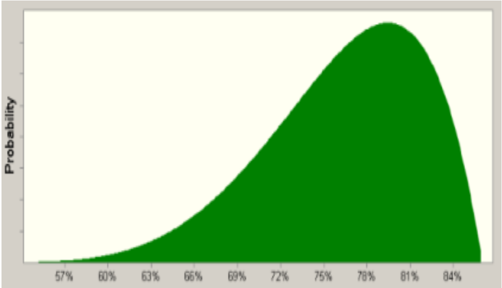
System performance factor, f_S. The system performance factor represents the average performance of sensors. Thus, it only impacts sensor-based ultrasonic and radar systems. Its effect on these two systems is assumed to be identical. Values of f_S are treated as uniformly distributed. Since the factor does not apply to the camera systems, it is set to be 1.

Two parameters maximum (f_{SMax}) and minimum (f_{SMin}) are required to establish a uniform distribution for f_s. With these two parameters, the uniform distribution can be represented as:
The mean of the distribution is set to be the point estimate presented in the previous chapter. The maximum and minimum of f_s are assumed to be a 10 percent deviation from the mean, i.e., $0.9*\text{mean} \le f_s \le 1.1*\text{mean}$. Therefore, for ultrasonic and radar systems, the mean of f_s is 70.37 percent, f_{SMin} = 63.33 percent, and f_{SMax} = 77.41 percent.

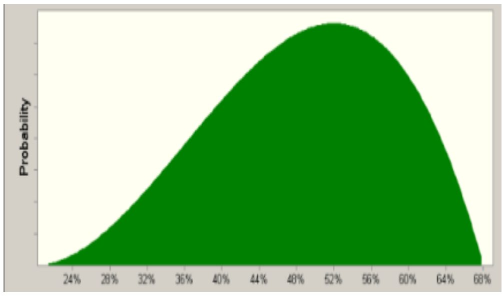
Figure IX-2
Beta Distributions for Avoidability Factor (f_A) by Technology

<table>
<tr>
<td>


180° View Camera

Minimum: 66%; Maximum: 94%
Mean: 90%
$\alpha = 11; \beta = 2$
</td>
<td>


130° View Camera

Minimum: 50%; Maximum: 86%
Mean: 76%
$\alpha = 5.5; \beta = 2$
</td>
</tr>
<tr>
<td>


Ultrasonic

Minimum: 20%; Maximum: 68%
Mean: 49%
$\alpha = 3; \beta = 2$
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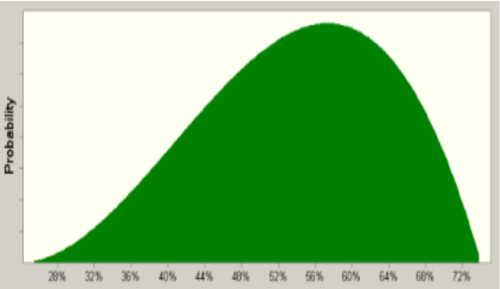
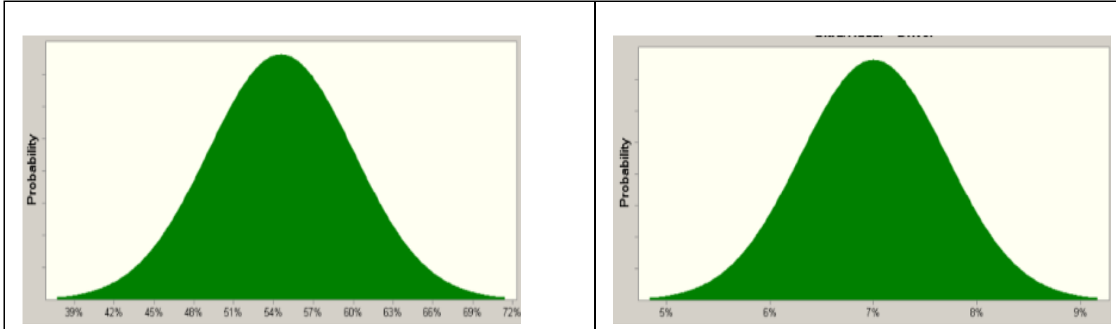
<td>


Radar

Minimum: 24%; Maximum: 74%
Mean: 54%
$\alpha = 3; \beta = 2$
</td>
</tr>
</table>

<u>Driver factor, f_{DR}</u>. This factor varies depending on whether the technology of interest is a camera- or sensor-based system. Values for this factor are assumed to be normally distributed for both systems. One standard deviation is set to be the 10 percent of the mean. Figure IX-3 depicts the normal distribution for f_{DR}.

