Attachment A

Intelligent Speed Assistance Feasibility Report

October 2023

King County

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III. Proviso Text

P1 PROVIDED THAT:

Of this appropriation, $50,000 shall not be expended or encumbered until the executive transmits an intelligent speed assistance ("ISA") feasibility report and a motion that should acknowledge receipt of report, and a motion acknowledging receipt of the report is passed by the council. The motion should reference the subject matter, the proviso's ordinance number, ordinance section and proviso number in both the title and body of the motion.

The report shall study non-revenue fleet vehicles, excluding vehicles within the fleet of the department of public safety, and include, but not be limited to, the following:

A. An analysis of which vehicles could be deployed with ISA, by make and model;

B. Costs for equipment and installation, as well as any other relevant fleet considerations for either electric or nonelectric fleet vehicles;

C. An analysis of potential economic, safety, climate or other benefits associated with installing ISA in fleet vehicles;

D. Lessons learned from other jurisdictions, domestically or internationally, that have pursued or are considering this approach, as well as a literature review on best practices and emerging intelligent speed assistance technologies; and

E. A discussion of policy considerations for the county to implement ISA on fleet vehicles, including implementation phasing options.

The executive should electronically file the report and motion required by this proviso no later than October 31, 2023, with the clerk of the council, who shall retain an electronic copy and provide an electronic copy to all councilmembers, the council chief of staff and the lead staff for the transportation, economy and environment committee.

Ordinance 19546, Section 123, Department of Executive Services, Fleet Services Division, P1[1]

[1] Ordinance 19546 [LINK]

IV. Executive Summary

Intelligent Speed Assistance (ISA) is a technology aimed at promoting safer driving practices by helping drivers comply with local speed limits. The 2023-2024 King County Adopted Budget called for a feasibility study of ISA in non-revenue fleet vehicles. This report presents the findings of the study conducted by the Department of Executive Services (DES), Fleet Services Division.

ISA systems provide real-time feedback, warnings, or interventions to encourage drivers to adhere to speed limits. There are three main types of ISA systems: Advisory ISA, Warning ISA, and Mandatory ISA. Two types of ISA systems are analyzed in this report: Mandatory ISA and Advisory ISA. The former is suitable for newer vehicles with an electronic throttle pedal, while the latter can be deployed across the entire fleet. Both systems offer potential economic, safety, and climate benefits.

Implementing ISA would require careful consideration of King County Information Technology (KCIT) support, implementation cost, ongoing program cost, impact to other telematics currently installed in vehicles, collective bargaining implications, training needs, resources and staffing, and driver acceptance. If ISA is recommended, a phased implementation plan is documented in this report, starting with a pilot program to assess the system's effectiveness and acceptance. Results and scalability could be evaluated, followed by an assessment of qualitative impacts. Vehicles would be prioritized based on suitability, and decisions would be made to refine the implementation plan before expanding it further.

In response to Ordinance 19546, this report conducts a comprehensive feasibility analysis of implementing ISA in King County's non-revenue fleet vehicles. The analysis encompasses vehicle suitability for ISA deployment, associated costs, potential benefits, insights from other jurisdictions, a literature review of ISA best practices and emerging technologies, and policy considerations for County implementation. Concurrently, King County's Fleet Services Division is undergoing a significant transformation, prioritizing the adoption of electric vehicles (EVs). This shift necessitates substantial resource allocation and strategic planning across multiple agencies including vehicle acquisition, infrastructure development, and workforce training. Notably, as EVs integrate advanced safety technologies, including speed limiters and collision avoidance systems, drivers are poised to benefit from enhanced road safety measures.

V. Background

Department Overview
The Department of Executive Services (DES) provides internal services to King County agencies and public services directly to King County residents. The divisions and offices that make up DES include Business Resource Center, Finance and Business Operations Division, Office of Emergency Management, Facilities Management Division, Fleet Services Division, Director's Office (including the Inquest Program), King County International Airport, Office of Risk Management Services, and the Records and Licensing Services Division. The Fleet Services Division (Fleet) is responsible for the development of this Proviso report.

The 2023-2024 King County Adopted Budget, as amended by Ordinance 19633, included a budget Proviso calling for a report on a feasibility study of Intelligent Speed Assistance (ISA) in non-revenue fleet vehicles. The following report includes identification of suitable vehicles for ISA, analyzes costs and considerations for electric and non-electric fleet vehicles, evaluates potential benefits of ISA implementation and experiences from other jurisdictions, and discusses policy considerations and implementation phasing options for implementing ISA on King County fleet vehicles.

Key Context
Intelligent Speed Assistance Overview: ISA, or Intelligent Speed Assistance, is a system designed to help drivers stay within the legal speed limit by providing information and warnings to alert speeding behavior. The system is capable of a range of interventions, including informing on excess speed, supporting speed reduction, or automatically setting the vehicle's speed limit based on the speed limits indicated on the road by using GPS and digital speed limit maps to keep the speed limit up to date with the road's limits. There are three main types of ISA:

1. Informative or Advisory ISA: This version provides feedback to the driver through visual or audio signals. An example of this is the Speed Alert System, which informs the driver of the current speed limits and alerts them if they are exceeding the limit.
2. Supportive or Warning ISA: This type applies gentle pressure to the accelerator pedal, encouraging the driver to stay within the speed limit. However, the driver can still override the system by pressing the accelerator harder if necessary.
3. Intervening or Mandatory ISA: This version takes a more active role in preventing speeding. It can reduce fuel injection or require the driver to use an emergency override action if they want to temporarily exceed the speed limit.

By implementing ISA technology, drivers can receive real time assistance in adhering to speed limits, promoting safer driving practices and potentially reducing the occurrence of speeding-related crashes.[2] See Appendix A for information about traffic crashes and fatalities.

Efforts to Improve Road Safety: In Washington State, the Strategic Highway Safety Plan: Target Zero, aims to reduce the number of traffic deaths and serious injuries on Washington's roadways to zero by the year 2030. The program serves as the state's Strategic Highway Safety Plan and is a data-driven,

[2] Intelligent Speed Adaptation (ISA) (europa.eu)

long-term plan to identify priorities and solutions, create goals, and develop a common understanding among the agencies working to keep Washingtonians safe.[3]

In King County, the Traffic Safety Coalition, also known as the King County Target Zero Task Force, works collaboratively with traffic safety and community partners to create equitable traffic safety programs and plans to reduce collisions, injuries, and fatalities in King County. The coalition operates under a three-year strategic plan and is governed by a steering committee that outlines the priority areas of focus for traffic safety work in King County. The coalition also supports the state's Strategic Highway Safety Plan: Target Zero.[4]

ISA is one of many tools proposed to help achieve the goal of zero traffic deaths and serious injuries. It is part of a larger effort to improve traffic safety through a combination of education, enforcement, engineering, and emergency medical services.

In the National Transportation Safety Board (NTSB) Reducing Speeding-Related Crashes Involving Passenger Vehicles Safety Study (2017), an ISA safety recommendation was made to the National Highway Traffic Safety Administration at the federal level. The recommendation urges incentivizing passenger vehicle manufacturers and consumers to adopt ISA systems. The NTSB's ISA recommendation was reiterated in September 2022, but as of the time of writing this report, it has not been adopted at the federal level.[5]

The European Union has recently made ISA required on all new models of cars sold in Europe as of 2022 and every new car by 2024. Advisory ISA meets this requirement. This regulation is part of the broader General Vehicle Safety Regulation and aims to reduce speeding and improve vehicle and passenger safety.[6]

King County Fleet Telematics[7] - Automatic Vehicle Location Technology: In April 2015, a performance audit of King County's light-duty fleet found that decision-makers lacked timely, consistent data on vehicle use limiting the ability to manage the fleet strategically. In subsequent years, the increased demand for Automatic Vehicle Location (AVL) led agencies to explore and pilot individualized solutions.

Fleet collaborated with Transit Non-Revenue Vehicles, the King County International Airport, and the Solid Waste Division to implement a countywide telematics AVL solution for non-revenue vehicles. The AVL project secured approval as a KCIT capital project in the 2017-2018 budget. A contract was finalized with a vendor in early 2018.

Following a pilot testing phase, the County made the decision to proceed with full-scale implementation across all non-revenue vehicles. AVL installations were carried out during regular maintenance sessions. The AVL devices capture an extensive range of data, including vehicle location, odometer readings, speed data, utilization, vehicle idling statistics, and user-defined events (such as the location and duration of street sweeping).

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[3] Strategic Highway Safety Plan: Target Zero | WSDOT [Link]
[4] King County Traffic Safety Coalition [Link]
[5] Safety Recommendation H-17-024 [Link]
[6] EU will require all new cars to include anti-speeding tech by 2024 | Engadget [Link]
[7] Definition of Telematics - Merriam-Webster [Link]

The device data helps agencies optimize routes, dispatch vehicles more efficiently, and decrease fuel consumption and greenhouse gas emissions. Ready access to AVL data allows fleet managers to proactively schedule maintenance based on real-time diagnostic trouble codes and improve projections for vehicle replacement. This technology captures speed data and gives managers the opportunity to review data relating to incidents or reported issues.

The potential implementation of ISA technology in King County's non-revenue fleet vehicles would necessitate a careful evaluation of its impact and compatibility with the current AVL system, including any potential for AVL system upgrades or improvements. It is essential to note that ISA would not replace the existing AVL capabilities, particularly for pursuit vehicles and off-road equipment like mowers. Consequently, Fleet could be tasked with maintaining and supporting two distinct technology systems. This dual-system scenario introduces challenges in synthesizing data gathering and reporting, potentially complicating the presentation of data in a coherent and practical manner. A thorough evaluation of these implications would be vital to ensure seamless integration and data management.

<u>New Vehicle Technology:</u> Newer model vehicles often come equipped with GPS speed data, displaying the speed limit for driver visibility on the electronic dash display as well as the ability to set a high-speed alert notification in the vehicle. High speed alert features enable the County to set an alert that sounds if a driver is speeding over the predetermined limit. The GPS speed feature coordinates the car's position via GPS, with a database of speed limit information to ensure the driver has access to speed limits at all times. This helps drivers maintain a safe driving speed. Newer systems may use a camera to read speed limit signs. The Chevrolet Bolt in the County fleet includes some of these features.

The King County Fleet Services Division is actively engaged in a substantial transition towards adopting electric vehicles (EVs). The King County 2020 Strategic Climate Action Plan[8] and Ordinance 19052[9] require electrification goals of 50 percent by 2025 and 100 percent by 2030 for light-duty vehicles. This strategic shift demands a significant allocation of the division's resources and focus, encompassing vehicle acquisition, agency short term and long-term planning, charging infrastructure access, and workforce training to effectively accommodate this transition.

EVs come equipped with various existing safety technologies, including speed limiters, adaptive cruise control, collision avoidance systems, and lane departure warnings. This technology offers an additional level of speed limit awareness, promoting adherence to speed limits and partially addressing some of the same aims as ISA. As Fleet adopts electric vehicles, these advanced safety features will become accessible, empowering drivers with crucial information to enhance overall road safety.

Report Methodology

This report was prepared by the Department of Executive Services, Fleet Services Division. Fleet staff performed a literature review of intelligent speed assistance and its potential benefits and analyzed the financial feasibility of implementation of ISA in Fleet non-revenue vehicles.[10]

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[8] King County 2020 Strategic Climate Action Plan [Link]

[9] Ordinance 19052 [Link]

[10] The analysis excluded King County Sheriff's Office, Medic One, Metro Transit and Solid Waste Division non-revenue fleet vehicles.

Fleet staff assessed the implementation of the King County enterprise-wide Automatic Vehicle Location (AVL) System in non-revenue vehicles to identify valuable insights from similar past work. Virtual interviews were conducted with vendors of ISA technology in the United States. These interviews were conducted to identify and compare the vehicle specifications for the type of ISA they offer. The primary goal was to understand the unique features, performance capabilities, and potential limitations of their respective ISA systems. Vehicle Master data from Fleet's asset management system and claims data from the King County Office of Risk Management were analyzed.

VI. Report Requirements

A. An analysis of vehicles that could be deployed with ISA, by make and model

This section includes an analysis of which vehicles could be deployed with ISA, by make and model. As a newer innovation in the automotive industry, the implementation of ISA is still in its early stages, resulting in a limited number of vendors available to provide this system in the United States. It is important to note that, despite efforts to gather comprehensive insights, a vendor specializing in Warning Intelligent Speed Assistance was not available for direct consultation.

The first system identified employs a Mandatory ISA type, which features the option for driver override while ensuring adherence to speed limits. This ISA system utilizes acceleration control of the pedal to manage both vehicle speed and acceleration rate. It maintains compliance with the identified speed limit. This feature reduces the risk of drivers unintentionally exceeding speed limits or engaging in behaviors such as harsh acceleration. It is specifically designed for vehicles equipped with an electronic throttle pedal, a feature that has been consistently available in models manufactured after 2005. This configuration allows the ISA system to integrate with modern vehicle models, providing drivers with the ability to intervene when necessary while still promoting safe and responsible driving practices.

The Mandatory ISA system is compatible with approximately 1,159 vehicles, encompassing fleet vehicles with a model year of 2005 or newer. The system's compatibility with modern vehicle models equipped with an electronic throttle pedal ensures seamless integration, making it a feasible option for 96 percent of the on-road fleet.

Another version of ISA available offers an Advisory ISA type that employs in-cab assistance with real-time feedback. This system utilizes audio "nudges" to promptly alert the driver whenever they exceed the speed limit, encouraging self-correction. Unlike a mandatory ISA, this advisory system does not enforce speed control, allowing the driver to adjust speed manually while benefiting from regular guidance.

This system can be integrated into any vehicle that does not have an open cab. This system can be installed on a wide range of on-road vehicles within the fleet, irrespective of their make or model. This feature is advantageous for fleets with diverse vehicle types and ages. By providing drivers with real-time feedback and the freedom to self-correct, the Advisory ISA system strikes a balance between promoting safe driving practices and respecting driver autonomy, making it a valuable option for enhancing road safety across different fleets and operations.

The Advisory ISA system offers additional versatility, as it can be deployed on all of King County Fleet's on-road vehicles, regardless of their make or model. This adaptability enables ISA to be deployed across the entire fleet without the need for modifications or replacements.

Overall, both systems present viable options for ISA implementation. The Mandatory system prioritizes speed control and acceleration management for selected newer vehicles, while the Advisory system focuses on wide-ranging applicability and in-cab guidance for all on-road vehicles.

For specific make and model details of vehicles eligible for ISA deployment, please refer to Appendix B.

B. Costs for equipment and installation, as well as any other relevant fleet considerations for either electric or nonelectric fleet vehicles

This section outlines the costs for equipment and installation, as well as any other relevant fleet considerations for either electric or nonelectric fleet vehicles.

In the previous section, Mandatory and Advisory ISA systems were reviewed for this report. Not only do these systems differ in features and functionality, but they also exhibit variations in equipment costs and installation expenses. The information presented in the following section and table is based on insights gathered from vendor interviews and provides a detailed breakdown of the associated costs for ISA equipment and installation.

The Mandatory ISA system can be obtained by purchasing equipment with a three-year warranty as well as a subscription service to maintain, support, and update the software. The estimated installation time for this system is approximately three hours per vehicle.

The Advisory ISA system is available through a license subscription and may not involve purchasing equipment or hardware. With a shorter estimated installation time of approximately 30 minutes, this system offers a more streamlined implementation process compared to the Mandatory ISA.

Table 1: ISA Estimated Implementation Project Costs[11]

ISA Type	Estimated Vehicles	Estimated Equipment Costs[12]	Estimated Fleet Installation Costs	Estimated KCIT/Fleet Project Management Costs[13]	Estimated Total Project Costs	Estimated Total Annual Operating Costs
Mandatory ISA	1159	$1.6 Million	$350,000	$1 Million	$2.9 Million	$350,000
Advisory ISA	1202	$450,000	$60,000	$1 Million	$1.5 Million	$720,000

The projected total project costs for the implementation of ISA are estimated to be approximately $2.9 million for the Mandatory ISA and $1.5 million for the Advisory ISA. These estimates are based on the project cost of a similar KCIT capital project carried out in 2017-2018, which involved the implementation of a telematics-Automatic Vehicle Location (AVL) System enterprise-wide. The projections account for inflation[14] and align with the previous project's expenditures, providing a reliable basis for cost assessment. These costs do not include estimated time to remove current telematics-AVL devices in vehicles if necessary.

Another key factor to consider alongside ISA equipment and installation costs is the ongoing transition to electric vehicles (EVs) within King County. This transition is a substantial and complex undertaking, driven by the County's ambitious sustainability goals of achieving 50 percent electrification by 2025 and full electrification by 2030 for light-duty vehicles, as outlined in the King County 2020 Strategic Climate Action Plan and Ordinance 19052. To meet these goals, the Fleet Services Division must engage in extensive coordination with various King County agencies. This collaborative effort involves streamlining vehicle acquisition processes, aligning with agency planning objectives, securing access to charging infrastructure, and conducting comprehensive workforce training while ensuring minimal impacts to ongoing operations. Coordinating these efforts across multiple agencies requires significant commitment, management, and effort. It is essential for the Fleet Services Division to maintain focus on the transition to EVs. It is important to recognize that the integration of ISA technology could introduce complexities and potential impacts on the achievement of EV goals.

C. An analysis of potential economic, safety, climate or other benefits associated with installing ISA in fleet vehicles

This section provides an analysis of potential economic, safety, climate or other benefits associated with installing ISA in fleet vehicles.

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[11] The costs identified in this analysis are subject to potential fluctuations due to the limited number of vendors offering ISA technology in the United States. Additionally, these estimates are based on 2023 dollars. To ensure accurate budgeting and accounting for potential changes in the market and inflation, a project proposal that includes adjustments for these variables would be needed prior to implementation.

[12] Excludes shipping and handling, and taxes.

[13] Includes project management and information technology costs

[14] $1 in 2017 → 2023 | Inflation Calculator (in2013dollars.com)

Potential Economic Benefits
Enhanced Fuel Efficiency and Cost Reduction: ISA systems offer a promising avenue for enhancing fuel efficiency and reducing operational costs. When vehicles exceed the optimal speed, they encounter greater resistance from both tires and air, negatively impacting fuel efficiency. [15] By implementing ISA systems, the County fleet may experience a reduction in fuel emissions and cost. Potential fuel consumption reduction using ISA systems is estimated to range from two percent to as high as 13 percent, depending on various factors such as the type of driving, whether urban or on highways, and the type of ISA system used.[16]

Lowered Claims Costs: Crash reduction studies have been conducted in various regions, but these studies were not large enough to provide empirical data on actual crash involvement. To assess the impact on injuries and fatalities, data models are often used as an alternative to actual crash data. These studies have yielded varying results regarding the predicted reductions in fatalities and serious injuries following the introduction of ISA, due to the use of different methodologies. The introduction of ISA is expected to contribute to a reduction in fatal and serious injury crashes; however, the exact magnitude of these savings remains uncertain.[17] After reviewing this research, it is not feasible to quantify crash reductions leading to claims cost savings for King County. Notably, from 2017 to 2022, King County paid $1,495,964.85 in vehicle crash claims from incidents involving non-revenue vehicles operating on the road. It is unclear whether ISA systems could impact this cost moving forward.

Potential Safety Benefits
Enhanced Road Safety: ISA systems have the potential to improve road safety. By actively preventing drivers from exceeding speed limits, ISA systems may reduce the likelihood of crashes caused by speeding, which is a leading cause of road fatalities. The technology provides real-time feedback and alerts to drivers, encouraging them to adhere to speed limits and drive more responsibly.

Reduced Crashes and Injuries: The installation of ISA systems can lead to a reduction in crashes and injuries. Studies have shown that excessive speed is a major contributing factor in crashes. By curbing speeding incidents, ISA can minimize the risk of collisions, thus reducing the associated costs of vehicle repairs, medical expenses, and loss of productivity. The rate of reduced crashes using ISA is influenced by a variety of factors, including the type of ISA system, crash severity, and penetration rate.[18] It ranged from two percent to 27 percent in one study. [19] Data on King County Fleet speed-related crashes and injuries is not available; it is unclear whether implementing ISA would have an impact on speed related-crashes or injuries for King County non-revenue fleet.

Data and Insights: ISA systems collect valuable data on driver behavior, including speed patterns and compliance with speed limits. Analyzing this data could provide insights for targeted training programs, identifying high-risk areas, and optimizing operational strategies to improve efficiency and safety within the fleet.

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[15] https://afdc.energy.gov/conserve/behavior_techniques.html#:~:text=Slow%20Down%20and%20Drive%20Conservatively&text=For%20light%2Dduty%20vehicles%2C%20for,by%207%25%E2%80%9314%25.
[16] http://perso.lcpc.fr/guillaume.saint-pierre/Publis/LAVIA_final_ITS%20New%20York.pdf
[17] https://www.rsa.ie/docs/default-source/road-safety/r4.1-research-reports/intelligent-speed-assistance/intelligent-speed-assistance-a-review-of-the-literature-2018.pdf?Status=Master&sfvrsn=3578f6f8_3
[18] The penetration rate in this case is the percentage of vehicles on the road that have ISA systems.
[19] https://pcaet.bruit.fr/pdf/speed-limit-adherence_and_its_effect_on_road_safety_and_climate_change.pdf

Potential Climate Benefits
Environmental Benefits: Reduced speed and improved fuel efficiency associated with ISA can contribute to environmental sustainability efforts. Lower fuel consumption leads to decreased greenhouse gas emissions, helping to mitigate climate change and improve air quality. One study found no significant change in emissions for Advisory ISA, except on 70 mile per hour roads where there was a 3.4 percent reduction. On the other hand, the impact of Mandatory ISA varied depending on the speed limit. Notably, on 70 mile per hour roads, there was a more significant reduction in carbon dioxide emissions of 5.8 percent.[20]

D. Lessons learned from other jurisdictions, domestically or internationally, that have pursued or are considering this approach, as well as a literature review on best practices and emerging intelligent speed assistance technologies

This section describes lessons learned from other jurisdictions that have pursued or are considering ISA implementation, as well as a literature review on best practices and emerging intelligent speed assistance technologies.

New York City ISA Pilot
In August 2022, New York City launched an ISA pilot program, equipping 50 fleet vehicles with this technology. The selected vehicles comprised a range of 16 different makes, from sedans to dump trucks. Utilizing a Mandatory ISA type that directly controlled vehicle speed, the system also offered drivers an optional 15-second override button for manual control.[21][22]

Since its inception, the ISA pilot program has demonstrated promising results. Vehicles equipped with ISA consistently adhered to speed limits 99 percent of the time, indicating effectiveness of the technology in promoting safer driving practices. Data on speed limit adherence prior to implementation was not available. Additionally, ISA implementation led to a 36 percent reduction in hard braking events, indicating an improvement in overall driving behavior.[23]

As the ISA pilot program is still in its early stages, New York City has taken other measures to enhance fleet safety. The city has installed telematics[24] across its entire fleet, gathering valuable data to support fleet operations, vehicle utilization, and driver safety. The program includes monthly risk reports for each vehicle based on the telematics data, and drivers are categorized as low, moderate, or high risk, considering factors such as excessive speed, accelerating, hard braking, hard turning, and seatbelt use.[25] This approach allows New York City to empower its agencies with data-informed insights into their drivers' behavior.

Ventura County ISA Pilot
Ventura County, California, is currently conducting a pilot program for ISA on a selection of its vehicles, utilizing the Mandatory ISA type. While analyzing their telematics data, the County discovered a

[20] https://pcaet.bruit.fr/pdf/speed-limit-adherence_and_its_effect_on_road_safety_and_climate_change.pdf
[21] NYC-Fleet-Newsletter-401-August-12-2022-Mayor-Adams-Announces-Intelligent-Speed-Assist-ISA-Initiative.pdf
[22] A new vehicle system could stop you from driving above the speed limit | CNN Business
[23] Mayor Adams Announces Results of Successful Pilot Program for City Fleet Vehicles | City of New York (nyc.gov)
[24] Why Your Public Safety Fleets Need Telematics Devices - Telematics - Government Fleet (government-fleet.com)
[25] Protecting Your Most Precious Assets - Safety - Government Fleet (government-fleet.com)

concerning number of excessive speed violations, particularly in residential areas and school zones. Acknowledging its focus on managing vehicles rather than drivers, it shared these reports with relevant departments. However, seeing limited success in reducing speeding incidents, the County explored technology options and decided to initiate an ISA pilot on some vehicles.[26]

The County fleet managers were impressed with the system's ability to customize speed parameter settings. Unlike a speed governor that only sets a fixed top speed for all situations, ISA's functionality based on road speed limits proved to be more versatile, extending beyond just highways. The feedback from department managers and supervisors was positive, as they no longer had to bear the burden of managing speed violations.

Encouraged by the initial results, Ventura County aims to expand the pilot to an additional 80 vehicles. Nevertheless, one of the primary challenges hindering full implementation is the cost of the system, resulting from budgetary constraints.

The County fleet managers are interested in assessing the potential impacts on fuel savings and maintenance costs. As the pilot is still in its early stages, comprehensive fuel savings and other outcome data are yet to be gathered.

Washington State Jurisdictions

In conversations concerning the implementation of ISA, other jurisdictions in Washington state expressed concerns about the use of vehicle data, which could potentially become subject to disclosure under the Public Records Act. These jurisdictions reported that they are not currently collecting vehicle data.

Literature Review on Best Practices and Emerging ISA Technologies

The literature review looks at references representing studies in both the United States and other countries. It is not intended to be exhaustive, but rather provide an overview of identification of best practice and emerging ISA technologies.

Best Practices

Ryan (2019) found in her review of ISA literature that the successful implementation of ISA relies greatly on driver acceptance of in-vehicle control and their willingness to use these systems correctly. Various types of ISA technologies have different impacts on driver behavior and traffic safety; more controlling systems are more effective in reducing speed and enhancing road safety but might be less acceptable to drivers. Research suggests the most significant benefits are from Mandatory ISA. However, drivers who participated in field trials showed the least acceptance of this form of speed control and were more accepting of Advisory ISA.[27] See Appendix C for the full report.

Ando et al. (2014) conducted an experiment on an Advisory ISA system's impact on driver behavior. The study revealed the ISA system effectively enhanced drivers' recognition of speed limits and influenced

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[26] Safer Fleets Challenge: How Adopting Intelligent Speed Assistance Can Make Your Communities Safer - YouTube

[27] https://www.rsa.ie/docs/default-source/road-safety/r4.1-research-reports/intelligent-speed-assistance/intelligent-speed-assistance-a-review-of-the-literature-2018.pdf?Status=Master&sfvrsn=3578f6f8_3

their driving behavior positively. Moreover, when the ISA provided audible information, drivers readily accepted it, leading to decreased driving speeds and contributing to improved traffic safety.[28]

According to the National Transportation Safety Board (NTSB) Reducing Speeding-Related Crashes Involving Passenger Vehicles Safety Study (2017), the effectiveness of an ISA system depends on the technology used for speed limit detection. Digital speed map systems require complete, accurate, and up-to-date speed limit data from map databases. Databases may be updated infrequently. [29]

On the other hand, sign-detecting camera-based systems rely on various factors for performance. Weather conditions, lighting conditions, obstructions like vegetation or other vehicles, speed limit sign format, and sign placement can impact their functionality. These variables play a crucial role in determining how well the system can detect and interpret speed limit signs.[29] See Appendix D for the full NTSB report.

Emerging ISA Technologies

Dacasa et al. (2022) conducted a case study on a dynamic speed limit system. Dynamic speed limits, also known as variable speed limits, allow cities to use real-time information about traffic and road conditions to adjust speed limits accordingly. This adaptive approach helps slow down traffic, preventing the formation of heavy congestion, and promoting smoother and more efficient traffic flow.[30]

In the future, dynamic Mandatory ISA systems could work alongside intelligent transportation systems and adapt to variable speed limits. This integration would further enhance the effectiveness of ISA technology in optimizing driving conditions, and ensuring safer and more reliable roadways.[31, 32]

Peiris et al. (2022) conducted a study of the effectiveness of camera-based ISA in remote areas of Australia, where incomplete digital speed maps posed a challenge. The absence of road speed limit signs hindered the proper functioning of ISA. The research findings indicated that investing in improved speed sign infrastructure in rural or remote areas would outweigh the associated costs, highlighting the potential benefits of such an initiative.[33]

E. A discussion of policy considerations for the county to implement ISA on fleet vehicles, including implementation phasing options

This section will include a discussion of policy considerations for the County to implement ISA, as well as implementation phasing options.

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[28] https://www.sciencedirect.com/science/article/pii/S1877050914006255
[29] https://www.ntsb.gov/safety/safety-studies/Pages/DCA15SS002.aspx#:~:text=The%20NTSB%20focused%20on%20the,and%20(5)%20national%20leadership.
[30] https://policy.tti.tamu.edu/strategy/variable-speed-limits/
[31] https://zenodo.org/record/6867211
[32] https://www.sciencedirect.com/science/article/pii/S095219762200104X
[33] https://www.mdpi.com/1424-8220/22/20/7765#:~:text=Annually%2C%2027%E2%80%9335%25%20of,AUD%2062%20and%20153%20million

KCIT Support
Implementation of an ISA system in fleet vehicles depends on KCIT support and expertise. KCIT plays a critical role in handling the data generated by ISA systems, including real-time vehicle location, speed, and driver behavior. To ensure secure data management, KCIT would need to support the project, develop appropriate processes and systems, gather business requirements, plan for integrations, create a governance plan, establish user protocols, and implement efficient records retention and response processes. This project would be required to go through the IT Project Review and Governance process prior to budget request.

Collective Bargaining
The implementation of ISA necessitates careful consideration of labor union bargaining and negotiation impacts. As the technology affects specific driving functions and data, addressing union concerns becomes vital in policy development and implementation. Securing union buy-in would be essential to achieving implementation of ISA in vehicles while effectively accommodating the needs and interests of the workforce and operations.

King County Executive Policies
Policy considerations would include the development of a new ISA Executive Policy or its integration into the existing AVL System Use Policy Executive Policy, FES 12-7-1 EP[34]. The policy would identify operational purposes and define ISA use for disciplinary actions ensuring it is based on specific incidents or concerns. It would outline the intended use of ISA and its likely impacts on employees and stress the importance of driver training for safe utilization. Additionally, the policy would detail data and records retention guidelines, ensuring compliance with relevant regulations and laws when responding to public records requests. The policy would ensure a balance between effective ISA implementation and employee rights and privacy.

Training Needs and Driver Acceptance
ISA systems aim to reduce crashes and fatalities, but they also pose potential challenges for employees unfamiliar with advanced vehicle technology.

One notable concern is the learning curve that accompanies the introduction of new technology, particularly for employees who lack regular exposure to advanced vehicle systems. This issue can disproportionately affect individuals from marginalized communities, who may encounter barriers to accessing and learning about such technology. Insufficient training on ISA systems can lead to a lack of understanding regarding their functionality and appropriate responses to alerts, potentially diminishing the system's effectiveness.[35]

To address these concerns, training and support is needed for drivers when implementing new technology like ISA systems. A commitment to empowering the workforce with adequate knowledge will foster a safer and more inclusive transition to ISA. Additionally, the Equity and Social Justice Strategic Plan's Workplace and Workforce Goal, which aims to provide Equitable Employee Development and Access to Opportunities, can be advanced by effectively training employees to use new ISA technology.

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[34] FES 12-7-1, Automatic Vehicle Location System Use Policy [Link]
[35] More Fleets Making ADAS Tech Mandatory - Safety - Automotive Fleet (automotive-fleet.com)

The type and duration of training will need to be determined. Currently, King County executive policy requires frequent operators[36] to complete the four-hour King County Safety and Claims Management Office Defensive Driving Class every three years.

Implementation Phasing Options
An effective phased ISA implementation process may utilize the following format.

Table 2: ISA Implementation Phases

Phase	Description
Pilot Testing	The first implementation phase would involve conducting a pilot test with a subset of vehicles. This pilot test would serve to assess the effectiveness and acceptance of the ISA system. During the pilot, feedback would be gathered from drivers, and key performance indicators related to safety, compliance, and fuel efficiency would be monitored.
Evaluate Results and Scalability	The outcomes of the pilot would be analyzed to determine the impact of ISA implementation on the desired objectives. Quantitative data from key performance indicators would be used to assess the system's effectiveness. An analysis would be conducted to identify potential challenges and considerations specific to King County. This assessment would consider factors such as local infrastructure, road conditions, and unique circumstances, such as terrain variations and the availability of wireless access countywide. Based on the results, decisions would be made regarding the scalability of the ISA system. If the pilot proves successful, implementation could be expanded to more vehicles.
Assess Other Qualitative Impacts	In addition to quantitative evaluation, qualitative impacts on road safety, operational efficiency, and sustainability would be assessed. Feedback from drivers and managers would be gathered to understand their experience with ISA. This includes evaluating any observed changes or improvements in driver behavior, increased compliance with speed limits, and the overall perception of safety and operator acceptance with the ISA system in place.
Prioritize Vehicles	Upon completion of assessments, vehicles in the fleet would be prioritized based on their suitability for ISA implementation. Factors such as vehicle maintenance schedule, age, mileage, and their role within operations would be considered. This prioritization process would help determine the order in which vehicles would be equipped with the ISA system. This approach allows for a gradual and controlled implementation process, as well as the opportunity to address specific fleet requirements based on vehicle characteristics.
Evaluate and Refine	With the evaluation of the pilot test and qualitative impacts, informed decisions could be made regarding the implementation and expansion of the ISA system within the fleet. Any challenges or issues that arise would be addressed and resolved before expanding the implementation to additional fleet vehicles. This step ensures that resources are allocated efficiently and effectively to maximize the benefits of ISA technology.

[36] FES 12-1-4-EP: Use of Vehicles for County Business [LINK] defines frequent operators as driving more than an average of once per month on county business unless more restrictive guidance is in place at the department level.

The pilot test and assessment phase would provide valuable insights into the system's effectiveness and operator acceptance. Together, these phases create an organized and data-informed approach to effectively implement the ISA system.

VII. Conclusions and Other Considerations

As called for by the Proviso, this report provides a feasibility analysis of intelligent speed assistance for non-revenue fleet vehicles in King County. The analysis included which vehicles could be deployed with ISA; costs for equipment, installation, and implementation; potential benefits associated with installing ISA; lessons learned from other jurisdictions; a literature review on best practices and emerging ISA technologies; and policy considerations for the County to implement ISA.

Fleet is actively engaged in a substantial transition towards adopting electric vehicles (EVs). This strategic shift demands a significant allocation of the division's resources and focus, encompassing vehicle acquisition, agency short-term and long-term planning, charging infrastructure access, and workforce training to effectively accommodate this transition.

EVs come equipped with various existing safety technologies, including speed limiters, adaptive cruise control, collision avoidance systems, and lane departure warnings. As Fleet adopts electric vehicles, these advanced safety features will become accessible, empowering drivers with crucial information to enhance overall road safety.

VIII. Appendices

Appendix A: Traffic Crashes and Fatalities
Appendix B: Vehicles Eligible for ISA Deployment by Make and Model
Appendix C: Intelligent Speed Assistance: A review of the literature
Appendix D: National Transportation Safety Board: Reducing Speeding-Related Crashes Involving Passenger Vehicles Safety Study
Appendix E: Literature Review References

Traffic Crashes and Fatalities

Traffic crashes have become an increasingly concerning problem, nationally and locally.[1,2] Exploring the potential of intelligent speed assistance systems presents an opportunity to address the impact of speeding-related incidents involving King County vehicles.

In 2021, 28 percent of fatal crashes, 13 percent of injury crashes, and nine percent of property-damage-only crashes in the United States were linked to speeding incidents. Between 2012 and 2021, there was a 19 percent increase in speeding-related fatalities.[3]

According to the Washington Traffic Safety Commission's State of the State: Washington Traffic Fatalities brief from June 2022, traffic fatalities in Washington State increased 23 percent from 2019 to 2021.[4] The brief also shows that all high-risk behaviors and factors contributing to fatal crashes have increased, and pedestrian fatalities are at historical highs.

In King County, between 2014 and 2021, fatal and serious crashes involving pedestrians and cyclists rose from 184 to 252, a 36 percent increase. The eight South King County cities saw the number of fatal and serious crashes involving pedestrians and cyclists climb from 50 to 106, a 112 percent rise.[5]

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[1] https://www.npr.org/2023/04/06/1167980495/americas-roads-are-more-dangerous-as-police-pull-over-fewer-drivers

[2] https://www.king5.com/article/news/local/seattle/felony-traffic-unit-king-county/281-db7a78b9-8df6-460a-9a21-6c48d7f71914#:~:text=Fatalities%20in%20King%20County%20have,have%20spiked%20the%20most%20dramatically.

[3] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813473

[4] http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2022/06/11_State-of-the-State-June-2022.pdf

[5] https://www.theurbanist.org/2023/01/10/south-king-county-sees-alarming-jump-in-pedestrian-fatalities/

Appendix B

Vehicles Eligible for ISA Deployment by Make and Model

Make	Model	Mandatory ISA	Advisory ISA
Autocar	MB-507P	1	1
Chevrolet	3500	0	1
Chevrolet	Astro	0	1
Chevrolet	Blazer	0	1
Chevrolet	Bolt	5	5
Chevrolet	Colorado	77	78
Chevrolet	Express	43	44
Chevrolet	Express 2500	19	19
Chevrolet	Express 3500	12	12
Chevrolet	HHR	1	1
Chevrolet	Impala	3	3
Chevrolet	Malibu	0	1
Chevrolet	Silverado	31	36
Chevrolet	Tahoe	5	5
Chevrolet	Traverse	1	1
Chevrolet	Uplander	6	6
Dodge	Caravan	5	5
Dodge	Grand Caravan	9	9
Dodge	RAM 1500	1	1
Dodge	RAM VAN	0	3
Elgin / freightliner	BROOMBEAR / M2	4	4
Farber	WFJ33S	2	2
Farber	WFJ38S	1	1
Ford	C-MAX	178	178
Ford	Crown Victoria	0	1
Ford	E-150	4	4
Ford	E-250	9	10
Ford	E-350	8	9
Ford	E-450	1	1
Ford	Econoline	2	2
Ford	Escape	133	133
Ford	Expedition	3	3
Ford	Explorer	12	12
Ford	F-150	78	79
Ford	F-250	138	139
Ford	F-250 HD	0	1
Ford	F-350	37	43

Make	Model	Mandatory ISA	Advisory ISA
Ford	F-450	25	28
Ford	F-550	25	27
Ford	F-59	1	1
Ford	Focus	28	29
Ford	Fusion	18	18
Ford	L8000	0	1
Ford	Ranger	21	22
Ford	Taurus	2	2
Ford	Transit	4	4
Ford	Transit 150	2	2
Ford	Transit 250	5	5
Ford	Transit 350	8	8
Ford	Transit Connect	37	37
Freightliner	M2	15	19
Freightliner	M2106MD	2	2
Freightliner	M2112V	12	12
Freightliner	V312LHAE	1	1
Freightliner	VPD42121	2	2
GMC	FUEL 1500 GAL	0	1
GMC	W5	3	3
Honda	Civic	2	2
Isuzu	NPR	3	3
Jeep	Cherokee	4	4
Jeep	Commander	1	1
Jeep	Liberty	1	1
Kenworth	K370	1	1
Kenworth	T270	1	1
Kenworth	T600	0	1
Kenworth	T800	9	9
Kenworth	Wrecker	0	1
Nissan	LEAF	13	13
Oshkosh	Striker	2	2
Oshkosh	T1500	0	1
Peterbilt	337	1	1
Peterbilt	348	2	2
Peterbilt	567	5	5
Peterbilt	Truck	0	1
Peterbilt / Swaploader	567 / SL400	5	5
Peterbilt/Labrie	348/LEACH ALPHA	1	1
Peterbilt/OSW	567/SDBSS	10	10

Make	Model	Mandatory ISA	Advisory ISA
Schwarze / Peterbilt	A7 TORNADO / 220	2	2
Schwarze / Peterbilt	A8 TWISTER / 220	1	1
Schwarze / Peterbilt	M6 AVALANCHE / 220	4	4
Toyota	Highlander	1	1
Toyota	Prius	41	41
Tymco / international	600 / 4300M7	1	1
Tymco / Isuzu	435 / NQR	1	1
Vacall / Peterbilt	AJV1215 / 567	4	4
Workhorse	W42	3	3
Total		**1159**	**1202**

Appendix C

Intelligent Speed Assistance: A review of the literature

A report commissioned by the Road Safety Authority (RSA)

Margaret Ryan

31/12/2018

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Executive summary

This report was commissioned by the Road Safety Authority of Ireland (RSA) and aims to examine and synthesise current knowledge in the field of Intelligent Speed Assistance (ISA) in motorised vehicles, with an emphasis on the application of ISA technologies in on-road (field) trials. The review focuses on four key themes which emerge consistently in the ISA literature; safety and the impact on driver behaviour, attitudes and acceptance, impact on the environment and ISA implementation.

Road traffic crashes are a major cause of premature death and unnecessary injury globally: Currently over 1.2 million people are killed and 50 million are injured every year (Ando & Mimura, 2015) and this is clearly unacceptable. In 2010 the EU developed an ambitious Road Safety Programme with the aim of halving the overall number of road deaths between 2010 and 2020 (EU Commission, 2010). In parallel, the Irish Government's Road Safety Strategy (2013 – 2020) set a target to reduce RTC fatalities to 25 per million inhabitants (or less) by 2020 in that period. More recently, the EU proposed a new policy framework for 2021 – 2030 which reaffirms the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050 (Vision Zero), with an interim target of reducing casualties by 50% between 2020 and 2030. As part of this strategy the Commission proposed to make vehicle safety and driver assistance features, including Intelligent Speed Assistance mandatory (EU Commission, 2018a).