Figure IX-3
Normal Distribution for Driver Factor (f_{DR})



Camera Systems
(180° and 130° View)

Mean: 55%; SD: 6%

Sensor-Based Systems
(Ultrasonic and Radar)

Mean: 7%; SD: 1%

2010-based adjustment factors, a_{ij}. The analysis treats these factors as constant. They vary by vehicle types (i.e., PCs and LTVs) and technology types. Table IX-2 lists these constants. As shown, for camera systems, a_{11} = 82.2%, a_{12} = 7.3%, a_{21} = 56.7%, and a_{22} = 13.2%. For sensor-based systems, a_{11} = 90.9%, a_{12} = 0.0%, a_{21} = 70.3%, and a_{22} = 0.0%. Note that the factor a_i used in the FE model is the sum of full and partial system factors as shown in the table. For example, a_1 = 89.5% and a_2 = 69.9% for camera systems and a_1 = 90.9% and a_2 = 70.3% for sensor-based systems.

Table IX-2
Constant Values for 2010-Based Adjustment Factors (a_{ij}) by Technology and Vehicle Type

Detection Technology		PCs	LTVs
Camera Systems	Full System	82.2%	56.7%
(180° and 130° View)	Partial System*	7.3%	13.2%
	Total	89.5%	69.9%
Sensor-Based Systems	Full System	90.9%	70.3%
(Ultrasonic and Radar)	Partial System*	0.0%	0.0%
	Total	90.9%	70.3%

*Needed only the camera, only applicable to camera-based systems

<u>Injury-to-fatality equivalent ratios (r_i)</u>. These factors are treated as constants. Table IX-3 lists the injury-to-fatality equivalent ratios which are used to translate non-fatal injuries to fatal equivalents.

Table IX-3
Injury-To-Fatality Equivalence Ratios (r_j)*

	Injury-To-Fatality Equivalence Ratios
MAIS 1 (r_1)	0.00275
MAIS 2 (r_2)	0.04356
MAIS 3 (r_3)	0.08037
MAIS 4 (r_4)	0.19981
MAIS 5 (r_5)	0.66558
Fatality (r_6)	1.00000

<u>Cumulative lifetime discount factors (d_i)</u>. These factors are treated as constants. At a 3 percent discount, $d_1 = 0.8304$ for PCs and $d_2 = 0.8022$ for LTVs. At 7 percent discount, $d_1 = 0.6700$ for PCs and $d_2 = 0.6303$ for LTVs.

<u>Unit lifetime property damage savings, u_i</u>. The analysis treats these factors as uniformly distributed. Table IX-4 lists the maximum and minimum values that are used to establish the uniform distribution. The mean values are also presented in the table. Note that negative values represent cost. As shown, both cameras systems would save property damage costs at both discount rates. In contrast, the ultrasonic and radar systems would not.

Table IX-4
Discounted Unit Lifetime Property Damage Savings Per Vehicle (u_i) Parameters for Uniform Distribution by Technology Type and Discount Rate
(2007 Dollar)

@3% Discount

	Mean	Minimum	Maximum
180° View Camera	$28.56	$25.70	$31.42
130° View Camera	$31.43	$28.29	$34.57
Ultrasonic	-$3.35	-$3.69	$-3.02
Radar	-$5.50	-$6.05	-$4.95

@7% Discount

	Mean	Minimum	Maximum
180° View Camera	$23.59	$21.23	$25.95
130° View Camera	$25.96	$23.36	$28.56
Ultrasonic	-$2.76	-$3.04	$-2.48
Radar	-$4.54	-$4.99	-$4.09

Note: negative numbers represent cost

Technology cost per affected vehicle, c_i. The analysis assumes the cost factors are uniformly distributed. As described earlier, a uniform distribution would be established by a maximum and a minimum value. Based on expert judgment and the agency's experience with cost assessment, a 10 percent cost fluctuation from the mean cost is believed to be sufficient to describe the overall technology cost variation. The cost varies by technology and its installation options. Table IX-5 lists the cost per affected vehicle by technology and installation options. These costs represent the investments paid now for future benefits and thus no discounting is needed.

Table IX-5
Parameters for Uniform Distribution for Technology Cost per Affected Vehicle (c_i) by Technology Type and Installation Option

(2007 Dollar)

Technology – Installation	Mean	Minimum	Maximum
180° View Camera – Mirror	\$202.94	\$182.65	\$223.24
130° View Camera – Mirror	\$172.74	\$155.47	\$190.02
180° View Camera – Dashboard			
Full System	\$189.05	\$170.15	\$207.96
Camera Only (Partial System)	\$88.18	\$79.37	\$97.00
130° View Camera – Dashboard			
Full System	\$158.85	\$142.97	\$174.74
Camera Only (Partial System)	\$57.98	\$52.19	\$63.78
Ultrasonic	\$51.49	\$46.34	\$56.64
Radar	\$92.26	\$83.03	\$101.49

Number of new vehicles, v_i,. These factors are constant. The total number of passenger vehicles is 16.6 million. Of these, 8,000,000 are PCs, and 8,600,000 are LTVs. In other words, v_1 = 8,000,000 and v_2 = 8,600,000

Cost per fatality, M, is an uncertainty factor for net benefits. The value of M largely depends on the value of statistical life (VSL). The cost is based on recent meta-analyses of the wage-risk value of VSL. These meta-analyses deployed different statistical methodologies and assumptions. But, generally, these studies show that an individual's willingness-to-pay (WTP) for reduction in premature fatalities is from \$1 million to \$10 million[44]. In the past, when a \$3.0 million VSL was the DOT guideline for cost-benefit analysis, the agency used this \$1-\$10 million as the range for M and assumed the value of M is normally distributed with its mean equal to \$5.5.million. However, in 2008 DOT has issued a new guideline requiring a \$5.8 million VSL to be used for cost-benefit analysis. The corresponding comprehensive cost is estimated to be \$6.1 million in 2007 dollars. To reflect this change and to be consistent with the cost-benefit analysis described in the previous chapters, the normal distribution for M has been revised to reflect the comprehensive cost per fatality. Thus, the distribution for M has a mean of

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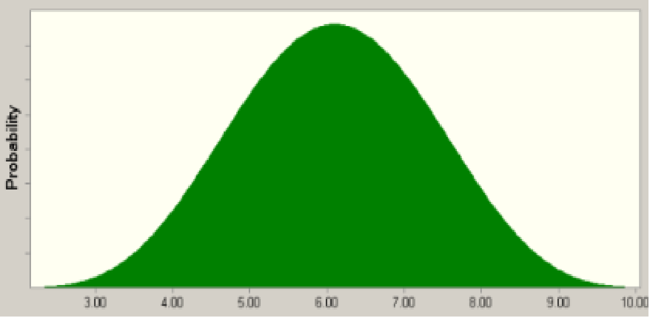
[44] See a: Mrozek, J.R. and L.O. Taylor, What determines the value of a life? A Meta Analysis, Journal of Policy Analysis and Management 21 (2), pp. 253-270,
b: Viscusi , W. K., The Value of Life: Estimates with Risks by Occupation and Industry, Economic Inquiry, Oxford University Press, vol. 42(1), pages 29-48, January, 2004, and
c: Viscusi, W. K. & Aldy, J.E., The Value of a Statistical Life: A Critical Review of Market Estimates through Out the World, Journal of Risk and Uncertainty, Kluwer Academic Publishers, vol. 27(1), pages 5-76, August, 2003.

$6.1 million. The range of this factor also shifts rightwards from 1 to 10 million to $1.6 to $10.6 million.

Figure IX-4
Normal Distribution for Cost Per Fatalities (M)
(2007 Dollar in Millions)



D. Simulation Results

The Monte Carlo simulation first randomly selects a value for each of the significant factors based on their probability distributions. Then, the selected values are fed into the model to forecast the results. Each process is a trial. The simulation repeats the process until a pre-defined accuracy has been accomplished. Since Crystal Ball is a spreadsheet-based simulation software, the simulation model actually is a step-wise process, i.e., the simulation estimates gross benefits, the net benefits (after redistribution of gross benefits through the injury redistribution process), fatal equivalents, cost-effectiveness, and net benefits. Therefore, each of these forecasted results had certainty bounds. This uncertainty analysis conducted a total of 10,000 trials before the forecasted mean results reached 99 percent precision. Even if the later criterion was reached first, the trial numbers generally are very close to 10,000. These criteria were chosen to ensure the simulation errors ($\approx \frac{1}{10,000}$) would be very close to 0. Therefore, the results would truly reflect the probabilistic nature of the uncertainty factors.