A vast accumulation of empirical evidence demonstrates conclusively that there is a positive link between speeding and the risk of crash involvement and the severity of crash outcomes. Nevertheless, the use of excessive or inappropriate speed remains prevalent in most driving cultures. Research suggests that the reasons that drivers exceed the speed limit can be broadly classified as instrumental (getting to a destination quicker) and emotional (pleasure, enjoyment, a sense of mastery). Research also suggests that factors such as beliefs and attitudes, social norms, perceived behavioural control and behavioural intentions all influence speeding behaviour and that efforts to reduce speeding should focus on these behavioural precursors. Notwithstanding this, some analysts recommend a more direct approach to tacking speeding and one of the most promising interventions that has been developed in recent years involves the use of Intelligent Speed Assistance (ISA) technology.

Intelligent Speed Assistance (ISA) is the generic term for an in-car Advanced Driver Assistance System (ADAS) that helps drivers to comply with the speed limit. The ISA concept has been developed and tested extensively over the past three decades in many countries. A variety of ISA systems have been developed which can provide information on safe speeds to the driver (*Advisory/Informative* ISA), warn the driver when he/she is exceeding the speed limit (*Supportive* ISA), or control the brakes or throttle to prevent speeding (*Mandatory/Limiting* ISA). Most of the ISA systems that are available currently are based on fixed speed limits. However, there is a growing trend towards the development and testing of more dynamic ISA systems.

Road Safety and Impact on Driver Behaviour

The safety effects of ISA technologies depend on the type of ISA system used, the type of road environment and the penetration level of ISA equipment in the vehicle fleet (OECD/ECTM, 2006). Outcomes from a wide range of field trials conducted in Europe, North America and Australia are reported in this review. However, none of the studies were sufficiently large to provide empirical evidence demonstrating a reduction in crashes as a result of using ISA. Indeed, it is likely that the true effects of ISA will only emerge when a larger percentage of vehicles equipped with ISA are being used.

However, data models which map the relationship between speed and crash risk have been used to assess the likely effects of ISA on road safety. Research outcomes using this approach indicate that substantial reductions in fatalities and serious injuries could be achieved following the introduction of *Mandatory* ISA, with lesser, but still significant reductions expected where *Advisory* and/or *Supportive* systems are used widely. Some individual differences have been reported with respect to drivers' reactions to ISA technology; for example, it seems that younger drivers were less likely to be influenced by *Advisory* ISA systems and were more likely to turn the device off at times. Also, an emerging trend suggests that male drivers, especially young males, tend to have a more negative attitude towards ISA systems than their female counterparts. Nevertheless, a clear consensus emerged from the studies reviewed here which clearly demonstrates the safety potential of ISA technologies in terms of reducing speed and speeding and thereby reducing crash risk.

Some negative aspects of the various ISA technologies were reported in many studies. These include direct effects such as driver distraction, and indirect effects such as behavioural adaptation. Any activity that distracts the driver, or competes for his/her attention while driving, can potentially degrade driving performance and thus have serious consequences for road safety. Thus, careful consideration is needed when deciding on the nature and positioning of in-vehicle warnings and displays. Behavioural adaptation constitutes an unintended consequence following the introduction of innovations such as ISA technologies. It is acknowledged that whereas this phenomenon does not occur consistently, where it does occur, it tends to reduce the size of the expected effects of an intervention, rather than eliminate them altogether. Some negative behavioural adaptations were reported in studies that feature in this review including; frustration, driving faster on road segments where ISA was inactive, using shorter headway and gaps, overreliance on the ISA system, a tendency for non-ISA users to intimidate ISA users, and decreasing impact of *Voluntary* ISA systems on driving speed over time. Some researchers suggest that drivers will come to appreciate the benefits of ISA over time, but others believe that ISA may become less effective over time.

User Attitude and Acceptance

When it comes to the introduction of different in-car systems, public acceptance is hugely important. Without popular support, ISA will not be adopted widely, and it is highly unlikely that any government would decide to mandate ISA without strong support. Attitudinal research featured prominently in many of the studies reviewed. In general, the findings indicate that the majority of drivers tested were in favour of ISA, but that support tended to vary according to the type of ISA system, the type of road environment and the type of driver. Acceptance levels were highest for *Advisory/Informative* ISA systems but tended to decrease as the level of intrusion and control increased and invariably, the most effective form of ISA, *Mandatory* speed limiting, proved least popular with users. Thus, it appears that support was inversely related to the amount of control that the system exerted over driving speed choice; the more controlling the system, the less the drivers favoured it. In general, drivers who participated in ISA field trials were more positive about these technologies than the average driver. Acceptance of ISA differed for different road types, the associated speed limits and driving speeds. Greater acceptance was seen for urban roads with 30km/h and 50km/h speed limits. Research outcomes also suggested that those who would most benefit from ISA (e. g. young, male and/or inexperienced drivers), are least willing to use it. This highlights the risk of self-selection bias if ISA is introduced on a voluntary basis.

Environmental Impact

Speed management strategies are consistent with other important EU and domestic policy goals related to the environment. These include reducing CO_2 emissions, air pollution, and congestion. Currently, transport is the only sector where greenhouse gas emissions have grown consistently over the past two decades. Both fuel consumption and carbon dioxide emissions depend on a vehicle's travelling speed, thus reducing speed and enforcing speed limits is seen as one of the most effective, equitable and potentially popular means to achieving a lower carbon economy (ESTC, 2008). A number of key studies in this review addressed the potential environmental impact of ISA technologies. The results indicate that the introduction of *Mandatory* ISA would result in fuel savings ranging from 1% to 11%.

Travelling time impacts on fuel usage and traffic congestion. One large scale UK study included in this review showed that ISA use resulted in an increase of approximately 4.4% in travel time across the day on national, regional and local roads but no increase on motorways. However, other studies showed that ISA helped to improve traffic flow, which should reduce average travelling times and also traffic congestion. A number of studies also indicated that fitting cars with ISA systems would contribute greatly towards reducing CO_2 emissions in relation to private and commercial motoring activities. Overall, the evidence reviewed suggests that the introduction of ISA would result in reductions in fuel consumption and emissions.

Implementation

Globally, the use of ISA as part of an overall speed management strategy has widespread support among network and safety institutes, government bodies and those who have a stake in this issue. Studies including the EU-funded PROSPER project showed that stakeholders including politicians, governmental institutes, research institutes, pressure groups and commercial groups regarded ISA as an effective safety measure.

Although ISA technology has been available for some time, and reducing crash risk has been high on the political agenda in Europe, little progress has been made with implementing ISA. Although initial estimates suggested that the date when *Mandatory* ISA is fitted and used in the whole of the European fleet would be around 2035, clearly such targets cannot be met in the absence of strong political backing for ISA. According to RoSPA (2016) two general scenarios are envisaged for implementing ISA; Authority Driven and Market Driven. In an authority driven scenario, adoption of ISA would be encouraged initially and eventually required. In this scenario bodies that could enable quicker up-take of ISA would play a more proactive role, mainly through financial incentives or legal punishment. In a market driven scenario, users choose to have ISA because they want it. This scenario emphasises the role of car manufacturers and the subsequent consumer choices made by fleet managers and private car buyers in the proliferation of ISA equipped vehicles on the roads. Euro NCAP has been awarding points for cars equipped with speed management technologies since 2008. The current Euro NCAP protocol (Euro NCAP, 2017) actively promotes the installation of speed assistance systems. To achieve the coveted 5-star rating, cars will almost certainly need to have a speed assistance system fitted as standard. This constitutes an important step in promoting the large-scale deployment of ISA in the future. A number of financial and non-financial incentives have been proposed to encourage drivers to install and use ISA technology. Financial incentives for the installation of ISA can be provided either by reducing installation costs or through continuous discounting. Non-fiscal incentives examined in this review include increasing the number of penalty points for speeding and also increasing the length of time these points remain on a driver's record. Bundling safety features with more attractive features (e.g. entertainment packages) at the point of sale has also been proposed. Driver willingness to pay some, or even all, of the costs involved in equipping their vehicles with ISA was explored in many of the studies reviewed. The findings suggest that willingness to pay tends to depend on the degree of support that the system provides.

Market penetration is an important issue for ISA implementation and the results reported indicate that *Advisory* ISA would predominate if a *Market Driven* approach is taken to the deployment of ISA technologies. In contrast, in an *Authority Driven* scenario, *non- Mandatory* systems would eventually be superseded by *Mandatory* systems by around 2045. Furthermore, it is estimated that the *Authority Driven* scenario would reduce fatal crashes by 30% and serious crashes by 25% whereas the *Market Driven* scenario would reduce fatal crashes by 13% and serious crashes by 8%. Research suggests that overall, 16% of crashes would be prevented in an *Authority Driven* scenario and 5% of crashes would be prevented under a *Market Driven* scenario.

Implementation of speed control using ISA technologies will require a substantial investment, so comprehensive cost benefit analyses have been undertaken as part of some of the studies reviewed. For safety schemes, a benefit to cost ratio equal to or greater than 3 is generally regarded as a threshold for justifying investment. Since this threshold was consistently exceeded in all the studies examined for this review, it seems that the implementation of ISA on a large-scale is wholly justifiable from a social investment perspective. Furthermore, the more forceful *Authority Driven* scenario seems to represent the best option in financial terms. However, the benefits also depend on the form of ISA used and the rate with which they are adopted.

A number of barriers to ISA implementation have been identified and these have hindered progress in implementing ISA on a wider scale. These include; issues with technical functioning, applicability to the road network, observed benefits to the customer, pricing, liability issues in the event of crashes, violations or malfunctions, user privacy, time needed to renew the vehicle fleet, image of the car industry and the need for additional driver education.

The need for official support for ISA was highlighted in many studies and the EU has acknowledged that it has a clear role to play in creating the favourable conditions for accelerated and coordinated deployment of Intelligent Transport Systems, including ISA. For instance, work is progressing on developing and planning the maintenance of accurate, up-to-date digital speed maps and the harmonisation of speed limits throughout the EU. Nevertheless, considerably more official support will be needed to facilitate the wide-scale introduction of ISA. In this regard, the ETSC (2008) recommended the adoption of European legislation for the compulsory fitting of European cars with *Informative (Advisory)* or *Supportive* ISA systems in the type approval procedures for cars, stating also that the Directive should include technical requirements and an implementation timetable. In 2017, a resolution was passed in the European Parliament that all cars sold in Europe should be fitted with life-saving technologies including ISA. In May 2018, the EU Commission adopted a proposal for a Regulation of the European Parliament and of the Council, suggesting a paradigm shift in standard vehicle safety equipment and this included ISA. The Commission believes that ISA along with other Advanced Driver Assistance technologies not only have the potential to reduce road casualties, but also pave the way for the deployment of Connected and Autonomous Vehicles (CAVs).

Conclusions and Recommendations

The evidence presented in this review demonstrates that ISA technologies are effective in supporting drivers with managing speed. Experts in this field agree that by restricting the vehicle to the posted speed limit, ISA provides one of the most effective strategies for reducing inappropriate speeds, thereby improving road safety (ETSC, 2015). Furthermore, due to rapid advances in the development of low-cost technologies (e.g. GPS and nomadic devices) it is clear that the widespread deployment of ISA to support speed management is entirely feasible. Indeed, from a technical point of view, large-scale implementation of ISA is possible in the short-term. In addition, strong evidence has been presented that indicates that the benefits of implementing ISA greatly outweigh the related costs.

The pace of the uptake of ISA technologies will be dictated by the implementation strategy that is used. The proliferation of ISA would proceed faster in an *Authority Driven* scenario than in a *Market Driven* scenario. *Market Driven* implementation will likely favour the fitment of ISA systems that *Advise* or *Support* drivers, whereas the safer *Mandatory* system could be introduced much faster under an *Authority Driven* scenario.

The roll-out of ISA in Ireland will be contingent on the development and testing of digital speed maps. This process will entail a full review and update of speed limits on national, regional and local roads, possible legislative and regulatory changes, and benchmarking against engineering guidelines and standards. The Department for Transport, Tourism and Sport (DTTAS) are working currently to progress a digital speed database for Ireland as set out in Action 13 in their Speed Limit Review (Department of Transport, Tourism & Sport, 2013).

Successful implementation of ISA depends heavily on driver acceptance of the principle of in-vehicle control generally and on their willingness to install these systems and to use them correctly. Different types of ISA technologies impact differently on driver behaviour and on traffic safety: The more controlling the system, the more effective it is in reducing speed and road safety generally, but the less acceptable it will be to drivers. There is general agreement that the greatest benefits would be derived using *Mandatory* ISA. However, this form of speed control has been shown to be least acceptable to drivers.

More public engagement is required here in Ireland to gauge acceptance of various forms of ISA and to identify the most effective ways to encourage voluntary uptake of ISA by individuals or fleets. For instance, a communication plan should be developed which uses evidence from ISA research trials to explain the benefits of ISA to fleet managers and to the general public. In addition, a survey should be conducted to gauge public opinion generally and qualitative research (e. g. interviews, focus groups) should also be conducted to elicit the viewpoints of key stakeholders so that these can be taken into account when formulating an implementation strategy. Also, since driver willingness to relinquish control over some and eventually all aspects of vehicle functioning will be key to the deployment of Connected and Automated Vehicles (CAVs), and since this review shows that many drivers appear reluctant to relinquish control of speed choice, it seems that more research is needed to identify the instrumental and psychological needs that are fulfilled by driving in general, and speeding in particular for some drivers, and to find ways to address such needs in a safer context.

Currently, much of the focus in terms of in-vehicle technology concerns so-called 'self-driving' cars i.e. vehicles that drive themselves for a large part of the time, vehicles that can drive themselves all of the time within designated areas, and ultimately, fully connected and autonomous vehicles (CAVs). Intelligent Speed Assistance constitutes the first step in the five-step process that is required to develop fully autonomous vehicles. Informed opinion predicts that large scale commercial production of more sophisticated vehicle control technologies will escalate between 2020 and 2025. Analysis conducted by McKinsey & Company (2016) suggests that subject to progress on technical, infrastructure and regulatory challenges, up to 15% of all new vehicles could be fully autonomous by 2030, rising to 80% by 2040. Clearly, however there is still quite a way to go before fully autonomous vehicles designed for commercial and domestic use can be developed, tested, approved, marketed and ultimately proliferate on our roads. The evidence presented in this review shows clearly that ISA technologies that are available currently represent an efficient and effective way of controlling speeding and thus improving road safety **immediately.** Furthermore, these systems are relatively cheap and easy to fit and retrofit. For these reasons, it is recommended that more effort should be invested in promoting and supporting the use of ISA technologies in the short to medium term while we await the widespread proliferation of Connected and Autonomous Vehicles (CAVs).

This approach, when coordinated with existing measures, will undoubtedly help to achieve the targets set out in the Government Road Safety Strategy, 2013 – 2020 in terms of reducing serious injury and deaths on Irish Roads.

Glossary

Term	Definition
Active accelerator	A force feedback mechanism used in some Supportive ISA systems which signals drivers when they are exceeding the speed limit. Also called Haptic Throttle in some studies
ADAS	Advanced Driver Assistance Systems
Advisory ISA (Informative)	System that alerts drivers to changes in the speed limit
Advisory ISA (Warning)	System that warns drivers when they are exceeding the posted speed limit in a given location. Drivers can then decide whether or not to heed the warning and adjust their speed
Authority Driven	Implementation strategy whereby the introduction of ISA is encouraged by legislative or policy changes
AVSAS	Advanced Vehicle Speed Adaptation System
Behavioural Adaptation	Unintended behavioural changes that can occur in response to measures designed to improve road safety
CAVs	Connected and Autonomous Vehicles
CO_2	Carbon Dioxide
Dead throttle	A mechanism used in some Mandatory ISA systems which modifies the fuel supply to the engine in order to prevent speeding
ECTM	European Council of Transport Ministers
EPA	Environmental Protection Agency
EU	European Union
EVSC	External Vehicle Speed Control
GHG	Green House Gasses
GPS	Global Positioning System
Haptic throttle	See Active Accelerator
HGV	Heavy Goods Vehicle
Incentive ISA	A variant of ISA technology that records speeding violations and the resulting data is used to reward or punish drivers for their speed-related behaviour
IRTAD	International Road Traffic and Accident Database
ISA	Intelligent Speed Assistance
Km	Kilometres
Km/h	Kilometres per hour
LAVIA	Limiteur s'Adaptant à la VItesse Autorisée – a Large-scale French ISA project
Mandatory ISA	A variant of ISA which limits the maximum speed of a vehicle automatically to the speed limit in force at any given location
Market Driven	An implementation scenario where the market sets the pace for the introduction of ISA
MASTER	Managing Speed of Traffic on European Roads
Mph	Miles per hour

Term	Definition
NHTSA	National Highway Traffic Safety Administration
Nomadic device	A portable communication or information device that can be brought inside the vehicle to support the driving task and/or the transport operation (e.g. a mobile phone)
NOx	Nitrous Oxide
PAYS	Pay-as-you-speed
PDA	Proportion of distance driven above the speed limit
Penalty Points	Legal punishment for driving offences which are recorded cumulatively on a driver's licence
OECD	Organization for Economic Cooperation and Development
Percentile speed	Speed below which n-percent of drivers were observed to travel e.g. the 85^{th} percentile speed represents the speed below which 85% of traffic is travelling
PROSPER	Project for Research on Speed Adaptation Policies on European roads
ROI	Republic of Ireland
RSA	Road Safety Authority
RTA-NSW	Large ISA field trial conducted in New South Wales
RTC	Road Traffic Crash
Supportive ISA	A variant of ISA technology which supports speed limit compliance by providing haptic feedback using active accelerator
SNRA	Swedish National Road Administration (Vägverket)
TAC	Transport Accident Commission (Australia)
TPB	Theory of Planned Behaviour
UN	United Nations
Url	Uniform Resource Locator which is a reference (an address) to a resource on the Internet
Voluntary ISA	A form of ISA technology that drivers could choose to switch to activate or deactivate
US	United States
WHO	World Health Organisation

1 AIM & METHODOLOGY

The aim of this review was to examine and synthesise current knowledge in the field of Intelligent Speed Assistance (ISA), focussing predominantly on the application of ISA technologies in on-road (field) trials. Although the available information and knowledge covers a wide variety of ISA-related topics, this review focuses on four key themes which emerge consistently in relation to this topic. These themes are; safety (including the impact on driver behaviour), road user attitudes and acceptance, impact on the environment and implementation. A number of review objectives were developed, using these categories (Table 1).

Table 1 Key review objectives

<table>
<tr><th>Ref.</th><th>Review Objectives</th></tr>
<tr><td></td><td>Impact on safety and driver behaviour
Crashes
Changes in speed and speeding
Following behaviour/Gap acceptance
Interactions with other road users
Individual difference effects
Males/females;
Younger/older;
Habitual speeders/non-speeders
Potential negative impacts</td></tr>
<tr><td></td><td>User attitudes and acceptance
Acceptability
Attitudes</td></tr>
<tr><td></td><td>Impact on the Environment
Travel Time
Fuel savings
Emissions</td></tr>
<tr><td></td><td>Implementation
Implementation scenarios
Cost and benefits
Barriers to implementation
Policy implications</td></tr>
</table>

This synthesis does not try to produce an exhaustive account of all ISA research conducted to date but focuses instead on providing in-depth coverage of the lessons learned (as reported by researchers) from key studies.

The information used for this review was gathered through general internet searches and also specific searches on websites and electronic databases. Initial searches were based on the following terms "Intelligent speed adaptation OR assistance; on-road field trials". A number of key individuals and organisations were also contacted directly for information on current developments in the field of ISA. A full list of the websites accessed, and the people and organisations contacted is provided in Appendix A.

The data gathering exercise yielded 197 papers, including literature reviews, observational studies, surveys and intervention studies. Results of some relevant ISA studies could not be accessed directly, and a small number were not translated into English. Where possible, reliable secondary sources were used to fill in these gaps.

1.1 Information management

The following set of databases were set up to facilitate information management;

1.1.1 Literature review database (Endnote)

An Endnote database was compiled which contained details of papers and reports identified as part of the information gathering process, including;

- ID number
- Reference (author, year, name and source)
- File name
- Study abstract
- URL (where applicable)

1.1.2 A summary table of on-road trials

This table was based initially on work done at Monash University (see Young & Regan, 2002). This table was expanded as part of this review and the updated version which is presented as Appendix B includes information in the following categories;

- Location
- Authors
- Study name
- Study type
- Road types
- Study duration
- Drivers/vehicles
- Interventions: ISA functionality
- Mechanisms: Measures investigated
- Outcomes

- Safety Benefits
- Negative aspects
- Acceptability

2 BACKGROUND AND CONTEXT

Intelligent Speed Assistance technologies are designed to improve speed management and thereby to improve road safety.

2.1 Current trends in road safety

Road traffic crashes (RTCs) constitute a modern-day 'epidemic' with over 1.35 million people killed and 50 million people injured globally each year (WHO, 2018). It is estimated that this level of impact imposes financial costs of between 1 and 3 percent of GDP in most countries (IRTAD, 2015). However, the full impact of this level of trauma on individuals, families, communities and society is generally impossible to quantify. The World Health Organization has also predicted that deaths resulting from RTCs will represent the fifth leading cause of death by 2030 unless urgent action is taken (WHO, 2015).

The United Nations (UN) launched the Decade of Action for Road Safety in 2011, with the objective of stabilising and reducing RTC fatalities by increasing road safety activities conducted at national, regional and global levels. Member states were encouraged to ensure that national action plans were developed organised around the five pillars of the "Safe System" approach which are shown in Figure 1.

Figure 1. Five pillars of road safety.

Road safety is also seen as a major societal issue in Europe: in 2010 the EU Commission adopted an ambitious Road Safety Programme which aims to half the overall number of road deaths between 2010 and 2020 (EU Commission, 2010). Records show that there were 25,300 deaths and no fewer than 135,000 injuries on EU roads 2017 with an estimated socio-economic cost of €120 billion in that year alone (European Commission, 2018a). Although the number of road deaths fell by 20% from 2010 to 2017, it is clear that it will be difficult to reach the ambitious target set out in the current Road Safety Programme. Nevertheless, the EU have now proposed a new policy framework for 2021 – 2030 which reaffirms the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050 (Vision Zero), with an interim target of minus 50% between 2020 and 2030. As part of this strategy the Commission proposes to make vehicle safety and driver assistance features, including Intelligent Speed Assistance mandatory on vehicles (EU Commission, 2018a).

The Irish Government also set out a Road Safety Strategy (2013 – 2020) including the following targets;

- A target to reduce RTC fatalities to 25 per million inhabitants or less by 2020
- Specific targets for reducing speed and increasing restraint use (EU Commission, 2016).

In recent years, there has been a general downward trend in RTC-related fatalities in Ireland, with the numbers decreasing from 472 in 1997 to 156 in 2017[1]. This constitutes a three-fold decrease in this 20-year period. In order to meet the target of 25 per million population (i.e. 124 deaths per year by 2020), a further 21% reduction in fatalities is required by the end of 2020.

2.2 Risk-increasing factors

It is widely-acknowledged that three types of factors; human factors, environmental factors and vehicle factors give rise to increased risk of RTCs (Haddon, 1968). Furthermore, research shows consistently that human behaviour, in the form of driving errors and/or violations are major causal factors in upwards of 90% of all RTCs. For instance, human behaviour was cited as a causal factor in 92% of fatal RTCs in Ireland in 2009 (RSA, 2010). Such findings indicate that efforts to reduce RTCs need to be focussed on improving road user behaviour.

2.3 The problem of speed

Speeding, which encompasses excessive speed (driving about the speed limit) and/or inappropriate speed (driving too fast for the prevailing conditions) is inherently dangerous (Fuller et al., 2008). A wealth of scientific evidence confirms that speeding is a major risk factor in RTCs. It is generally accepted that speeding is a causal factor in approximately one third of fatal RTCs (OECD/ECTM, 2006). This relationship was famously modelled by Nilsson (2004), who showed that the risk of crashing increases exponentially as speed increases, to the extent that we can reliably predict that a 1% increase in speed will result in a 3% increase in fatal RTCs and a 5% to 6% increase in serious and fatal injury crashes (for details see Aarts & Van Schagen, 2006; Elvik, Høye, Vaa, & Sørensen, 2009; Nilsson, 2004). Research conducted in Australia by Kloeden and his colleagues further clarified the relationship between speed and crash likelihood (Kloeden, McLean, & Glonek, 2002; Kloeden, McLean, Moore, & Ponte, 1997; Kloeden, Ponte, & McLean, 2001). Their research focused on quantifying the risk of being involved in a casualty crash relative to travelling at the average traffic speed (i.e. 60 km/h in a 60 km/h speed limit zone on urban roads and between 80-120 km/h on rural roads). The main findings, shown in Figure 2, demonstrate clearly that travelling at speeds slower than the average speed did not increase the risk of involvement in a casualty crash. However, once the speed limit of 60 km/h was exceeded on urban roads, the risk of being involved in a casualty crash increased exponentially i.e., the risk doubled (approximately) with each 5 km/h increase in travelling speed. Based on this analysis, it was estimated that if none of the vehicles in the study had exceeded the 60 km/h speed limit on urban roads, then 50% of the crashes in the 65 km/h zone might have been avoided (or been reduced from a casualty crash to one not requiring an ambulance), increasing to 98% of the 85 km/h crashes and almost all of the crashes where vehicles were travelling above 87 km/h. It was further estimated that on rural roads, a reduction in speed of 5 km/h would result in a 30.5% reduction in casualty crashes, increasing to 46.5% and 59.6% where speed is reduced by 10 km/h and 20 km/h respectively.

[1] Please note, this is a provisional figure, and may be subject to change.

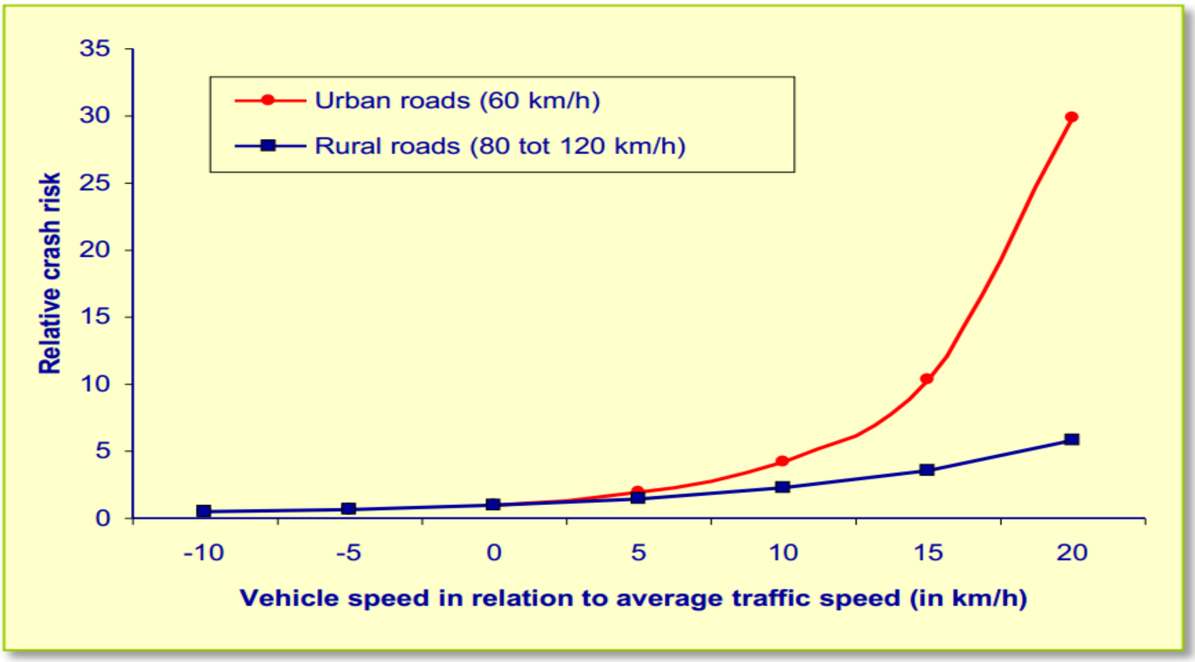

Figure 2. The relative risk of involvement in a casualty crash on urban roads (Kloeden et al., 2002) and rural roads (Kloeden et al., 1997; 2001) for vehicles driving faster or slower than the average speed on that road (=0 km/h deviation). (Source SWOV (2015)).

2.3.1 Speed Limit Compliance

Despite the evident risk, and irrespective of efforts to encourage speed limit compliance by means of improved engineering, enforcement and education, speeding remains a ubiquitous feature in most driving cultures (OECD-ECTM, 2010; OECD - ECMT, 2006a; RSA, 2011; United Nations Road Safety Collaboration, 2011). For instance, the OECD estimated that 50% of individuals who are driving in OECD member countries are exceeding legal speed limits at any given moment, albeit that most of these drivers were exceeding the limit by just a few km/h. The OECD also reported that speeding constitutes the biggest road safety problem in many regions, contributing to approximately one third of fatal crashes, while simultaneously constituting an aggravating factor in all crashes (OECD/ECTM, 2006).

Similarly, speeding represents a significant challenge when it comes to improving safety on Irish roads. An in-depth analysis of fatal collisions that occurred in Ireland from 2008 to 2012 showed that excessive speed for the road and conditions was the main contributory factor in one in three fatal collisions during that period (RSA, 2016). Observational research conducted periodically by the RSA “The Free Speed Survey” provides some insight into the nature of speeding in Ireland. Free speeds represent speeds at which drivers choose to travel when unconstrained by environmental factors. Of the 17,591 vehicles observed in 2016, more than half (57%) of car drivers were observed exceeding the posted speed limit on urban roads and more than one in five drivers were recorded exceeding the speed limits on rural roads (22%), motorways (21%) and dual carriageways (28%). Speeding was even more prevalent among professional drivers. On urban roads, 55% of rigid and articulated truck drivers and 38% of single deck bus drivers were speeding. Significant levels of speeding were also recorded on rural roads, where over 1 in 3 rigid truck (36%) and articulated truck (38%) and 11% of single deck busses were observed speeding. These findings show clearly that speeding is a widespread problem in Ireland and for that reason, speeding has been identified as a key target in the Irish Government's Road Safety Strategy 2013 – 2020 (RSA, 2013).

2.3.2 Characteristics of drivers who tend to speed

The National Highway Traffic Safety Administration (NHTSA) (2003) reported results of a survey that they conducted to define the nature and scope of speeding in the US. This showed that whereas a majority of drivers of all ages admitted to speeding, compared to older drivers, younger drivers reported more speeding on a monthly basis, with eight in ten admitting to speeding on all types of roads. Males were 50% more likely to report driving over the posted speed limit than females. Similarly, a national survey of drivers in the Republic of Ireland found that drivers under the age of 25 were more risky in terms of rule violations and speeding behaviours than those over 25 (Sarma, Carey, Kervick, Bimpeh (2013).

2.3.3 Speed choice: Why drivers exceed the speed limit

At a societal level, speed is generally perceived as an asset. In the transport sector, technological advances have made it possible to travel faster by car, train and aircraft, thus significantly decreasing travel time and supporting efficiency and greater mobility.

In principle, increased driving speeds result in a reduction in travel times. However, the perceived gains of time, particularly on short journeys, is much larger than the actual (objective) gain in time, which in reality is merely marginal (see Table 2). This is poorly understood by drivers and motorcyclists. In addition, higher speeds result in more crashes, which in turn lead to traffic congestion (SafetyNet, 2009).

Table 2 Extra time taken for a 10 km journey when speed is reduced by 5 km/h (Source: ETSC (1995))

Original speed	50 km/h	70 km/h	90 km/h	110 km/h	130 km/h
Extra time taken (minutes)	1.33	0.66	0.39	0.26	0.18

In terms of individual drivers, speed can also represent a source of pleasure for some, providing a sense of freedom and excitement (OECD/ECTM, 2006). Delhomme and Cauzard characterised speeding as 'an ambivalent dimension', because, besides being an indicator of pleasure, sensation and driving ability, it is also a source of risk to drivers (2000; as cited in Delhomme, Verlhiac, & Martha, 2009). For instance, the results from the EU SARTRE 3 study (2004) showed that more than 80% of European drivers believed that driving too fast is 'often', 'very often' or 'always' a contributory factor in RTCs. Nevertheless, the available evidence shows clearly that many drivers persist in exceeding the posted speed limits. Many do so out of choice often for instrumental reasons (e.g. getting to a destination quicker) or for emotional reasons (e.g. pleasure, enjoyment and/or a sense of freedom).

2.3.4 Theoretical perspective on speeding: The Theory of Planned Behaviour

Several theories have been used in an attempt to explain the psychological basis of speeding, most notably Ajzen's Theory of Planned Behaviour (TPB; Ajzen, 1991). The TPB focuses on rational decision making and models the relationship between a range of behavioural determinants including behavioural beliefs (attitudes), normative beliefs and control beliefs and behavioural intentions. Behavioural beliefs represent subjective estimates of the likely consequences of a particular behaviour, which in turn give rise to an attitude towards that behaviour. Normative beliefs describe the normative expectations of others, which give rise to perceptions of social pressure, which are described in terms of a subjective norm. Control beliefs are derived following an evaluation of factors that may make the performance of the behaviour either more or less likely and measurements on this scale describe perceived behavioural control (Francis et al., 2009). These three determinants operate in tandem to form a behavioural intention, the strength of which is dictated by variations in attitude and subjective norm, combined with perceptions of control. A review of 185 TPB studies conducted by Armitage and Connor (2001) found that attitudes, subjective norms and perceived behavioural control accounted for 39% of the variation in intentions and that intentions accounted for 31% of variation in actual behaviour.

Compelling evidence has been produced that demonstrates the relationship between TPB variables and drivers' intention to speed. Early studies conducted by Diane Parker and her colleagues (Parker, 1997; Parker, Manstead, Stradling, & Reason, 1992) found that attitudes, subjective norms and perceived behavioural control together accounted for 47% of the variance in intentions to speed. Furthermore, these three variables accounted for between 47% and 56% of the variance in intentions to exceed the speed limit in 30mph, 40mph and 60mph speed zones.

An analysis conducted by Brown and Cotton (2003) further highlighted the importance of TPB components in relation to speeding as follows;

Beliefs and attitudes: Speeders (compared to non-speeders) believed that speeding was less likely to result in negative outcomes, particularly when they themselves were speeding Stradling (1999). Speeders believe that they get to their destination quicker and that speeding makes the journey more pleasant (Parker, Manstead, Stradling, Reason, & Baxter, 1992; SARTRE 4, 2011; Wallén Warner & Aberg, 2008).
Social norms: In comparison with drink-driving, speeding entails less stigma and may be viewed as a normative behaviour engaged in by the majority of drivers (Stradling, 1999).
Perceived behavioural control: Many speeders have an illusory sense of control over their driving. For instance, drivers speeding in urban areas believed that they are better adjusted to speed of other drivers (Parker, Manstead, Stradling, & Reason, 1992).

2.3.5 Improving speed limit compliance – speed management

Many strategies are adopted to improve speed limit compliance (see Elvik et al., 2009 for a comprehensive review), including;

- Infrastructural interventions (e.g. roundabouts, speed bumps)
- Legislative measures (e.g. reduced speed limits, higher fines for speeding violations)
- Stricter enforcement of existing legislation (e.g. more speed cameras)
- Educational initiatives (e.g. public awareness campaigns, education programmes for learner and novice drivers, schools and in the community generally)

Furthermore, when the OECD asked leading road safety practitioners to identify key measures to reduce speeding (see OECD - International Transport Forum, 2008) they recommended;

- Enforcement of existing speed limits can provide immediate safety benefits, and do so more quickly than any other single safety measure
- Ensuring that speed limits are appropriate for the prevailing environmental conditions
- Mobilisation of public support for reduced speed limits

Clearly, none of these measures can be applied everywhere and at all times. Therefore, it is not realistic to expect conventional anti-speeding measures to ever be applied to such an extent that compliance with speed limits approaches 100% (Vaa, Assum, & Elvik, 2014).

2.4 Intelligent Speed Adaptation/Assistance (ISA)

Intelligent Speed Assistance (ISA) is the generic name for an in-car Advanced Driver Assistance System (ADAS) that helps drivers to comply with the speed limit (European Commission, 2016). The ISA concept has been developed and tested extensively over the past three decades in many countries. It is important to note however, that none of the studies selected for inclusion in this review were sufficiently large to provide empirical evidence demonstrating a reduction in crashes as a result of using ISA.

2.4.1 Core elements of ISA systems

ISA systems require four basic elements (see Figure 3).

1. A speed limit database to provide detailed information on the speed limit in force in each section of the road. Since local or national authorities are responsible for determining speed limits, it follows that they should also play a major role in the development of such databases.
2. The means to determine the position and direction of travel of a vehicle which is usually achieved using GPS technology. However, more advanced so called 'dynamic' ISA systems can also use information from vehicle sensors or roadside information systems.
3. Actual speed is measured by the vehicle's own speed measurement system.
4. Determination of the relationship between the appropriate speed and the actual speed. This dictates how, when and in what way the ISA system is activated.

Figure 3. The ISA concept (Source: Vlassenroot et al., 2004).

Elements 2-4 are generally developed by those who manufacture the equipment, so, it is likely that multiple diverse systems will be developed and evolve unless standardised requirements are mandated by appropriate standard-setting bodies.

2.4.2 Technology options for ISA

Different types of ISA systems have been developed, which provide different levels of support and feedback to drivers. These fall into three general categories, *Advisory*, *Supportive* and *Mandatory* ISA systems, as outlined in Table 3. *Advisory* systems provide drivers with information about speed limits, *Supportive* systems warn the driver if he/she is exceeding the speed limit in a given location. *Mandatory/Limiting* devices make it impossible for the driver to exceed the posted speed limit.

Table 3 Overview of different types of ISA (Adapted from Morsink et al. (2006))

Level of support	Type of feedback	Definition
Advisory/Informative	Mainly visual	The speed limit is displayed, and the driver is alerted to changes in the speed limit
Advisory/Warning (open)	Visual/auditory	The system warns the driver if he/she is exceeding the posted speed limit at a given location. The driver then decides whether to use or ignore this information to adjust his/her speed
Supportive/Intervening (half-open)	Haptic throttle/Active accelerator (moderate/low force feedback)	The driver receives force feedback via the accelerator if he/she tries to exceed the speed limit. By applying sufficient force, drivers can still exceed the speed limit
Mandatory Limiting/ Automatic control (closed)	Haptic throttle (strong force feedback) & Dead throttle	The maximum speed of the vehicle is automatically limited to the speed limit in force. Drivers' requests for a speed beyond the speed limit are simply ignored

A further variant of *Advisory* ISA, *Incentive* ISA, has been developed which records speeding violations and the logged data is used subsequently to reward or punish drivers for their speed-related behaviour.

ISA systems can use speed limits in various ways (see Carsten & Tate, 2005);

- Static speed limits – The driver is informed of posted speed limits.
- Variable speed limits – The driver is additionally informed about lower speed limits at specific locations (e.g. road construction sites, pedestrian crossings, sharp curves etc.), thus the speed limit information is dependent on location.

- Dynamic speed limits – This system uses speed limits that account for the actual road and traffic conditions (weather, traffic density). Thus, in addition to depending on location, the dynamic speed limits are also dependent on time.

Most of the ISA systems that are available currently are based on fixed speed limits. In some cases, they may also include location-dependent (*Advisory*) speed limits. However, there is a growing trend towards the development and testing of dynamic ISA systems (European Road Safety Observatory, 2016).

3 ISA FIELD TRIALS

Research on Intelligent Speed Assistance (ISA) technologies began in 1982 when French researchers, Saad and Malaterre, tested an in-vehicle speed limiter. Drivers using this system set the desired maximum speed, which could not be exceeded unless the driver actively disengaged it. The results showed that drivers generally set the maximum speed limit significantly higher than the legal speed limit. Drivers also reported that the system was too effective and thus limited their freedom to manoeuvre (Saad & Malaterre, 1982).

The systematic investigation of ISA systems began in earnest in the early 1990s in Sweden (Almqvist & Nygård, 1997; Persson, Towliat, Almqvist, Risser, & Magdeburg, 1993). Subsequently, from the late 1990s to the mid-2000s there was a continual stream of research in various European countries including Sweden (Swedish National Road Administration (Vägverket), 2002), the UK (Carsten & Tate, 2000), the Netherlands (Duynstee & Martens, 2001), Denmark (Lahrmann, Agerholm, Tradisauskas, Berthelsen, & Harms, 2012), France (Driscoll, Page, Lassarre, & Ehrlich, 2007), Belgium (Vlassenroot et al., 2004) as well as EU-funded research projects e.g. MASTER (Varhelyi, 1998) and PROSPER (Cunningham & Sundberg, 2006). Thereafter, large-scale projects such as the "ISA-UK" initiative have progressed knowledge about the effects of ISA (Carsten, Fowkes, et al., 2008). A number of ISA trials have also been conducted in Australia (see Barnes et al., 2010; M. A. Regan et al., 2006) and in North America (see Waibl et al., 2013). A list of trials and their key results originally developed by Young & Regan (2002) at Monash University was extended and expanded as part of this current review and appears as Appendix B to this document.

3.1 Sweden

3.1.1 Lund and Eslöv

A series of field trials conducted in the 1990s placed Sweden at the cutting edge of research in ISA, beginning with two small studies, one in Lund and the other in Eslöv. The Lund study involved 75 motorists, who drove a Volvo car for one hour on a test route. The vehicle was equipped with an *Advisory* speed limit display and a *Mandatory* ISA system (active throttle), which limited speed to a maximum of 50 km/h. Upon entering a 50 km/h zone, drivers would feel increased resistance in the accelerator pedal and were unable to increase speed beyond this limit. General speed reductions were recorded during the trial as well as reduced incidences of red light running. However, some speed increases were recorded on approaches and in turnings and driver behaviour worsened during interactions with other road users. Driver acceptance of the ISA systems improved after they tested the system (Persson et al., 1993). A similar ISA system was used in the Eslöv trial, which was also set at a maximum speed of 50 km/h. The outcome of this study was generally encouraging. There was a general reduction in speed and speeding and driver behaviour improved in interactions with other road users. Travel times increased by 5%. Driver attitudes towards ISA improved after they had used the system. Also, participants tended to believe that the speed limiter provided safety benefits and did not perceive it as providing unwelcomed control. Clear differences emerged between participants' speed-related behaviours with and without the speed limiter. Initial measurements revealed that the participants regularly exceeded the speed limit.