Table XI-6 summarizes the simulated injury benefit results at no discount level after about 10,000 trials. As shown, undiscounted, the 180° view cameras would eliminate 40 to 144 fatalities and 2,908 to 10,369 MAIS 1-5 injuries. These fatalities and injuries equate to 89 – 318 equivalent lives. The 130° view cameras would eliminate 31 to 126 fatalities and 2,233 to 9,037 MAIS 1-5 injuries. This indicates that 130° view cameras would save 68 – 277 equivalent lives. By contrast, ultrasonic systems would eliminate 1 to 9 fatalities and 89 to 632 MAIS 1-5 injuries. These fatalities and injuries equate to 3 – 19 equivalent lives. Radar systems would eliminate 1 to 11 fatalities and 98 to 756 MAIS 1-5 injuries. These benefits are equivalent to 3 – 23 lives saved.

Table IX-6
Simulated Injury Benefits (No Discount)

	180^o View Camera	130^o View Camera	Ultrasonic	Radar
Fatalities Reduced				
Mean	84	71	4	5
Range	40 – 144	31 – 126	1 – 9	1 – 11
90% Certainty	64 – 104	53 – 90	3 – 6	3 – 7
MAIS Injuries Eliminated				
Mean	5,998	5,107	299	331
Range	2,908 – 10,369	2,233 – 9,037	89 – 632	98 – 756
90% Certainty	4,626 – 7,480	3,831 – 6,500	181 – 428	205 – 469
Equivalent Lives Saved				
Mean	184	157	9	10
Range	89 – 318	68 – 277	3 – 19	3 – 23
90% Certainty	142 – 229	117 – 199	6 – 13	6 – 14

Tables IX-7 and IX-8 summarize the simulated cost-effectiveness and net benefit results at 3 and 7 percent discount, respectively. As shown in Table IX-7, at a 3 percent discount rate, the 180^o view camera systems would save 116 - 187 equivalent lives with a 90 percent certainty. With the same level of certainty, the 130^o view camera systems would save 96 - 162 equivalent lives, the ultrasonic systems would save 5 - 11 equivalent lives, and the radar systems would save 5 - 12 equivalent lives.

With the same 90 percent certainty, the net cost would range from $1.7 (dashboard systems) to $2.5 billion (mirror systems) for the 180^o view camera systems, $1.3 to $2.1 billion for the 130^o view camera systems, $0.7 to $0.8 billion for the ultrasonic systems, and $1.2 to $1.4 billion for the radar systems.

At a 7 percent discount rate, as shown in Table IX-8, the 180^o view camera systems would save 92 - 149 equivalent lives with a 90 percent certainty. At this certainty level, the 130^o view camera systems would save 76 - 129 equivalent lives. Both ultrasonic and radar systems each would save 4 - 9 equivalent lives.

The net cost would range from $1.8 to $2.6 billion for the 180^o view camera systems, $1.4 to $2.1 billion for the 130^o view camera systems, $0.7 to $0.9 billion for the ultrasonic systems, and $1.2 to $1.4 billion for the radar systems (cost ranges are similar to those at 3% discount rate due to rounding).

All four technologies examined in the PRIA are not cost effective based on the $6.1 million per fatality and $0 net benefit measurements. At both discount rates, none of the four technologies would have chance to produce a cost per equivalent fatality of no more than $6.1 million. Also, none of these technologies would generate a positive net benefit.