However, two months after the installation of the speed limiters, the participants' average speed had decreased and was within the speed limits (Almqvist & Nygård, 1997).

3.1.2 Umeå: Borlänge: Lidköping: and Lund

The earlier trials paved the way for the world's largest ISA trial which was initiated to provide the Swedish government with advice as to which system to select to improve road safety. The study was conducted in four cities: Umeå: Borlänge: Lidköping: and Lund, involved several thousand vehicles and was coordinated by the Swedish National Road Administration (Vägverket) (2002). The objectives of the studies were to increase knowledge about motorists' attitudes towards ISA, assess the potential traffic safety and the environmental costs and benefits of various ISA systems. The project commenced in 1999 and the ISA-equipped vehicles were in operation from August 2000 to December 2001. More than five thousand cars were equipped with *Advisory (Informative)* and *Supportive* systems to help motorists (including over 10,000 private and professional drivers) to comply with the speed limit. The design of the trials varied substantially between the cities. Notably, each city implemented and evaluated different variants of ISA: An *Advisory* ISA (audio and visual warning signal) was tested in Umeå; an *Advisory* ISA with additional display indicating existing speed limit was used in Borlänge; a *Supportive* (active accelerator) ISA system was examined in Lund and a combination of *Informative* and *Supportive* systems was used in Lidköping (Swedish National Road Administration (Vägverket), 2002).

The results of this study showed that there was a clear reduction in average speed, speed variations and lower speeds approaching intersections. Table 4 provides an overview of the reductions in average speeds in Lund and in Borlänge at the end of the trial (post period 1) and then again one month later (post period 2).

Table 4 Average driving speed changes in Lund and Borlänge for one pre-ISA and two post-ISA periods (Adapted from Swedish National Road Administration (Vägverket) (2002))

Driving speeds	Speed (km/h)		
	Pre-activation period	Difference, post period 1	Difference, post period 2
Lund (Supportive - Active accelerator)			
30km/h	21.9	-0.8	-0.2
50km/h	36.4	-1.1	-1.2
70/km/h	58.7	-2.0	-2.0
Borlänge (Advisory – informative)			
30km/h	25.3	-0.6	-0.6

Driving speeds	Speed (km/h)		
	Pre-activation period	Difference, post period 1	Difference, post period 2
50km/h	38.7	-1.5	-1.5
70/km/h	58.7	-2.8	-3.0
Driving speeds	Speed (km/h)		
	Pre-activation period	Difference, post period 1	Difference, post period 2
90km/h	84.4	-2.5	-3.4
110km/h	97.3	-1.1	n.a.

In post period 1, the lowest reductions were recorded in 30-50km/h zones and the highest reductions occurred in 70km/h zones. Overall, the effect shown here is clear but small. However, it should be noted that speeds in the pre-activation period were already well under the legal speed limits. Also, there is a clear trend evidencing the diminishing effects of ISA on driving speeds over time. Somewhat surprisingly, the speed reduction with the *Advisory* system was greater than that achieved with the *Supportive* system, however this difference only amounted to 0.3-0.4km/h in 30-50km/h zones which were the main focus of the trial. This was likely due to the fact that users found the audio warning irritating and often attempted to override it. Speed variation was reduced by 40% on 70km/h roads and approaches at 50km/h. Variation in general speeds on 30 and 50km/h roads was reduced by between 30-35%. The reduction in speed variation was significantly lower in Borlänge compared to the active accelerator test in Lund. Journey times were unaffected due to the fact that there were less stopping and fewer braking situations with ISA.

Approximately 10% of the trial vehicles were public or commercial transport vehicles and professional drivers and those driving company cars generally held more negative attitudes towards ISA. Acceptance in this group was low: Compared to private motorists, professional drivers graded the usefulness of ISA as somewhat lower and its attractiveness as much lower. Warning ISA was seen as disturbing, especially when driving with passengers. This lower acceptance might be explained by workplace stress, for instance bus drivers yielded less often at pedestrian crossings, which could be interpreted as an attempt to compensate for lost time due to slower speeds elsewhere. However, sufficient evidence was not found to support a definite conclusion on this. Most of the professional drivers (65%) agreed that speed limits should be observed in densely built-up areas, however the remainder believed that the rhythm of traffic often demands higher speeds than the one stipulated. Even so, very few drivers objected to making ISA compulsory for certain groups e.g. school and ordinary busses and vehicles transporting sick and elderly people.

3.1.3 Stockholm

The "ISA for Stockholm" project tested a *Supportive* ISA system, based on active accelerator pedal technology which was installed on 20 vehicles (130 drivers). The trial lasted for 6 months at the end of which, average driving speed decreased especially on roads with higher speed limits and speeding violations were reduced by 30%. Although two-thirds of drivers reported some frustration when using the system, driver acceptance was good e.g. 75% of users wanted to keep the system at the end of the trial. After the trials, the City Council of Stockholm decided to set a target to have ISA in all vehicles driving in the city before 2010 (Transek & SWECO VBB, 2005).

3.1.4 Gothenburg

Trials involving 16 busses that were equipped with *Supportive* (active accelerator) ISA were held in Gothenburg from November 2002 to April 2003. The route used passed through speed zones including 15, 20, 30, 50 and 70km/h and the drive took 42-49 minutes in total. The use of ISA reduced speeding, especially in the lower speed zones, where the proportion of speeding was highest before the trials. There was no perceived increase in travel times using the system. Some drivers reported pain and discomfort in their calves and knees due to the pressure from the active accelerator and this was most acute in the transition from 50-30km/h. Drivers also expressed some negative attitudes towards the system. Whereas 10% said they would feel uncomfortable with this level of 'supervision' at the start of the trials, one-third expressed this attitude at the end of the trial. Just 10-20% of drivers though that in-vehicle technology was a good way of reducing speed. Many suggested external measures (e.g. variable message signs and physical street design) as equally good or even better alternatives. On the positive side, drivers expressed the greatest acceptance for ISA on 30km/h roads and were in favour of using ISA as grounds for changing the existing bus timetable. In contrast to the drivers, many passengers (40%) expressed confidence in new technology in vehicles for preventing speeding. All age groups were predominantly positive about the use of ISA on public transport. No gender differences in attitudes were observed (Transek, 2003).

3.2 The Netherlands

3.2.1 Groningen

Field trials of ISA in the Netherlands began with a study conducted in Groningen (Brookhuis & de Waard, 1999). Twenty-four volunteers drove a vehicle equipped with an *Advisory* ISA system which provided auditory and visual warnings when the speed limit was exceeded by 10%. The route taken included motorways and built-up areas with speed zones of 50, 70, 80, 100, 120km/h. Each trial took approximately 35 minutes to complete. Workload was measured using heart rate monitors and a questionnaire. A 4% decrease in speeding was recorded as a result of using the ISA feedback and this effect was strongest in zones where the drivers tended to violate speed limits regularly (e.g. 50km/h). Significant reductions in speed variability were also recorded. Some slight increases in mental workload were reported in the questionnaires but this was not reflected in the physiological data. Driver acceptance varied according to the type of ISA feedback that was provided. Drivers preferred to receive continuous feedback.

3.2.2 Tilburg

ISA research in the Netherlands began in 1999 with a nationally funded field trial in the city of Tilburg (Duynstee & Martens, 2001). This one-year trial involved 20 cars (120 drivers) and one city bus (20 drivers) which were equipped with a *Mandatory* form of ISA, based on 'active accelerator' technology, which automatically restricted the fuel inlet when the speed limit was exceeded. An 'escape' was installed to allow drivers to override the system in case of emergency. Three speed limits were used; 30, 50 and 80 km/h. The study examined driving behaviour, user ergonomics, user acceptance and public support. Because this was a relatively small-scale trial, it was not possible to demonstrate significant effects of ISA on road safety, emissions and energy consumption.

The data from the trial showed that this *Mandatory* system prevented speed limit violations completely within the trial area. Average speeds decreased significantly (-3% to -8.3%). Table 5 shows the 95th percentile speed differences between ISA and non-ISA driving, with recorded reductions of 6.7, 9.7 and 2.8 km/h in 30, 50 and 80 km/h zones respectively. More homogeneous speed patterns were also achieved. It was also noted that the effect of ISA increased where there were no traffic calming measures.

Table 5 Speed reductions in Tilburg (Adapted from Duynstee & Martens, 2001).

Speed Limit (km/h)	Unrestricted v95 (km/h)	ISA v95 (km/h)	Difference v95 (km/h)
30	44.4	28.9	<u>-6.7</u>
50	57.0	47.3	<u>-9.7</u>
80	77.9	75.1	<u>-2.8</u>

Note: Underlined results were statistically significant at the level $p<0.05$.

The results of a driver survey showed that one quarter of test drivers reported lower speeds within the speed limit, committed fewer other traffic violations and kept more distance from other road users. Half of the test drivers reported hardly any speed compensation outside of the ISA test area. Outside of the test area, some ISA drivers reported irritation from other road users (tailgating) which caused them to feel embarrassed. Contradictory findings were reported regarding the effect of ISA on driver attention: Almost a third of test drivers reported a reduction in attention to the driving task, while an equal number reported an increase in attention.

User acceptance was measured also, and the results showed that whereas the majority of the car drivers experienced ISA-equipped driving as less enjoyable (52%) a larger percentage were in favour of ISA use (64%). The majority of the bus drivers tested experienced the ISA system as more enjoyable (60%) and most of the bus drivers were in favour of ISA use (90%). User support was determined by surveying attitudes towards ISA before and during the trial. Although there was a slight decrease from 'slightly and very positive' to 'neutral' over the course of the trial, the majority of the test drivers continued to support ISA (55%), 19% were 'neutral' and a minority of drivers (16%) had a negative attitude towards ISA by the end of the trial. Public support was assessed by surveying attitudes towards ISA before and during the test. The results showed that the majority of the public held a 'neutral' to 'positive' attitude towards ISA (79%) before the test, which decreased slightly during the test (67%).

In sum, the results from Tilburg trials demonstrated that *Mandatory* ISA had a positive effect on driving behaviour and speed patterns, notwithstanding that interactions with non-ISA drivers sometimes lead to risky manoeuvres (passing and tailgating). Users are generally in favour of ISA, and the majority of the public were either not averse or positive about the speed limiting systems (van Loon & Duynstee, ND).

3.2.3 ISA for serious speed offenders

A field trial was conducted in the Netherlands in 2011 to investigate the potential for using restrictive ISA as a penalty system for serious speed offenders (van der Pas, Kessels, Vlassenroot, & van Wee, 2014). Two forms of ISA were tested; a speed monitoring device (Speedmonitor) and a more restrictive speed limiting system (Speedlock). Fifty-one, known speed offenders drove cars equipped with one of these systems over a total of 650,000kms. Effects on traffic safety were calculated (e.g. Kloeden et al., 1997; Nilsson, 2004). Depending on the type of road, the results predicted reductions in serious injury crashes of between 7-25% for Speedlock and of between 3-33% for Speedmonitor. Speedlock produced an 11-35% reduction in the likelihood of a fatal crash and Speedmonitor produced a 4-47% reduction. Reductions in speed variation were also reported. System users reported that they engaged in less tailgating and reduced abrupt and hard braking, fast acceleration and also that they anticipated more. Some negative behavioural adaptation by other drivers were reported, including increased tailgating and more frequent overtaking.

3.3 Finland

In Finland, on-road ISA trials were conducted in 2001 with 24 drivers, who used *Informing (Advisory)*, *Mandatory* or *Recording* ISA technologies (Päätalo, Peltola, & Kallio, 2002). The former have been defined previously, and the latter consisted of a system that recorded driving speed so that it could be inspected at a later stage. All systems had the effect of reducing the amount of time spent speeding, especially excessive speeding. The *Mandatory* system was most effective in reducing speed producing reductions of 3.4km/h in average speed and 74% in speeding violations. The *Informing* system was also effective, resulting in reductions of 2.8km/h in average speed and a 39% reduction in speeding violations. Smaller reductions were seen with the *Recording* system. User acceptability was inverse to the level of control exerted; the *Recording* system was most popular, followed by the *Informing* system but the *Mandator*y system was found least enjoyable. Drivers approved of the *Informing* system more because they felt that they still had control of their car, although they found the voice alerts annoying. They also felt that the *Recording* system would be most useful in the future, although it should be noted that no actual penalties were applied when drivers exceeded the limit. Mental demand, frustration and insecurity levels was higher when using the *Mandatory* system.

3.4 Denmark

3.4.1 INFATI

A trial involving *Advisory* (audio warning) ISA was conducted in 2001, in Alborg. Twenty-four drivers used this system for four weeks and during that time there was a clear decrease in the

85th percentile for speed violations (- 5% to -6%) in that group. The decrease was larger in rural as opposed to urban areas. Users reported that the feedback provided by the system was accurate. They understood that the concept of freedom in the context of speeding is about 'freedom to break the law' and they did not feel that ISA had limited their freedom. Drivers also reported increased awareness of speed and speeding violations and a reduction in mental effort from not having to actively monitor speed limits. However, acceptance was lower in lower speed zones than in higher zones. Drivers became annoyed with the warnings when they were busy and tended to increase speed, despite the warnings, in such situations (FOT-Net Data, 2016).

3.4.2 Pay-as-you-speed

As a result of positive reactions from drivers involved in the earlier INFATI project and in order to simulate a market introduction of ISA, the Pay-as-You-Speed (PAYS) concept was trialled in Jutland from 2007 to 2009. The PAYS concept linked three key factors; ISA technology, driver behaviour and incentives. An *Informative/Recording* ISA system was used to monitor speed-related behaviour and the participants were offered an economic incentive, amounting to a 30% discount on their insurance premium, for driving below the speed limit. When drivers exceeded the speed limits they received penalty points, which in turn reduced the amount of discount awarded. This project was designed initially to study the effects of incentives on younger drivers (under 24-year-olds) to reduce the danger for this high-risk category and also in an effort to instil good speed choice habits. Initially, however, this market-driven approach did not seem appealing to the target group. Apparently, the discount offered was not enough to encourage a sufficient number of young drivers to take part in the trial and so the participant base was widened to cover the broader driving community (Lahrmann, Agerholm, Tradisauskas, Næss, et al., 2012).

The data collected in this trial covered almost 1 million kilometres of driving. Participants used information only, incentive only and a combination of both successively, in a baseline (normal) and three experimental phases. The overall effect of the PAYS systems on driver speed choice across all speed zones, in terms of the proportion of distance travelled at 5km/h or more over the speed limit (PDA), is illustrated in Figure 4. This shows that participants in all of the test groups tended to exceed the speed limits at the start of the trial i.e. before the PAYS systems were operational. Following activation, significant reductions (-3.6% to -8.5%) in speeding were recorded when the *Information* system and the *Incentive* scheme were in force. The reductions seen when all participants were using a combination of *Information* and *Incentive* are quite convincing. These show that the proportion of distance driven above the speed limit (PDA) dropped from 16% to 4% in the first period. The greatest effect was seen on 80km/h roads where a drop of 9% in the PDA was recorded during the first period. However, the PAYS system had no educational effects: Speeding behaviours returned to their previous level when the system was turned off. No statistically significant gender or age effects were found in behavioural responses to the PAYS system. Travel times did not increase when the system was operational (Lahrmann, Agerholm, Tradisauskas, Berthelsen, & Harms, 2012).

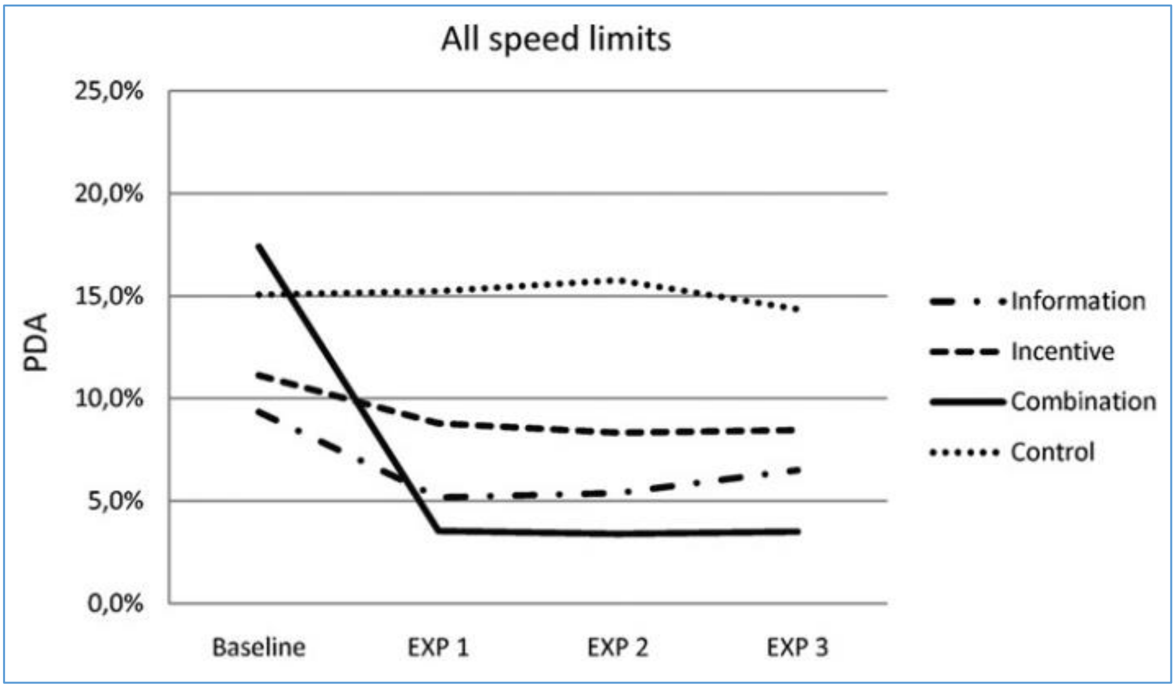

Figure 4. Proportion of distance driven above the speed limit +5km.h (PDA) for each group across all speed zones (Source: Lahrmann et al. (2012)).

3.5 Belgium

3.5.1 Ghent

ISA testing in Belgium began in October 2002 and involved 34 cars and 3 busses which were equipped with a *Supportive* (active accelerator) ISA system. The study assessed the effects of ISA on speed change, traffic safety, driver attitudes, behaviour and acceptance (see Vlassenroot et al., 2004). The results showed that the ISA technology had little impact on average speed, apart from the 90 km/h zone where a reduction of 1.1 km/h was recorded. The effect in 30 km/h zones was minimal and speeding violations were rife. As a result, it was concluded that the counterforce exerted by the pedal wasn't strong enough to discourage drivers from exceeding the speed limit. Indeed, speeding appeared to increase (+0.7km/h on average) during the trial, especially in low speed zones. Large differences between users were recorded. For instance, the distance spent speeding varied between 3% and 50%. The average speed for less frequent speeders tended to increase as drivers accelerated faster to the speed limit and drove exactly at the speed limit rather than below it. Nevertheless, the average speed for most frequent speeders tended to decrease. Half of the drivers said that they found it easier to maintain a constant speed and that they overtook less when using the ISA system. Driver attitude towards speeding was measured before, during and after the trial. Before the trial, 20% of drivers agreed that "driving fast saves time", during the trial this fell to just 5%, but rose again to 10% after the trial. After the trial, private motorists could choose to keep the ISA-system in their cars and 44% chose to do so, which indicates their acceptance of the system (Broekx, Vlassenroot, De Mol, & Int Panis, 2005).

3.6 France

3.6.1 LAVIA

The French LAVIA[2] project commenced in 2001 and involved prototype vehicles supplied by Renault and PSA (10 vehicles each). These cars were equipped with an ISA system that had three active modes; *Advisory*, *Voluntary* and *Mandatory*. The *Advisory* mode informed the drivers of the current speed limit and provided an auditory warning when this limit was exceeded. In *Voluntary* mode, the driver was free to activate and deactivate a speed limiter at will. With the *Mandatory* system, the fuel supply to the engine was restricted until the posted speed limit was reached. Twenty test vehicles, used by 92 households were driven for approximately 130,000km during the trials. There were an equal number of male and female drivers, 31% were under 30-years-old, and 13% were above 50-years-old. Substantial reductions in mean travelling speed were recorded using all three modes; -0.8km/h (-7%)) for the *Advisory* mode, -2km/h (-23%) for the *Mandatory* mode, and -1.4km/h (-13%) for the *Voluntary* limiting mode. The highest reductions in speeding were recorded on inter-urban and motorway networks. Drivers using the system perceived increased pressure from other drivers. The *Voluntary* system was deemed more acceptable than the *Mandatory* system, which was even considered dangerous by some drivers (Erlich et al., 2003; Saint Pierre & Erlich, 2008).

The potential safety benefits of the different LAVIA modes were assessed using a simulation model which calculated the number of serious or fatal injuries that could be saved in speed-related RTCs if all vehicles were equipped with an ISA system (see Driscoll et al., 2007), based on the speed distributions observed in the field trials. The results, presented in Table 6, suggest that following the introduction of the various ISA systems trialled in this LAVIA project, savings of between 2% and 13% could be made in serious and fatal injuries arising from frontal impact RTCs and savings of up to 16% could be made in serious and fatal injuries arising from side impact RTCs. For the most part, the driver activated *Voluntary* system produced the highest percentage savings, ranging from 6% to 16%. The estimated benefit of the *Mandatory* system was also substantial, up to 16% for fatal injuries on motorways. The *Advisory* system produced the lowest percentage savings, ranging from 0% to7%. Overall, the benefits were generally higher in terms of reduced fatalities than for serious injuries and in side impact RTCs.

[2] LAVIA is the acronym for Limiteur s'Adaptant à la VItesse Autorisée (Limiter which adapts to the authorised speed).

Table 6 LAVIA safety gains estimates (Source: Driscoll et al., (2007)).

Network Type	LAVIA Model	Frontal Impact		Side Impact	
		Serious Injury	Fatal Injury	Serious injury	Fatal injury
Urban	Informative	4%	4%	3%	4%
	Driver activated	11%	14%	1%	3%
	Mandatory	9%	11%	0%	n.a.
Inter-urban	Informative	2%	5%	0%	7%
	Driver activated	3%	8%	9%	17%
	Mandatory	2%	8%	8%	6%
Motorway	Informative	3%	7%	n.a.	4%
	Driver activated	6%	13%	5%	16%
	Mandatory	5%	13%	4%	16%

3.7 UK

3.7.1 External Vehicle Speed Control (EVSC)

A comprehensive assessment of ISA, the External Vehicle Speed Control (EVSC) study, was conducted in the UK by the University of Leeds (Carsten & Fowkes, 2000). Starting in 1997, this three-year project reviewed a broad range of factors with respect to the possible introduction of an automatic system for limiting the top speed of road vehicles. The project provided information on driver behaviour while using the system, on the likely costs and benefits associated with a range of speed-limiting systems, on the network side effects of limiting maximum speed and on possible implementation scenarios. This study involved on-road and driving simulator trials.

3.7.2 EVSC field trial

The on-road EVSC trials were conducted in 1998 along a 67km route that included urban and rural roads and a stretch of motorway. Twenty-four drivers participated in the trial and drove a single test car on three occasions. This car was fitted with a *Mandatory*, ‘dead’ throttle system rather than a ‘haptic’ throttle mechanism i.e. rather than providing force feedback via the accelerator pedal, the system modified the fuel supply to the engine, thus preventing speeding. Two types of ISA were fitted: A *Voluntary* system that drivers were free to switch on or off and a *Mandatory* system that was switched on all the time. The results showed that the *Mandatory* system was successful in reducing speeding and also resulted in improved following and braking behaviour.

Some problems were observed in the trials. Although use of the driver select system was high, drivers were prone to disengage the system in areas where speeding was the norm. Drivers sometimes found themselves being left behind by other traffic and were overtaken more frequently by other vehicles when they were using the ISA system. This lead to frustration and low satisfaction ratings. In one instance, it was decided that the posted temporary speed limit of 30mph could not be implemented due to the fact that other traffic, including HGVs were travelling at 50-60mph through this zone. For this reason, Carsten and Tate (2000) concluded that it may be unwise to implement *Mandatory* ISA until a significant number of vehicles are equipped with this technology.

3.7.2.1 EVSC Data modelling

The EVSC team also used simulation models to derive 'best estimates' for crash reduction at three levels of accident severity, for a variety of ISA systems, which were broadly defined as *Advisory, Driver Select (Supportive)* and *Mandatory*. Each system had speed limits in fixed, variable or dynamic forms. The estimates were derived using Nilsson's Power Model (2004), which was described earlier in this document. The results suggested that the wholesale deployment of ISA would impact substantially on the percentage of injuries and fatalities sustained as a result of RTCs. Depending on the power and versatility of the ISA system used, it was estimated that injury crashes could be reduced by between 10% to 36%, and Fatal and Serious crashes and Fatal crashes could be reduced by 14% to 59% (Table 7).

Table 7 Best estimates of accident savings by EVSC type and by crash severity (Source: Carsten and Tate (2000))

System Type	Speed Limit Type	Best Reduction Estimates		
		Injury Accident	Fatal & Serious Accident	Fatal Accident
Advisory	Fixed	10%	14%	18%
	Variable	10%	14%	19%
	Dynamic	13%	18%	24%
Driver Select	Fixed	10%	15%	19%
	Variable	11%	16%	20%
	Dynamic	18%	26%	32%
Mandatory	Fixed	20%	29%	37%
	Variable	22%	31%	39%
	Dynamic	36%	48%	59%

3.7.3 ISA-UK

The ISA-UK study aimed to build on and expand the findings of the Swedish large-scale trials. The on-road trials in this project were conducted from 2004 to 2006 and involved cars, trucks and motorcycles. This review reports the results of the car trial only, however full details of all the trials can be found in Carsten, Fowkes, et al. (2008). The car trial was conducted in three phases, (pre-activation, activation and post-activation) over six months and involved 79 participants. The sample embodied a wide variety of driver characteristics in terms of gender, age, private and fleet motorists, intentions to speed or not to speed. The test vehicles were equipped with *Supportive* (active accelerator) ISA technology.

The results of this study showed that whereas the ISA system had virtually no effect on drivers' speed choice when they were travelling below the speed limit, it had a marked impact on top-end speeds. Although drivers were able to override the ISA system at will, driving with ISA available reduced the 85th percentile speed on 30mph (48km/h) urban roads by approximately 2.5mph, and the proportion of distance travelled when exceeding the speed limit declined from 40% to 35%. On 70mph (112km/h) roads, the 85th percentile speed fell by over 4mph (6km/h) and the proportion of distance travelled when driving over the speed limit declined from 31% to 25%. The researchers pointed out that although these reductions may not seem dramatic, ISA was very effective in preventing large excesses in speed. Generally, the amount of speeding decreased in the active phase, except in 60 mph zones, where there was little speeding in the first place. Speeding increased to the final phase but did not reach pre-activation levels.

The use of a *Voluntary* ISA system also allowed the researchers to examine individual differences in driver willingness to either accept or override speed control. Figure 5 details the extent of overriding of the ISA system on 30 mph roads which are typical of urban areas and on 70 mph roads which are generally inter-city dual carriageways (often motorways). The patterns for age and gender are very similar for both types of roads. Intending and non-intending speeders behaved similarly on urban roads. However, there was a notable difference in behaviour between private and fleet drivers: Private drivers overrode the system more frequently than fleet drivers on urban roads, whereas fleet drivers overrode more frequently on 70mph roads. The researchers concluded that this might indicate that the compliance with speed limits in urban areas was more important to fleet drivers than compliance on inter-city roads and motorways. These results also showed clearly that those who might benefit most from ISA (males, young, speed intenders) tended to use it least.

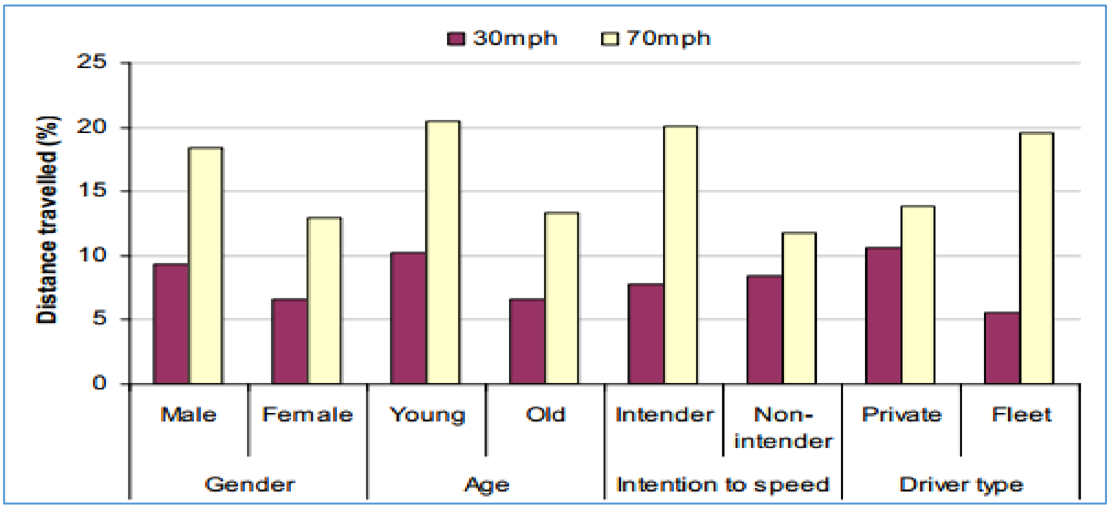

Figure 5. Comparison of overriding behaviour by user group in 30 and 70mph zone (Source: Carsten, Fowkes, et al. (2008)).

3.7.4 Lancashire ISA project[3]

The Lancashire project tested a low-cost, non-over-ridable *Informative* ISA system which provided drivers with visual and auditory alerts when they exceeded the speed limit and when they were approaching crash black spots. The system was installed in 430 vehicles for a period of 9 months, from April 2010 to March 2011 and over 2.8 million miles of driving data was recorded. A wide range of drivers participated, including novices and experienced drivers, generic drivers, and also taxi, bus and fleet drivers. The ISA was delivered by means of a nomadic device (i.e. mobile phones), so drivers could decide whether or not to use the system before they started each journey. The effectiveness of the system was examined by defining the data in two different ways; 'ISA available" (ISA in use intermittently) and 'ISA in use' (drivers choose to receive the speed information). The results showed that *Informative* ISA had a small positive effect on speed across the majority of speed limit zones. The greatest reduction was the 85th percentile speeds on 70mph roads. However, there was a large reduction in the proportion of speeding; reductions of 30% on 30mph roads and 56% on 70mph roads were recorded. Even when the system was only used intermittently, it was still effective in reducing the percentage of time spent speeding, with reductions of 18% in 30 mph roads and 31% on 70mph roads registered (Table 8).

Table 8 Reduction in speeds and speeding from 'No ISA' to 'ISA available' and 'ISA in use' (Adapted from Waibl et al. (2013))

Speed limit zone	ISA available			ISA in use		
	Mean	85th	% speeding	Mean	85th	% speeding
20	-1%	0%	-6%	-1%	-3%	-7%
30	-3%	-2%	-18%	-2%	-5%	-30%

[3] The review of this project is derived from a secondary source, i.e. (Waibl et al., 2013).

40	-2%	-2%	-23%	-3%	-4%	-40%
50	-2%	-1%	-25%	-2%	-3%	-44%
60	-1%	-1%	-16%	-1%	-2%	-21%
70	-2%	-2%	-31%	-4%	-6%	-56%

Note: The underlined results were statistically significant at the level p<0.05.

Some demographic factors that appeared to influence the effectiveness of the *Informative* ISA system were also identified. The system was found to be less effective generally with drivers over 60-years-old, mainly because baseline speeds were lower in this group than in any of the other age categories. Nevertheless, the system was still effective at reducing speeding in drivers within the older age group. Conversely, drivers aged 25 and younger were more resistant to remaining below the speed limit. Driving experience was also a notable factor. *Informative* ISA was effective in reducing higher speeds in novices (i.e. the 85th percentile speeds), but this group were more resistant generally to keeping their speed under the speed limit. Higher-mileage drivers were also more resistant to keeping their speed under the speed limit on in all but 30mph speed zones. No gender effects were found in the influence of ISA across the speed limit zones (as reported in Waibl et al., 2013).

3.7.5 London Bus ISA

Transport for London tested an after-market ISA system on 47 busses in June 2015. The system was fitted on two bus routes; No 19 (from Battersea to Finsbury Park) and No 486 (from North Greenwich to Bexleyheath). The trial used a *Mandatory* ISA system, using GPS data matched against an on-board map and speed-limit database. This prevented the busses from exceeding the local speed limit, by controlling the amount of acceleration that was possible. Drivers were not able to override the system, except in case of an emergency. The system's effectiveness was assessed by comparing pre-trial and trial data. The results showed that the system was effective with reducing speeds, particularly with preventing speeding in 20mph zones. Busses fitted with ISA remained within the speed limit 97-99% of the time: the only exception was on hills due to the effect of gravity. The percentage of time spent travelling above the speed limit reduced from a range of 15-19% to 1-3% in 20mph zones and 0.5-3% to 0-1% in 30mph zones (+/-50km/h) (TRL (2016) as cited in; ETSC, 2018).

No adverse effects on driving behaviour were recorded, despite an expected increase in riskier overtaking by surrounding traffic. Some increase in platooning from vehicles behind the busses was noted which resulted in a reduction in average speeds in 20mph zones and a marginal journey time increase was recorded. Modelling based on the trial predicted a safety improvement following the introduction of ISA. Given the short duration of the trial, it was not possible to examine actual casualty data. Although there was no significant difference in fuel usage, there was some evidence of improved emissions in some of the 20mph zones. Feedback from the drivers showed that they rated their experience as negative in the early part of the trial due to problems with system installation and calibration. However, once these had been rectified, far fewer issues were noted. Some concerns were raised by the drivers that other road users would become frustrated with the busses complying with the speed limit. Bus passengers were unaware of the effects of ISA on their journeys, but once it was explained, they reacted positively (ETSC, 2018).

Following the success of the trial, the Mayor of London announced in late 2017 that TfL would require all new buses to be fitted with ISA. It is expected that by the end of 2018, over 500 buses will have the technology fitted. Following this, ISA will be introduced onto new buses at the point of manufacture. As TfL buys around 900 buses a year, it is expected that by 2028 the whole London fleet of 9000 buses will be renewed.

3.8 EU-funded research

The European Union has also funded research projects that investigated ISA, most notably MASTER (Várhelyi & Mäkinen, 1998) and PROSPER (Cunningham & Sundberg, 2006).

3.8.1 MASTER

Field tests were conducted as part of the Managing Speed of Traffic on European Roads (MASTER) project using a *Mandatory* speed limiting ISA system in Sweden, the Netherlands and Spain (Varhelyi, 1998). Twenty to 24 drivers in each country drove twice along a test route; once with the limiter switched off and once again when it was switched on. The results showed that when the system was in use mean speeds were reduced significantly in all three countries in 30, 40, 50, 60, 70 and 90km/h zones in urban and rural areas under normal and free (unobstructed) driving conditions. Reductions in mean driving speeds ranging from -2% to -16.1% were recorded in urban areas. Mean speeds decreased in rural areas, except in 80km/h zones where increases of 2.4% and 1.4% were recorded in normal and free-flowing traffic respectively (Table 9). Overall, the use of ISA in this trial resulted in reductions of -3.5% and -7.4% in mean speed in normal and free driving conditions respectively. Variations in speed were also reduced except for an increase of 4% in normal traffic on 90km/h limit roads and a marginal increase of 1% in speed variation was also recorded on 40km/h roads in free-flowing traffic. Safer car following distances were also observed at speeds under 50km/h, although decreased headway was observed in the 70-90km/h zones. Speeds were recorded approaching roundabouts, intersections and curves. Travel times increased by between 2.5% to 8.9% across the three countries and when combined these increases were statistically significant.

Table 9 Effects of mandatory ISA on mean speed and speed variation in normal and free-flowing traffic conditions in the MASTER project (Adapted from (Varhelyi, 1998)

Speed Limit (km/h)	Average Effect on Mean Speed		Effect on speed variation	
	Normal	Free	Normal	Free
Urban Roads				
30	-2.0%	-1.5%	-1.4%	-1.5%
40	-16.1%	-27.4%	-7.2%	+1.0%
50	-3.0%	-4.3%	-1.8%	-0.3%

60	-6.9%	-12.5%	-6.4%	-5.1%
Rural Roads				
70	-4.3%	-4.4%	-3.9%	-4.1%
80	+2.4%	+1.4%	-1.3%	-1.6%
90	-1.9%	-4.5%	+4%	-6.1%
Motorways				
110-120	+0.5%	-3.7%	-2.1%	-0.4%
Overall	-3.5%	-7.4%	-2.9%	-1.5%

Although no negative behavioural adaptation was observed in terms of interactions with other road users, drivers reported increased frustration, stress and impatience. User attitudes towards *Mandatory* ISA improved during the trials where 30% thought that speed limiters should be *Mandatory* in all cars, 59% were in favour of self-operated ISA, while just 10% were completely against the use of ISA to limit speed. Half of the test drivers said that they would install a speed limiter on their car if it was provided free of charge. Some national differences in attitudes were also found, for instance;

- The majority of drivers in Sweden (62%) said that they would install speed limiters in their cars, this fell to 50% in the Netherlands and 30% in Spain
- Dutch drivers reported more frustration with the system
- A larger proportion of Dutch drivers (23%) opposed mandatory speed limiting, although 59% agreed that limiting speed in poor visibility was a good idea
- The overwhelming majority of Spanish drivers (80%) were in favour of mandatory compulsory speed limiting in darkness, whereas drivers in the other two countries were doubtful or disagreed entirely with this suggestion

3.8.2 PROSPER

The Project for Research on Speed Adaptation Policies on European Roads (PROSPER) tested the impact of ISA using simulator and field studies in Hungary and Spain (Cunningham & Sundberg, 2006). 64 drivers used vehicles that were fitted with *Advisory* (auditory warning) or *Supportive* (active accelerator) ISA systems. The results showed that both ISA systems lowered mean and 85th percentile speed[4] and also speed variance. The largest effects were found for higher speeds, as evidenced by changes in the 85th percentile speeds. The *Supportive* system was more effective than the *Advisory* system. The authors of this study noted that this result is in line with the findings of the large-scale Swedish trials, where both systems were also tested. Taken together, the findings of both of these studies provide strong evidence that *Supportive* (active accelerator) ISA is more effective in reducing speed that *Advisory* (warning beep) systems. In the PROSPER study, both the Spanish and Hungarian

[4] The 85th percentile speed represents the speed below which 85% of drivers are travelling.

participants expressed positive attitudes towards ISA. However, after using the systems for one month, attitudes became more differentiated and also less positive. Hungarian drivers experienced the same level of speed reduction regardless of the speed limit, whereas the Spanish drivers experienced larger decreases at lower speed limits. The Hungarians experienced an increase in time pressure whereas the Spanish reported a decrease. Both sets of drivers perceived that their driving performance was affected negatively. Nevertheless, both systems were seen as useful. Simulator trials were also conducted to see how the Human Machine Interface design of ISA systems might affect driver behaviour and acceptance. However, a review of ISA HMI was deemed as out-of-scope for the current review.

3.9 Australia

3.9.1 Victoria – TAC SafeCar

The TAC SafeCar project was conducted in collaboration between the Australian Transport Accident Commission, the Ford group and Monash University Accident Research Centre, in order to evaluate the effects of ITC on driver performance and gauge driver acceptability (Regan, 2005). Twenty-three drivers drove the SafeCar vehicles that were equipped with *Supportive* (active accelerator) ISA for a total distance of 16,500kms.

The results showed that the system reduced mean, maximum and 85th percentile speeds and reduced speed variability in most speed zones. ISA also reduced the percentage of time drivers spent travelling in excess of the speed limit while not impacting negatively on travel times. Mean speeds were reduced significantly by up to 1.4 km/h in the 60 km/h and 100 k/m/h zones. However mean speeds rose significantly in the 70 and 80 km/h zones (by up to 1.5 km/h) after the ISA was deactivated. Overall however, no significant difference in mean speeds was found between the pre- and post-ISA installation conditions. This suggests that there were no real long-term benefits of ISA. Moreover, the data suggested an upward trend for mean speed to increase during the ISA activation period. The researchers considered that this might have been an indication that drivers were becoming habituated to the speed warnings and ignoring or tolerating them for longer periods of time. Alternatively, they speculated that drivers may have started to use the upward pressure on the accelerator as a kind of cruise control system (Regan, 2006). Nevertheless, based on the data gathered, it was estimated that the ISA system could reduce the incidence of fatal and serious injury crashes up to 8% and 6% respectively.

Participants from both the active and control group in this study rated the ISA system significantly less useful to them at the end of the study, compared to their assessment at the beginning of the study. Reasons proffered for this relative dissatisfaction included that other cars around them were speeding, drivers should be responsible for adopting appropriate speed, and others cited inaccuracies with GPS. Over 80% of participants believed that the ISA system would decrease speed effectively in 50, 60, 80 and 100 km/h zones and in residential zones. The majority also believed that ISA would reduce speeds on freeways (68%), rural roads (62%), in low-volume traffic (65%) and when road conditions are poor (60%). Most participants judged that the ISA system was likely to reduce the incidence and severity of RTC. However, belief in crash-related safety benefits of the system decreased significantly after use (from 100% to 73%).

This study also examined the effects of other driver support technologies. Interestingly, it seemed that the ISA system was most effective in reducing speeding when it was combined with a forward driver warning system. It appears that receiving guidance from two separate systems produced this cumulative effect.

3.9.2 New South Sales (RTA-NSW)

The New South Wales ISA trial (RTA-NSW) was the largest test of intelligent road safety technology ever conducted by a road safety agency in Australia, involving over 110 private and non-government fleet vehicles (Wall, 2010). The objectives of the research were to assess the potential safety benefits, economic effects (fuel consumption and travel times) and to gauge the acceptability of *Advisory* ISA systems to drivers and fleet managers.

Over 110 light vehicles including private and company fleets were equipped with an *Advisory* ISA device. More than seven million vehicle speed records were analysed to measure changes in speed compliance. The *Advisory* system reduced speeding in 89% of the vehicles and the median probability of speeding was also reduced by almost 30% when the system was active. Following the removal of the *Advisory* ISA system, incidences of exceeding the speed limit increased in 85% of the vehicles. The researchers on this project concluded that ISA technology could potentially realise substantial road safety benefits by increasing compliance with speed limits.

3.10 North America

Three trials conducted in North America were considered in this review; Michigan (Regan, 2012) and also the Speed Choice and SafeMiles projects in Canada which were reported in Waibl et al. (2013).

3.10.1 Kalamazoo, Michigan

An ISA field trial was conducted in Kalamazoo, Michigan in 2011 (Regan, 2012). This involved 50 participants, 40 of whom who drove eight vehicles equipped with *Informative* ISA systems that issued auditory and visual signals when speed exceeded the posted limit by 5 mph or more. Half of the active group were also provided with a monetary incentive for some of the trial period. They were issued with a €25 bonus credit, which declined by 3 cents for every six-second period that the driver remained 5-8 mph. above the speed limit. The penalty increased to six cents if the driver went 9 mph. or more above the limit. A visual display provided updated bonus amounts when the ignition was turned on or off. The results showed that the incentive system produced significant reductions in excessive speed and the feedback system led to modest reductions in speeding. When incentives were in operation, drivers consistently increased the percentage of time driving at or under the speed limit and also reduced their average speeds in several speed zones.

3.10.2 Speed Choice and Modelling the Impacts of Speed on Safety and the Environment (Canada)[5]

The Speed Choice and Modelling the Impacts of Speed on Safety and the Environment study (Taylor, 2006 as cited in: Waibl et al., 2013) evaluated two ISA systems on 10 private and 10 commercial vehicles, involving 70 datasets. The IMITA SA system, similar to the one used in the Lund study, provided information (audio-visual), and support (haptic accelerator pedal) feedback. The OttoMate system provided information only. Private motorists using the IMITA SA visual feedback system, which emitted repetitive warnings when the speed limit was exceed, recorded decreases in speed violations of 12% (8% in 80 km/h zones and 15% in 100 km/h zones). No significant additional reductions were recorded when haptic support was added subsequently. Drivers of commercial vehicles also benefitted from the audio-visual and the haptic feedback, with the haptic feedback achieving larger reductions. The impact of the haptic support was largest in 100 km/h zones, where violations decreased from 23% to 14%. Private motorists using the OttoMate system, which sounded a warning only as the speed limit was broken, recorded increased speed violations (up by 4%), particularly in the 100 km/h zone (up by 14%). This may be evidence of behavioural adaptation: It seems that some drivers were annoyed with repeated warnings and intentionally drove over the speed limit to avoid having to listen to these frequently.

3.10.3 SafeMiles

The SafeMiles project commenced in 2006 and involved a replication of an earlier Dutch Belonitor study which rewarded participants for complying with speed limits and maintaining safe headway. The rewards consisted of points which could be redeemed for goods and services. During the active phase, participants were provided with feedback on their driving habits, providing them with the opportunity to improve their driving skills. The total reward points that were accumulated during each trip were displayed during and at the end of each trip. Participants drove for 234,480kms using the system and speed compliance rates improved significantly in all speed limit zones and compliance remained high during a 2-week post trial period. The highest compliance rates during the feedback phase occurred in the 100km/h zones and the lowest compliance rates were in the 50km/h zones. Some age and gender differences in compliance were also observed. Drivers aged between 30-39-years exhibited the largest change in compliance during the active phase and males aged between 20-29-years lost all the rewards they earned during the active phase during the post-trial period. Participants reported high acceptance of this system and believed that it should be applied more widely (Transport Canada (2007), as cited in: Waibl et al., 2013)).

3.10.4 Limiting the speed of HGVs

The EU requires that speed limitation devices are installed on large Heavy Goods Vehicles (Directive 92/6/EEC) and buses and also Heavy Commercial Vehicles (Directive 2002/85/EC). It was assumed that speed limiters and ISA can contribute to key policy objectives set out in the 2011 White paper on Transport, in particular advancing towards zero fatalities in road transportation in 2050 and reducing 1990 GHG emission levels by 60% in 2050. Subsequent research indicated that these directives had a positive effect on traffic safety, with an

[5] Details of the Canadian ISA trials were derived from secondary sources.

estimated reduction of 9% in fatal crashes on motorways and a 4% reduction in serious injuries and a 3% reduction in injury crashes. It was further estimated that there was a reduction of approximately 50 fatalities annually following the introduction of the Speed Limitation directives. It was further estimated that the introduction of speed limiters resulted in a reduction of the total CO2, NO_X and PM emissions of HCVs of around 1% (EU Commission, 2013).

4 ISA IMPACT

The expected impact of ISA technologies is summarised in this chapter in terms of road safety and driver behaviour, acceptance and environmental factors. The potential for negative impacts is also considered.

4.1 Effect on road safety and driver behaviour

The safety effects of ISA technologies depend on the type of ISA system, the type of road environment (urban, rural, motorways etc.) and the penetration level of ISA equipment in the vehicle fleet (OECD/ECTM, 2006). Some individual differences in driver reactions to ISA systems were also observed in terms of their willingness to use the systems correctly (Barnes et al., 2010).

4.1.1 Crash reduction

ISA has been evaluated in numerous trials in Europe, North America and Australia, a representative selection of which have been described in this review. However, none of these trials have been large enough to capture empirical information about actual crash involvement. For instance, as part of the Swedish large-scale ISA trial, researchers in Lund tried to assess the system effect of having 284 ISA-equipped vehicles circulating in the city however they could not find any effect of ISA on crash trends (Swedish National Road Administration (Vägverket), 2002). This is not surprising, given that road traffic crashes occur relatively rarely, and this trial was relatively small. In fact, the true effects of ISA are only likely to emerge when a larger percentage of vehicles have been equipped with the technology.

4.1.1.1 Impact of injuries and fatalities

As an alternative to using actual crash data, data models which map the relationship between speed and crash risk are often used to assess the effectiveness of ISA on road safety. Specifically, the observed (or estimated) changes in speed choice are used to predict changes in crash or injury risk (Lai, Carsten, & Tate, 2012). One of the most famous examples of this approach was demonstrated in the U.K. ESVC study. The results, shown in Table 10, predict reductions of between 18-59% in fatalities and reductions ranging from 14-48% in serious injuries following the wholesale introduction of ISA (Carsten & Tate, 2000). The largest reductions would be achieved using *Mandatory* systems, however substantial reductions were also predicted for *Advisory* and *Supportive* systems. A similar pattern of reductions was reported in the French LAVIA project although the effects estimated were considerably smaller than those derived in the ESVC study.

There are several reasons for the apparent differences in safety benefits between these two studies. First, the study design and calculation methods varied between the studies. The ESVC values were based on results derived from a simulator study and also a field test which involved just one vehicle equipped with the ISA system, whereas the LAVIA field test was conducted on a larger scale, with 22 equipped vehicles over a one-year trial period. Second, the ESVC results were obtained using statistical formulae linking average speed to the fatality and injury rate. However, the LAVIA study relied mainly on real-world, in-depth crash data (distribution of travel speed before crash and distribution of magnitude of impact, injury risk curves) and on travel speed distributions in traffic that were collected as part of the trial. Third, the LAVIA study was based on distributions rather than means, which are regarded as more accurate (Driscoll et al., 2007). Fourth, whereas the values computed by ESVC were for all crashes, those examined in LAVIA related to front and side impact crashes only.

Table 10 Comparison of estimated safety benefits

ISA Type	Injury Severity		Study			
		ESVC	LAVIA	ISA-UK	TAC SafeCar	Doecke & Wooley
Advisory	Fatal	18-24%	4-7%			11%
	Serious	14-18%	0-3%			8.3%
Supportive	Fatal	19-32%	3-17%	21%	9%	18.4%
	Serious	15-25%	1-11%		7%	15.6%
Mandatory	Fatal	37-59%	8-16%	46%		28.3%
	Serious	29-48%	0-9%			26.5%

Further analysis conducted by Oliver Carsten and his colleagues as part of the ISA-UK study suggested that ISA could reduce RTCs on all roads by 28.9% (33% on urban roads; 18.1% on motorways. *Supportive* ISA could reduce fatalities by 21% and *Mandatory* ISA could reduce this to 46% (Carsten, Fowkes, et al., 2008; Carsten & Tate, 2005).

Expected crash savings were also reported in two Australian studies. Here again, the results differed substantially. The analysis conducted in Australia by the Centre for Automotive Safety (Doecke & Woolley, 2010) suggested that the use of ISA across the road network could reduce the risk of fatal crashes by 11% (*Advisory*), 18.4% (*Supportive*) and 28.3% (*Mandatory*). Reductions of 8.3%, 15.6% and 26.5% were predicted for serious crashes for *Advisory, Supportive* and *Mandatory* systems respectively. However, the estimated crash savings for *Supportive* ISA that were reported in the TAC SafeCar study (Regan et al 2006) were more than 50% lower than those calculated by Doecke and Wooley; a 9% reduction in fatalities and a 7% reduction in serious crashes.

Overall, there seems little dispute that the introduction of ISA will result in a reduction in fatal and serious injury crashes. However, because different methods were used to derive the crash reduction estimates presented in Table 10 it is hard to predict with any certainty what the magnitude of these savings would be following the introduction of *Advisory, Supportive* or *Mandatory* ISA.

4.1.1.2 Impact by speed zone

Doecke and Woolley (2010) also estimated the potential reduction in the risk of injury crashes in Australia in terms of speed zones. The results, summarised in Table 11 show clearly that the *Mandatory* system was most effective in reducing the risk of speeding across all speed zones. In general, the higher the level of intervention, the more the potential for risk reduction. However, *Advisory* systems were judged as more effective than the *Supporting* system in 80 km/h zones.

Table 11 Percentage reduction in the risk of injury crashes in Australia (SOURCE: DOECKE AND WOOLLEY, 2010)

Speed Limit (km/H)	Advisory	Supportive	Mandatory/Limiting
50	6.5%	19.6%	42.4%
60	2.1%	9.4%	15.8%
80	14.4%	12.3%	23.3%
100	17.3%	28.8%	35.9%
110	4.6%	12.4%	21.7%

The estimates shown in Table 11 were also used to calculate the potential annual savings that could be realised through the full implementation of these three types of ISA. The results showed that savings of $1.2, $2.2 and $3.7 billion Australian dollars could be expected following the introduction of *Advisory, Supportive* or *Mandatory* ISA systems respectively.

4.1.1.3 Impact for different implementation scenarios

Realistically though, ISA cannot be introduced overnight, so the impact on crashes in the future depends on the number of vehicles fitted with each type of ISA at any given time. According to the OECD, where just a few vehicles are equipped with ISA, there may be an increase in overtaking manoeuvres, leading to increased risk. However, when critical mass is achieved, the ISA-equipped vehicles will effectively reduce the speed of the rest of the vehicles in the traffic stream (OECD/ECTM, 2006). Simulation modelling has been used effectively to estimate the likely impact of ISA for different implementation scenarios. For instance, researchers in the Institute of Transport Studies at Leeds University, used a mathematical model to estimate the proportions of injury crashes that would be prevented on the entire U.K. road network with increasing penetration of ISA. The estimates, shown in

Table 12, indicate that both the *Supportive/Voluntary* and *Mandatory* variants of ISA would be considerably more effective than *Advisory* ISA and that effectiveness increases with penetration level: At 100% penetration reductions of 12% were predicted for *Supportive/Voluntary* ISA, reductions of 28.9% were estimated for *Mandatory* ISA, whereas reductions of just 2.7% can be expected for *Advisory* ISA (Carsten, Lai, et al., 2008).

Table 12 Percentage of injury crashes on all U.K. roads that would be prevented with ISA fitment

Penetration	***ISA Variant***		
	Advisory	***Voluntary (Supportive)***	***Mandatory***
20%	0.5%	2.4%	5.8%
40%	1.1%	4.8%	11.6%
60%	1.6%	7.2%	17.3%
80%	2.2%	9.6%	23.1%
100%	2.7%	12.0%	28.9%

The crash reduction potential of *Mandatory* ISA was also examined as part of the ISA-UK study in terms of two implementation strategies; Market Driven and Authority Driven (Carsten, Fowkes, et al., 2008). The results, shown in Table 13, demonstrate clearly that savings associated with the Authority-Driven implementation scenario far outstrip those to be made under Market-Driven conditions

Table 13 Crashes saved from 2010 to 2070

Crash type	**Market-Driven**	**Authority-Driven**
Slight (Minor)	4%	15%
Serious	8%	25%
Fatal	13%	30%

4.1.2 Impact on driver behaviour

4.1.2.1 Impact on Speed-related behaviour

A high-level summary of the impacts of the various ISA systems on drivers' speed–related choices from the 24 key studies that featured in this review is shown in Table 14. This shows that the ISA systems used in all but the Ghent trial had the effect of reducing speed and speeding.

Table 14 Summary influence of ISA on driving speed choice reported in 24 key studies

Date	Study Location	Driver/Vehicles	Advisory	Supportive	Mandatory	Recording	Average	Variation	Maximum	Speeding	% spent	85th Percentile
		Nos.	ISA System				Speed Choice					
	Sweden											
1993	Lund	75	√		√		↓					
1996	Eslöv	25	√		√		↓			↓		
2000-2001	"Right Speed" - Borlänge	400	√				↓	↓			↓	
2000-2001	"Lund ISA"	290		√			↓	↓				
2000-2001	"SmartSpeed" -Umeå	4000	√				↓					
2000-2001	Lidköping – Spearheading the way to vision zero"	280	√	√			↓		↓			
2004	"ISA for Stockholm"	130	√				↓			↓		
2002-2003	Gothenberg	16 busses		√						↓		
	Netherlands				√							
1998	Groningen	24	√				↓	↓				
1999	Tilburg	479			√		↓	↓		↓		
2011	ISA for serious offenders	51			√	√		↓				
2001	**Finland**	24			√	√	↓			↓	↓	
	Denmark											
2001	Alborg INFATI	24	√				↓					↓
2007-2009	Alborg - "Pay-as-you-Speed"	146	√			√				↓		
2002	**Belgium** - Ghent	37 vehicles		√			↔					
2001	**France** - LAVIA	100	√		√		↓					
	UK											
1997-2000	EVSC	24			√				↓			
2001-2005	ISA UK	79		√					↓		↓	↓
2010-2011	Lancashire	402	√				↓				↓	↓
2015	London Bus				√		↓				↓	
	EU											
-1998	Master	60			√	√	↓	↓				
-2006	PROSPER	64	√	√			↓	↓				↓
	Australia											
2002-2004	"TAC Safe Car"	23		√			↓	↓	↓	↓	↓	↓
2010	New South Wales "RTA-NSW"	110	√				↓				↓	↓
	North America											
2011	USA - Kalamazoo, Michigan	50	√			√	↓			↓	↓	
-2006	**Speed Choice, Canada**	**79**	√	√								
2006	Safe Miles, Canada					√				↓		

Key: Tick marks indicate ISA system used in each test. Downward arrows indicate decreases in speed. Horizontal arrows indicate no change in speed.

Since mean and excessive speeds are critical factors in road safety many studies that feature in this review examined these parameters. Arguably the strongest evidence showing the speed reduction potential of ISA was collected as part of the Swedish large-scale trials, which were conducted between 1999 and 2002, and involved up to 5,000 vehicles, and more than 10,000 drivers. Irrespective of which type of ISA that was used (*Advisory, Supportive, Mandatory*) mean speeds were reduced by 1-2km/h in all speed zones, and overall decreases in speeding violations were also recorded (Swedish National Road Administration (Vägverket), 2002). Interestingly, findings from the Ghent trial showed increases in average speed for drivers who exceeded the speed limit less frequently. It appears the information provided by the ISA system acted as cue to drive 'up' to the speed limit.

Table 155 summarises the findings from key studies that feature in this review in terms of the impact of *Advisory, Supportive* and *Mandatory* ISA on mean speed and speeding.

Table 15 Impact of Advisory, Supportive and Mandatory ISA on mean speed and speeding

Ist Author/Study	Location	Study Year	Vehicles/ Drivers	Speed Zones (Km/h)	Mean speed change (km/h)	Speeding reduction
Advisory/Informative ISA trials						
SNRA/ Borlänge	Sweden	2000	/400	30-70	-0.6 to -2.8	10-77%
Lahrmann/INFATI	Denmark	2001	20/24	Undefined	-	5-6%
Päätalo	Finland	2001	24	40-80	-2.8	39%
Driscoll/LAVIA	France	2001	10	Undefined	-0.8	-
Brookhuis/Groningen	Netherlands	1998	/24	50-120		-4%
Taylor/Ottawa	Canada	2006	20	14-100	-	13-22%
/Lancashire	UK	2011		30-70mph	- 1 to – 3	30-70%
Advisory/recording ISA involving incentives						
Lahrmann/PAYS	Denmark	2008	/146	50-130	-3.6 to -8.5	-77%*
Supportive ISA trials						
MASTER	Netherlands Spain & Sweden	1997	64-68	30-120	+2.4 to -16.1	-
SNRA/Lund	Sweden	2001	/290	30-70	-0.8 to -2.0	20-53%
Driscoll/LAVIA	France	2001	10	30-120	-1.4 to -2.0	-
Vlassenroot/Ghent	Belgium	2002	37	30-90	+0.7 to -1.1	-
Regan/Melbourne	Australia	2003	15	60-100	-1.4	57%

I[st] Author/Study	Location	Study Year	Vehicles/ Drivers	Speed Zones (Km/h)	Mean speed change (km/h)	Speeding reduction
Lai/ISA-UK	UK	2007	80	32-113	-0.4-3.1	2-22%
Transek/Stockholm	Sweden	2005	20/120		-	30%
Taylor/IMITA	Canada	2006	10	40-100	-	2-19%
Carsten/ISA-UK	UK	2006	79	30-100mph	n.a.**	n.a.**
Mandatory/Limiting ISA trials						
Besseling/Tilburg	Netherlands	2000	21/140	30-80	-3 to -8.3	-
Päätalo	Finland	2001	24	40-80	-3.4	74%
Carsten/EVSC	UK	1998	1/24	30-100mph	n.a.**	n.a.**

*Percentage of speeding by more than 5km/h
**No definitive figures were reported by the authors of these reports

This table demonstrates a clear trend regarding the safety potential of the various ISA systems in terms of reducing mean speed and speeding. *Advisory/recording ISA involving driver incentives* and *Mandatory* ISA were the most effective systems. *Supportive* ISA was more effective than *Advisory* ISA.

4.1.3 Individual differences in behavioural effects of ISA

Some individual differences in the behavioural effects of ISA have been noted in the field trials. For instance, researchers working on the NSW trials reported that younger drivers (under 25-year-olds) were less likely than older drivers to reduce the proportion of time spent speeding using an *Advisory* ISA system and this group were also more likely to turn the device off at times (Barnes et al., 2010). In the Swedish large-scale trials, young male drivers expressed more negative attitudes towards ISA than young females. Older females were more positive than older males, and drivers who did not want to keep the ISA system at the end of the trial drove significantly faster both before and during the ISA trials than did drivers who wanted to keep the system (Hjälmdahl & Várhelyi, 2004; Hjälmdahl, Várhelyi, Hydén, Risser, & Draskoczy, 2002).

4.2 Impact on the environment

Safety concerns are not the only reason why speed management is necessary. Speed management strategies are also consistent with other important EU and domestic policy goals such as reducing fuel consumption, CO_2 emissions, air pollution, and congestion. In addition to safety targets, the EU has set a target of reducing transport-related greenhouse gas (GHG) emissions by 60% by 2030, when compared to 1990. Irrespective of EU targets, research shows that in 2015 the transport sector (excluding international aviation and maritime emissions) contributed 21% of total EU-28 greenhouse gas emissions, with road transport up by 19% from 1990 levels. Furthermore, road transport was responsible for almost 73% of total greenhouse gas emissions from transport in 2015, with passenger cars contributing 44.5%, and heavy-duty vehicles contributing 18.8% (European Environment Agency, 2017)

Here in Ireland, the most recent emissions figures compiled by the Irish Environmental Protection Agency (EPA) show that the share of CO_2 in total greenhouse gas emissions has increased to 64.9% in 2016 compared to 59.2% in 1990. Between 1990 and 2016, transport showed the greatest overall increase (139.3%), with road transport increasing by 145.4%. These data also show that transport was the third largest contributor to greenhouse gas emissions (20%), after agriculture (32%) and industry (20.5%) (Environmental Protection Agency, 2018).

Since fuel consumption and carbon dioxide emissions depend on a vehicle's travelling speed… lower and better enforced speed limits are '...one of the most certain, equitable, cost-effective and potential popular routes to a lower carbon economy" (Anable et al., 2006: as cited in ETSC, 2008, p. 9).

4.3 Environmental factors

A number of the key studies in this review examined the environmental impact of ISA and these are summarised at a high-level in the table below.

Table 16 Impact of ISA on environmental factors

Study Location	Drivers/Vehicles	Journey time	Fuel Consumption	NO_x Emissions	CO_2 Emissions
	Numbers	Environment			
Sweden					
Lund	75	↑	↔	↓	↓
Eslöv	25	↑	↑	↓	↑
"Right Speed" - Borlänge	400	↔	↓		
"Lund ISA"	290	↔	↓	↓	↓
"SmartSpeed" -Umeå	4000	↔			
Lidköping – Spearheading the way to vision zero"	280	↔			
Gothenberg	16 busses	↔			
Netherlands					
Tilburg	479		↓		
Alborg - "Pay-as-you-Speed"	146	↔			
UK					
EVSC	24	↑	↓		

Study Location	Driver/Vehicles	Journey time	Fuel Consumption	NO_x Emissions	CO_2 Emissions
	Numbers	Environment			
EU					
Master (Sweden, Spain, Netherlands) (3X20 subjects)	60	↑			
Australia					
"TAC Safe Car"	23	↔	↓		↓

Key: Tick marks indicate ISA system used in each test. Downward arrows indicate decreases. Upward arrows indicate increases. Horizontal arrows indicate no change.

4.3.1 Fuel Savings

Emissions are linked to fuel consumption and the most frequently cited research findings regarding possible reductions in fuel consumption when using ISA systems were the conclusions reached in the EVSC project (Carsten & Fowkes, 2000), where simulation models were used to estimate potential savings. The results showed that savings of 1%, 3% and 8% respectively could be expected from the introduction of *Mandatory* speed limiting devices on motorways, and in non-built up and built up areas on other road types in the UK. A similar study conducted as part of the Tilburg trial estimated fuel savings of 11%, based on full implementation of *Mandatory* ISA (Dutch Ministry of Transport, 2001, as cited in; Oei & Polak, 2002).

4.3.2 Travel time and congestion

Travel time impacts on fuel usage and traffic congestion. Studies that investigated the effects of ISA on travel times have reported mixed findings. Some have revealed increases in travel times with the use of ISA particularly limiting systems, while others have found no change, or even a decrease in travel times, on some road types. For instance, expected increases in travel time were calculated by the U.K. EVSC research team, who showed that there would be an increase of 2.6% in rush hour travel time, rising to 6.4% outside of rush hour if drivers were forced to comply with speed limits. The mean increase across the whole day would be 4.4%. There would be a 4.3 % increase in built-up areas, a 0.4% increase in non-built up areas and no increase in travel times on motorways (Carsten & Tate, 2000; Liu & Tate, 2004). Although most studies that investigated the impact of ISA on travel times predicted that travel times would increase due to the overall reduction in travelling speeds, some also found that traffic flow improved which should reduce average travel times and also traffic congestion.

4.3.3 Emissions

A number of studies have indicated that fitting cars with ISA systems would contribute greatly to reducing CO_2 emissions. For instance, Anable et al. (2006) developed a model to calculate the emission savings in the U.K. between 2006 and 2010 in relation to two scenarios;

enforcing the 70mph (112km/h) speed limit and reducing this limit to 60 mph (96 km/h). The results showed that;

- A properly enforced 70mph (112km/h) speed limit would cut carbon emissions by nearly 1 million tonnes per annum.
- A new 60mph (96km/h) speed limit would nearly double this reduction, reducing emissions by an average of 1.88 million tonnes per annum.

Similar research conducted in France, for the French Environment Ministry, estimated that the potential impact of full compliance with speed limits would reduce carbon emissions by 2.1 tonnes of CO2 for private cars, 0.4 million tonnes for HGVs and 0.5 million tonnes for utility vehicles, resulting in a total reduction of 3 million tonnes of CO2 emissions annually (ETSC, 2008). The results from the Swedish Lund trial showed average reductions of 11% and 8% for NOx and Hydrocarbons respectively when using *Supportive* (active accelerator) ISA (Várhelyi, Hjälmdahl, Hydén, & Almqvist, 2000; Várhelyi, Hjälmdahl, Hydén, & Draskóczy, 2004). The Australian SafeCar trial reported a 4% reduction in fuel consumption and CO2 emissions when ISA was used with following distance warnings in 80km/h zones (Regan et al., 2006). A micro simulation model was used to predict the network effects of the EVSC *Mandatory* ISA system in the UK (Carsten & Tate, 2000). The key results, summarised in Table 177, suggest that the use of *Mandatory* ISA would result in increases in travel time, decreases in fuel consumption, but would have very little impact on emissions. However, the authors noted that the Mandatory ISA EVSC system was likely to reduce variability in travel time by making traffic flow more smoothly, which in turn would make journey times more predictable.

Table 17 Impact of Mandatory EVSC ISA system on different road networks

Network	Saturation Penetration	Travel Time	Fuel Consumption	Emissions*
Urban Peak	100%	+2.6%	-8.0%	No impact
Urban Off-Peak	100%	+6.4%	-8.5%	No impact
Rural	60%	+0.4%	-3.0%	+1%
Motorway	0%**	0%#	0%#	No impact

*The emissions predictions were for current vehicles.
**The motorway modelled was so congested that the EVSC ISA system had negligible effect.

More detailed estimates of vehicle CO_2 emissions were calculated using comprehensive data collected for the UK ISA project and these indicated that ISA would have a stronger impact on CO_2 emissions on high speed roads. For instance, on 70mph (112km/h) speed zones, the use of *Voluntary* and *Mandatory* ISA would reduce CO_2 emissions by 3.4% and 5.8% respectively.

However, the change in emissions in other speed zones remained variable and small (Carsten, Fowkes, et al., 2008).

Controlling the speed of commercial vehicles can also have a significant impact on CO_2 emissions. Trials conducted in the Netherlands showed that fitting vans and light trucks with devices that limited speed to 110km/h yielded fuel savings of 5%, which reduced emissions. According to the European Transport Safety Council (ETSC), the effectiveness of such measures is likely to increase over time because the increasing use of motorways and also the increasing power capabilities of vehicles generally means that speeds of above 110km/h will be reached more easily (ETSC, 2008).

The findings summarised here suggest that the introduction of ISA will result in reductions in fuel consumption and emissions. The European Transport Safety Council also noted that vehicle manufacturers are likely to respond to the widespread adoption of ISA by optimising engine performance to suit these new 'typical' driving conditions, rather than the marketed top speed capability of a vehicle and this should ultimately result in reduced emissions (ETSC, 2006).

4.4 ISA User Acceptance and psychological factors

When it comes to the introduction of different in-car systems, public acceptance is hugely important. Without popular support, ISA will not be adopted widely, and it is highly unlikely that any government would decide to require ISA without strong such support. Attitudinal research has featured prominently in many ISA research studies. In general, the findings indicate that driver acceptance tends to vary according to the type of ISA system, the type of road environment and the type of driver.

4.4.1 ISA type

Results of the SARTRE 3 (2004) and SARTRE 4 surveys (2011) showed that around one quarter of European drivers believed that having a device in the car that would restrain them from exceeding the speed limit would be useful. The results from field trials showed that acceptance levels were highest for *Advisory/Informative* ISA systems but tended to decrease as the level of intrusion and control increased and invariably, the most effective form of ISA, *Mandatory* speed limiting, proved least popular with users.

A nation-wide survey was used to gauge the attitudes of 1,000 Swedish driver towards various forms of ISA technologies (Várhelyi et al., 2000). The results showed that the majority of respondents had a positive attitude towards a device which automatically lowers the maximum possible speed of cars in slippery conditions and poor visibility and also towards a device which warns the driver or reduces speed automatically if the car is about to collide with another road user. However, just one-third of drivers were in favour of *Mandatory* limiting i.e. systems which prevent drivers from exceeding the prevailing speed limit (

Table 18).

Table 18 Driver acceptance of different systems for influencing speed behaviour

Acceptance	Mandatory Speed Limiter			Collision Risk	
	Generally	On Slippery roads	In poor Visibility	Warning	Intervention
In Favour	34%	59%	59%	80%	65%
Opposed	48%	23%	23%	7%	19%
Neither	16%	16%	16%	11%	14%

Attitudinal research conducted in Belgium and the UK among people without any experience with ISA found that the majority of respondents were in favour of ISA, even the *Mandatory* version: 88% of respondents were in favour of *Voluntary* ISA systems and 59% supported the introduction of *Mandatory* systems (De Mol et al., 2001; as cited in Katteler, 2005). Carsten (2002) also reported that 53% of UK drivers favoured the installation of *Mandatory* ISA.

Early trials in Lund (Persson et al., 1993) and in Eslöv (Almqvist & Nygård, 1997) found that drivers were more positive about ISA after they had used the system. Drivers in Eslöv indicated a strong preference for the feedback from the haptic throttle (*Supportive* ISA) over warnings given by buzzers or lights (*Advisory* ISA).

In the large-scale Swedish trials, user acceptance grew initially, but tended to decrease slightly over time. However, most drivers wanted to keep the system, particularly those who tested the informative versions (Figure 6). Half of the participants in the MASTER study (Varhelyi, 1998) and many of those in the Ghent trials (Vlassenroot et al., 2004) were also willing to keep the system at the end of the trials.

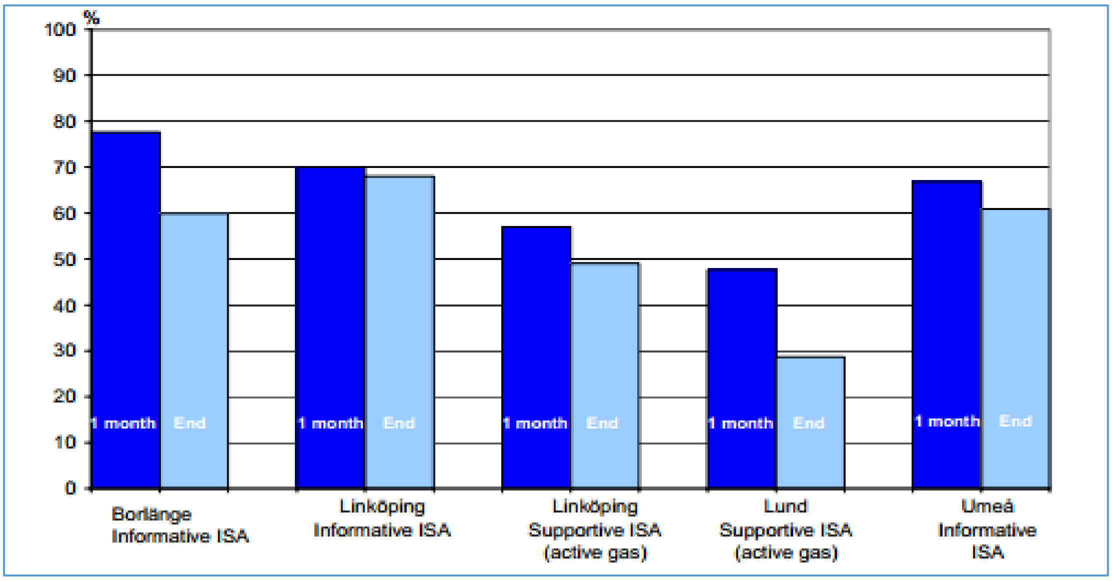

Figure 6. Share of test drivers who wanted to keep the ISA equipment in the Swedish trials. (Source: Bidding and Lind (2002).

An acceptability scale was used in the U.K. EVSC project, which allowed drivers to express opinions about two types of ISA: *Voluntary* and *Mandatory*. The results showed that drivers were much more positive about the *Voluntary* as opposed to the *Mandatory* system. A comparison of pre and post-test attitudes showed that drivers' evaluation of the usefulness of the *Mandatory* system improved during the course of the trial. However, satisfaction levels for the *Mandatory* system remained low (Carsten & Tate, 2000). Conversely, findings from the Dutch, Tilburg trial showed that the majority of test drivers (64%) had a positive attitude towards the *Mandatory* ISA system used. The general public also reported positive attitudes towards ISA and this support increased with greater exposure to the system (Duynstee & Martens, 2001). Some negative aspects of Mandatory ISA were also reported. For instance, drivers in the LAVIA (Cunningham & Sundberg, 2006) and Tilburg (Duynstee & Martens, 2001) trials reported feeling pressure from other drivers and perceptions of increased danger from other traffic was also noted in the EVSC project (Carsten & Tate, 2000).

Overall, the results from field trials show that the majority of drivers were in favour of ISA and that support was inversely related to the amount of control that the system exerted over driving speed choice; the more controlling the system, the less the drivers favoured it. In general, drivers who participated in ISA field trials were more positive about these technologies than the average driver.

4.4.2 Type of road environment

Acceptance of ISA differed for different road types, the associated speed limits and driving speeds. As shown in the earlier detailed review and also illustrated in the summary table in Appendix B, greater acceptance was seen for urban roads with 30km/h and 50km/h speed limits.

4.4.3 Type of driver

The research findings also suggested that drivers who would most benefit from ISA, are least willing to use it. For instance, in the Safe Miles study, males aged from 20 – 29 years lost all the rewards they gained very quickly after the trial ended and the *Advisory* system used in the Lancashire study was less effective affecting speed choice among drivers aged 25 years and under (Waibl et al., 2013). The results of the Australian SafeCar study showed that inexperienced drivers were less accepting of ISA than more experienced drivers after they had actually used this technology. This suggests that there is a danger of self-selection bias if ISA is introduced on a voluntary basis.

When assessing the effectiveness of measures for controlling speed, it can be useful to identify different groups of speeding drivers. Paine (1996) estimated the proportion of speeders and the related risk of crashing in terms of four speeder types: Recidivist, intentional, inadvertent and reluctant (

Table 19). This shows clearly that about two-thirds of drivers (i.e. the inadvertent and reluctant speeders) might be assisted by an *Advisory* system that informed them when they exceeded the speed limit. “Reluctant” speeders would be further supported if other drivers knew that an ISA system was in operation. For instance, the ESVC ISA trial in Leeds used a car sticker for this purpose.

Table 19 Estimated proportion of speeding drivers and contribution to speed-related crashes (SOURCE: PAINE, 1996)

Category of speeding driver	Estimates for drivers and crashes
***Recidivist* –** Grossly excessive speed. Risk taker	3% of drivers: 10% of crashes
***Intentional* –** Feels "safe" at 10-15 km/h above the speed limit. Thinks that the risk of penalties is low	30% of drivers: 35% of crashes
***Inadvertent* –** Drivers a powerful/smooth car, which is too easy to drive at over the speed limit, or misses speed signs, or forgets current speed zoning	35% of drivers; 30% of crashes
***Reluctant* –** Under pressure, drives at the speed of the traffic stream, which is exceeding the speed limit. Does not want to impede traffic. Is intimidated by tailgaters	30% of drivers; 25% of crashes

Sometimes, however, drivers exceed the speed limit unintentionally. For instance, 87% of drivers who took part in the TAC SafeCar ISA speed alerting trial reported that they sometimes exceed the speed limit inadvertently (M. A. Regan et al., 2005). Participants in that study also tended to agree that ISA systems should be compulsory for all drivers and to disagree that ISA systems should only be compulsory for habitual speeders. Nevertheless, findings from other studies show that when serious offenders face a choice of losing their license or installing the system, their acceptance could increase considerably (van der Pas et al., 2014).

4.5 Negative impact on driver behaviour

Negative aspects of the various ISA technologies were reported in many of the studies in this review and some have also been hypothesised (OECD/ECTM, 2006). These include direct effects such as driver distraction, and indirect effects such as behavioural adaptation.

4.5.1 Driver distraction

Any activity that distracts the driver, or competes for his/her attention while driving, can potentially degrade driving performance and thus have serious consequences for road safety (K L Young & Regan, 2007). The deployment of ISA could potentially add to the increased levels of driver distraction within the vehicle and careful consideration is needed regarding the location and nature of any in-vehicle warnings and displays. For instance, results from the EU HASTE project showed that visual distraction and cognitive distraction due to using in-vehicle systems impact differently on the primary driving task. Visual distraction resulted in poor steering behaviour and degradation of lateral control, whereas cognitive distraction dis-improved longitudinal control, particularly in relation to car following. The HASTE studies also showed that some elderly drivers experienced problems particularly in situations where secondary task demand was high (Carsten et al., 2005). Although a detailed review of the opportunities and challenges that arise in developing automotive HMI is beyond the scope of this document several EU-funded projects have explored this issue, notably the Adaptive Integrated Driver-vehicle interface (AIDE) project (http://www.aide-eu.org/).

4.5.2 Behavioural adaptation

Aside from safety benefits, ISA use is likely to impact on driver behaviour in a number of other ways. Indeed, it is widely accepted that drivers tend to prioritise mobility over safety and as a result, tend to adapt their behaviour in response to the introduction of new safety-enhancing features (anti-lock braking systems etc.) (Sagberg, Fosser, & Saetermo, 1997). This phenomenon, known as 'behavioural adaptation' refers to "those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change" (OECD, 1990, p.23). This phenomenon has been examined extensively in road safety research and there is general agreement that while behavioural adaptation does not occur consistently, when it does occur, it tends to reduce the size of the expected effects of an intervention, rather than eliminate them altogether. In road safety research the primary concerns are negative behavioural adaptations related to frustration, risk compensation, diffusion of responsibility and habituation. Some negative behavioural adaptations were reported in studies that feature in this review including;

- Frustration, leading to unsafe actions and/or less safe interactions with other road users
- Driving faster on road segments where ISA is not active
- Using shorter headway and gaps when driving in traffic (risk compensation)
- Overreliance on the system to the extent that drivers neglect to monitor and/or adjust driving speeds appropriately (diffusion)
- Tendency for non-ISA users to intimidate ISA users
- Decreased effects of voluntary ISA systems on driving speed over time (habituation)

Increased frustration when using ISA was reported in many studies (Carsten & Fowkes, 2000; M. A. Regan et al., 2005; Swedish National Road Administration (Vägverket), 2002; Varhelyi, 1998). Some studies also indicated that long-term use leads to more frustration (Lai, Hjälmdahl, Chorlton, & Wiklund, 2010). Persson et al. (1993) reported that drivers in the early Lund study tended to compensate for having to drive slower in the area covered by the ISA system that was used by driving faster where the system was not active. Participants in the EVSC trial tended to disengage the system in areas where speeding was the norm (Carsten & Fowkes, 2000).

A certain degree of frustration regarding the auditory alerts that featured in some types of *Advisory* ISA systems was also noted. For instance, drivers in the Swedish trials often attempted to override the system because they felt annoyed by the alerts (Swedish National Road Administration (Vägverket), 2002). Canadian drivers in the Speed Choice project were observed to intentionally drive over the speed limit to avoid having to listen to the alerts frequently (as cited in; Waibl et al., 2013).

In some trials participants tended to adopt shorter headways in car following (Carsten & Fowkes, 2000; Varhelyi, 1998; Várhelyi et al., 2004). Riskier gap acceptance when interacting with other vehicles at junctions was also observed (Carsten & Tate, 2000; Persson et al., 1993.

Another adaptation effect that emerged in many field trials was that drivers without ISA tended to 'crowd' (follow too closely) the ISA-equipped cars (Duynstee & Martens, 2001; Persson et al., 1993; Saint Pierre & Erlich, 2008). Drivers in the Lund trial sometimes forgot to monitor their speed outside of the test area, suggesting overreliance on ISA in speed choice decision making (Swedish National Road Administration (Vägverket), 2002; Varhelyi, 1998). Overreliance on the haptic feedback provided by some ISA systems was reported in several studies. In the Swedish and Belgian trials evidence was shown that the information provided by haptic feedback ISA systems sometimes resulted in increases in average speed in drivers who previously drove slower without the ISA support (Hjälmdahl, Almqvist, & Várhely, 2002). A tendency towards 'driving up' to the speed limit, was noted in the Ghent study, in causing average speeds to increase (Vlassenroot, 2011). Participants in the Australian TAC SafeCar study agreed that they would lose trust in ISA systems if it was unreliable, i.e. if it issued false warnings (87%) or failed to issue warnings when it should (84%) (M. A. Regan et al., 2006).

In contrast, a number of improved safety-related behaviours were also reported such as reductions in the number of traffic conflicts (Almqvist & Nygård, 1997). Drivers in the Tilburg trial reported less overtaking and maintaining larger following distances when using ISA (Duynstee & Martens, 2001). However, it is hard to say for certain whether or not these effects would persist with long-term acclimatisation to ISA. Jamson, Carsten, Chorlton, and Fowkes (2006) suggested that frustration associated with ISA use may subside as drivers become more accustomed to using the system and come to appreciate the nature of the trade-off between safety and mobility that results from ISA use. However, some studies indicate that ISA may become less effective over time. For instance, findings from large-scale studies in the UK and Sweden indicated that the longer drivers had the ISA system, the more they overrode it or drove a large proportion of their journey with it overridden (Lai et al., 2010).