Table IX-7
Simulated Cost-Effectiveness and Net Benefits
(2007 Dollar)

@3% Discount

	Camera Systems			
Technology Costs*	180° View Mirror	130° View Mirror	180° View Dashboard	130° View Dashboard
Mean	$2,673 M	$2,276 M	$2,317 M	$1,919 M
Total Range	$2,406 – $2,940 M	$2,048 – $2,503 M	$2,085 – $2,548 M	$1,728 – $2,111 M
90% Certainty Range	$2,433 – $2,914 M	$2,070 – $2,480 M	$2,122 – $2,512 M	$1,756 – $2,083 M
Equivalent Lives Saved				
Mean	150	128	150	128
Total Range	73 – 259	56 – 226	73 – 259	56 – 226
90% Certainty Range	116 – 187	96 – 162	116 – 187	96 – 162
Lifetime Property Damage Savings				
Mean	$376 M	$414 M	$376 M	$414 M
Total Range	$339 – $414 M	$373 – $455 M	$339 – $414 M	$373 – $455 M
90% Certainty Range	$342 – $410 M	$377 – $451 M	$342 – $410 M	$377 – $451 M
Net Cost**				
Mean	$2,297 M	$1,862 M	$1,941 M	$1,505 M
Total Range	$1,993 – $2,600 M	$1,593 – $2,130 M	$1,678 – $2,208 M	$1,275 – $1,737 M
90% Certainty Range	$2,056 – $2,539 M	$1,654 – $2,069 M	$1,743 – $2,138 M	$1,336 – $1,674 M
Lifetime Property Damage Cost				
Cost-Effectiveness (CE)				
Mean	$15.7 M	$15.0 M	$13.2 M	$12.1 M
Total Range	$8.2 – $33.1 M	$7.6 – $36.4 M	$6.8 – $27.2 M	$6.0 – $29.4 M
90% Certainty Range	$11.9 – $20.3 M	$11.1 – $19.9 M	$10.1 – $17.2 M	$9.0 – $16.1 M
Certainty that CE ≤ $6.1 M	0%	0%	0%	0%
Net Benefit (NB)				
Mean	-$1,383 M	-$1,083 M	$-1,029 M	$-727 M
Total Range	-$2,248 to -$93 M	-$1,873 to $21 M	-$1,874 to $359 M	-$1,457 to $420 M
90% Certainty Range	-$1,825 to -$909 M	-$1,469 to -$667 M	-$1,441 to -$578M	-$1,086 to -$333M
Certainty that NB > $0	0%	0%	0%	0.2%

M: million
* No discount required, same for all discount rates
** = Technology Cost – Lifetime Property Damage Savings

Table IX-7 - Continued
Simulated Cost-Effectiveness and Net Benefits
(2007 Dollar)

@3% Discount

	Sensor Systems	
Technology Costs*	Ultrasonic	Radar
Mean	$686 M	$1,229 M
Total Range	$617 – $754	$1,106 – $1,352
90% Certainty Range	$524 – $747	$1,118 – $1,339
Equivalent Lives Saved		
Mean	7	8
Total Range	2 – 16	2 – 19
90% Certainty Range	5 – 11	5 – 12
Lifetime Property Damage Savings		
Mean	-$45 M	-$73 M
Total Range	-$49 to -$40 M	-$81 to -$66 M
90% Certainty Range	-$49 to -$41 M	-$80 to -$67 M
Net Cost**		
Mean	$731 M	$1,302 M
Total Range	$657 – $803 M	$1,172 – $1,432 M
90% Certainty Range	$669 – $792 M	$1,191 – $1,413 M
Cost-Effectiveness (CE)		
Mean	$104.8 M	$168.0 M
Total Range	$44.1 – $349.3 M	$63.1 – $574.0 M
90% Certainty Range	$67.5 – $162.7 M	$109.8 – $255.5 M
Certainty that CE ≤ $6.1 M	0%	0%
Net Benefit (NB)		
Mean	-$585 M	-$1,252 M
Total Range	-$786 to -$555 M	-$1,410 to -$1,063 M
90% Certainty Range	-$752 to -$618 M	-$1,366 to -$1,139 M
Certainty that NB > $0	0%	0%

M: million
* No discount required, same for all discount rates
** = Technology Cost – Lifetime Property Damage Savings

Table IX-8
Simulated Cost-Effectiveness and Net Benefits
(2007 Dollar)