5 ISA IMPLEMENTATION

The use of ISA as part of an overall speed management strategy has widespread support among network and safety institutes, government bodies and those who have a stake in this issue in the EU, North America, and Australia and further afield. For instance, research conducted as part of the EU-funded PROSPER project showed that stakeholders (politicians, governmental institutes, research institutes, pressure groups and commercial groups) in the eight countries involved in the project regarded ISA as an effective safety measure. An introduction among all driver groups, on all road types and on a *Mandatory* basis was preferred. A half-open, *Supportive* (active accelerator) system, was considered as the best option at that time: Stakeholders believed that that this scenario would produce the best results in terms of safety, environment and congestion (Cunningham & Sundberg, 2006). A survey conducted by the OECD also indicated that almost all of its member countries support the installation and use of *Informative* ISA (OECD/ECTM, 2006). Although ISA technology has been available for some time, and reducing crash risk has been high on the political agenda in Europe, little progress has been made with implementing ISA. Whereas initial estimates suggest that the date when *Mandatory* ISA is fitted and used in the whole of the European fleet would be around 2035, clearly such targets cannot be met in the absence of strong political backing for ISA (RoSPA, 2016).

5.1 Implementation scenarios

Two general scenarios are envisaged for implementing ISA; Authority Driven and Market Driven and these are summarised as follows by the Royal Society for the Prevention of Accidents (see RoSPA, 2016).

5.1.1 Authority driven implementation

In an authority driven scenario, adoption of ISA would be encouraged initially and eventually required. In this scenario bodies that could enable quicker up-take of ISA would play a more proactive role, mainly through financial encouragement or legal punishment. For instance,

- Government bodies could lead by example by equipping their vehicle fleets with ISA technologies
- Compulsory fitting of ISA devices could be specified as a licencing requirement for public services vehicles such as busses and taxis
- Lower insurance premiums could be offered, based on *Mandatory* speed limiting and to a lesser extent for vehicles equipped with *Advisory* or *Supportive* ISA systems
- ISA could be used to help prevent crashes and injuries among high-risk groups of road users including; younger and older aged drivers and those who have a known propensity for speeding

5.1.2 Market driven Implementation

In a market driven scenario, users choose to have ISA because they want it. This scenario emphasises the role of car manufacturers and the subsequent consumer choices made by fleet managers and private car buyers in the proliferation of ISA equipped vehicles on the roads.

5.1.2.1 Euro NCAP

The Euro NCAP protocol began awarding points for safety assist technologies as part of their Safety Assist score in 2009. This score is determined from tests to the most important driver assist technologies that support safe driving to avoid crashes and mitigate injuries. The recognition of ISA technologies constitutes an important step in promoting the large-scale deployment of ISA in the future: Cars will almost certainly need to have a speed assistance system fitted as standard in order to qualify for the coveted 5-star rating. The current Euro NCAP protocol (Euro NCAP, 2017) actively promotes the installation of speed assistance systems that;

- Inform the driver on the present speed limit;
- Warn the driver when the car's speed is about the set speed threshold;
- Actively prevent the car from exceeding or maintaining the set speed

The Euro NCAP tests also take account of the functionality of the system to ensure that it can be used without undue distraction to the driver. For systems that actively control speed, tests are carried out to ensure that the system does this accurately (Euro NCAP, 2018).

5.1.2.2 Stimulating demand

A number of financial and non-financial incentives have been proposed to encourage drivers to install and use ISA technology. Financial incentives can be provided either by reducing installation costs or through continuous discounting. The former will encourage drivers to purchase the system, whereas the latter would be more effective in encouraging drivers to use the system once it has been installed. A number of variants of these approaches were discussed by Chorlton, Hess, Jamson, and Wardman (2012). In addition to financial rewards, the non-fiscal incentives discussed included; increasing the number of penalty points for speeding and also the length of time these points remain on a driver's record. Bundling safety features with more attractive features (e.g. entertainment packages) at the point of sale were also considered. Two variants of post-installation discounting were also discussed; fuel rebates or cash back on a driver's insurance premium provided they use the system for a certain proportion of their driving.

Some of the studies reviewed in this report examined schemes designed to drive market demand for ISA systems. For instance, the participants in the Danish Pay-as-You-Speed study were awarded bonus points, linked to a discount on their insurance for driving below the speed limit. Whereas this scheme was very successful in reducing speed and speeding, researchers in the study found that the offer of a 30% discount on insurance premiums was not sufficient to encourage younger drivers (under 24-year olds) to participate in the research (Lahrmann, Agerholm, Tradisauskas, Berthelsen, & Harms, 2012).

5.1.2.3 Willingness to pay

Private motorists would have to bear some (or perhaps all) of the costs involved in equipping their vehicles with ISA so many studies have attempted to determine how much drivers would be willing to pay to have ISA installed. In the early Lund trial, Almqvist and Nygard (1997) established that 58% of drivers could envisage paying to have ISA installed, but 42% would not pay the average estimated cost (approximately £66.57). It seems that willingness to pay is also influenced by the nature of the ISA systems. For instance, Bidding and Lind (2002, as cited in; Jamson, Carsten, Chorlton, & Fowkes, 2006) reported that 50% of drivers using an *Informative* ISA system, 34% using an *Advisory* (warning) system and between 20-40% of those who used *Supportive* (active accelerator) systems were willing to pay to keep it after the end of the trial, suggesting that willingness to pay may be contingent on the degree of interventional support that the system provides.

5.1.3 Market penetration

Market penetration of ISA under these different deployment scenarios for the 60-year period between 2010 and 2070 was modelled by U.K. researchers (see Lai, Carsten, & Tate, 2012) and the results are shown in Figure 7. This indicates that *Advisory* ISA would predominate if a market driven approach is taken to the deployment of ISA technologies. In contrast, in an authority driven scenario, *non- Mandatory* systems would eventually be superseded by *Mandatory* systems by around 2045.

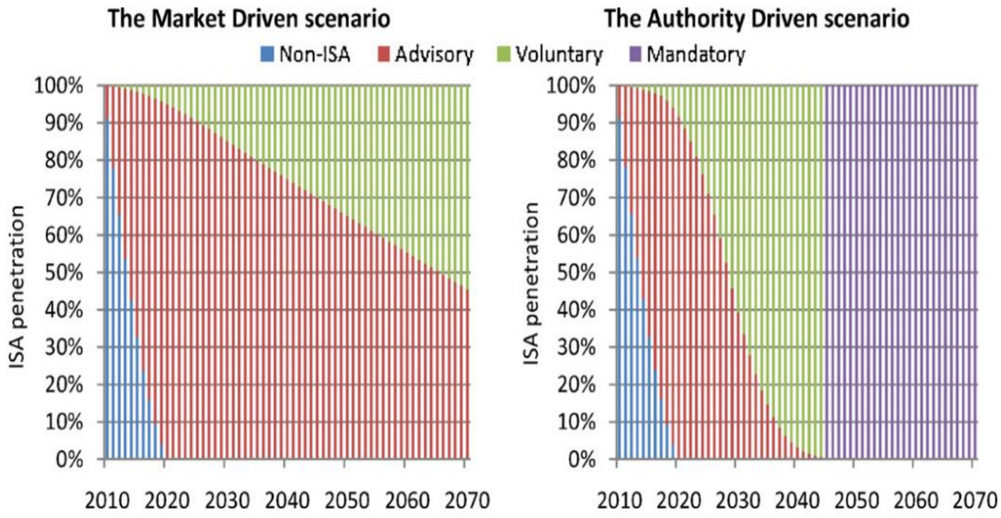

Figure 7. Penetration of ISA under different deployment scenarios (Source: Lai et al., 2012).

Crash outcomes were also predicted based on these two scenarios. The estimates suggested that ISA would deliver substantially greater safety benefits in an Authority Driven rather than in a Market Driven scenario. It was predicted that the Authority Driven scenario would reduce fatal crashes by 30% and serious crashes by 25% whereas the Market Driven scenario would reduce fatal crashes by 13% and serious crashes by 8%. Overall, 16% of crashes would be prevented in an Authority Driven scenario and 5% of crashes would be prevented under a Market Driven scenario (Lai et al., 2012).

5.2 Costs and benefits analyses

Implementation of speed control using ISA technologies will require a substantial investment, so it is prudent to consider whether or not this initiative would be worthwhile from a financial perspective. Benefit-to-cost ratios (B/CRs) are used to compare the net present values of the overall benefits of an intervention to the overall costs. As a rule of thumb, for an intervention to be implemented, benefits should outweigh the overall costs substantially. For safety schemes, a B/C ≥ 3 is generally regarded as a threshold for justifying investment. Comprehensive cost benefit analyses have been undertaken as part of some of the ISA studies discussed in this review, including the EU-funded PROSPER study, the ESVC and ISA-UK projects. The results of a cost benefit analysis that was conducted in Australia are also summarised in this review.

5.2.1 PROSPER

A cost benefit analysis was conducted as part of the EU-funded PROSPER project (Cunningham & Sundberg, 2006). The results, shown in Table 200 detail the B/CRs for Market Driven and Authority Driven scenarios, under *Mandatory* ISA conditions. This shows that in all countries and for both implementation scenarios the benefits of *Mandatory* ISA outweighed the costs by a margin of at least 2 to 1. The Authority Driven scenario outperformed the Market Driven scenario substantially and also exceeded the justification threshold (i.e. B/CR ≥ 3) in all countries except Spain. It is interesting that the B/CR for Spain was lowest, given that speeding was more problematic there than in some of the other countries in this study. However, the researchers suggested that since the Spanish vehicle fleet was large for the volume of travel undertaken, the cost of equipping such a large fleet is relatively high, compare to these other countries.

Table 20 Benefit-to-cost ratio of ISA scenarios calculated in PROSPER (Adapted from Cunningham and Sundberg (2006))

Country	Market-Driven Scenario	Authority-Driven Scenario
Belgium	3.5	4.5
Britain	3.1	4.0
France	2.4	3.3
Netherlands	2.6	3.8
Spain	2.0	2.5
Sweden	2.5	3.4

5.2.2 EVSC

A cost benefit analysis was also carried out as part of the UK EVSC project (Carsten & Tate, 2005). The results are summarised in Table 211 in terms of *Advisory, Driver Select* (drivers could enable or disable control of maximum speed) and *Mandatory* ISA (vehicle speed was limited at all times). Speed limits were classified as 'fixed' (posted limit), variable (additional information about slower sections on the network) and dynamic (additional lower limits to account for current conditions e.g. weather, traffic, incidents etc.).

Table 21 Benefit-to-cost ratios for ISA variants estimated in the UK EVSC project (Adapted from Carsten & Tate, (2005))

System	Low GDP growth[a]			High GDP growth[b]		
	Fixed	Variable	Dynamic	Fixed	Variable	Dynamic
Advisory	5.0	5.3	7.0	6.9	7.2	9.6
Driver select	3.7	4.0	6.1	5.0	5.4	8.3
Mandatory	7.4	8.0	12.2	10.0	10.9	16.7

[a]Annual vehicle kilometres of travel is predicted to increase by 1.8% per annum.
[b]Annual vehicle kilometres of travel is predicted in increase by 2.9% per annum.

All of the B/CRs that were estimated exceeded the 3.0 threshold. The lowest B/CRs were calculated for the *Driver Select* system, and this was followed by the *Advisory* system. The largest B/CRs were estimated for the *Mandatory Dynamic* system: 12.2 for the low GDP growth scenario and 16.7 in the high GDP growth scenario. The B/CRs for Compulsory usage of *Mandatory* ISA (i.e. all vehicles would be required to use *Mandatory* speed limiting ISA) were in a range from 7.4 to 16.7, i.e. the payback would be between 7 and 16 times the cost of implementing the scheme. This study also estimated some 'one-off' costs for implementing ISA in the UK in 2010 including; establishing the ISA mapping system (£8 million for a 'fixed' speed limit system', £12 million for a 'variable' speed limit system and £43 million for a 'dynamic' speed limit system. Additional, annual costs were estimated as £2.25 million and £1 per vehicle for a fixed or variable system and £4.5 million plus £5 per vehicle for a dynamic system (Carsten & Tate, 2005).

5.2.3 ISA-UK

A cost benefit analysis was also performed as part of the ISA-UK project (Carsten et al., 2008). Lowest and highest estimates from this analysis are shown in Table 222 in terms of one Market-Driven and three Authority-Driven scenarios (depending on the date of full implementation). The overall B/CRs were also calculated and these amounted to 3.4 for the Market Driven scenario and 7.4 for the Authority Driven scenario. These estimates are broadly in line with those produced in the PROSPER project and further confirm the superior potential of the Authority Driven approach in terms of providing value for money.

Table 22 Lowest and best estimated BCRs for Market-Driven and Authority-Driven implementation of Mandatory ISA in the UK (Adapted from Carsten et al., (2008))

Implementation Scenario	Lowest estimated BCR	Highest estimated BCR
Market-Driven	1.6	3.1
Authority Driven (2045)	2.8	5.5
Authority-Driven (2040)	3.0	5.7
Authority-Driven (2035)	3.1	5.7

5.2.4 Australia

A comprehensive analysis of the potential of ISA was also conducted in Australia by Doecke and Woolley (2010). The results of their economic analysis for two commercial ISA systems Speed Alert and Speedshield are shown in Table 233 in terms of B/CRs and Payback Period at 0-8% discount rates if all vehicles were fitted with ISA over the 20 year duration of the scenario that was used. The discount rates were included to reflect the return on investment that could be gained elsewhere, and these have the effect of devaluing benefits (and costs where warranted).

Table 23 Economic analysis results if ISA was implemented in all vehicles in Australia (Source: Doecke & Woolley, (2010))

ISA device	BCR			Payback Period (years)		
	0%	4%	8%	0%	4%	8%
Advisory-Speed Alert	2.89	2.36	1.92	3.7	4.0	4.3
Advisory Speedshield	2.29	1.89	1.58	6.1	6.7	7.5
Supportive-Speedshield	2.42	2.09	1.79	5.7	6.2	6.9
Limiting - Speedshield	4.03	3.48	2.98	3.0	3.2	3.5

These results show that the *Limiting* ISA system would produce the greatest return on investment: The B/CRs were consistently highest for *Limiting* (*Mandatory)* ISA where discounted values were very close to or exceeded the threshold of 3. The payback periods ranged from three years for the *Limiting* system up to 7.5 years for other forms of ISA.

Further economic analyses were reported in this Australian study for a number of different implementation scenarios e.g. market-driven, new vehicles only, fleet vehicles only, heavy vehicles only, for young drivers only and for systems using Navaid devices. Due to the complexity of these analyses it is not possible to represent them adequately within the scope of this review. Interested readers should consult Doecke and Woolley (2010) for full details. However, the overall findings are summarised as follows;

- The B/CR and payback period were heavily influenced by the unit price
- B/CRs range from 0.29 to 4.03 over 20 years for ISA implementation
- Payback periods range from 3 to 100+ years for ISA implementation
- Break even prices increased as the level of ISA intervention increased
- The B/CR was greatest in the ‘all vehicles’ and the ‘new vehicles’ implementation scenarios
- Even if Navaid ISA devices are seldom used and are less effective than dedicated ISA devices they may still prove a cost-effective option
- If the increased risk for young drivers could be taken into account, implementation of ISA on vehicles used by young drivers may present a cost-effective option
- Limiting ISA generally produced the greatest B/CR for a given scenario
- Installing the strongest possible ISA device on young drivers’ vehicles and in new vehicles may represent the most cost-effective method of implementation

The researchers also cautioned that care should be taken when deciding on an ISA implementation path that older, less safe vehicles are not made more attractive to drivers who are more likely to be responsible for a speeding crash, such as young drivers.

In all of the cost benefit analyses reported in this review, almost all of the costs were attributable to the in-vehicle equipment. The consistency with which the critical threshold B/CR (≥ 3) was exceeded suggests the implementation of ISA on a large-scale is entirely justifiable from a social investment perspective. These analyses also demonstrate that the more forceful Authority Driven scenario represents the best option in financial terms. However, the benefits also depend on the form of ISA used and the rate with which they are adopted. Studies conducted in the late 1990s and early 2000s suggest that between 20-58% of drivers who tested various ISA systems expressed willingness to purchase these systems, and such willingness was dependent on the level of support offered by the system. More recently, Vlassenroot (2011) assessed willingness to pay for four different types of ISA systems (Informative, Warning, Supportive and Restrictive) in a sample of almost 6,000 Belgian and Dutch drivers. The results showed that although free placement was preferred for every system, most respondents expressed willingness to pay for less controlling systems i.e. Informative (30%) or Warning (24%). Supportive ISA was resisted more strongly (36%), but incentives such as smaller insurance charges (15%) and other subsidies (14%) would help to convince drivers to install this. Support for Restrictive ISA was lowest: over half of those surveyed indicated that they would never buy this ISA.

5.3 Barriers to implementation

Some barriers to ISA implementation have been identified and these have hindered progress in implementing ISA on a wider scale. Researchers from the EU-funder PROSPER project, which was conducted in Belgium, France, the UK, Sweden, Spain, the Netherlands, Germany and Hungary (Cunningham & Sundberg, 2006) tested stakeholder opinion regarding barriers to ISA. Five stakeholder groups were consulted; political, government and governmental institutions; scientists and research centres; pressure groups and mobility actors; and commercial companies. Nine main issues were identified, and these are presented in order of importance;

- Technical functioning (reliability, accuracy etc.)
- Applicability to the road network
- Observed benefit to the customer
- Price of ISA
- Liability problems in case of accidents/violations/malfunctioning
- Customer's privacy
- Needed time for renewal of the vehicle fleet
- Image of the car industry
- Need for extra driving education

More recently, van der Pas, Marchau, Walker, van Wee, and Vlassenroot (2012) compiled a systematic and representative inventory of 'uncertainties' surrounding ISA implementation and asked experts in this field to assess the extent to which these uncertainties represented real barriers to implementation. A summary of the most important barriers identified in this study is shown in Table 24.

Table 24 Uncertainties that represent the most important barriers to ISA implementation by ISA type (Adapted from van der Pas et al., (2012))

Uncertainty Description	Ranking*		
	Advisory/ Informative	Supportive	Mandatory
Technical characteristics and updating of the speed limit database	1	5	7
Liability allocation in case the ISA system malfunctions	2	1	1
Factors that contribute to driver acceptance of ISA and the degree to which these factors influence acceptance	3	7	5
Willingness of drivers to use ISA	4	2	2
Identity and relative importance of stakeholders involved with implementation	5	4	3
Effects of different implementation strategies (i.e. choice of ISA types)	6	3	4

*Item ranking from highest (1) to lowest (7) uncertainty.

These findings suggest that both the long-term effects and the effects of large-scale implementation of ISA remain uncertain and that these are the most important barriers to the implementation of the most effective types of ISA. Van der Pas and his colleagues suggested that one way to deal with these uncertainties would be to commence with small-scale implementation and then expand penetration gradually in order to see how ISA influences the transport system over time.

Concerns regarding technical functioning, liability issues, and applicability to the whole road network as well as driver acceptance of and willingness to use ISA also constitute significant barriers to implementation of ISA technologies. The ETCS position paper on ISA "Intelligent Speed Assistance – Myths and Reality" shed further light on some of these barriers and how these might be addressed (ETSC, 2006). Regarding technical functioning, they state that accumulated evidence from field trials confirm the accuracy, efficiency and robustness of ISA technologies. ISA technologies are technically much simpler than other automatic devices e.g. collision avoidance systems. The next step involves integrating ISA technology into the original system architecture of cars and this should be done in such a way as to ensure compatibility. The ETSC see the liability issue as a 'red herring' because industry has already implemented other ITS systems (e.g. advanced cruise control etc.) that intervene in controlling a vehicle to assist the driver without significant concern for liability. Regarding public/driver support, the ETSC cites the results of the SARTRE 3 survey and field trials (which were described in this review) which showed that a majority of drivers are in favour of ISA systems and support increased as they gained experience with using the technology. They also believe that the choice of implementation strategy (Market Driven or Authority Driven) will affect the speed at which ISA proliferates in the road traffic system and this is the domain of policy makers in general and legislators in particular.

5.4 Official support for ISA

Whereas the findings from surveys and field trials indicate that there is considerable public support for ISA, an implementation strategy is needed to speed up the process of implementation of ISA in vehicles and this requires inputs from policy makers in general and legislators in particular. Stakeholder views about the legal obstacles to ISA deployment were elicited in PROSPER (Cunningham & Sundberg, 2006) and these are presented in order of importance;

- Development of EU-directives for use of ISA in different vehicle types
- Legislation about liability issues (accidents/violations/malfunctioning
- International harmonisation of standards and test procedures
- Translation of EU-directives into national legislation
- Homologation of vehicles with an ISA system

In 2008 the EU Commission acknowledged that it has "a clear role to play in creating the right framework conditions for accelerated and coordinated deployment of ITS" (EU Commission, 2008 p.4). Thereafter, the EU Commission published Directive 2010/40 which addresses standards, rules on liability and the intention to set up a group to advise on ITS.

Some progress was made subsequently on a number of these issues. For instance, work is being carried out on developing and planning the maintenance of accurate, up-to-date digital speed maps. The Transport Network ITS Spatial Data Deployment Platform (TN-ITS), (which evolved from work performed in several EU-funded projects), was established in an inaugural General Assembly in Dublin in June 2013. Supported by the EU Commission, the TN-ITS platform serves to facilitate and foster the exchange of ITS-related spatial data between public road authorities as data providers and map makers and other parties as data users. TN-ITS focuses on the exchange of information on changes in static road attributes e.g. speed limits. Current members include transport authorities in Norway, Sweden, Finland, Estonia, Lithuania, Slovenia, Hungary, Belgium, The Netherlands, France, Spain, Portugal, Greece, Ireland and the UK, along with the map makers TomTom and Nokia Here and key stakeholders such as the ETSC and ERTICO (TN-ITS, 2018). The EU Commission also supported the harmonisation of speed limits throughout the EC as a basis for the introduction of legally enforceable speed limits in the region (EU Commission, n.d.).

Whereas much progress has been made in overcoming the technical, legal, commercial and attitudinal barriers to ISA implementation, until recently, the pace of this progress has been somewhat slow, indicating that more needed to be done at EU and national level to support the widespread introduction of ISA technologies within the EU as a whole.

5.4.1 Recent developments within the EU

On 17 May 2018, the EU Commission published a large package of transport policy proposals termed "The Third Mobility Package" involving key measures to improve road safety in the EU. This included revision of the "General Safety Regulation" which incorporates a set of new vehicle safety measures, including mandatory installation of new driver assistance technologies which are expected to come into force from 2020 onwards. The Commission stated that;

"Intelligent speed assistance, lane-keeping systems, driver drowsiness and attention monitoring and distraction detection and reversing detection systems have a high potential to reduce casualty numbers considerably. In addition, those systems are based on technologies which will be used for the deployment of connected and automated vehicles too. Therefore, harmonised rules and test procedures for the type approval of vehicles as regards those systems and for the type-approval of those systems as separate technical units should be established at Union level" (EU Commission, 2018, p.14).

The ETSC supports the proposed measures, especially those with the most potential for reducing death and injury such as overridable ISA and Automated Emergency Braking (AEB), both of which are already widely available on the market. However, the ETSC also believes regulation is needed to make sure that the benefits are extended to all new vehicles as standard (ETSC, 2018). Euro NCAP also promotes installation of Intelligent Transport Systems (ITS) to help drivers to control their speed. It assesses the three ITS functions that have been the central focus of this review i.e. *Voluntary, Advisory* and *Mandatory* ISA taking into consideration system accuracy and potential for driver distraction (Euro NCAP, 2018).

5.5 ISA in the context of Connected and Automated Vehicles

The automation of any system usually follows a well-defined developmental trajectory (Endsley, 2018) and the five levels of vehicle automation that were outlined by the Society of Automotive Engineers (2018) are set out in Figure 9. This illustrates that driver assistance technologies such as ISA represent the first level of automation.

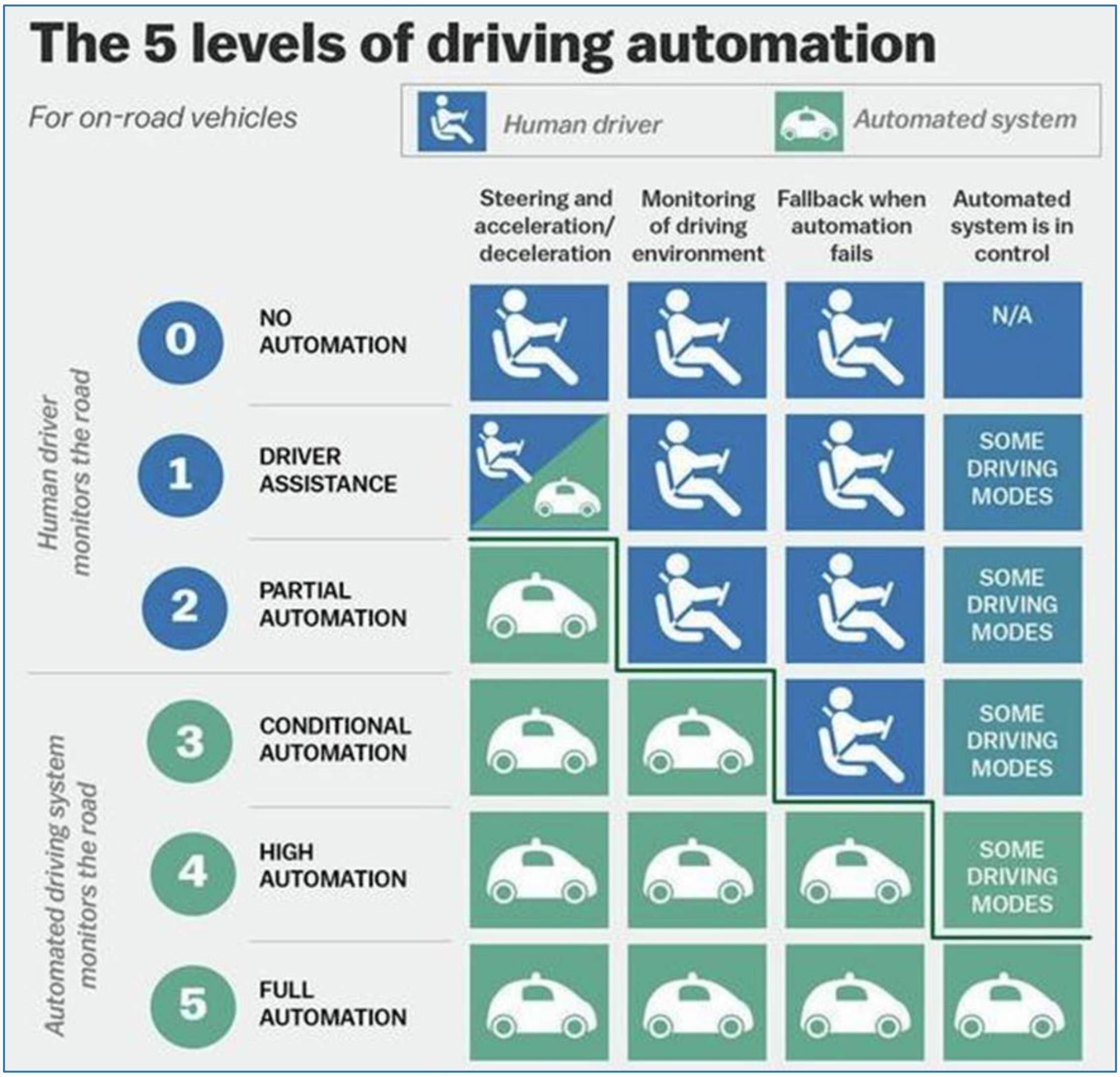

Figure 8: The 5 levels of driving automation. (Source: SAE https://www.sae.org/standards/content/j3016_201806/)

It is widely acknowledged that systems such as Driver Assistance employ technologies that will also be used as part of the development of connected and autonomous vehicles (EU, 2018).

Currently much of the focus in relation to vehicle automation concerns so-called 'self-driving' cars i.e. vehicles that drive themselves for a large part of the time (level 3) or cars that can drive themselves all the time within designated areas (level 4). Some vehicle manufacturers such as Ford reportedly plan to skip over level 3 and go straight to level 4. Their CEO Mark Fields claims that they will have cars with no gas pedal and no steering wheel deployed in certain cities in 2021. Toyota also plan deployment of level 4 autonomous vehicles for use by ride-sharing companies. Daimler expects large scale commercial production of level 4 and 5 vehicles to take off between 2020 and 2025 (Emerj, 2018). Analysis conducted by McKinsey

& Company (2016) suggests that subject to progress on technical, infrastructure and regulatory challenges, up to 15% of all new vehicles could be fully autonomous by 2030, rising to 80% by 2040.

Clearly, however there is still quite a way to go before fully autonomous vehicles designed for commercial and domestic use can be developed, tested, approved, marketed and ultimately proliferate on our roads. For instance, Euro NCAP has not included Automated Driving systems yet in the safety star ratings because they are still learning how these systems are currently designed, what their physical limitations are, and what safety benefits can be expected. Instead, Euro NCAP focuses on providing information about the current state-of-the art and comments on the design strategy taken by the car manufacturer, within the context of what is legally allowed according to European regulation and this includes ISA technologies (Euro NCAP, 2018)

The evidence presented in this review shows that ISA technologies which are available currently are effective at reducing crash risk and thus can help to reduce crash-related injury and death significantly in the short to medium term.

6 CONCLUSIONS AND RECOMMENDATIONS

The evidence presented in this review demonstrates that ISA technologies are effective in supporting drivers with managing speed. Experts in this field agree that by restricting the vehicle to the posted speed limit, ISA provides one of the most effective strategies for reducing inappropriate speeds, thereby improving road safety (ETSC, 2015). Furthermore, due to rapid advances in the development of low-cost technologies (e.g. GPS and nomadic devices) it is clear that the widespread deployment of ISA to support speed management is entirely feasible. Indeed, from a technical point of view, large-scale implementation of ISA is possible in the short-term. In this regard, the ETSC reported recently that a major new study conducted by TRL for the EU commission identified ISA among a number of technologies that are suitable for mandatory fitting as part a review of EU vehicle safety legislation because it is technologically feasible, currently on the market and provides a positive B/CR (ETSC, 2018).

All of the ISA systems that were examined as part of the review were effective in reducing speed at some level, during a specific timeframe. A substantial accumulation of research evidence demonstrates comprehensively and conclusively that there is a clear relationship between speed and crash risk. Evidence cited in this report also shows that the introduction of ISA would undoubtedly improve road safety to the extent that, when used correctly, these systems are very effective in reducing driving speeds, and speeding is a major risk increasing factor in terms of crashes, injury and death. However, some of the studies in this report also indicated that the anticipated safety benefits of ISA may be offset to some extent as a result of negative behavioural adaptation and/or driver distraction. Moreover, successful implementation of ISA depends heavily on driver acceptance of the principle of in-vehicle control generally and on their willingness to install these systems and to use them correctly. Different types of ISA technologies impact differently on driver behaviour and on traffic safety: The more controlling the system, the more effective it is in reducing speed and road safety generally, but the less acceptable it will be to drivers. Research shows that the greatest benefits will be derived through the use of *Mandatory* ISA. However, this form of speed control was least acceptable to drivers who participated in field trials.

The pace of the uptake of ISA technologies will be dictated by the implementation strategy that is used. The proliferation of ISA would proceed faster in an *Authority Driven* scenario than it would in a *Market Driven* scenario. However, the evidence in this report suggests that this approach would be less acceptable to the general public. In addition, a *Market Driven* approach to implementation will likely favour the fitment of ISA systems that *Advise* or *Support* drivers, which have been shown to be less effective in reducing speeding and consequently in reducing the frequency and severity of road traffic crashes.

More public engagement is required in Ireland to gauge acceptance of various forms of ISA and to identify the most effective ways to encourage voluntary uptake of ISA, by individuals or fleets. For instance, a communication plan should be developed which uses evidence from ISA research trials to explain the benefits of ISA to fleet managers and to the general public. In addition, a survey should be conducted to gauge public opinion generally and qualitative research (e.g. interviews, focus groups) should also be conducted to elicit the viewpoints of key stakeholders so that these can be taken into account when formulating an implementation strategy. Interestingly, research conducted by the RSA into Irish peoples' perceptions and attitudes towards next generation technologies such as Connected and Autonomous Vehicles (CAVs) showed that while 42% of those surveyed believed that self-driving cars will improve road safety, just 26% expressed a strong interest in owning such a vehicle (RSA, 2018). Given that ISA would be much easier and cheaper to implement, this suggests that the promotion of ISA should be undertaken the short to medium term. Also, since driver willingness to relinquish control over some and eventually all aspects of vehicle functioning will be key to the deployment of Connected and Automated Vehicles (CAVs), and since this review shows that many drivers appear reluctant to relinquish control of speed choice, it seems that more research is needed to identify the instrumental and psychological needs that are fulfilled by driving in general, and speeding in particular for some drivers, and to find ways to address such needs in a safer context.

The costs and benefits related to different types of ISA devices will have to be taken into account. Elaborate systems such as *Voluntary* ISA are likely to be too expensive for many drivers. However, ISA can be delivered much more cheaply using *Advisory* ISA systems via GPS and nomadic devices such as mobile phones.

In any event, the roll-out of ISA in Ireland will be contingent on the development and testing of digital speed maps. In his address to the RSA International Road Safety Conference in 2016, John McCarthy, a Senior Advisor in the Department for Transport, Tourism and Sport (DTTAS), outlined this process which entails a full review and update of speed limits on national, regional and local roads, possible legislative and regulatory changes, and benchmarking against engineering guidelines and standards, and reported that DTTAS has been tasked with a number of actions supporting this process. DTTAS, in collaboration with the Local Government Management Agency (LGMA), are working currently to progress a digital speed database for Ireland as set out in Action 13 in their Speed Limit Review (Department for Transport, Tourism & Sport, 2013).

The evidence presented in this review shows clearly that ISA technologies that are available currently represent an efficient and effective way of controlling speeding and thus improving road safety **immediately.** Furthermore, these systems are relatively cheap and easy to fit and retrofit. For these reasons, it is recommended that more effort should be focused on promoting and supporting the use of ISA technologies in the short to medium term while in preparation for the widespread proliferation of Connected and Autonomous Vehicles (CAVs).

6.1 ISA in the context of a Safe System approach

Traffic safety depends on creating safe roads, safe vehicles and safe drivers. As illustrated by Cunningham and Sundberg (2006), ISA forms part of an ICT solution which straddles the interface between Safe vehicles and Safe drivers (see Figure 9). The speed of motorised vehicles is a central issue because it affects both crash causation and severity and influences the effectiveness of a range of measures. This understanding is central to the Safe System approach (EU Commission, 2018c). The evidence presented in this review shows that ISA technology can play an important role in preventing speeding.

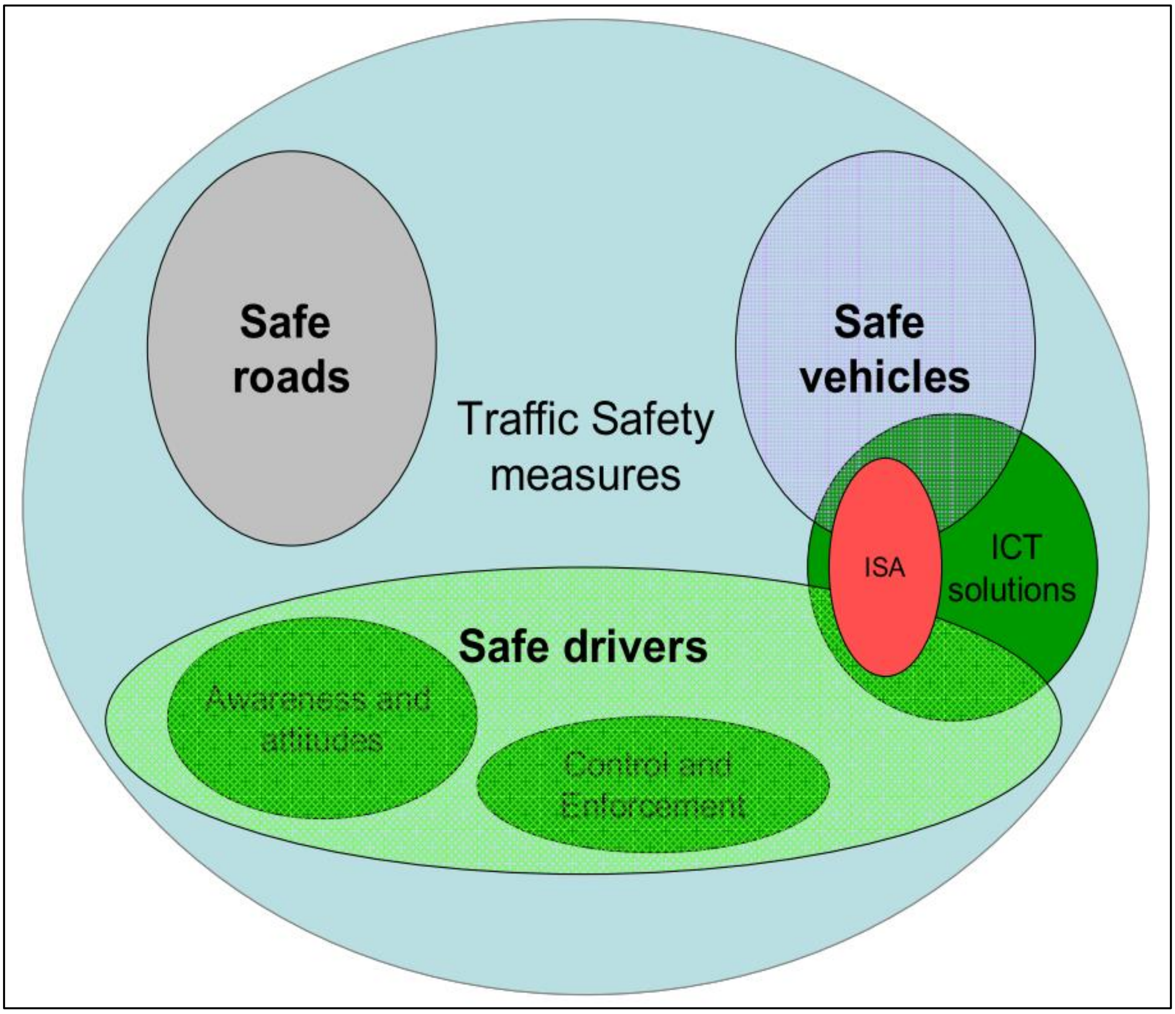

Figure 9. ISA in the context of traffic safety measures (Source: Cunningham and Sundberg (2006)).

As demonstrated clearly in this document, this approach, when coordinated with existing measures, will undoubtedly help to reach the targets set out in the Government Road Safety Strategy (2013 – 2020) in terms of reducing collisions, deaths and injuries on Irish roads.

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APPENDIX A INFORMATION SOURCES

Table 25 List of websites and electronic databases used as sources for literature on ISA

Source	Host	Date[6]
FOT-NET DATA	http://wiki.fot-net.eu/index.php?title=Intelligent_Speed_Adaptation_trials	16/09/2018
Google	www.google.ie	01/09/2018
Europa	http://europa.eu/pol/trans/index_en.htm	17/09/2018
European Transport Safety Council (ETSC)	http://etsc.eu/	20/09/2018
Eurostat	http://ec.europa.eu/eurostat	20/09/2018
Institute for Transport Studies (ITS) University of Leeds	http://www.its.leeds.ac.uk/projects/isa/publications.htm	01/04/2018
International Road Traffic and Accident Database (IRTAD)	http://internationaltransportforum.org/irtadpublic/index.html	15/03/2018
Organization for Economic Co-operation and Development	http://www.oecd-ilibrary.org/	04/03/2018
SWOV	http://www.swov.nl/index_uk.htm	17/08/2018
Royal Society for the Prevention of Accidents (RoSPA)	http://www.rospa.com/	24/08/2018
RSA	http://rsa.ie/	01/09/2018
Science Direct	www.sciencedirect.com	01/09/2018
Transport Research Innovation Portal (TRIP)	http://www.transport-research.info/	25/08/2018
Transportation Research Information Database (TRID)	http://trid.trb.org/	14/08/2018
Web of Science	apps.webofknowledge.com	31/08/2018

[6] Date when the most recent comprehensive search was conducted

Table 26 Individuals and organisations contacted for information on ISA

Country/Region	Organisation	Individual
EU	EU/Europa	Rudolf Koronthály
	ERTICO	Maxime Flament
		Kees Wevers
	ETSC	Ellen Townsend
	Euro NCAP	Michiel Van Ratingen
UK	ITS, Leeds University	Professor Oliver Carsten
Ireland	Road Safety Authority	Sharon Heffernan
Sweden	Trafikverket Swedish Transport Agency	Anders Lie
Finland	VTT, Finnish Transport Agency	Harri Peltola
Belgium	Flemish Transport Ministry	Nele Dedene
Netherlands	Dutch Ministry of Transport	Marcel Otto

APPENDIX B SUMMARY TABLE OF ON-ROAD ISA TRIALS[7]

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Europe										
France	Saad & Malaterre, 1982	ONSER	Urban	1 drive of 200km	12 drivers/ 1 vehicle	Mandatory Limiting - Driver-set maximum speed	Observations & Interviews		Speeds tended to be set above limit	
Sweden	(Persson et al., 1993)	Lund	Urban	1 hour	75 drivers/ 1 Volvo 750	Advisory- Speed limit display; Limiting - Speed limiter (active throttle with no override). Limit set to 50 km/h	Speed; Travel time; Red running; Car following interactions; Conflicts; Emissions; Attitudes	General speed reduction; Less red light running; Less conflicts	Increased speed on approaches and in turnings; Deteriorated behaviour in interactions	Improved after testing the system
Sweden	(Almqvist & Nygård, 1997)	Eslöv	Urban	2 months	25 drivers/ Drivers own vehicles	Advisory - Speed limit display Limiting - Speed limiter (active throttle with no override possibility)	Speed; Travel time; Interactions; Conflicts; Emissions; Opinions	General speed reduction; Improved behaviour in interactions	Travel time increased by 5%	Improved after testing the system

[7] Adapted from Young and Regan (2002)
[8] This describes the amount of exposure each driver had to ISA or the total distances driven in the trial. In some instances, only an approximate duration or distances are known.

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Sweden	Vägverket, 1999, 2002; 2003a; Lind, 2000; Wallen, Warner & Aberg, 2008	"Right Speed" - Borlänge	On-road		400 private and commercial drivers & vehicles	Advisory (Informative) ISA system for Quality Insurance	Mean, maximum speed; % time spent speeding; Travel time; Fuel consumption	Mean speed reductions of 3 to 4 km/h observed; Greatest effect 50 km/h speed zones; Reduced amount of time above speed limit; Reduced speed variance; Lower approach speeds at intersections; Financial incentive increased driver motivation to reduce speed; Reductions in fuel consumption; No increase in travel times	Decreasing effect over time (on speed)	Easier to adhere to speed limits; Commercial drivers not as positive as private drivers; Auditory warning annoying
Sweden	Adell, 2007; Adell & Várhelyi 2008; Hjälmdahl et al., 2002; (90) Hjälmdahl, 2002;	"Lund ISA"	On-road	3-11 mths.	290 vehicles 50% private 50% commercial	Supportive (Active Accelerator Pedal-AAP)	Speed; Following behaviour; Interaction with road users; Travel time; Emissions;	Sig. reduction in average speed and speed variation; AAP improved interactions with pedestrians & headway; Better car following behaviour; Decreased fuel consumption & emissions	Drivers forgot to change speed outside test area, suggesting delegation of responsibility; Decreasing effect over time (on speed); Drivers with negative	Driver acceptance high within built-up areas; Younger male drivers more negative: Older female drivers more positive; Drivers found the system useful but not satisfactory;

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
	Hjälmdahl, 2003						Acceptance		attitude more likely to use kick-down function to exceed speed limit	Perceived decrease in risk of getting fined; Attitudes towards the system tended not to change after use
Sweden	Sunberg, 1999; Vägverket, 2002; 2003d	"Smart Speed" - Umeå	On-road		Private and public transport drivers/ 4,000 vehicles	Advisory (Informative) Light and auditory signal presented when limit was exceeded	Speed: Acceptance	Mean speed reductions of up to 0.9 km./h on 30-50 km/h roads; No decrease in speed in 70 km/h zones (measured at the roadside)	Driving pleasure decreased; Frustration increased; Perceived longer travel times	Greater awareness of speed limits and vulnerable road users; Easier to adhere to speed limits; Over two-thirds of drivers wanted to keep ISA at end of trial
Sweden	Vägverket, 1999, 2002; 2003b	"Lidköping – Spearhead-ing the way to vision zero"	On-road		Private, company and municipal authority drivers/ 150 vehicles (Informative); 130 vehicles (Active	Advisory (Informative) Supportive (AAP)	Speed; Acceptance	Reduction in average and maximum speeds; Calmer traffic flow (fewer stops and braking); No evidence of increased travel times		Drivers reported highly positive attitudes towards the ISA systems; Systems (especially AAP) made it easier to comply with speed limits and improved road safety; Perceptions of 'holding up' the

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
					Accelerator)					other traffic with AAP
Sweden Stockholm	Transek & SWECO VBB, 2005	ISA for Stockholm	On-road	6 mths.	20 vehicles; 130 drivers	Supportive (AAP); (3 mths.) Vibrating accelerator (3 mths.)	Speed; Acceptance	Decrease in perceived speeding violations (less often and less serious); Mean speed decreased especially on higher speed- limited roads		75% of drivers wanted to keep the system Two-thirds of drivers found the system impairs driving pleasure. Many found it effortful and frustrating (esp. the active system). Perceptions of 'holding up' traffic. Perceived longer travel times.
Sweden Gothenburg	Transek, 2003		On-road (2002 – 2003)	6 mths.	16 busses	Supportive (Active accelerator)	Speed; Acceptance	Decrease in speeding violations; No perceived increase in travel times		Bus drivers had negative attitude to ISA
Nether-lands Groningen	(Brookhuis & de Waard, 1999)		On-road	1 drive with ISA active	24 drivers	Advisory – Audio/visual feedback	Speed; Mental workload; Acceptance	Reductions in mean speed, speeding and speed variability	No sig. effect on workload	Continuous feedback most acceptable; Found system reduced speed variability

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Nether-lands Tilburg	(Duynstee & Martens, 2001) Van Loon & Duynstee	AVV Tilburg trial	On-road	12 months	20 cars – 479 drivers; 1 bus – 20 drivers	Limiting - Mandatory speed enforcement	Speed; Acceptance	Average speed lower; Less violation of other traffic laws	Mixture of ISA and non-ISA cars causes some irritations between the two groups.	Negative response in low speed areas (e.g. 18 km/h): Acceptance increases as speed limit increases 52% agreed ISA increased pedestrian and cyclist safety. 3% agreed ISA was safer for driver. Up to 65% of test drivers supported ISA. 30% other reference groups opposed it. Appreciation highest for 80 KM/H roads. Information and communication has a large effect on acceptance.

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Nether-lands	Van der Pas et al., 2014	ISA for speed offenders	On-road	650,000 kms	51 speed offenders	Speedmonitor (recording ISA) Speedlock (Mandatory Limiting)	Crash likelihood; Speed variation	Reductions in crash likelihood Reduced speed variation, Smoother manoeuvring Improved interactions	Negative reactions from other drivers (tailgating and increased overtaking)	
Finland	Päätalo et al., (2002)		On-road		24 drivers	Advisory - Informing; Limiting - Compulsory; Recording	Speed acceptance; Travel time	All systems reduced percentage of time spent speeding; Limiting system was most effective No significant difference in driving times across systems	Mental demand highest for mandatory system. Effort, frustration and insecurity levels greatest for mandatory system	Poor acceptance of Compulsory system; Recording system most popular
Belgium, Ghent	Broekx et al. (2005) Valssenroot, 2008	PROSPER	On-road		34 cars; 3 buses	Supportive (Active Accelerator Pedal)	Speed; Acceptance; Voluntary use of the system	Small effect on speed; Not effected in 30 to 70 km/h zones; Decrease in 85 percentile in all speed zones; Effect larger in higher speed zones	Speed increases for some drivers; Average driving speed increases for infrequent speeders; Drivers more likely to drive at speed limit than under- causes increase in average speed Fast acceleration	30% of drivers voluntarily used system outside test period; Good acceptance and belief that the system is useful

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
									towards speed limit	
Denmark, Aalborg	Lahrmann, Madsen & Boroch, 2001; Nielsen & Lahrmann, 2005	INFATI	On-road	4 weeks	24 drivers	Advisory	85th percentile speed; Speed violations; Acceptance; Workload	Speeds reduced; Speeding violations reduced; Greater awareness of speed and of speed violations; Reduced mental strain monitoring speed limits		Lower acceptance in lower speed zones than in higher speed zones
Denmark. Aalborg	Agerholm et al., 2008; Lahrmann et al., 2007	Pay-as-you-speed (PAYS)	On-road Urban & Rural		146 drivers	Advisory-visual/audible warning i.e. Penalty points to reduced insurance costs	Speed	Most education in speed on rural roads with 80 km/h limit. Less on 110 km/h motorways and on urban 50 km/h roads; Most effective when incentive and information are provided	None	
France	Ehrlich et al, 2003; Driscoll et al, 2007	LAVIA	On-road	130,000 kms (approx.)	100 drivers/ 20 vehicles	Advisory; Voluntary: Mandatory	Speed; Acceptance; Driver behaviour	Mean speed reduced; Greater reductions for voluntary system	Increased pressure from other drivers	Mandatory system deemed less acceptable than voluntary system and even considered dangerous
Spain	Jiménez et al., 2008		On-road		8 drivers	Dynamic advisory	Speed; Acceptance	No change in mean and maximum speed; Percentage of travel distance spent speeding reduced;		Suggested safe speed deemed to be reasonable

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
								Speeding on bends reduced		
UK	Comte, 1996		Simulator		30 drivers	Limiting	Speed; Gap Acceptance; Following behaviour (headway); Red light violations	Reduced speeds; Longer headways; Reduced red light violations;	Increased frustration and time pressure; Risky gap acceptance behaviour	Less physical effort required to drive
UK	Carsten & Fowkes, 2000; Carsten et al., 2000	External Vehicle Control (EVSC) Project	On-road; Micro-simu-lation	1 X 67km route	24 drivers	Limiting - Mandatory; Driver Select (voluntary) limiting	Speed; Braking; Following behaviour; Acceptance; Workload	Excessive speeds reduced, especially with Mandatory ISA and in urban areas; Voluntary (driver select) system half as effective as Mandatory; Improved following behaviour; Less abrupt braking; Micro-simulation: Improved fuel consumption; Predicted decrease in injury; Full cost-benefit will be realised when fleet penetration is 60% or more	Time pressure and frustration increased; Driver select disengaged in high speed areas	The voluntary, Driver Select was considered “more useful” as a safety feature than the Mandatory system

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
UK	Lai et al., 2007a; Lai et al., 2007b; (also Carsten et al., 2008)	ISA UK Car & Truck Trial	On-road		79 car drivers (20 private & 20 fleet); 1 truck driver	Car & truck; Limiting	Speed; Workload; Attitudes and acceptance; Self-reported behaviour	Car: ISA reduced 85th percentile speeds & amount of time spent over the speed limit; Less effect in 20mph & 60mph zones: ISA reduced speed variability in low speed zones and incidents of severe braking; Physical demand reduced when driving with ISA; Non-significant reduction in mental demand and effort; Increased time pressure; Truck: Tolerance allowed for uphill meant not precise limit, but shifted speed distribution down & very rarely>5mph over limit; Speed variation reduced; Driver used override 0.2% of time on 30mph roads, slightly less on 50kph roads	Car: Drivers did not feel less vigilant with ISA; Reported more aware of speed limit, more likely to check speedometer, more likely to anticipate conflicts and more likely to attend other road users when driving with ISA Truck: Less speeding in 30mph zones but more in 40, 50mph zones in post period than baseline	Car: More likely to override system in 70mph (highest) speed zones, and if male, young, and/or prior intention to speed; Private drivers more overrides in urban, fleet drivers on motorways; Experience with ISA reduced intentions to speed and belief that speeding leads to shorter journey time; After trial, 54% willing to install on own car. 62% approved fitting to new vehicles, 56%approved fitting to all vehicles. Truck: Perceived usefulness & satisfaction low to start with &declined following experience with system Trust declined after using ISA Would not be willing to install

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
UK	Jamson et al., 2007; (also Carsten et al., 2008	ISA UK Simulator Trial	Simulator		32 drivers	Mandatory	Overtaking attempts and success rate; Time to collision; Maximum speed; Following behaviour; Workload; Acceptability	Little difference between 50% and 100% penetration scenarios; Using ISA, fewer attempts to overtake and more of those attempts abandoned; No difference in number of hatch encroachments, but ISA lengthened time in hatch area; No difference in minimum headway at start of manoeuvre but ISA shortened headway distance at end (drivers cut back in closer); Without ISA, drivers exceeded speed limits during overtaking; No change in headway during car following sections		No difference in workload & acceptability between 50% equipped and 100% equipped conditions

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
UK	Simpkins et al., 2007	ISA UK Motorcycle Trial	Test track		33 riders	Advisory; Informative; Assisting	Acceptance; Limited data on speed behaviour	Advisory/Informative system had little effect on speed; Assisting system reduced speed violations		Advisory system most useful; Informative not as good as expected (ratings lower post ride than pre-ride); Negative satisfaction for Assisting - least willing to install this; Majority of riders would consider installing Advisory or Informative systems; All systems thought to decrease crash risk; No concerns with stability
UK		Lancashire	On-road	9 months Over 4.5 million kms	402 regular, novice, fleet, taxi and bus drivers	Advisory (Visual & Auditory Warning) using nomadic devices		Small reduction on speed Larger reduction in proportion of speeding in 30 and 70 mph zones Significant reductions even when the system was used intermittently	Less effective with older drivers, whose baseline speeds tended to be lower Younger drivers more resistant to reducing speed	

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
UK	TRL	London Bus	On-road			Mandatory (controlled accelerator)	Speed Attitudes & Acceptance Emissions	Speed reduced Percentage time spent travelling over the speed limits reduced from a range of 15-19% to 1-3% in 20mph zones and 0.5-3% to 0-1% in 30mph zones (+/- 50km/h)	Some vehicle platooning. Some drivers concerned that other road users would become frustrated.	No significant difference in fuel usage. Reduced emissions. Some calibration problems initially but after these were sorted, driver acceptance increased.
EU Trans-national										
Sweden, NL Spain		MASTER	Urban; Rural; Motorway	2 Test drives	20 – 24 drivers in each country	Advisory – Speed limit display; Limiting – Active throttle with no override facility	Speed; Travel Time; Time-gap in car following Behaviour interactions; Workload; Opinions	General speed reduction; Smoother speed on approaches; Car following improved on 30 – 50 Km/h roads	Travel time increased by 7% Car-following deteriorated on 70-90 km/h roads Reported increases in frustration and decreases in performance	The majority accepted the advisory system. Half of the drivers would accept the limiting system in their cars voluntarily.
UK	Várhelyi et al., 1998	MASTER	Simulator		60 drivers	Advisory; Fixed & dynamic speed limiting	Speed; Following behaviour; Overtaking manoeuvres; Traffic violations; Collisions	Large speed reductions; Reduced speed variance; Better speed adaptation	Less safe following distances; Negative behavioural adaptation in fog, due to loss of vigilance	Increased frustration

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Netherlands	Rook & Hogema, 2005; Rook, Hogema & van der Horst, 2004	PROSPER	Simulator		64 drivers	Supporting - Haptic gas pedal – low force; Haptic gas pedal – high-force; Tactile pedal – vibrates as indicator; Limiting - Dead throttle-restricts speed	Speed; Workload; Acceptance	ISA reduced mean speed; Tactile pedal less effective than dead throttle in reducing speed; Low-force haptic reduced speed less than the high-force haptic	Mean speed in curves not affected	Low-force Haptic and tactile increases workload slightly; Other systems did not increase work load; Acceptance generally good; Satisfaction low; Low-force haptic perceived as most satisfying & useful; 44% would like tactile pe haptic pedal in own car; 25% would like dead throttle; 23%would like high-force haptic pedal
Hungary & Spain	(Cunningham & Sundberg, 2006)	PROSPER	On-road		64 drivers	Advisory (BEEP) Supportive - Active Accelerator Pedal (AAP);	Speed (mean and percentile)	Reductions in mean and 85^{th} percentile speed; AAP most effective	None	50% of drivers willing to use system; Higher willingness for beep system
		North America								
Canada	Taylor, 2006	Speed Choice	On-road		10 vehicles; 79 datasets (drivers)	Advisory (OTTOMate) Information only Supportive (IMITA-SA) auditory and haptic support	Speed; Travel time; Acceptance; Fuel consumption	Decrease in time spent speeding in all speed zones for Limit Advisor system; Fuel consumption reduced during ISA usage	Increase in over-speed percentage with OttoMate system	ISA and speed management not liked; Limit Advisor preferred system

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Canada		SafeMiles		3 mths approx. 234,480 km		Recording ISA Compliance with speed limited rewarded		Compliance improved significantly especially in 30-39 age group. Compliance highest in 100km/h and lowest in 50km/h zones		High overall acceptance Users wanted to see the system used more widely
USA Michigan (2,24)	Regan et al., 2012; Regan & Bliss, 2013	Kalamazoo trial	On-road		8 vehicles/ 50 drivers	Advisory - (auditory and visual signals) Cash Incentive	Speed; Perceived mental workload; Trust and Acceptance	Advisory ISA: Modest reduction in speeding; Incentive system: Significant reduction in speeding; Combined ISA and Incentive system: Reductions in speeding similar to incentive only condition		
Asia-Pacific										
Australia - Melbourne	(M. A. Regan et al., 2006)	TAC SafeCar	On-road 2002 – 2004)	16,500kms	23 drivers 15 Ford Falcons	Supportive (Actively Supporting)	Speed; Following distance; Travel times; Fuel consumption and emissions; Crash estimates; Acceptance; Workload	Reductions in mean, maximum, 85^{th} percentile and speed variability; No significant change in travel times	No compensatory behaviour observed; Drivers experienced increased frustration due to speed limit inconsistencies in the ISA digital map	High – ISA deemed useful, effective and socially acceptable

Context						Intervention	Mechanism	Outcomes		
								Key Results		
Region/ Location/	Author(s)/ Date/ Endnote	Study Name	Study type	Study Duration[8]	Drivers/ Vehicles	ISA Functionality	Measures Investigated	Safety Benefits	Negative Aspects	Acceptability
Australia – NSW	(Barnes et al., 2010; Wall, 2010)	RTA-NSW	On-road		110 vehicles	Advisory		Reduction in amount of time spent speeding.	Technology was "unforgiving". Did not allow driver to travel a few km/h over the limit without beeping. Drivers under 25-yrs were less likely to time spent speeding and more likely to turn devices off	Raised awareness of speed zones and speeding violation. Reduced worry re speeding. 65% found it very useful. 21% wanted to keep it.
Australia	(Fitzharris et al., 2012)	ISA-Heavy Vehicles	On-road	12 weeks 4 weeks pre and 8 weeks with ISA	6 vehicles	Advisory Auditory & Visual warnings	Pre and post questionnaire, logged trip data & Operator Trip Logs	Reduction in speed violations. Biggest effect in zones =>80 Km/h (25%). Little benefit in zones <= 70 km/h.		Divergence of opinion re acceptability

Reducing Speeding-Related Crashes Involving Passenger Vehicles

Safety Study

NTSB/SS-17/01
PB2017-102341

National Transportation Safety Board

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Notation 56821
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Safety Study

Reducing Speeding-Related Crashes Involving Passenger Vehicles

National Transportation Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2017. ***Reducing Speeding-Related Crashes Involving Passenger Vehicles*****. Safety Study NTSB/SS-17/01. Washington, DC.**

Abstract: In this safety study, the National Transportation Safety Board (NTSB) examines causes of and trends in speeding-related passenger vehicle crashes and countermeasures to prevent these crashes. The countermeasures presented represent several, of many, potential solutions to the issue of speeding-related crashes. They do not address every cause of speeding or type of speeding-related crash, but they are intended to be widely applicable to a significant portion of these crashes.

The NTSB focused on the following five safety issues pertaining to the effective application of proven and emerging countermeasures for speeding: (1) speed limits, (2) data-driven approaches for speed enforcement, (3) automated speed enforcement, (4) intelligent speed adaptation, and (5) national leadership.

As a result of this safety study, the NTSB makes recommendations to the US Department of Transportation, the National Highway Traffic Safety Administration, the Federal Highway Administration, 50 states, the Governors Highway Safety Association, the International Association of Chiefs of Police, and the National Sheriffs' Association.

For more detailed background information on this report, visit http://www.ntsb.gov/investigations/dms.html and search for NTSB accident ID DCA15SS002. Recent publications are available in their entirety on the Internet at http://www.ntsb.gov. Other information about available publications also may be obtained from the website or by contacting:

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ASE	automated speed enforcement
BAC	blood alcohol concentration
CFR	*Code of Federal Regulations*
DDACTS	Data-Driven Approaches to Crime and Traffic Safety
DOT	US Department of Transportation
FARS	Fatality Analysis Reporting System
FAST Act	Fixing America’s Surface Transportation Act
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GES	General Estimates System
GHSA	Governors Highway Safety Association
GIS	geographic information system
GPS	global positioning system
HVE	high-visibility enforcement
IACP	International Association of Chiefs of Police
IIHS	Insurance Institute for Highway Safety
ISA	intelligent speed adaptation
ITE	Institute of Transportation Engineers
km/h	kilometers per hour
LIDAR	light detection and ranging
MADD	Mothers Against Drunk Driving
MAP-21	Moving Ahead for Progress in the 21st Century Act
MMUCC	*Model Minimum Uniform Crash Criteria*

MUTCD	*Manual on Uniform Traffic Control Devices*
MV PICCS	Motor Vehicle Prioritizing Interventions and Cost Calculator for States
NASS	National Automotive Sampling System
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration
NSA	National Sheriffs' Association
NSC	National Safety Council
NTSB	National Transportation Safety Board
RITA	Research and Innovative Technology Administration
SCOHTS	Standing Committee on Highway Traffic Safety
TSM	Traffic Safety Marketing
USC	*United States Code*
VMT	vehicle miles traveled

Executive Summary

Speeding—exceeding a speed limit or driving too fast for conditions—is one of the most common factors in motor vehicle crashes in the United States. In this safety study, the National Transportation Safety Board (NTSB) examines causes of and trends in speeding-related passenger vehicle crashes and countermeasures to prevent these crashes.

Why the NTSB Did This Study

From 2005 through 2014, crashes in which a law enforcement officer indicated a vehicle's speed was a factor resulted in 112,580 fatalities, representing 31% of all traffic fatalities. Speeding or speed has been cited as a safety issue, or a causal or contributing factor in 49 major NTSB highway accident investigations since 1967. Although recent speeding-related NTSB investigations have primarily involved large trucks and buses, most speeding-related crashes involve speeding passenger vehicles. In 2014, passenger vehicles constituted 77% of speeding vehicles involved in fatal crashes, and 78% of all speeding-related fatalities involved a speeding passenger vehicle. This study leverages prior NTSB investigations, together with other research, to address the national safety issue of speeding among passenger vehicle drivers.

In this study, the NTSB used a combination of quantitative and qualitative methods to summarize the risks of speeding, describe the scope of the problem, and promote the use of proven and emerging speeding countermeasures. This included a literature survey; analyses of speeding-related crash data; and interviews with national, state, and local traffic safety stakeholders. The stakeholders were representatives from transportation and highway safety agencies, law enforcement agencies, automobile manufacturers, research institutions, advocacy groups, equipment vendors, personal auto insurance providers, and professional associations.

This study assessed speeding among passenger vehicle drivers in a broad sense, as a factor that contributes to crashes and injury severity. Several, of many, potential solutions to the issue of speeding-related crashes are discussed. The solutions do not address every cause of speeding or type of speeding-related crash, but they are intended to be widely applicable to a significant portion of these crashes.

What the NTSB Found

Speed—and therefore speeding—increases crash risk in two ways: (1) it increases the likelihood of being involved in a crash, and (2) it increases the severity of injuries sustained by all road users in a crash.

The relationship between speed and crash involvement is complex, and it is affected by factors such as road type, driver age, alcohol impairment, and roadway characteristics like curvature, grade, width, and adjacent land use. In contrast, the relationship between speed and injury severity is consistent and direct. Higher vehicle speeds lead to larger changes in velocity in a crash, and these velocity changes are closely linked to injury severity. This relationship is especially critical for pedestrians involved in a motor vehicle crash, due to their lack of protection.

Typically, speed limits are set by statute, but adjustments to statutory speed limits are generally based on the observed operating speeds for each road segment—specifically, the 85th percentile speed of free-flowing traffic. Raising speed limits to match the 85th percentile speed can result in unintended consequences. It may lead to higher operating speeds, and thus a higher 85th percentile speed. In general, there is not strong evidence that the 85th percentile speed within a given traffic flow equates to the speed with the lowest crash involvement rate for all road types. Alternative approaches and expert systems for setting speed limits are available, which incorporate factors such as crash history and the presence of vulnerable road users such as pedestrians.

Speed limits must be enforced to be effective, and data-driven, high-visibility enforcement is an efficient way to use law enforcement resources. The success of data-driven speed enforcement programs depends on the ability to measure and communicate their effectiveness. However, law enforcement reporting of speeding-related crashes is inconsistent, which leads to underreporting of speeding-related crashes. This underreporting leads stakeholders and the public to underestimate the overall scope of speeding as a traffic safety issue nationally and hinders the effective implementation of data-driven speed enforcement programs locally.

Automated speed enforcement (ASE) is also widely acknowledged as an effective countermeasure to reduce speeding-related crashes, fatalities, and injuries. However, only 14 states and the District of Columbia use it. Many states have laws that prohibit or place operational restrictions on ASE, and federal guidelines for ASE are outdated and not well known among ASE program administrators. Point-to-point enforcement, which is based on the average speed of a vehicle between two points, can be used on roadway segments many miles long. This type of ASE has had recent success in other countries, but it is not currently used in the United States.

Vehicle technologies can also be effective at reducing speeding. Intelligent speed adaptation (ISA) uses an onboard global positioning system or road sign-detecting camera to determine the speed limit; it then warns drivers when they exceed the speed limit, or prevents drivers from exceeding the speed limit by electronically limiting the speed of the vehicle. Although passenger vehicle manufacturers are increasingly equipping their vehicles with technologies relevant to speeding, these technologies often are not standard features and require the purchase of certain option packages. New car safety rating systems are one effective way to incentivize the manufacture and purchase of passenger vehicles with advanced safety systems such as ISA.

Finally, the current level of emphasis on speeding as a national traffic safety issue is lower than warranted. Current federal-aid programs do not ensure that states fund speed management activities at a level commensurate with the national impact of speeding on fatalities and injuries. Also, unlike other traffic safety issues with a similar impact (such as alcohol-impaired driving) there are no nationwide programs to increase public awareness of the risks of speeding. Although the US Department of Transportation (DOT) has established a multi-agency team to coordinate speeding-related work throughout the DOT, this team's work plan does not include means to ensure that the planned actions are completed in a timely manner.

Recommendations

As a result of this safety study, the NTSB makes recommendations to the US Department of Transportation, the National Highway Traffic Safety Administration, the Federal Highway Administration, 50 states, the Governors Highway Safety Association, the International Association of Chiefs of Police, and the National Sheriffs' Association.

1 Introduction

Speeding—exceeding a speed limit or driving too fast for conditions—is one of the most common factors in motor vehicle crashes in the United States (Blincoe and others 2015). Over the past 15 years, the National Transportation Safety Board (NTSB) has identified speeding as a safety issue among drivers of heavy vehicles (NTSB 2012), in work zones (NTSB 2015), and at locations with site specific hazards (NTSB 2006; NTSB 2005a; NTSB 2005b). However, the NTSB has not often addressed this pervasive safety issue among passenger vehicle drivers.[1] This study examines speeding-related crashes involving passenger vehicles and countermeasures to prevent these crashes in the United States.[2]

1.1 Goals

The goals of this study are to summarize the risks of speeding, describe the scope of the problem, and promote the use of proven and emerging speeding countermeasures. In particular, this study focuses on countermeasures addressing passenger vehicle driver behavior.

1.2 Scope of the Study

This study assessed speeding among passenger vehicle drivers in a broad sense, as a factor that contributes to crashes and injury severity. Other crash factors, environmental conditions, and driver characteristics are known to be associated with speeding-related crashes, such as alcohol impairment, nighttime driving, and young male drivers (Council and others 2010; Neuner and others 2016). Some of these features of speeding-related crashes are discussed to highlight misconceptions about speeding and to illustrate the complexity of the relationship between speed and crash risk, but this study generally does not consider the many other factors that cause crashes and crash-related injuries, such as distraction or drug impairment. The countermeasures presented in this study represent several, of many, potential solutions to the issue of speeding-related crashes. They do not address every cause of speeding or type of speeding-related crash, but they are intended to be widely applicable to a significant portion of these crashes.

1.3 Methodology

The NTSB used a combination of quantitative and qualitative methods for this study, including a literature survey; analyses of speeding-related crash data; and interviews with national, state, and local traffic safety stakeholders.

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[1] As defined by the National Highway Traffic Safety Administration (NHTSA), *passenger vehicles* include automobiles, utility vehicles, and trucks with a gross vehicle weight rating less than or equal to 10,000 pounds. For a detailed list of vehicle types, refer to appendix C of the *FARS Analytical User's Manual* (NHTSA 2015a).

[2] As defined by NHTSA, a *speeding-related crash* is a crash in which the speed of at least one vehicle was related to the crash, as indicated "by the police issuing a citation for a speed offense, by their indicating a related or contributing factor, or through a description in the narrative" (NHTSA 2016a). The national crash databases used for this study do not indicate the probable cause of a crash.

1.3.1 Literature Survey

To identify speeding countermeasures with demonstrated effectiveness, the NTSB conducted a literature survey of relevant recent and foundational US studies. The NTSB also reviewed recent studies performed in other countries to identify successful speeding countermeasures. Information gathered from the literature survey also helped the NTSB develop topics for discussion with stakeholders.

1.3.2 Data Analysis

The NTSB analyzed data from the following national databases to summarize the scope of the speeding problem, illustrate the variability of speeding-related crashes, and confirm viewpoints expressed in stakeholder interviews:

- The Fatality Analysis Reporting System (FARS) is a census of fatal motor vehicle crashes occurring on US public roads since 1975, which is maintained by the National Highway Traffic Safety Administration (NHTSA) and based on data extracted from police crash reports (NHTSA 2015a).
- The National Automotive Sampling System (NASS) General Estimates System (GES) is a nationally representative sample of fatal and nonfatal motor vehicle crashes occurring on US public roads since 1988. Like FARS, NASS GES is also maintained by NHTSA and based on police crash reports (NHTSA 2015b).

The majority of the analyses in section 2 used 2014 FARS data, as these were the most recent data available when the NTSB conducted this study.

1.3.3 Stakeholder Interviews

The NTSB conducted semi-structured interviews with representatives from the following traffic safety stakeholder organizations.[3] The purpose of these interviews was to identify areas of common concern among stakeholders, including obstacles to the effective implementation of speeding countermeasures.

- **Federal Government**: The NTSB interviewed members of the US Department of Transportation (DOT) Speed Management Team (which consists of subject matter experts within NHTSA, the Federal Highway Administration [FHWA], and the Federal Motor Carrier Safety Administration [FMCSA]) and the NHTSA Office of Impaired Driving and Occupant Protection. Interview topics included current and recently completed speeding-related research projects, public awareness programs, and the federal role in addressing speeding.
- **State Government**: The NTSB interviewed employees of five state transportation departments, seven state highway safety offices, one office of the attorney general, and one public health department. Interview topics included methods for setting speed limits, engineering countermeasures, enforcement, federal and state highway safety grant program

[3] *Semi-structured interviews* primarily consist of open-ended questions. Interview topics and potential questions are developed beforehand. However, the order and wording of the questions may vary among interview subjects, and questions may be added as the interview progresses to explore topics in greater detail (Britten 2006, 12-20).

administration, the role of the courts, and procedures for recording and analyzing crash data.

- **State Law Enforcement**: The NTSB interviewed officers from five different state law enforcement agencies.[4] Most of the officers were in a supervisory role and were familiar with statewide speed enforcement activities. Interview topics included in-person and automated speed enforcement (ASE); the use of data to target enforcement; and coordination with other state agencies, states, and localities.
- **Local Government**: The NTSB interviewed employees of seven city transportation departments, one planning and zoning department, and one public health department. Interview topics included methods for setting speed limits, engineering countermeasures, enforcement, coordination with state and federal agencies, the impact of speeding on vulnerable road users such as bicyclists and pedestrians, and local initiatives to reduce traffic fatalities.
- **Local Law Enforcement**: The NTSB interviewed officers from nine city and county law enforcement agencies. The interviews included supervisors of traffic enforcement divisions (for those departments with discrete traffic enforcement divisions), officers responsible for traffic enforcement, and data analysts. Interview topics included in-person enforcement and ASE, the use of data to target enforcement, the role of speed enforcement within other law enforcement duties, and coordination with other state and local agencies.
- **Automobile Manufacturers**: The NTSB interviewed four US automobile manufacturers. Interview topics included speeding-related vehicle technologies and technologies designed to prevent unsafe behaviors by teen drivers.

The NTSB also interviewed representatives from traffic safety research institutions, advocacy groups, equipment vendors, personal auto insurance providers, and professional associations.

The NTSB selected stakeholders for interviews with a goal of gathering varied input, in terms of both geography (urban, suburban, and rural) and the types of countermeasures used. For example, some cities had extensive automated enforcement programs, whereas others had a strong focus on engineering countermeasures. Likewise, the automobile manufacturers selected for interviews offered varying levels of automation and driver support systems in their vehicles. Information gathered from the stakeholder interviews helped the NTSB identify the safety issues examined in this study.

1.4 Previous NTSB Investigations and Recommendations

Speeding or speed has been cited as a safety issue, or a causal or contributing factor in 49 major NTSB highway accident investigations, including the NTSB's first highway accident investigation, which involved a series of collisions among 11 vehicles in dense fog in Joliet, Illinois, on August 12, 1967 (NTSB 1967).[5] The NTSB conducts major highway accident investigations when the accident involves an issue related to a current NTSB safety study or special

[4] Throughout the remainder of this report, the term *officer* will be used to refer to law enforcement officers in local police, county sheriff, constable, state police, state patrol, and highway patrol agencies.

[5] Appendix A provides a complete list of NTSB major highway accident investigations in which speeding or speed was found to be a safety issue, or a causal or contributing factor.

investigation, has a significant impact on the public confidence or highway safety, or is determined by the NTSB to be catastrophic. Generally, NTSB highway investigations focus on commercial vehicles; as a result, most of the recent speeding-related NTSB investigations have primarily involved large trucks and buses. The following are examples of recent NTSB accident investigations that resulted in speeding-related safety recommendations. Each of these safety recommendations is currently classified by the NTSB as having an acceptable status, indicating that planned or completed actions satisfy the intent of the recommendation.

On March 12, 2011, in New York City, New York, a motorcoach departed from interstate highway travel lanes, struck a guardrail, overturned, and struck a highway signpost, resulting in 15 fatalities. The motorcoach was traveling 64 mph on a highway with a posted speed limit of 50 mph. As a result of its investigation, the NTSB identified heavy vehicle speed limiters as a safety issue and issued recommendations to NHTSA to develop performance standards for advanced speed limiting technology for heavy vehicles and to require this technology on newly manufactured heavy vehicles (NTSB 2012).[6] These recommendations were later reiterated in the NTSB's investigative report on a June 7, 2014, accident in Cranbury, New Jersey, in which a tractor-trailer struck the rear of a limo van at the end of a work zone traffic queue, resulting in one fatality. The NTSB found that the tractor-trailer was traveling 65 mph in a work zone with a posted speed limit of 45 mph, and the traffic in the queue had slowed to less than 10 mph. The NTSB identified reducing vehicle speeds in work zones as a safety issue in this accident (NTSB 2015).

On May 1, 2003, a Mercedes Benz CLK320 crossed a raised highway median in Linden, New Jersey, and struck a Ford Taurus head-on, resulting in six fatalities. The NTSB identified speed enforcement as a safety issue and issued a recommendation to the city of Linden to develop a speed enforcement plan for the road segment on which the accident occurred (NTSB 2006).[7]

On February 14, 2003, in Hewitt, Texas, the driver of a motorcoach was unable to maintain control of the vehicle while traveling on Interstate 35 in overcast weather with reduced visibility and heavy rain. The motorcoach crossed the interstate highway median and collided with a Chevrolet Suburban, resulting in seven fatalities. Among the safety issues identified in the NTSB investigation were (1) sight distance and speed as they relate to roadway design, and (2) the need to better identify areas with a high risk of wet weather accidents and implement the necessary roadway improvements. The NTSB recommended that the FHWA issue guidance for the use of variable speed limits in wet weather at locations where the operating speed exceeds the design speed and the stopping distance exceeds the available sight distance. The NTSB also recommended

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[6] The motorcoach in this accident was equipped with a fixed speed limiter, but because it was set to 78 mph, it was ineffective at limiting the speed of the motorcoach to the posted speed limit at the accident location. NTSB Safety Recommendations H-12-20 (to develop performance standards) and H-12-21 (to require speed limiters) are currently classified "Open—Acceptable Response." These recommendations and all NTSB recommendations referenced in this report as well as relevant excerpts of associated correspondence are available via the NTSB safety recommendations database.

[7] NTSB Safety Recommendation H-06-14 is classified "Closed—Acceptable Action."

that the Texas Department of Transportation install variable speed limit signs at such locations (NTSB 2005a).[8]

These examples illustrate that the NTSB has a long history of investigating individual speeding-related accidents, particularly involving bus and truck drivers. This study extends that prior work by addressing the national safety issue of speeding among passenger vehicle drivers. As shown in section 2, these drivers are involved in the majority of speeding-related fatal crashes.[9]

[8] NTSB Safety Recommendation H-05-14 (for the FHWA to issue guidance) is classified "Closed—Acceptable Action" and Safety Recommendation H-05-20 (for the Texas Department of Transportation to install variable speed limit signs) is currently classified "Open—Acceptable Response."

[9] A *fatal crash* is a crash in which there was at least one fatality.

2 Speeding

This section provides definitions of speeding, describes the scope of speeding as a traffic safety issue, examines the risks of speeding, and describes the characteristics of speeding-related crashes that are relevant to effective speeding countermeasures. Public attitudes toward speeding and the roles federal, state, and local governments play in addressing speeding are also discussed.

2.1 Definitions

The traffic safety community, including NHTSA, considers drivers to be speeding if their vehicles are traveling at a speed that (1) exceeds the speed limit or (2) is too fast for conditions (NHTSA 2013).[10] The first definition (exceeds the speed limit) refers to legal speed limits—known as *statutory speed limits*—established by states for each road type.[11] These limits generally apply to all roads of a given type even if no physical speed limit signage is present, but they can be superseded by speed limits posted for specific road segments. The second definition (too fast for conditions) is based on the *basic speed law*.[12] All states have a variation of this law, which typically requires drivers to operate at a speed that is reasonable and prudent, taking into account weather, road conditions, traffic, visibility, and other environmental conditions (Goodwin and others 2015).

[10] The third category is racing (Goodwin and others 2015). *Racing* (on a roadway) is defined as "driving any vehicle in any race, speed competition or contest, drag race or acceleration contest, test of physical endurance, exhibition of speed or acceleration, or for the purpose of making a speed record" (NHTSA 2013).

[11] (a) Some states may set statutory speed limits for cars and trucks differently. (b) Examples of road types include rural interstates, urban freeways, urban collectors, and local residential streets. These road types are also referred to as road (or highway) function classes. Appendix B provides descriptions of the FHWA road function classifications.

[12] *Basic speed law* is also known as the basic speed rule. "This rule requires vehicle operators to drive at a speed that is reasonable and prudent. As a corollary to this rule, State laws usually provide that every person shall drive at a safe and appropriate speed when approaching and crossing an intersection or railroad grade crossing, when approaching and going around a curve, when approaching a hill crest, when traveling upon any narrow or winding roadway, and when special hazards exist with respect to pedestrians or other traffic, or by reason of weather or highway conditions" (NHTSA 2013).

2.2 Scope of the Problem

From 2005 through 2014, FARS data show that speeding-related crashes accounted for 112,580 fatalities (see table 1). Although the annual numbers of total traffic fatalities and speeding-related fatalities both decreased during this period, speeding-related fatalities have consistently accounted for about 31% of all traffic fatalities (NCSA 2016a; NCSA 2017). During the same period, there were 112,948 traffic fatalities involving alcohol-impaired driving, which represents 31% of all traffic fatalities (NCSA 2015; NCSA 2016b).[13] Thus, speeding-related fatalities represent a large portion of the total traffic fatalities in the United States; this portion is comparable to that attributed to alcohol-impaired driving.

Table 1. Total and speeding-related traffic fatalities, 2005-2014

Year	Total Fatalities	Speeding-Related Fatalities	% Speeding Related
2005	43,510	13,583	31.2
2006	42,708	13,609	31.9
2007	41,259	13,140	31.8
2008	37,423	11,767	31.4
2009	33,808	10,664	31.5
2010	32,999	10,508	31.8
2011	32,479	10,001	30.8
2012	33,782	10,329	30.6
2013	32,894	9,696	29.5
2014	32,744	9,283	28.4
Total	**363,606**	**112,580**	**31.0**

Sources: NCSA 2016a; NCSA 2017

[13] (a) The crash categories of "speeding-related" and "alcohol-impaired driving" are not mutually exclusive. From 2005 through 2014, FARS data show that 49,023 traffic fatalities involved both speeding and alcohol-impaired driving. The overlap of these two categories is addressed in section 2.4.2. (b) The analyses presented in this study used NHTSA data, in which drivers are considered to be alcohol-impaired when their blood alcohol concentrations (BACs) are 0.08 gram per deciliter or higher.

2.2.1 Fatalities and Injuries

Of the 9,283 speeding-related fatalities in 2014, 5,933 (64%) were the drivers of the speeding vehicles; 1,835 (20%) were passengers in the speeding vehicles; 1,136 (12%) were occupants in other vehicles; 314 (3%) were pedestrians; and 46 (0.5%) were bicyclists, as shown in table 2. This table also includes NASS GES data indicating that an estimated 336,742 people sustained nonfatal injuries due to speeding in 2014. More than 40% of the people injured were occupants of non-speeding vehicles, pedestrians, or bicyclists. Therefore, speeding poses a significant risk of death and injury to not only the drivers and passengers of speeding vehicles but also other road users.

Table 2. Estimated injuries in speeding-related crashes, by person type and injury severity, 2014

Person Type	Fatal[a]		Serious[b]		Possible/Minor[b]		Total Nonfatal Injuries	
	Number	%	Number	%	Number	%	Number	%
Drivers in speeding vehicles	5,933	63.9	18,745	62.3	128,466	41.9	147,211	43.7
Passengers in speeding vehicles	1,835	19.8	5,499	18.3	43,310	14.1	48,809	14.5
Occupants in other vehicles	1,136	12.2	5,171	17.2	132,408	43.2	137,579	40.9
Pedestrians	314	3.4	510	1.7	1,285	0.4	1,795	0.5
Bicyclists	46	0.5	134	0.4	555	0.2	689	0.2
Other/Unknown[c]	19	0.2	24	0.1	633	0.2	657	0.2
Total	**9,283**	**100.0**	**30,084**	**100.0**	**306,658**	**100.0**	**336,742**	**100.0**

[a] Source: FARS
[b] Source: GES
[c] The fatal injuries category includes other non-occupants. The serious and possible/minor injuries categories include occupants of a motor vehicle not in transport, persons on personal conveyances, and persons in or on buildings.