@7% Discount

	Camera Systems			
Technology Costs*	180° View Mirror	130° View Mirror	180° View Dashboard	130° View Dashboard
Mean	$2,673 M	$2,276 M	$2,317 M	$1,919 M
Total Range	$2,406 – $2,940 M	$2,048 – $2,503 M	$2,085 – $2,548 M	$1,728 – $2,111 M
90% Certainty Range	$2,433 – $2,914 M	$2,070 – $2,480 M	$2,122 – $2,512 M	$1,756 – $2,083 M
Equivalent Lives Saved				
Mean	119	102	119	102
Total Range	58 – 206	44 – 180	58 – 206	44 – 180
90% Certainty Range	92 – 149	76 – 129	92 – 149	76 – 129
Lifetime Property Damage Savings				
Mean	$311 M	$342 M	$311 M	$342 M
Total Range	$280 – $342 M	$308 – $376 M	$280 – $342 M	$308 – $376 M
90% Certainty Range	$283 – $339 M	$311 – $373 M	$283 – $339 M	$311 – $373 M
Net Cost**				
Mean	$2,363 M	$1,934 M	$2,006 M	$1,577 M
Total Range	$2,065 – $2,660 M	$1,672 – $2,194 M	$1,750 – $2,266 M	$1,354 – $1,800 M
90% Certainty Range	$2,122 – $2,603 M	$1,727 – $2,140 M	$1,810 – $2,203 M	$1,411 – $1,744 M
Cost-Effectiveness (CE)				
Mean	$20.2 M	$19.6 M	$17.2 M	$15.9 M
Total Range	$10.8 – $43.3 M	$9.9 – $47.5 M	$9.0 – $35.2 M	$7.8 – $38.7 M
90% Certainty Range	$15.5 – $26.2 M	$14.6 – $25.9 M	$13.2 – $22.0 M	$11.9 – $21.1 M
Certainty that CE ≤ $6.1 M	0%	0%	0%	0%
Net Benefit (NB)				
Mean	-$1,635 M	-$1,314 M	-$1,279 M	$-958 M
Total Range	-$2,397 to -$607 M	-$1,955 to -$391 M	-$1,983 to -$155 M	-$1,559 to -$29 M
90% Certainty Range	-$2,020 to -$1,231 M	-$1,648 to -$960 M	-$1,634 to -$902 M	-$1,264 to -$628 M
Certainty that NB > $0	0%	0%	0%	0%

M: million
* No discount required, same for all discount rates
** = Technology Cost – Lifetime Property Damage Savings

Table IX-8 - Continued
Simulated Cost-Effectiveness and Net Benefits
(2007 Dollar)

@7% Discount

	Sensor Systems	
Technology Costs*	Ultrasonic	Radar
Mean	$686 M	$1,229 M
Total Range	$617 – $754	$1,106 – $1,352
90% Certainty Range	$524 – $747	$1,118 – $1,339
Equivalent Lives Saved		
Mean	6	7
Total Range	2 – 13	2 – 15
90% Certainty Range	4 – 9	4 – 9
Lifetime Property Damage Savings		
Mean	-$37 M	-$60 M
Total Range	-$40 to -$33 M	-$67 to -$54 M
90% Certainty Range	-$40 to -$33 M	-$66 to -$55 M
Net Cost**		
Mean	$723 M	$1,289 M
Total Range	$651 – $795 M	$1,161 – $1,418 M
90% Certainty Range	$661 – $784 M	$1,179 – $1,400 M
Cost-Effectiveness (CE)		
Mean	$130.3 M	$209.1 M
Total Range	$54.8 – $435.6 M	$78.6 – $718.8 M
90% Certainty Range	$83.9 – $202.3 M	$136.7 – $318.0 M
Certainty that CE ≤ $6.1 M	0%	0%
Net Benefit (NB)		
Mean	-$686 M	-$1,249 M
Total Range	-$782 to -$568 M	-$1,401 to -$1,068 M
90% Certainty Range	-$751 to -$622 M	-$1,362 to -$1,137 M
Certainty that NB > $0	0%	0%

M: million
* No discount required, same for all discount rates
** = Technology Cost – Lifetime Property Damage Savings

Appendix A

Comprehensive Costs and Relative Value Factors Reflecting $5.8 million
Value of a Statistical Life (VSL), in 2007 Economics