2.2.2 Vehicle Types

In 2014, 8,393 speeding vehicles were involved in fatal crashes. Figure 1 shows the distribution of these vehicles by type. Of these speeding vehicles, 6,422 (77%) were passenger vehicles, which were involved in 6,369 fatal crashes, resulting in 7,273 fatalities. These fatalities represented 78% of all speeding-related fatalities in 2014. According to the FHWA, there were about 240 million registered passenger vehicles and 8 million motorcycles in 2014, which respectively represented 92% and 3% of the total number of registered vehicles. Buses and trucks represented 0.3% and 4% of the total, respectively. Figure 1 also shows that 1,548 speeding motorcycles (18% of all speeding vehicles) were involved in fatal crashes in 2014. This safety study focused on passenger vehicles, which constitute the majority of vehicles involved in speeding-related fatal crashes. Some of the countermeasures examined in this study are applicable to both passenger vehicles and other types of motor vehicles, including motorcycles.

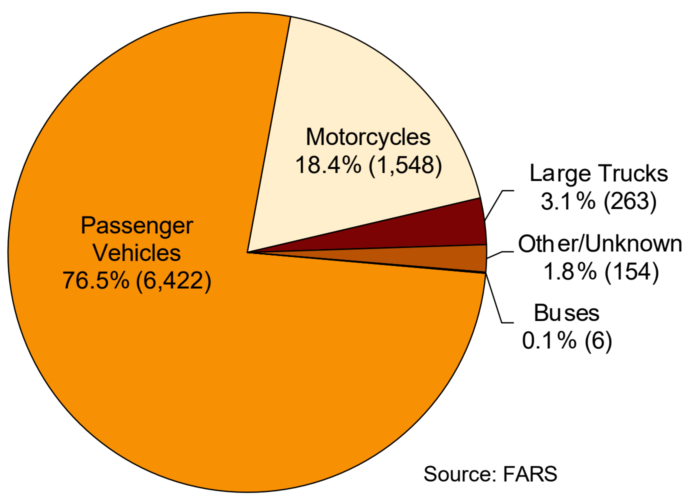

Figure 1. Speeding vehicles involved in speeding-related fatal crashes, by type, 2014

2.3 Risks

Risk is quantified as the product of the likelihood of exposure to an adverse event and the consequence of such exposure. Countermeasures to improve traffic safety are used to reduce the likelihood of exposure (that is, crash involvement rates) and to mitigate the consequence (that is, injury severity).

2.3.1 Injury Severity

The severity of a crash, as typically measured in injury severity, is linked to the velocity change in a crash.[14] As the speed prior to a crash increases, the velocity change in a crash also increases (TRB 1998). Therefore, higher vehicle speeds lead to larger changes in velocity, which, in turn, lead to higher injury severity in a crash. This relationship can be seen in figure 2, which uses 2014 NASS GES data to show the estimated percentage of passenger vehicle occupants involved in non-pedestrian single vehicle crashes who died or sustained serious injuries, as a function of reported vehicle speed.[15] The slopes of the two curves shown in figure 2 indicate that occupants were more likely to experience serious injury at higher vehicle speeds when they were reported as speeding.

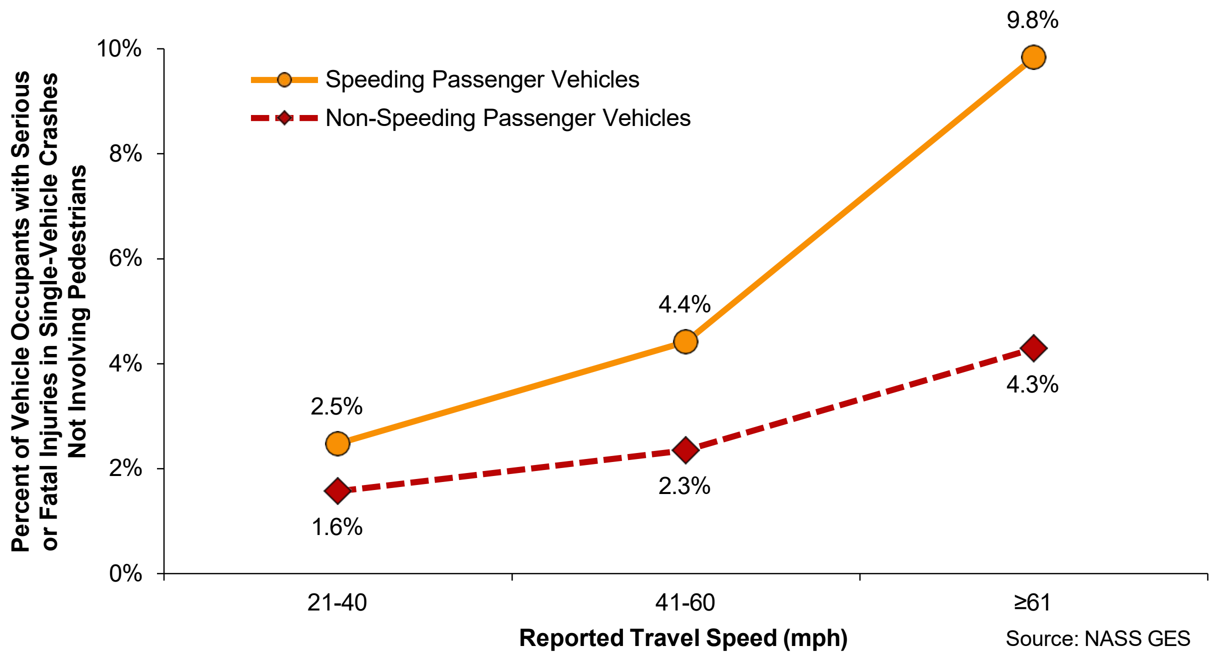

Figure 2. Percent of passenger vehicle occupants sustaining serious or fatal injuries in speeding-related and all crashes, by reported travel speed, 2014

[14] Velocity change in a crash is also known as Delta V.

[15] *Vehicle speed* in the NASS GES refers to the vehicle traveling speed prior to the crash as reported by the investigating officer. Therefore, it is reported, not measured, speed prior to the crash. This serves as the best estimate available of potential velocity change in a crash.

Other studies have also confirmed that as speed increases, so does injury severity. A study of sample crashes between 1980 and 1986 using NASS data (limited to passenger cars of model years 1980 and later) showed a statistically significant relationship between the fatality risk of drivers and velocity change in a crash. This relationship showed that as the velocity change in a crash increases, the fatality risk increases, and the rate at which the risk increases also increases (Joksch 1993). More recently, using crash data between 1983 and 2010, a United Kingdom study examined the fatality risk of belted drivers in non-rollover, frontal- and side-impact crashes. The study established that the estimated fatality risk in a frontal impact crash was 3%, 17%, and 60% at 30 mph, 40 mph, and 50 mph velocity change in a crash, respectively. For side-impact crashes, the estimated fatality risk was 25% and 85% at 30 mph and 40 mph velocity change, respectively (Richards 2010).

Further, the link between injury severity and speed extends to pedestrians involved in a motor vehicle crash. According to the European Transport Safety Council, 5% of pedestrians struck by a vehicle at 20 mph are fatally injured. This likelihood increases to 45% at 30 mph, and 85% at 40 mph (ETSC 1995). The AAA Foundation for Traffic Safety similarly found that the average risk of severe injury to a pedestrian increased from 10% at 16 mph, to 25% at 23 mph, 50% at 31 mph, 75% at 39 mph, and 90% at 46 mph (Tefft 2011).

2.3.2 Crash Involvement

Unlike the straightforward relationship between speed and injury severity, the association between speed and crash involvement is more complex, often leading to conflicting results. However, research has generally shown that the crash involvement rate increases with speed (Baruya and Finch 1994; Fildes, Rumbold, and Leening 1991; Kloeden, McLean, and Glonek 2002; Taylor, Lynam, and Baruya 2000). A comprehensive analysis of 98 studies confirmed the statistical relationship between speed and crash involvement; the speed-crash relationship was consistent among crashes of all injury severity levels (Elvik, Christensen, and Amundsen 2004). A driver-based study that combined on-road observation and questionnaire surveys of over 10,000 drivers in the United Kingdom in the 1990s showed that "drivers who habitually travel faster than average are involved in more accidents in a year's driving" (Taylor, Lynam, and Baruya 2000).

The relationship that the crash involvement rate increases with speed can be explained by the fact that increased speed reduces the available time for the driver to receive and process information (AASHTO 2011). Further, the stopping distance of a vehicle and the chance of a vehicle being driven off the road while negotiating a curve both increase with vehicle speed (Srinivasan and others 2006).

Some older research has illustrated that the crash involvement rate decreases with speed (Baruya 1998; Garber and Gadirau 1988), whereas other research has not demonstrated a statistically significant relationship between speed and crash involvement (Kockelman and Ma 2007; Quddus 2013). There are many reasons for these contradicting results. The relationship between speed and crash involvement can be affected by traffic flow and roadway geometry, such as curvature, grade, and width (Milton and Mannering 1998; Abdel-Aty and Radwan 2000; Chang 2005; Anastasopoulos and Mannering 2009). Other factors may include geography, road type, land use, driver age, and alcohol-impairment. Further, different research methodologies may contribute to the inconsistency of the relationship found between speed and crash involvement. For example, one study found that the crash involvement rate decreases with speed using distance-based measures (for example, crashes per vehicle mile), but it also found that the crash involvement rate increases with speed using time-based measures (for example, crashes per vehicle hour) (Pei, Wong, and Sze 2012).

More recently, based on an analysis of the naturalistic driving data of 3,500 participants, researchers showed that the odds ratio of speeding was 12.8, meaning speeding increased the odds of crash involvement by a factor of almost 13 relative to control situations (Dingus and others 2016).

Another factor that contributes to the complexity of the relationship between speed and crash involvement is speed variance.[16] Two studies from the 1960s showed that vehicles traveling at much lower and higher speeds than average contributed to increased rates of crash involvement (Solomon 1964; Cirillo 1968). In the 1980s, another study showed that it was speed variance, not speed, that contributed to fatalities (Lave 1985). However, there were several limitations in these studies. The speed data and crash data were not collected during the same time period; crashes involving turning vehicles were included in the crash analysis; and speed prior to the crash was self-reported by the driver (TRB 1998). Research has also shown that "when turning vehicles were removed from the analysis only those driving at speeds significantly above the traffic speed remained over-involved in crashes" (Fildes and Lee 1993). Another often cited study was conducted in Virginia in the 1980s and demonstrated that the crash involvement rate increased with speed variance on all road types (Garber and Gadirau 1988). However, this study and later research pointed out that speed variance increases as the difference between roadway design speeds and speed limits increases (Garber and Gadirau 1989; Stuster, Coffman, and Warren 1998).[17] These studies generally provided consistent evidence that driving faster than the surrounding traffic increased crash involvement rates; the evidence was less conclusive with respect to driving slower than the surrounding traffic (Aarts and van Schagen 2006).

There are numerous interrelated factors that complicate the relationship between speed and crash involvement. Although speed variance within a traffic flow exists and is often cited as a concern, the degree to which speed variance contributes to crash involvement is inconclusive. However, the link between speed and injury severity in a crash is consistent and direct.

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[16] *Speed variance* refers to the variability of individual vehicle speeds within the overall traffic flow. Similar terms include speed dispersion and speed variation.

[17] See section 3.1.1 for further discussion of design speeds and speed limits.

2.4 Characteristics of Speeding-Related Crashes

In this section, the NTSB focuses on fatal crashes in 2014 to highlight some characteristics of speeding-related crashes, including how they vary by road type, land use, alcohol-impairment, and driver age. The purpose of these analyses is not to describe in detail all factors associated with speeding, but to address some common misconceptions and illustrate the complexity of the relationship between speed and crash involvement.[18]

2.4.1 Road Types and Land Use

Different road types serve different functions and they have different characteristics, such as traffic volume, access, geometry, and speed limits.[19] Table 3 illustrates that the percentage of fatal crashes that involved a speeding passenger vehicle in 2014 varied among the different road and land use types. One misconception about speeding-related crashes is that they primarily occur on high-speed roads such as interstate highways. However, local roads had the highest percentage (30%) of fatal crashes involving speeding passenger vehicles. Collector roads had the second-highest percentage (29%). Twenty-six percent of fatal crashes that occurred on freeways involved a speeding passenger vehicle. Table 3 also shows that a higher percentage of fatal crashes involved speeding passenger vehicles on rural roads (27%) than on urban roads (22%) in 2014. Local roads experienced the largest difference by land use; 35% of fatal crashes on rural local roads involved speeding passenger vehicles, whereas 25% of fatal crashes on urban local roads involved speeding passenger vehicles.

Table 3. Number and percent of fatal crashes involving speeding passenger vehicles, by road type and land use, 2014

Road Type	Rural		Urban		All	
	Number	%	Number	%	Number	%
Interstate and Freeway	316	24.9	711	26.6	1,027	26.1
Other Principal Arterial	598	18.9	699	16.6	1,297	17.6
Minor Arterial	687	25.6	551	21.3	1,238	23.5
Collector	1,019	29.3	282	28.2	1,301	29.0
Local	808	35.2	626	25.4	1,434	30.1
Total	**3,469**	**26.7**	**2,892**	**22.2**	**6,369**	**24.4**

Source: FARS

[18] For more detailed discussions of crash characteristics related to speeding, see the FHWA reports *Development of a Speeding-Related Crash Typology* (Council and others 2010) and *Integrating Speed Management within Roadway Departure, Intersections, and Pedestrian and Bicyclist Safety Focus Areas* (Neuner and others 2016).

[19] Appendix B provides descriptions of the FHWA road function classifications (road types). NHTSA also uses this classification system to tally fatality statistics.

Further, of the 6,369 fatal crashes involving speeding passenger vehicles, 3,469 occurred on rural roads (55%). According to the FHWA, 920 million vehicle miles traveled (VMT) occurred on rural roads, which represented 30% of the total VMT in 2014 in the United States. Among all of the rural road types, 18% of fatal crashes involving speeding passenger vehicles occurred on local roads while such roads comprised only 14% of all rural VMT. Similarly, in urban areas, it was local roads that had the largest over-involvement of speeding passenger vehicles (22% of fatal crashes involving passenger vehicles versus 15% of all urban VMT). These observations indicate that the risk attributed to speeding among passenger vehicles varies among road types and land uses.

Figure 3 shows the distribution of fatal crashes involving speeding passenger vehicles by land use and reported speed limit.[20] On rural roads, most of these crashes occurred on roads with reported speed limits of 55 to 60 mph, whereas in urban areas most occurred on roads with reported speed limits of 35 to 40 mph. Eighty-two percent of all fatal crashes involving speeding passenger vehicles on rural roads (2,796 of 3,418) occurred at locations with reported speed limits of 45 mph and above. In contrast, these reported speed limits accounted for 40% of all urban fatal crashes involving speeding passenger vehicles, a total of 1,383 such crashes. Therefore, speeding as a contributing factor represented different percentages of fatal crashes involving passenger vehicles on roads that serve different functions, with different speed limits, and in different land use areas.

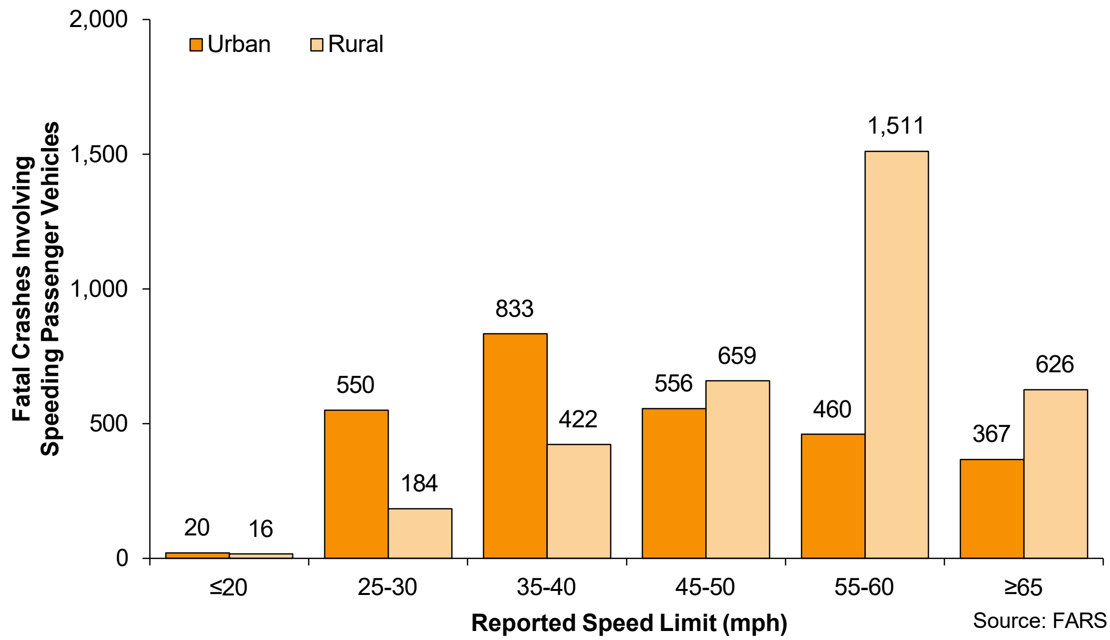


Figure 3. Fatal crashes involving speeding passenger vehicles, by reported speed limit and land use, 2014

[20] Speed limit is reported in FARS data at the vehicle level. This variable represents the speed limit of the road on which the vehicle was traveling before the crash.

2.4.2 Alcohol-Impaired Driving

Another misconception about speeding is that it is a problem that can be largely solved by focusing on alcohol impairment. The NTSB examined alcohol-impairment information for 6,409 speeding passenger vehicle drivers involved in fatal crashes in 2014 and found that 2,739 (43%) were alcohol-impaired.[21] The remaining 3,670 speeding passenger vehicle drivers (57%) were not alcohol-impaired. For comparison, among all passenger vehicle drivers involved in fatal crashes, 22% were alcohol-impaired. Thus, although there is considerable overlap between alcohol impairment and speeding, more speeding drivers in fatal crashes are not alcohol-impaired than impaired. Figure 4 illustrates the distribution of fatalities in crashes involving passenger vehicles by speeding and alcohol-impairment categories. In 2014, 28,615 fatalities involved passenger vehicles. Of these, 3,958 fatalities (14%) were attributed to crashes in which speeding was identified as a factor while alcohol impairment was not. Fatalities involving speeding passenger vehicles represent a pervasive and complex safety issue that cannot be mitigated by reducing alcohol-impaired driving alone.

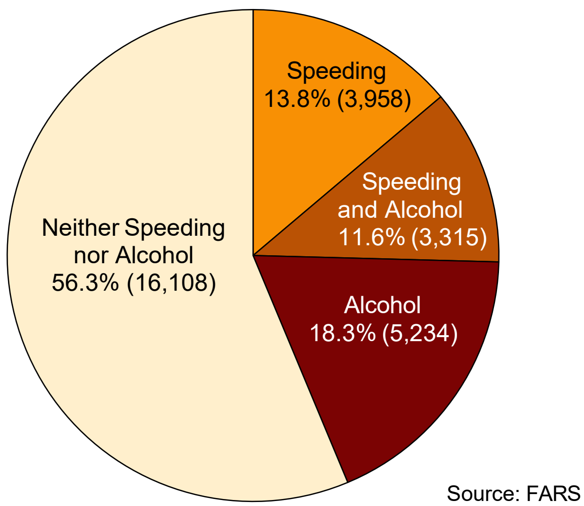


Figure 4. Fatalities involving passenger vehicles, by crash factors, 2014

[21] Because a large number of drivers do not have their BAC level reported in FARS, NHTSA uses a statistical algorithm known as *multiple imputation* to estimate the BAC level. Ten BAC estimates are produced for each driver. The NTSB performed the same analysis 10 times using each set of imputed BAC estimates. The counts and percentages reported here are the average values of the 10 analyses. In addition, of the 6,422 speeding passenger vehicle drivers involved in fatal crashes in 2014, 13 drivers had no person-level information (such as imputed BAC), so the results presented here are based on 6,409 drivers.

2.4.3 Driver Age

Driver age is also an important factor in speeding-related crashes. Figure 5 illustrates the age distribution of speeding passenger vehicle drivers in fatal crashes, passenger vehicle drivers in fatal crashes, and driver license counts. The three age groups with the most speeding passenger vehicle drivers in fatal crashes are under 20, 20- to 24-year-olds, and 25- to 29-year-olds. Just these three groups include 3,167 drivers, representing 50% of all speeding passenger vehicle drivers in fatal crashes. For comparison, these three age groups comprised 33% of crash involvement in all fatal crashes and 21% of licensed drivers. These observations indicate that the risk of speeding is higher among younger drivers.

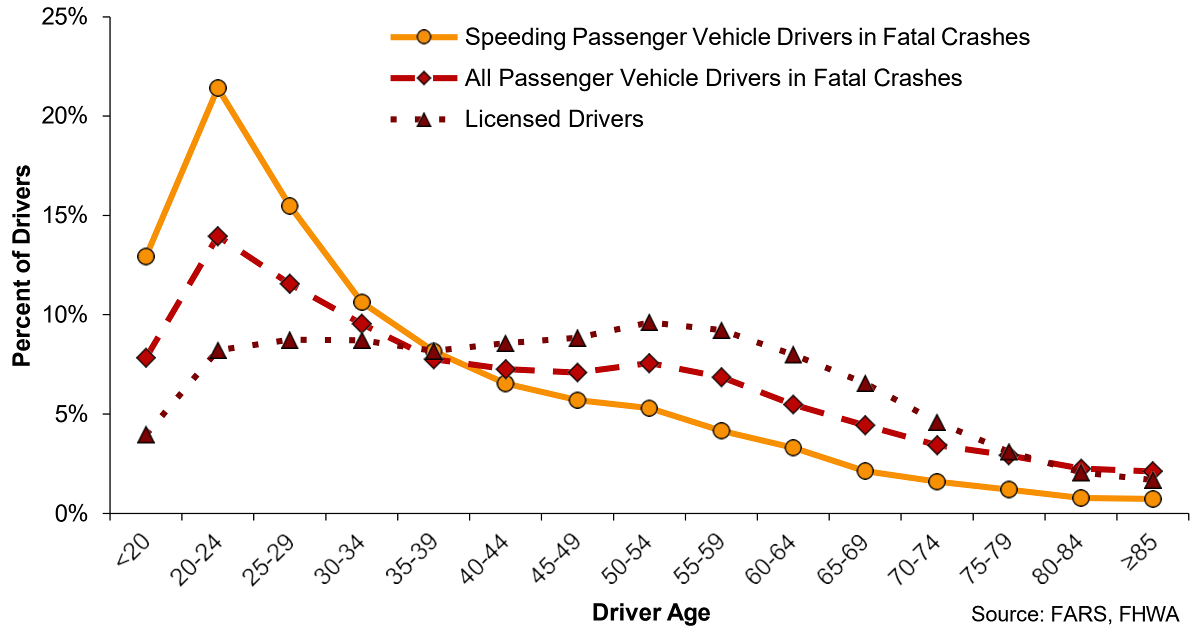


Figure 5. Age distribution of speeding passenger vehicle drivers in fatal crashes, all passenger vehicle drivers in fatal crashes, and licensed drivers, 2014

Although factors such as speed variance, road type, land use, alcohol impairment, and driver age affect the specific relationship between speed and crash involvement, there is strong evidence indicating that fatal and serious injury crash involvement rates increase with speed. Therefore, the NTSB concludes that speed increases the likelihood of serious and fatal crash involvement, although the exact relationship is complex due to many factors. In comparison, existing research literature and crash data illustrate a more straightforward and direct relationship between speed and crash severity. Therefore, the NTSB further concludes that speed increases the injury severity of a crash.

2.5 Attitudes Toward Speeding

The NTSB reviewed two large-scale, periodic surveys of individual attitudes toward speeding in the United States. In both surveys, participants consisted of a nationally representative sample of drivers. The first survey, the *National Survey of Speeding Attitudes and Behavior*, was most recently conducted by NHTSA in 2011.[22] This self-reporting survey examines several aspects of speeding, including drivers' attitudes about speeding and various speeding countermeasures (Schroeder, Kostyniuk, and Mack 2013). The survey results reveal a general contradiction among US drivers between what is considered acceptable in society and individual behavior. For example, most drivers (91%) agreed (either strongly or somewhat) that everyone should obey the speed limits because it is the law, and 87% agreed that it is unacceptable to exceed speed limits by more than 20 mph. Yet, 27% of respondents agreed that speeding is something they do without thinking, and 42% agreed that driving at or near the speed limit makes it difficult to keep up with traffic.

The second survey, the *Traffic Safety Culture Index*, has been conducted annually since 2008 by the AAA Foundation for Traffic Safety. The NTSB examined the results for the most recent survey, conducted in 2015 (AAA Foundation for Traffic Safety 2016).[23] Figure 6 illustrates that 70% and 80% of respondents stated their opinion that drivers speeding on freeways and residential streets, respectively, are a very serious or somewhat serious threat to their personal safety.

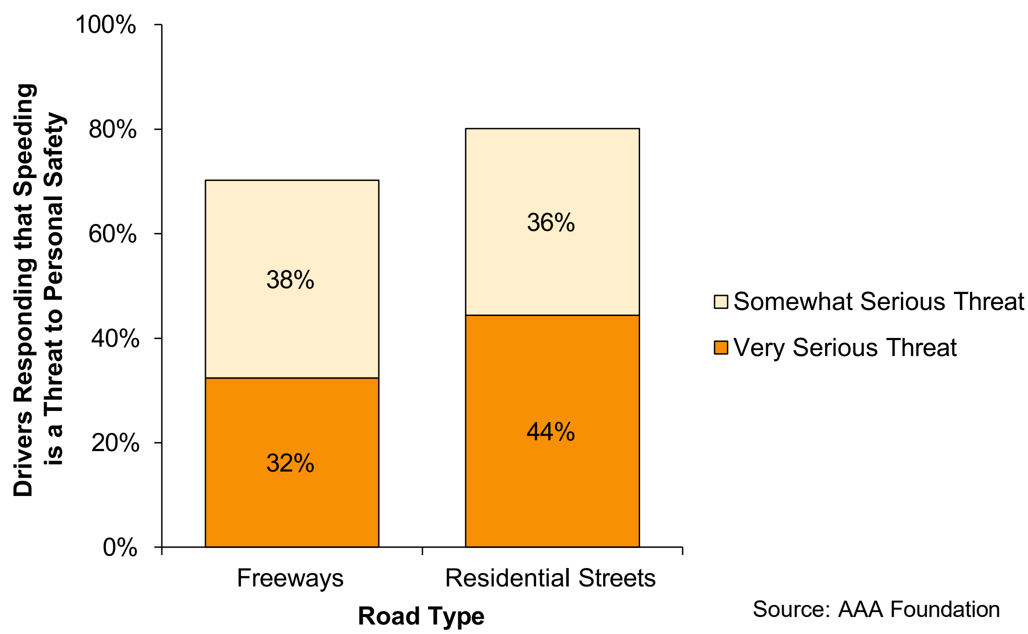


Figure 6. Drivers responding that speeding is a threat to personal safety, by road type, 2015

[22] This survey was previously conducted in 2002 and 1997.

[23] The surveys for 2011 through 2014 were also examined; the speeding-related responses showed little year-to-year variation.

However, the perceived risks and acceptance of speeding were not reflected in the drivers' own behaviors. For example, 89% of respondents considered it unacceptable to drive 10 mph over the speed limit on a residential street, yet 45% reported having done so in the past 30 days. Similarly, 74% of respondents considered it unacceptable to drive 15 mph over the speed limit on freeways, yet 48% admitted to having done so in the past 30 days. Therefore, the NTSB concludes that drivers report understanding that speeding is a threat to safety but acknowledge it is a common driving behavior in the United States.

2.6 Countermeasures

Strategies for improving traffic safety in general, and addressing speeding in particular, have traditionally been grouped into three categories: engineering, enforcement, and education (Donnell and others 2009).[24] Engineering refers to roadway infrastructure changes. Enforcement refers to strategies to ensure drivers obey existing laws. Education refers to efforts to inform drivers and other stakeholders about traffic safety laws and the consequences of risky behavior. Table 4 lists examples of speeding countermeasures in these three categories. Some emerging speeding countermeasures researched for this study expand these three categories beyond their current definitions. For example, vehicle technologies are becoming available to prevent drivers from speeding, which may be considered an engineering countermeasure.

Table 4. Examples of speeding countermeasures

Countermeasure Type	Examples
Engineering	Variable speed limits Speed feedback signs Roundabouts Speed humps Road diets[a]
Enforcement	Regular traffic patrols High-visibility enforcement Automated enforcement
Education	Driver education courses Public awareness campaigns Judicial education

[a] Road diets "reallocate travel lanes and utilize the space for other uses and travel modes," for example, by converting a four-lane roadway to one with two through lanes and a center left-turn lane (FHWA 2016).

A comprehensive approach to speeding typically involves multiple countermeasures. For example, NHTSA states that "no single strategy will be appropriate for all locations, and combinations of treatments may be needed to obtain speed limit compliance and achieve crash reduction goals" (Goodwin and others 2015).

[24] Some organizations add other categories, such as emergency medical services, evaluation, and encouragement (Cambridge Systematics 2010; State of Vermont 2016).

2.7 National, State, and Local Roles

National, state, and local organizations all play roles in addressing speeding-related crashes. Speeding countermeasures are typically implemented at the state and local level, while federal government agencies conduct research, issue guidance material, set standards, and coordinate activities among states. Three DOT agencies play critical roles in addressing speeding-related issues: the FHWA, NHTSA, and the FMCSA.[25] The FHWA's responsibilities include engineering and roadway infrastructure topics, NHTSA's responsibilities include driver behavior research and vehicle safety, and the FMCSA's responsibilities include large truck and bus operations.[26]

To coordinate speeding-related work across these agencies, the DOT established a Speed Management Team in 2000, composed of representatives from the FHWA, NHTSA, and the FMCSA. The Speed Management Team works to "reduce speeding-related fatalities, injuries, and crashes through the application and promotion of enforcement, engineering, educational, and evaluative approaches in a collaborative manner among member agencies in support of the US DOT goal of reducing the number of traffic fatalities" (DOT 2011).

Congress establishes and provides funding for traffic safety programs through legislation. Most recently, the Fixing America's Surface Transportation (FAST) Act (Public Law 114-94), was signed into law in December 2015. This law superseded the Moving Ahead for Progress in the 21st Century Act (MAP-21) (Public Law 112-141), which was signed into law in July 2012. DOT agencies are responsible for implementing these traffic safety programs, including the following federal-aid programs designed to encourage traffic safety activities at the state and local levels:

- **Highway Safety Improvement Program**: The FHWA administers this program in conjunction with state departments of transportation; it provides grants to states for engineering countermeasures (Title 23 *United States Code* (*USC*) section 148).
- **Highway Safety Program**: NHTSA administers this program in conjunction with state highway safety offices; it provides grants to states for behavioral (that is, non-engineering) countermeasures in 10 areas, including projects "to reduce injuries and deaths resulting from motor vehicles being driven in excess of posted speed limits" (23 *USC* section 402).
- **National Priority Safety Programs**: NHTSA also administers this program in conjunction with state highway safety offices; it provides incentive grants to states for non-engineering projects in seven priority areas, each of which is specified in legislation along with a funding amount (23 *USC* section 405).[27] Speeding is not one of the seven priority areas.

Funds distributed under these federal-aid programs are then awarded by the state departments of transportation and highway safety offices to individual state and local projects

[25] The Research and Innovative Technology Administration (RITA) also provides research support to these and other DOT agencies.

[26] Because the FMCSA does not focus on passenger vehicles, its speeding-related activities were not examined in detail for this study.

[27] The seven priority areas are impaired driving, occupant protection, state traffic safety information system improvement, motorcycle safety, distracted driving, graduated driver licensing, and nonmotorized safety.

through selection committees and competitive application processes. Table 5 summarizes the federal-aid traffic safety programs.

Table 5. Federal-aid programs for traffic safety

Program	Type of Projects Funded	Responsible Federal Agency	Responsible State Agency	Funds Speeding-Related Projects?
Highway Safety Improvement Program	Engineering-based countermeasures	FHWA	Department of Transportation	Yes
Highway Safety Program	Non-engineering countermeasures	NHTSA	Highway Safety Office	Yes
National Priority Safety Programs	Non-engineering countermeasures in seven priority areas	NHTSA	Highway Safety Office	No

In addition, several non-governmental organizations play significant roles in setting standards and providing guidance. For example, the Governors Highway Safety Association (GHSA), which represents state highway safety offices, works with NHTSA to produce standards for states to report crash data (GHSA and NHTSA 2012). The American Association of State Highway and Transportation Officials (AASHTO), which represents state departments of transportation, produces standards for roadway design, and provides guidance for predicting crash frequency and the effects of engineering countermeasures on roadway segments (AASHTO 2011; AASHTO 2010). The Institute of Transportation Engineers (ITE), which is an international association of transportation professionals, publishes guidance on traffic engineering studies (ITE 2016).

3 Safety Issues

The NTSB focused on the following five safety issues pertaining to the effective application of proven and emerging countermeasures for speeding: (1) speed limits, (2) data-driven approaches for speed enforcement, (3) ASE, (4) intelligent speed adaptation, and (5) national leadership. The NTSB identified these issues in part because stakeholders repeatedly and consistently expressed concerns about them during study interviews.[28]

3.1 Speed Limits

NHTSA states that speed limits are an effective way to control driving speeds (Goodwin and others 2015). Speed limits represent the driving speeds above which the risk is deemed by transportation officials as unacceptable, and the act of driving above those speeds is discouraged. Such limits form the legal basis upon which speed enforcement activities are implemented. Despite being recognized as an effective method to control driving speeds, there is no standard approach to setting or adjusting speed limits in the United States. In practice, the operating speed of free-flowing traffic is the most prominent factor used. Other factors, such as crash experience and the risk of injury to vulnerable road users, are not given similar emphasis as operating speed.

3.1.1 Background

This section provides a general discussion of the relationship among design speed, operating speed, and speed limits. The publication *Speed Concepts: Informational Guide* provides explanations of many terms and concepts used in this study (Donnell and others 2009).

Speed is an important consideration in the design phase of a road. Design speed refers to a selected speed for a road upon which all geometric design features are based, and it is selected according to anticipated traffic characteristics, such as operating speed and traffic volume, along with topography, adjacent land use, and road type (AASHTO 2011).[29] Because many of these factors are based on anticipated use, a design speed does not always match the actual operating speed of a road. Table 6 shows the ranges of minimum design speeds for level roads by road type according to the AASHTO publication *A Policy on Geometric Design for Highways and Streets* and examples of posted speed limits provided by the FHWA (AASHTO 2011; FHWA 2000). These minimum design speeds range from 20 mph for local urban streets to 75 mph for rural

[28] The NTSB examined other countermeasures, but stakeholder concerns about their implementation were not as substantial. For example, there are many engineering countermeasures for speeding, including roundabouts, speed bumps, and road diets. However, the effectiveness of these countermeasures is well established and information about them is available in several sources, including the AASHTO *Highway Safety Manual* (AASHTO 2010) and the FHWA's online Crash Modification Factors Clearinghouse. Engineering countermeasures for speeding are also promoted in the National Association of City Transportation Planners' *Urban Street Design Guide* (NACTO 2017) and are increasingly being adopted by state and local transportation departments. For instance, about $96 million in Highway Safety Improvement Project funds were used for 70 projects to convert intersections to roundabouts in 2014; this increased to $103 million for 91 projects in 2015 (Smith 2015; Smith and Signor 2016).

[29] Title 23 *CFR* Part 625 provides design standards for highways. Design speed is 1 of 10 "controlling criteria" for which state transportation departments are required to evaluate and document any decision to deviate from the standard. The FHWA's May 5, 2016, memorandum, Revisions to the Controlling Criteria for Design and Documentation for Design Exceptions, provides a detailed listing of these criteria.

arterial roads. These are called minimum design speeds because AASHTO encourages road designers to select design speeds equal to or greater than the design speed values (AASHTO 2011). Once the design speed is selected for a new road, various design criteria (such as minimum sight distances, maximum grade, and minimum horizontal curve radii) for geometric features of a roadway are determined. AASHTO recommends using above-minimum criteria when practical (AASHTO 2011; Donnell and others 2009). Thus, a road designer often selects a design speed above the minimum design speed associated with the road type, its function, and predicted traffic volume, and then uses design criteria above the minimum criteria associated with the selected design speed. Therefore, some roads are built to accommodate traffic flows and speeds above what was originally anticipated.

Table 6. AASHTO's recommended minimum design speeds and typical posted speed limits, by road type

Road Type	Minimum Design Speeds (mph)[a]	Typical Posted Speed Limits (mph)[b]
Freeway[c]	50–70	55–75
Rural arterial	40–75	50–70
Urban arterial	30–60	50–70
Rural collector	40–60	35–55
Urban collector	30	35–55
Local rural road	30–50	20–45
Local urban street	20–30	20–45

[a] Minimum design speeds are dependent upon design volume. High design speed values are typically associated with anticipated volume greater than 2,000 vehicles per day; other factors may include available right of way, terrain, likely pedestrian presence, adjacent development, and other area control (AASHTO 2011). In this table, only those values for level roads are used.
[b] Source: FHWA 2000
[c] Freeways include interstate highways and expressways.

Once a road is built, speed limits are established by state or local authorities. For example, a state may have a statutory speed limit of 65 mph for all rural freeways (such as interstates) and 55 mph for all rural undivided arterial roads. Ideally these statutory speed limits are lower than the design speeds established during the design phase. However, some road segments may have speed limits that are higher or lower than the statutory speed limits. These road segments are generally known as *speed zones*, and their speed limits, which can be higher or lower than the statutory speed limits, are commonly known as *posted speed limits*.[30]

Once a newly built road is open for traffic, over time a traffic flow develops with diverse vehicle types and drivers. Each driver is influenced by the geometric characteristics of a roadway (for example, curvature and width), roadside development, the surrounding traffic flow, topography, and the posted speed limit, and they individually choose operating speeds. Because each driver is different, driver operating speeds vary, which results in a speed distribution (that is, a range of operating speeds). The range of operating speeds may not match the anticipated

[30] The FHWA *Speed Concepts: Informational Guide* provides an in-depth discussion of these terms (Donnell and others 2009).

operating speeds. When a mismatch occurs, an adjustment of the posted speed limit may be appropriate.

3.1.2 Engineering Studies, Speed Surveys, and the 85th Percentile Speed

Stakeholders can request adjustments to speed limits. Requests can come from private citizens, from local or state transportation officials, or as a result of legislation. When such a request is made (that is, to set up a speed zone, whether it is above or below the statutory speed limit), state and local transportation departments typically require that an engineering study of the road segment be conducted to determine if raising or lowering the speed limit is appropriate. Although the specific procedures may vary, state and local transportation departments typically refer to the FHWA's *Manual on Uniform Traffic Control Devices* (*MUTCD*), which states that "speed zones shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall include an analysis of the current speed distribution of free-flowing vehicles" (FHWA 2012a).[31] The ITE publication *Manual of Transportation Studies* provides guidance on conducting an engineering study and the ITE *Traffic Engineering Handbook* outlines the professional practices of traffic engineering studies (ITE 2010; ITE 2016). Although there is guidance on conducting engineering studies, "a universal process for conducting these studies does not exist" (Donnell and other 2009). Still, FHWA guidance states that "when a speed limit within a speed zone is posted, it should be within 5 mph of the 85th percentile speed of free-flowing traffic" (FHWA 2012a). As a result, the predominant factor used in establishing posted speed limits remains the 85th percentile speed of free-flowing traffic (Donnell and others 2009; TRB 1998).

The 85th percentile speed refers to the speed at or below which 85% of vehicles are traveling (FHWA 2012a). This measurement is obtained by conducting a speed survey, which is part of an engineering study. Each state transportation department has its own procedure for conducting a speed survey.[32] However, it generally consists of measuring a sample of vehicles representative of the overall traffic along the road segment for which a proposed speed limit change is requested. The locations where speed measurements are made must represent free-flowing speeds (that is, avoiding intersections or narrowing road segments), and they must be appropriately spaced along the proposed segment. The 85th percentile speed is then computed by analyzing the speed measurements of the sample vehicles at these locations.

The use of the operating speed, more specifically the 85th percentile speed, is based on the assumption that the majority of drivers (1) are capable of selecting appropriate speeds according to weather conditions, traffic, road geometry, and roadside development; and (2) operate at reasonable and prudent speeds (Krammes and others 1996). The use of the 85th percentile speed for adjusting speed limits emerged as early as the 1940s (TRB 1998). Support for its use came from empirical research of self-reported crashes on 2- or 4-lane rural highways in the late 1950s. This research showed that drivers operating at much lower and much higher speeds than the majority of drivers were involved in a disproportionately high number of crashes (Solomon 1964). Focusing on higher speeds, the research therefore indicated that a small group of drivers traveling

[31] Appendix C provides the relevant sections of the *MUTCD*.

[32] For example, Chapter 3 of the *California Manual for Setting Speed Limits* provides a detailed description of what an engineering study and speed survey include (California Department of Transportation 2014).

at speeds much higher than average were responsible for more crashes. By definition, 15% of all drivers were traveling above the 85th percentile speed. This small fraction of drivers was considered to be operating at unsafe speeds that disproportionately contributed to crash risk. "The 85th percentile speed not only represents the upper bound of the preferred driving speed of most drivers, but, according to some studies, for some roads it also corresponds to the upper bound of a speed range where crash involvement rates are lowest" (TRB 1998). Over time, setting the speed limit near the 85th percentile speed has become common practice and is considered "the traffic engineers' traditional rule of thumb" (Shinar 2017). However, it is unclear whether this relationship between crash involvement rates and the 85th percentile speed applies to all road types (TRB 1998). Further, "the original research between speed and safety which purported that the safest travel speed is the 85th percentile speed is dated research and may not be valid under scrutiny" (Forbes, Gardner, McGee, and Srinivasan 2012). Therefore, the NTSB concludes that the *MUTCD* guidance for setting speed limits in speed zones is based on the 85th percentile speed, but there is not strong evidence that, within a given traffic flow, the 85th percentile speed equates to the speed with the lowest crash involvement rate on all road types.