CPI	Factor	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
1.346066	Medical	$3,204	$21,032	$62,585	$176,747	$447,509	$29,741
1.204077	EMS	$117	$255	$443	$999	$1,026	$1,003
1.277512	Market Prod	$2,234	$31,960	$91,283	$135,977	$560,451	$760,577
1.277512	Household Produce	$731	$9,354	$26,924	$35,782	$190,743	$244,696
1.204077	Ins. Adm.	$892	$8,319	$22,749	$38,934	$82,114	$44,695
1.277512	Workplace	$322	$2,495	$5,450	$6,002	$10,464	$11,117
1.204077	Legal	$181	$5,998	$19,034	$40,559	$96,153	$122,982
1.277512	Travel Delay	$993	$1,081	$1,201	$1,276	$11,697	$11,687
1.204077	Property Damage	$4,628	$4,761	$8,187	$11,840	$11,374	$12,369
1.277512	QALYs	$9,118	$186,525	$262,189	$784,777	$2,674,628	$4,889,799
New Comprehensive Costs		$22,420	$271,780	$500,045	$1,232,893	$4,086,149	$6,128,666
Injury Subtotal		$16,799	$265,938	$490,657	$1,219,777	$4,063,088	$6,104,610
QALY Relatives		0.0019	0.0381	0.0536	0.1605	0.5470	1.0000
Comprehensive relatives (Crash Avoidance)		0.0037	0.0443	0.0816	0.2012	0.6667	1.0000
Comprehensive relatives (Crashworthiness)		0.0028	0.0436	0.0804	0.1998	0.6656	1.0000

QALYs: Quality-Adjusted Life-Years

Note that the $5.8 million value of a statistical life contains elements found in 3 of the factors in the above table (QALY's, household productivity, and the after-tax portion of market productivity). The value of statistical life is thus represented within these 3 factors and is not shown separately.

In Chapter V, we estimated "property damage" benefits separately. Thus, the comprehensive relatives for crash avoidance above should not include the property damage related costs. For the estimates of the "property damage" related to vehicles involved in crashes, property damage and <u>travel delay</u> costs that resulted from the crash were included. When the property damage and travel delay costs were excluded from the new comprehensive costs in the table above, the comprehensive relatives for crash avoidance became the same as the comprehensive relatives for crashworthiness crashes, as shown below:

Relative Value Factors Used in Analysis

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
Comprehensive Relatives	0.0028	0.0436	0.0804	0.1998	0.6656	1.000

Appendix B

Year/Make/Model	Vehicle Type	Laser BZ50x 50	Laser BZ50x 20	Laser BZ50x 8	Laser BZ50x 6	Laser Sight Dist	Back ing Risk
2008 Mazda Mazda6 4-door	Car	932	376	164	123	21.0	1.5
2008 Hyundai Accent 4-door	Car	938	391	198	141	25.3	
2003 Nissan Sentra 4-door	Car	974	344	154	104	17.4	1.6
2008 Hyundai Azera 4-door	Car	1167	494	233	173	29.6	
2008 Nissan Versa 5-door	Car	1184	435	144	99	17.4	
2005 Volkswagen Jetta 4-door	Car	1227	666	249	179	31.6	1.6
2008 Dodge Caliber 4-door	Car	1253	652	249	159	31.6	
2009 Hyundai Sonata 4-door	Car	1299	631	281	207	29.4	
2007 Chevrolet Monte Carlo 2-door	Car	1300	479	175	136	22.4	2.1
2008 Volkswagen New GTI 3-door	Car	1332	441	154	109	19.8	
2007 Ford Five Hundred 4-door	Car	1372	651	235	170	29.9	2
2008 Honda Fit 5-door	Car	1384	491	161	101	20.3	
2008 Volkswagen New Beetle 3-door	Car	1388	477	155	100	13.8	1.4
2008 Volvo S80 4-door	Car	1393	604	229	152	29.1	
2008 Toyota Prius 5-door	Car	1415	642	257	191	12.1	1.9
2008 Pontiac G6 4-door	Car	1436	733	313	226	39.5	1.6
2008 Ford Focus 4-door	Car	1489	726	289	216	36.6	
2008 Honda Accord 4-door	Car	1499	742	264	174	33.5	
2008 Mazda Mazda3 4-door	Car	1545	689	285	200	36.1	1.9
2006 BMW 3-Series 4-door	Car	1546	788	318	232	40.0	
2009 Acura RL 4-door	Car	1547	641	271	202	34.4	
2008 Dodge Charger 4-door	Car	1552	755	283	199	35.9	
2008 Kia Spectra 4-door	Car	1558	710	255	169	26.1	
2005 Saturn Ion 4-door	Car	1561	863	380	290	47.9	1.1
2008 BMW 5-Series 4-door	Car	1584	756	234	156	29.8	
2005 Chrysler 300 4-door	Car	1619	816	303	228	38.3	2.3
2008 Buick Lucerne 4-door	Car	1620	792	325	240	41.0	
2008 Infiniti EX35 Stationwagon	Car	1668	641	274	202	34.5	
2008 Hyundai Elantra 4-door	Car	1676	755	270	192	28.1	
2008 Volkswagen Jetta 4-door	Car	1681	803	301	207	31.9	
2008 Chevrolet Aveo 4-door	Car	1685	671	255	182	32.3	
2009 Subaru Legacy 4-door	Car	1689	866	344	250	37.2	
2006 Volkswagen Passat 4-door	Car	1693	852	339	257	42.8	
2008 Toyota Avalon 4-door	Car	1704	819	298	198	37.6	
2005 Cadillac STS 4-door	Car	1753	891	366	266	45.9	
2008 Ford Fusion 4-door	Car	1825	878	363	273	39.5	
2007 Lexus ES 4-door	Car	1848	867	370	270	40.3	
2009 Toyota Corolla Matrix 5-door	Car	1848	875	360	260	40.1	
2008 Dodge Dakota Quad Cab	Pickup	1508	606	201	139	25.6	4.6
2007 Chevrolet 1500 Silverado Crew Cab	Pickup	1586	767	311	235	39.4	
2008 Honda Ridgeline	Pickup	1662	652	255	200	30.8	
2008 GMC 1500 Sierra Regular Cab Short Bed	Pickup	1664	729	345	259	43.6	
2008 Ford F-150 Super Cab Long	Pickup	1804	939	395	297	49.3	

Bed							
2005 Honda CR-V	SUV	1217	545	191	140	24.4	3.1
2008 Chevrolet Trailblazer	SUV	1268	602	239	158	30.3	3.1
2005 Ford Explorer	SUV	1284	435	157	121	19.0	3
2008 Jeep Wrangler	SUV	1323	679	302	216	38.1	
2008 Hyundai Santa Fe	SUV	1350	528	206	141	26.3	
2007 Dodge Magnum	SUV	1369	619	218	155	27.8	2
2008 Kia Sportage	SUV	1408	639	266	191	33.8	
2008 Jeep Grand Cherokee	SUV	1411	674	248	178	31.5	3.4
2009 Chevrolet HHR	SUV	1475	715	274	194	34.6	
2008 Toyota RAV4	SUV	1516	713	279	204	28.0	
2008 Toyota 4Runner	SUV	1518	655	201	128	25.6	4.1
2008 Honda CR-V	SUV	1538	595	217	161	27.6	
2007 Suzuki Grand Vitara	SUV	1547	760	252	161	31.3	
2006 Honda Pilot	SUV	1594	775	290	190	36.6	3.3
2008 Saturn Vue	SUV	1625	839	337	243	42.4	
2008 Scion xB	SUV	1625	820	298	211	37.5	
2008 Ford Edge	SUV	1648	866	327	227	41.1	
2008 Ford Expedition EL	SUV	1664	698	280	201	35.5	
2008 Chevrolet 1500 Suburban	SUV	1778	838	374	274	46.9	
2007 Jeep Commander	SUV	1792	941	400	300	50.0	4
2008 Chevrolet Equinox	SUV	1805	877	387	294	48.5	2.9
2008 Ford Taurus X	SUV	1814	843	349	249	41.3	2.3
2008 Subaru Tribeca	SUV	1842	943	400	300	50.0	
2008 Mazda CX-9	SUV	1880	873	365	272	40.4	
2007 Cadillac Escalade	SUV	1890	843	352	261	44.3	
2008 Saturn Outlook	SUV	1955	956	400	300	50.0	
2008 Chevrolet 1500 Avalanche	SUV	2010	923	387	290	48.8	
2008 Dodge Caravan Wagon	Van	1174	595	200	139	25.5	
2006 Chrysler PT Cruiser Wagon	Van	1265	573	215	140	24.0	
2005 Chevrolet Uplander Wagon	Van	1442	796	333	246	41.9	3.2
2007 Honda Odyssey Wagon	Van	1812	874	335	235	42.1	5.1
2008 Ford E-250 Cargo	Van	2500	1000	400	300	50.0	5.3