3.1.3 Unintended Consequences of Using the 85th Percentile Speed

Using the 85th percentile speed to set speed limits on road segments may have unintended consequences. Raising the speed limit to match the 85th percentile speed may lead to higher operating speeds, and hence a higher 85th percentile speed. This generates an undesirable cycle of speed escalation and reduced safety (Donnell and others 2009). As a 2016 Insurance Institute for Highway Safety (IIHS) report stated, "The 85th percentile speed is not a stationary point. It is, rather, a moving target that increases when speed limits are raised" (Farmer 2016).

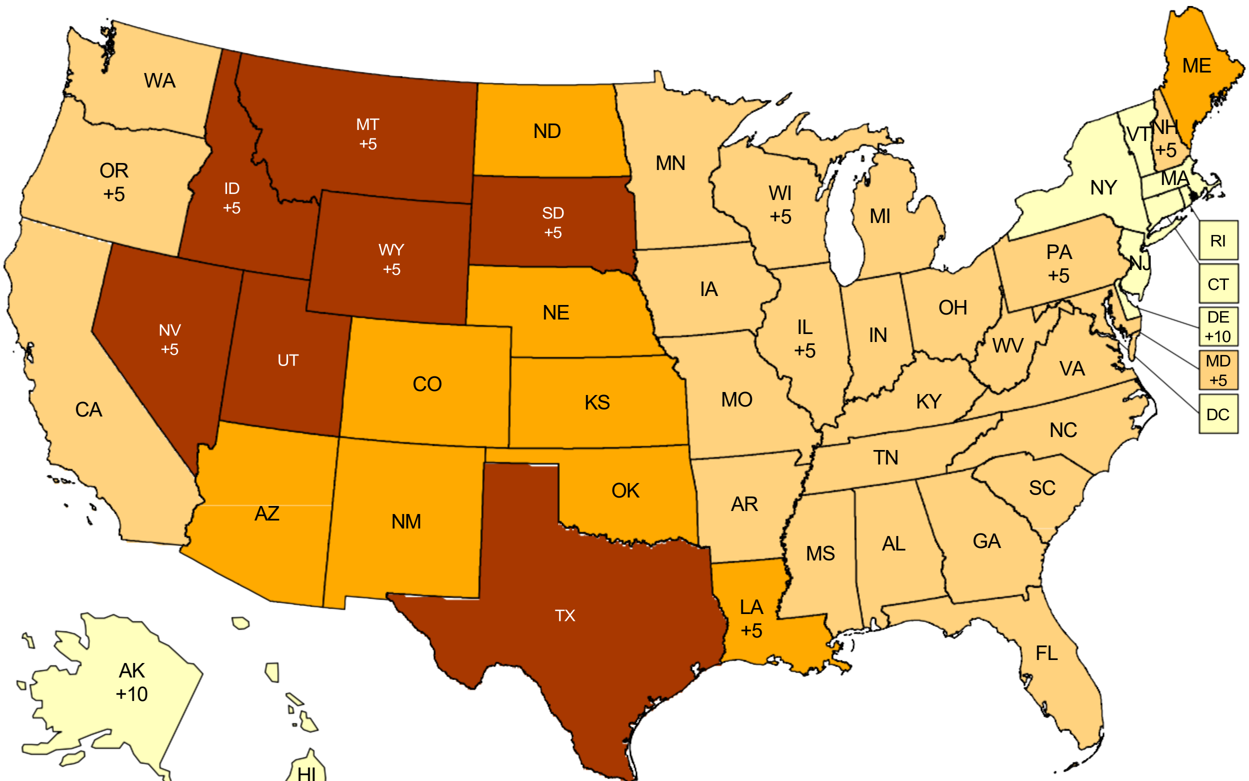
In recent years, several western US states have raised speed limits in segments of their rural interstate highways. For example, the Texas Transportation Code states that the speed limit is 70 mph for a highway numbered by Texas (for example, State Highway 130) or the United States (for example, Interstate 10) outside an urban area.[33] It also gives authority to the Texas Department of Transportation to increase or reduce the posted speed limit as long as it is supported by an engineering study.[34] The Texas Transportation Code requires that such engineering studies follow the "Procedures for Establishing Speed Zones," which emphasizes the use of the 85th percentile speed (Texas Department of Transportation 2015).[35] In 2011, Texas raised the posted speed limit from 70 to 75 mph on a 45-mile long segment of State Highway 130. One year later in 2012, the limit was increased to 80 mph on the same segment (Texas Department of Transportation 2017). Currently, the toll portion of this segment has a posted speed limit of 85 mph, the highest posted speed limit in the United States.

[33] See Texas Transportation Code, Title 7, Subtitle C, Chapter 545, Section 352.

[34] See Texas Transportation Code, Title 7, Subtitle C, Chapter 545, Section 353.

[35] Specifically, the "Procedures for Establishing Speed Zones" states "speed limits on all roadways should be set based on spot speed studies and the 85th percentile operating speed" (Texas Department of Transportation 2015).

The trend of raising speed limits is not limited to Texas. In 2012, 35 states had maximum speed limits at or above 70 mph (GHSA 2012).[36] By 2016, the number of states with maximum speed limits at or above 70 mph had increased to 41. Figure 7 shows the maximum speed limits by state in 2016, along with the respective increases in maximum speed limits from 2012 to 2016. There are seven states with maximum speed limits at or above 80 mph; they are all located in the western half of the United States. Texas and Utah, which are highlighted in figure 7, already had maximum speed limits at or above 80 mph in 2012. The remaining five states all had 5 mph increases between 2012 and 2016. Figure 7 also highlights the regional trend of maximum speed limit increases in the Northwest.



Maximum Speed Limit (mph)[a]	Number of States and DC 2012	2014	2016
≤ 65	16	13	10
70	20	23	25
75	13	11	9
≥ 80	2	4	7

[a] Maximum speed limit refers to day time speed limit on rural interstates and may apply only to specified segments on the interstates.

Figure 7. Maximum speed limits by state and the District of Columbia in 2016 and changes in maximum speed limits from 2012 to 2016

[36] *Maximum speed limit* refers to the maximum posted daytime speed limit on any segment of any road within a state. Such segments are most likely located on rural interstates and the speed limit is applied to passenger cars only. For example, Texas has a maximum speed limit of 85 mph and it is limited to the 41-mile toll portion of State Highway 130. The IIHS maintains a regularly updated summary of maximum posted speed limits by state (IIHS 2017).

When speed limits are raised along segments of roads, such as those in rural Texas and Utah, the overall impact on vehicle speeds may not be limited to those segments. Impacts to road segments adjacent to the speed zones are known as spillover effects. These effects are supported by the theory of speed adaptation, which suggests that a driver perceives a lower traveling speed after operating the vehicle at a higher speed earlier (Schmidt and Tiffin 1969; Matthews 1978). A case control study of the effects of raising the speed limit from 75 to 80 mph on segments of rural interstate highways in Utah found that passenger vehicle speeds within the 80 mph speed zones increased by an average of 3.1 mph, and the probability of passenger vehicles exceeding 80 mph was 122% higher after the speed limit increase than would have been expected without it. The study also illustrated spillover effects because passenger vehicle speeds increased by 2.6 mph, and the probability of passenger vehicles exceeding 80 mph was 89% higher at three nearby locations where speed limits remained 75 mph (Hu 2016). Therefore, there is often an unintended increase in operating speeds in areas outside of the speed zones where the speed limit has been raised. Further, California raised the speed limit on some rural interstates from 55 mph to 65 mph in 1987. Researchers found that higher vehicle speeds were observed in both the freeway and the connecting road locations in 1988, compared to 1985. However, the freeways used in the studies were not eligible for the speed limit increase and the nearest rural interstates with an increased speed limit of 65 mph were 2 hours driving distance away. This research showed that speed limit increases on roads in highly rural areas may have significant impacts on other roads that are geographically distant and disconnected (Casey and Lund 1992). The NTSB concludes that unintended consequences of the reliance on using the 85th percentile speed for changing speed limits in speed zones include higher operating speeds and new, higher 85th percentile speeds in the speed zones, and an increase in operating speeds outside the speed zones.

3.1.4 Expert System

Although the 85th percentile speed is the predominant factor used in establishing speed limits, the *MUTCD* indicates several additional factors that may be considered. Specifically, it includes the following factors as options to the standard engineering study: "(A) road characteristics, shoulder condition, grade, alignment, and sight distance; (B) the pace; (C) roadside development and environment; (D) parking practices and pedestrian activity; and (E) reported crash experience for at least a 12-month period" (FHWA 2012a). However, the *MUTCD* does not provide any specific guidance on how these factors are to be considered. Engineers typically rely on their experience and judgement, which may lead to inconsistent practices in setting speed limits.

The transportation research community recognized the need to provide a systematic and consistent method for setting speed limits that incorporates factors other than operating speed (National Research Council 1998; Srinivasan and others 2006). An expert system is a software program that simulates the decision-making process of an expert in solving complex problems (Srinivasan and others 2006). In the United States, the FHWA developed a web-based expert system, known as USLIMITS2, for recommending credible and enforceable speed limits in speed zones (Forbes and others 2012).[37] The FHWA and AASHTO approved USLIMITS2 as a "priority,

[37] The USLIMITS2 expert system can be accessed via its website page. USLIMITS2 is the second version of an expert system (the first version was named USLIMITS) that was built on the lessons learned from the XLIMITS expert system of Australia in the 1980s. Input from an expert panel consisting of traffic engineers, officers, decision makers, and researchers across the United States improved upon the first version (FHWA 2012b).

market-ready technology and innovation" in 2008, and the FHWA began hosting USLIMITS2 and promoting its use to state and local agencies in 2012 (FHWA 2017).

USLIMITS2 can be used as a complementary tool to validate the results of engineering studies described in section 3.1.2. One advantage of USLIMITS2 is that crash statistics are listed as required input data.[38] In contrast, the *MUTCD* includes crash statistics as an optional factor. Therefore, in USLIMITS2, crash statistics, along with other factors such as road geometry characteristics, roadside characteristics, and traffic volume, are used to adjust the posted speed limits between the 50th and 85th percentile speeds (FHWA 2012b). The NTSB concludes that expert systems such as USLIMITS2 can improve the setting of speed limits by allowing traffic engineers to systematically incorporate crash statistics and other factors in addition to the 85th percentile speed, and to validate their engineering studies.

3.1.5 Vulnerable Road Users on Urban Roads

In highly populated urban areas, there are more interactions between vehicular traffic and vulnerable road users such as pedestrians and bicyclists. In 2014, 314 pedestrians and 46 bicyclists died in speeding-related crashes in the United States; 275 of these fatalities (76%) occurred in urban areas. Pedestrians and bicyclists are especially vulnerable because of their lack of protection. The direct relationship between vehicle speed and injury severity adversely affects pedestrians. The likelihood of pedestrian death increases from 5% at a vehicle impact speed of 20 mph, to 45% at 30 mph, and 85% at 40 mph (ETSC 1995). Similarly, the AAA Foundation for Traffic Safety analyzed NHTSA's NASS Pedestrian Crash Data Study data (July 1994 through December 1998), which showed that the average risk of severe injury for a pedestrian increased from 10% at a 16 mph vehicle impact speed, to 25% at 23 mph, 50% at 31 mph, 75% at 39 mph, and 90% at 46 mph (Tefft 2011). Although local residential streets typically have a 25 mph speed limit, there are many connecting roads in urban areas where speed limits are set at 35 to 45 mph, such as urban collectors and minor arterials.

The vulnerability of pedestrians in urban areas is a main reason why some municipalities have adopted a strategy called Vision Zero. This strategy was first developed and implemented in the 1990s in Sweden. It acknowledges that traffic fatalities and serious injuries are preventable and sets the goal of eliminating both in a specific time period. Vision Zero uses a multi-disciplinary approach that involves diverse stakeholders (ITE 2017). According to the Vision Zero Network, as of March 2017, there are 26 Vision Zero cities in the United States.[39]

Research has found that lowering speed limits can lead to sustained traveling speed reductions (Kloeden and Woolley 2012; De Pauw and others 2014) and crash reductions in urban areas (Islam, El-Basyouny, and Ibrahim 2014; D'Elia, Newstead, and Cameron 2007). Several transportation officials from Vision Zero cities interviewed by the NTSB for this study stressed

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[38] It is possible to use USLIMITS2 to generate a speed limit recommendation without crash statistics even though it is listed as a required input variable in USLIMITS2 (FHWA 2012b). However, a warning statement is displayed recommending the input of crash statistics to regenerate the recommendation.

[39] To be considered a Vision Zero city, a city must meet the following criteria: "(1) sets clear goal of eliminating traffic fatalities and severe injuries, (2) mayor has publicly, officially committed to Vision Zero, (3) Vision Zero plan or strategy is in place, or mayor has committed to doing so in clear time frame, and (4) key city departments (including police, transportation, and public health) are engaged" (Vision Zero Network 2017).

the importance of lowering speed limits to minimize the injury risk for vulnerable users, but they indicated this was often difficult because state transportation department policies emphasize the use of the 85th percentile speed.

The growth of the Vision Zero strategy in the United States reflects the emergence of the safe system approach in traffic safety. The safe system approach is a holistic approach to prevent crashes, or to at least prevent serious injuries resulting from crashes. Setting an appropriate speed limit is one aspect of the safe system approach. It recognizes that the responsibility for crash prevention resides not only with drivers but also with all stakeholders of the road system. These include those who design, manage, and use the road; those who set and enforce the speed limit; and those who provide emergency response. Therefore, how the road is designed and how the speed limit is set both play a role in crash prevention. It calls for the strengthening of all elements so that road users are still protected if one of these elements fails (ITF 2016). Road users, such as drivers and pedestrians, are viewed in the safe system approach as the "weakest link" (OECD 2008).

The safe system approach to speed limits differs from the traditional view that drivers choose reasonable and safe speeds. In the safe system approach, speed limits are set according to the likely crash types, the resulting impact forces, and the human body's ability to withstand these forces (Forbes and others 2012). It allows for human errors (that is, accepting humans will make mistakes) and acknowledges that humans are physically vulnerable (that is, physical tolerance to impact is limited). Therefore, in this approach, speed limits are set to minimize death and serious injury as a consequence of a crash (Jurewicz and others 2014). This approach is far more commonly applied outside of the United States, such as in Sweden (where it is called Vision Zero), the Netherlands (where it is called Sustainable Safety), and several jurisdictions in Australia (OECD 2008). However, it is now gaining acceptance in the United States, particularly in Vision Zero cities and municipalities.

The safe system approach calls for road designers to move from the conventional design (in which the posted speed limit is determined by the anticipated operating speed) to a proactive urban street design approach (in which the posted speed limit is determined by a target speed based on a desired safety result). The safe-system-approach-recommended maximum target speeds for urban roads are typically near the low end of the AASHTO minimum design speeds shown in Table 6. For example, the target speed for urban arterial roads is 35 mph compared to a 30 to 60 mph minimum design speed; for urban collector roads, the safe system target speed and the AASHTO minimum design speed are both 30 mph (NACTO 2017).

Based on an analysis of 3,603 speeding-related fatal crashes that occurred in cities in 2015, the NTSB estimated that 49% of these fatal crashes occurred on state-operated roads.[40] Therefore, although these roads pass through cities, local jurisdictions have no direct authority to adjust their speed limits. Although local officials may wish to incorporate the safe system approach by proposing speed zones with lower limits in urban areas with vulnerable road users, they may be unable to do so because state transportation departments require engineering studies that are driven

[40] Starting in 2015, FARS data include a variable that identifies road ownership. The NTSB used a geographic information system (GIS) analysis to estimate that 3,603 speeding-related fatal crashes occurred within city limits in 2015.

by the 85th percentile speed. The NTSB concludes that the safe system approach to setting speed limits in urban areas is an improvement over conventional approaches because it considers the vulnerability of all road users.

3.1.6 Rethinking How to Set Speed Limits

Section 2B.13 of the FHWA's *MUTCD* serves as the standard for setting speed limits in speed zones. It requires the use of engineering studies that emphasize the use of the 85th percentile speed.[41] The *MUTCD* also lists crash experience as one of several optional factors to be considered, but it lacks specific guidance on how to include these optional factors. In practice, most state transportation departments use the 85th percentile speed as the primary factor in setting speed limits in speed zones (Parker 1985; Fitzpatrick and others 1995; ITE 2001). The FHWA has developed, adopted, and promoted an expert system, USLIMITS2, that requires the use of crash statistics. USLIMITS2 is a valuable validation tool for engineering studies when setting speed limits, but its methods are not included in the FHWA's *MUTCD*.

Therefore, the NTSB recommends that the FHWA revise Section 2B.13 of the *MUTCD* so that the factors currently listed as optional for all engineering studies are required, require that an expert system such as USLIMITS2 be used as a validation tool, and remove the guidance that speed limits in speed zones should be within 5 mph of the 85th percentile speed.

The relationship between speed and injury severity affects more than just speeding vehicle occupants. This is particularly true in urban areas where the interaction between vehicles and vulnerable road users such as pedestrians is considerably higher. A safe system approach to setting speed limits emphasizes the consideration of human biomechanical tolerances and shifts the focus from vehicles to all road users. Especially in urban areas, it has emerged as an alternative to the use of the 85th percentile speed in setting speed limits in speed zones.

Transportation officials in cities, such as those represented by National Association of City Transportation Officials, are already engaged in the discussion of a shift of emphasis from vehicle-based practices to multi-modal approaches to traffic safety. The AASHTO Subcommittee on Traffic Engineering, the National Committee on Uniform Control Devices, and the Institute of Transportation Engineers are active participants in the research and development of best practices. These organizations may be well equipped to assist the FHWA in assessing the current practices of setting and adjusting speed limits, including but not limited to examining the use of the 85th percentile speed and incorporating the safe system approach. Therefore, the NTSB recommends that the FHWA revise Section 2B.13 of the *MUTCD* to, at a minimum, incorporate the safe system approach for urban roads to strengthen protection for vulnerable road users.

[41] As discussed in section 3.1.2, the ITE provides general guidance for engineering studies, which is commonly used by traffic engineers (ITE 2010; ITE 2016).

3.2 Data-Driven Approaches for Speed Enforcement

Appropriately set speed limits must be enforced to be optimally effective. However, speed limit enforcement is only one of the duties of an officer. Several of the law enforcement agencies the NTSB interviewed indicated that staffing levels have been reduced, and that they have had difficulty recruiting and retaining officers. Further, according to the International Association of Chiefs of Police (IACP), a speed enforcement program involves many costs; they include staffing, procuring speed measurement equipment, equipment servicing, development or improvement of data processing systems, and increased court time and its associated staffing requirements (IACP 2004). Therefore, to adequately manage such staffing and cost issues, law enforcement agencies must efficiently allocate their resources.

One approach that law enforcement agencies use to promote traffic safety is high-visibility enforcement (HVE), in which conspicuous enforcement activities are conducted in areas with a high risk of crashes.[42] This method has proven effective in detecting alcohol-impairment and ensuring seat belt use (Goodwin and others 2015). The most recognized type of HVE is accompanied by nationwide, large scale public media campaigns. HVE can also be integrated into the daily patrol routine, thereby indicating to the public that traffic enforcement is a law enforcement priority.

3.2.1 Data-Driven Approaches to Crime and Traffic Safety

Stakeholders interviewed for this study repeatedly stated that HVE is more effective when data are used to target the locations for enforcement. For example, in 2008, NHTSA and the US Department of Justice partnered to start an initiative known as Data-Driven Approaches to Crime and Traffic Safety (DDACTS) (National Institute of Justice 2014). Under this initiative, law enforcement agencies use geographic information systems (GIS) to analyze location-based crash and crime data to effectively deploy HVE to targeted areas known as *hot spots*, where both criminal activities and traffic incidents frequently occur (Kerrigan 2011; Hardy 2010). DDACTS specifically emphasizes data collection and analysis; disseminating information and outreach; using data to monitor, evaluate, and make adjustments; and measuring outcomes (NHTSA 2014; Hardy 2010).

Many local law enforcement agencies have reported that they effectively used DDACTS to allocate enforcement resources to reduce crashes and crime. The Metropolitan Nashville Police Department implemented an HVE program in 2004 that was based on DDACTS. The program collected traffic and crime data across the city, produced multilayered crime maps overlaying traffic violations with criminal activities, and used statistics-driven methods to identify hot spots down to specific street corners. The department then used HVE in those identified areas. Between 2003 and 2009, the Nashville metropolitan area experienced 16% and 31% decreases in fatal and injury crashes, respectively (Perry and others 2013).

In 2008, the Baltimore County Police Department launched a DDACTS-based HVE program called the Crash-Crime Project. GIS mapping tools were used to build multilayered maps detailing crime, traffic violations, and crash patterns. These maps helped the police department

[42] Another term for HVE is highly visible traffic enforcement.

identify neighborhoods and street segments to which they should deploy high-visibility patrols and conduct vehicle stops (Hall and Puls 2010; Perry and others 2013). On December 4, 2012, the background and results of this DDACTS-based HVE program were presented at the NTSB "Geographic Information Systems (GIS) in Transportation Safety" forum (Wilson and others 2012). The Baltimore County Police Department reported 6% and 15% decreases in all crashes and injury crashes, respectively, between 2007 and 2008 (Perry and others 2013).

In 2010, the Shawnee Police Department of Kansas deployed a DDACTS-based HVE program. Officers were assigned to conduct HVE in hot spots during specific times based on analysis of crime and crash data. Comparing data from the 3 years before and after the 2010 implementation of the Shawnee program, vehicle crashes decreased by 24% (Bryant, Collins, and White 2015).

Although some evidence suggests that data-driven, HVE programs such as DDACTS can be effective in improving traffic safety, there has been no systematic assessment of these programs. All of the reports the NTSB reviewed used aggregate performance measures such as crash counts, traffic stops, and citation issuances (Bryant, Collins, and White 2015; Perry and others 2013; Wilson and others 2012). Although these measures have some merit, an evaluation with performance measures specific to speeding would be useful for identifying best practices for law enforcement agencies when conducting speeding-related, data-driven, HVE and for communicating the benefits of these programs. Speeding-related performance measures may include the numbers and locations of speeding-related crashes, citations, warnings, and the injury severity of speeding-related crashes. Consistent evaluation methods may require the use of minimum before and after time periods for comparison. The *DDACTS Operational Guide* recommends using specific types of crashes and 3 to 5 years of crash data when conducting evaluations (NHTSA 2014). In addition, the guide highlights that "the findings from the data analysis are an important tool for garnering internal and external support for DDACTS implementation within identified hot spots" (NHTSA 2014). Officers interviewed by the NTSB also stated that the ability of senior officers to communicate the value of data-driven enforcement both within their agency and to the public was essential to the success of data-driven, HVE programs.

Therefore, the NTSB concludes that speeding-related performance measures are needed to determine the effectiveness of data-driven, HVE programs and to communicate the value of these programs to law enforcement officers and the public. The NTSB recommends that NHTSA identify speeding-related performance measures to be used by local law enforcement agencies, including—but not limited to—the numbers and locations of speeding-related crashes of different injury severity levels, speeding citations, and warnings, and establish a consistent method for evaluating data-driven, HVE programs to reduce speeding. Disseminate the performance measures and evaluation method to local law enforcement agencies. The NTSB further recommends that NHTSA identify best practices for communicating with law enforcement officers and the public about the effectiveness of data-driven, HVE programs to reduce speeding, and disseminate the best practices to local law enforcement agencies.

3.2.2 Limitations of Speeding-Related Crash Data

FARS uses seven categories to describe the type of speeding in fatal crashes: "exceeded speed limit," "too fast for conditions," "racing," "speeding but specifics unknown," "unknown if it is speeding-related," "no driver present," and "not speeding related" (NHTSA 2015a).[43] Each vehicle involved in a fatal crash is assigned one of these categories.[44] The assignment of these categories is based on analysts' interpretations of police crash reports. There were 35,055 passenger vehicles involved in fatal crashes in 2014; figure 8 shows how they were distributed among the 7 speeding categories. The two most common types of speeding—"exceeded speed limit" and "too fast for conditions"—each represent 8% of all passenger vehicles involved in fatal crashes. A very small portion (less than 1%) of vehicles were categorized as racing. There were also 888 passenger vehicles (3%) identified as speeding, but it was not possible to assign them to specific categories. In total, 6,422 passenger vehicles were identified as speeding.

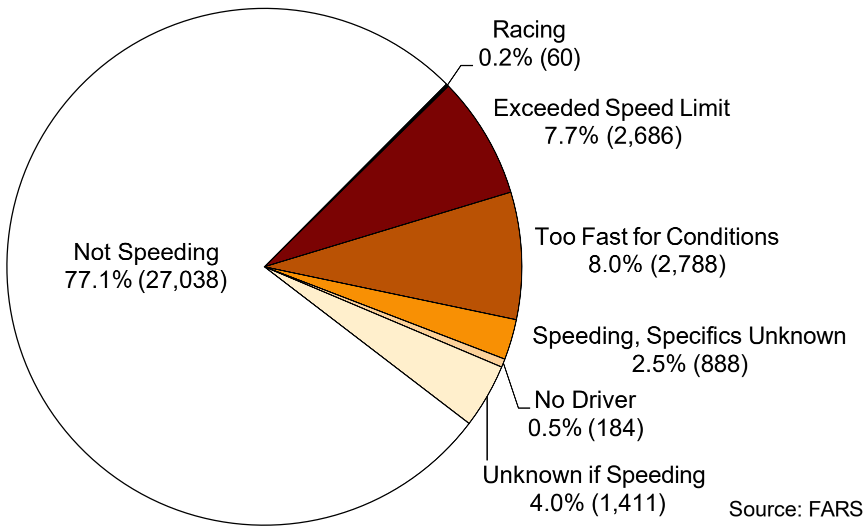

Figure 8. Passenger vehicles in fatal crashes, by speeding category, 2014

Whether the vehicles were speeding could not be determined for 1,411 passenger vehicles (4%), and 27,038 passenger vehicles (77%) were categorized as not speeding. The NTSB further examined these vehicles using travel speed and posted speed limit data in FARS. Among the 27,038 vehicles categorized as not speeding, 918 were traveling at least 10 mph above the posted speed limit prior to the crash. In addition, 57 passenger vehicles categorized as "unknown if speeding" were traveling at least 10 mph above the posted speed limit. This indicates that some vehicles categorized as "not speeding" or "unknown if speeding" were traveling at speeds above the posted speed limit prior to the crash. Therefore, the NTSB concludes that the involvement of speeding passenger vehicles in fatal crashes is underestimated.

[43] The category "no driver present" is used when "there is no person who was controlling the associated vehicle at the time of the crash" or "when it is unknown if there was a driver present in the vehicle at the time of the crash" (NHTSA 2016a).

[44] Appendix D provides definitions for each FARS speeding category.

Crashes involving the speeding types "exceeded speed limit" and "too fast for conditions" are used in analyzing speeding as a safety issue and formulating strategies to address it. The numbers of vehicles for the two speeding types are comparable, yet they deal with different aspects of speeding. Although the first speeding type is objectively defined by speed limits, the second is subject to the interpretation of officers. There is a large degree of variation among states in the way they apply these definitions. For example, 85% of all speeding-related passenger vehicles involved in fatal crashes were assigned "exceeded speed limit" in Massachusetts, whereas 7% of these vehicles were assigned this category in Arkansas (for comparison, the average was 42% for the United States). Although this variation can potentially be explained by posted speed limits and the physical characteristics of the states, it is unclear how much of the variation is due to inconsistencies in police crash reporting.

In some states, there is little distinction between "exceeded speed limit" and "too fast for conditions." For example, although Michigan and New Mexico use these two categories in their crash report forms, 63% and 52% of all speeding-related vehicles were simply categorized as "speeding, specifics unknown" in these states, respectively. The NTSB examined all state police crash report forms and found that 14 states do not have the category "exceeded speed limit" and 7 states do not have the category "too fast for conditions." In addition, six states' police crash report forms only have the category "unsafe speed."

There are three issues concerning crash reporting at the national level: (1) inconsistent categorization of "exceeded speed limit" and "too fast for conditions," (2) a lack of detailed categorization of speeding type, and (3) crashes for which speeding involvement is unknown. To develop a national strategy to address speeding as a traffic safety issue, it is essential to identify the types of speeding-related crashes (requiring consistent, detailed categorization of speeding) and to determine the scope of the problem (requiring known speeding involvement). Therefore, the NTSB concludes that the lack of consistent law enforcement reporting of speeding-related crashes hinders the effective implementation of data-driven speed enforcement programs.

NHTSA and the GHSA jointly publish the *Model Minimum Uniform Crash Criteria* (*MMUCC*) *Guideline*, which contains standards for state crash reporting (GHSA and NHTSA 2012). The guideline is periodically updated and serves as a key document used to "generate the information necessary to improve highway safety within each State and nationally" (GHSA and NHTSA 2012). Regarding speeding, it includes five attributes: "exceeded speed limit," "too fast for conditions," "racing," "unknown," and "no speeding." However, adoption of the *MMUCC Guideline* by states is voluntary. Even if all state crash report forms were compliant with *MMUCC Guideline* standards, the NTSB interviews with law enforcement agencies indicated that there would continue to be inconsistencies among officers in how the crash forms are filled out. The National Sheriffs' Association (NSA) and the IACP are professional associations that provide training and model policies to law enforcement agencies; as such, they may be well positioned to assist NHTSA in improving the quality of speeding-related crash data to help law enforcement agencies more effectively implement data-driven enforcement programs. Therefore, the NTSB recommends that NHTSA work with the GHSA, the IACP, and the NSA to develop and implement a program to increase the adoption of speeding-related *MMUCC Guideline* data elements and improve consistency in law enforcement reporting of speeding-related crashes. Further, the NTSB recommends that the GHSA, the IACP, and the NSA work with NHTSA to develop and implement a program to increase the adoption of speeding-related *MMUCC Guideline* data elements and improve consistency in law enforcement reporting of speeding-related crashes.

3.3 Automated Speed Enforcement

To use limited resources efficiently, some law enforcement agencies are employing data-driven, technology-based solutions for speed enforcement in addition to using data-driven approaches for in-person speed enforcement.

ASE refers to the use of a vehicle speed detection system coupled with a camera to identify speeding vehicles.[45] When a speeding vehicle is detected, the camera system is triggered to automatically take photographs of the vehicle, including the license plate and, in some implementations, the driver. Law enforcement and ASE vendor personnel then review the photographic evidence (typically off site and at a later time) to confirm that a speeding violation occurred, and state motor vehicle administration records are used to determine where to mail a speeding citation (Roadway Safety Consortium 2012). In some jurisdictions, the vehicle owner may be cited and assessed a fine (similar to a parking ticket); in others, the vehicle driver may be cited and be assessed a fine and license points (similar to a speeding citation issued in person by an officer).[46]

ASE has some advantages over in-person speed enforcement by an officer. It provides a force multiplier effect that can free up limited law enforcement resources to be used for other purposes. ASE can operate in locations and under conditions that would make traffic stops dangerous or impractical, and it may reduce congestion from other drivers distracted by traffic stops. Finally, its high rate of speeding detection may provide a higher general deterrence effect (FHWA and NHTSA 2008).[47]

Several limitations of ASE have also been noted. Because ASE does not stop a driver at the time of the speeding offense, the driver may continue to speed and be unaware of the offense. Also, the time lag between committing a violation and receiving an ASE penalty may have a lower specific deterrence effect (FHWA and NHTSA 2008).

ASE has been, and continues to be, challenged on several constitutional grounds, including that it violates rights of due process, equal protection (because penalties may differ between ASE citations and in-person citations), and privacy, but courts have consistently found ASE to be constitutional (FHWA and NHTSA 2008). ASE has also been criticized by the public as a tool to generate revenue rather than increase safety. This concern appears to stem from well-publicized cases of automated red light and speed enforcement programs not following best practices, such

[45] The speed detection system typically uses radar or light detection and ranging (LIDAR) technology, similar to handheld devices used by officers for speed enforcement.

[46] Many states use a point system to account for moving violations, in which greater points are assigned to more severe violations; the accumulation of a particular number of points within a set time period can lead to higher insurance premiums or license suspension.

[47] In traffic law enforcement, general deterrence refers to "the impact of the threat of legal punishment on the public at large…result[ing] from a belief in the community that traffic laws are being enforced and that a real risk of detection and punishment exists." In contrast, specific deterrence is "the influence of enforcement on the road user behaviour of convicted offenders, due to previous detection, prosecution, and punishment experiences" (Zaal 1994).

as paying vendors on a per-citation basis, giving vendors responsibility for site selection, and not ensuring that yellow lights are appropriately timed (Farmer 2017). Some states have passed laws designed to increase public acceptance of ASE. For example, Maryland requires local jurisdictions to hold a public hearing prior to authorizing ASE and to designate an employee to respond to citizen concerns and review contested citations. Local jurisdictions in Maryland are also prohibited from paying ASE vendors on a per-citation basis (see Maryland Code, Transportation, Section 21-809).

The concern about ASE as a revenue-generation tool was also raised at the most recent congressional hearings on automated enforcement in 2010.[48] MAP-21 made it illegal for states to use federal funds to "carry out a program to purchase, operate, or maintain an automated traffic enforcement system" (Title 23 *Code of Federal Regulations* (*CFR*) 1200.13(b)).[49] This was a change from previous legislation, which stated that "the [DOT] Secretary may encourage States to use technologically advanced traffic enforcement devices (including the use of automatic speed detection devices such as photo-radar) by law enforcement officers" (Highway Safety Act of 1991, Public Law 102-240).

3.3.1 Historical and Current Usage

Friendswood and La Marque, Texas, became the first US communities to use modern ASE systems when they conducted short-lived trials in 1986.[50] The next year, Paradise Valley, Arizona, started the first sustained ASE program, which is still active (Town of Paradise Valley 2017).

As illustrated in figure 9, in the first 20 years of ASE operations, usage grew slowly; by January 2006, 26 ASE programs were active but over one quarter of the 36 programs that had been started up to this point had been discontinued. Between 2006 and 2013, ASE usage increased dramatically, peaking at 148 active programs in 2013. Since then, ASE usage has declined slightly, with 141 active programs as of April 2017, including statewide work zone programs in Illinois, Maryland, and Oregon (IIHS 2016a). These programs are concentrated in 14 states and the District of Columbia. For example, communities in Maryland account for 46 of the ASE programs.

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[48] *Utilization and Impacts of Automated Traffic Enforcement: Hearing Before the Subcommittee on Highways and Transit of the Committee on Transportation and Infrastructure*, House of Representatives, 111th Congress, 2nd session, June 30, 2010.

[49] Title 23 *USC* section 402 defines an automated traffic enforcement system as "any camera which captures an image of a vehicle for the purposes only of red light and speed enforcement, and does not include hand held radar and other devices operated by law enforcement officers to make an on-the-scene traffic stop, issue a traffic citation, or other enforcement action at the time of the violation."

[50] The IIHS provided the NTSB with historical data on ASE programs, including locations, start dates, and (if applicable) end dates, covering the period from March 1986 to April 2017.

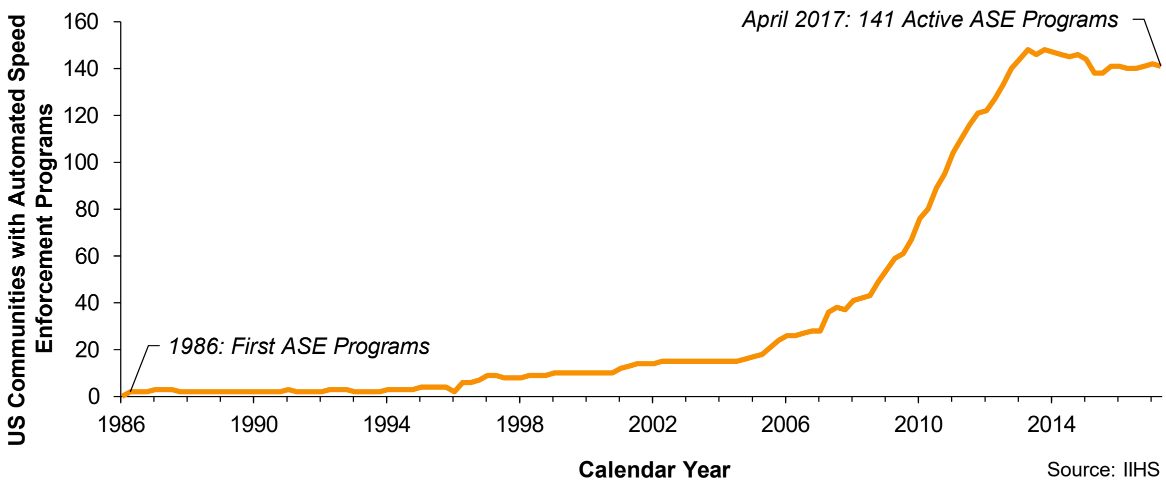

Figure 9. US communities with ASE programs, by year

There are four general types of ASE units (Miller and others 2016):

- **Fixed**: These ASE units are permanently mounted in fixed locations.
- **Speed-on-green**: These fixed units are primarily designed to detect red light violations at intersections, but they can also be used for ASE.
- **Semi-fixed**: These units use fixed housings with removable cameras. With fewer cameras than housings, cameras are rotated among the housings to maintain a deterrent effect at a lower cost, as drivers do not know which housings have cameras at any given time.
- **Mobile**: These units are mounted inside a vehicle (which may be occupied by law enforcement or ASE vendor personnel) or on a towed trailer, and they can be moved to different locations as needed.

3.3.2 Effectiveness

A 2005 systematic review of 14 studies of ASE programs in Canada, Europe, Australia, and New Zealand found crash reductions of 5 to 69%, injury reductions of 12 to 65%, and fatality reductions of 17 to 71% at ASE locations after ASE program implementation (Pilkington and Kinra 2005).

In 2007, NHTSA published a review of 13 studies of ASE programs (including 1 US program). Four of the 13 studies examined fixed ASE programs and generally found that injury crashes at fixed ASE locations declined between 20 and 25% after ASE implementation. The other 9 studies examined mobile ASE programs and found that injury crashes in mobile ASE zones declined between 21 and 51%. Two of the studies in the NHTSA review looked at the wider effects of ASE; one Canadian study found a provincewide 25% reduction in daytime speeding-related crashes, and the other, a US study, found a statewide 30% reduction in daytime crashes resulting in injuries (Decina and others 2007).

A 2010 review of 28 studies of ASE in the United States, Canada, Europe, Australia, and New Zealand determined that all 28 studies had found a lower number of crashes in ASE areas after ASE implementation. These studies reported reductions of 8 to 49% for all crashes and reductions of 11 to 44% for crashes causing serious injuries or fatalities (Wilson and others 2010).

Most recently, in 2015, the IIHS published a study of the ASE program in Montgomery County, Maryland, which first began in 2007. Montgomery County operates an ASE program on residential streets and in school zones, via a combination of fixed, semi-fixed, and mobile units. Starting in 2012, some cameras were used in a corridor approach, in which semi-fixed units were rotated among various locations on signed road segments to encourage speed limit compliance along the entire segment. The IIHS study found that, 7.5 years after the program began, ASE was associated with a 10% reduction in mean speeds and a 62% reduction in the likelihood of speeding more than 10 mph over the posted speed limit at ASE sites. The likelihood that a crash involved an incapacitating injury or fatality decreased by 39% on ASE-eligible roads, and the corridor approach further reduced this likelihood by 30% compared to what would have been expected without the corridor approach.[51] The likelihood that a crash was speeding-related decreased by 8%. The IIHS also found that, on similar but ASE-ineligible roads in Montgomery County, the likelihood that a crash involved an incapacitating injury or fatality decreased by 27% and the likelihood that a crash was speeding-related decreased by 22%.[52] This demonstrated a positive spillover effect, in which the benefits of ASE extended beyond ASE sites (Hu and McCartt 2016).

Several federal agencies consider ASE to be one of the most effective speeding countermeasures. NHTSA evaluated eight speeding countermeasures and gave ASE their highest rating for effectiveness (Goodwin and others 2015).[53] In addition, the Centers for Disease Control and Prevention notes that ASE "can reduce crashes substantially" and includes ASE as the only speeding-related countermeasure in their Motor Vehicle Prioritizing Interventions and Cost Calculator for States (MV PICCS), an online tool for states to choose cost-effective interventions to prevent motor vehicle related casualties (CDC 2015a; CDC 2015b).[54] Based on studies of operational ASE programs in the United States and other countries, the NTSB concludes that ASE is an effective countermeasure to reduce speeding-related crashes, fatalities, and injuries.

[51] To analyze the effects of ASE on crashes, the IIHS study compared the crash experience of Montgomery County residential roads eligible for ASE (that is, those with speed limits from 25 to 35 mph, whether ASE cameras were actually installed) to the crash experience of similar roads in nearby Fairfax County, Virginia, which did not operate an ASE program.

[52] To analyze spillover effects on crashes, the IIHS study compared the crash experience of Montgomery County residential roads with similar characteristics as the ASE-eligible roads (aside from having a higher, 40 mph speed limit) to residential roads in Fairfax County, Virginia, with 40 mph speed limits.

[53] This rating indicates a countermeasure is "demonstrated to be effective by several high-quality evaluations with consistent results" (Goodwin and others 2015).

[54] Each intervention included in MV PICCS is chosen based on (1) empirical evidence that it can substantially reduce motor-vehicle-related injuries and fatalities; (2) currently low usage across the 50 states, with a corresponding potential for additional impact through wider adoption; and (3) the ability of states to implement the intervention.

3.3.3 Stakeholder Perceptions

The GHSA has advocated for ASE programs since 2005, calling for (1) states to enact enabling legislation for ASE, (2) a federal incentive grant program to encourage the use of ASE, and (3) the promotion of ASE best practices by NHTSA (GHSA 2005; GHSA 2012; GHSA 2013; GHSA 2016).

AASHTO has supported the use of ASE since 2004, when it called for all states to build public support for ASE, to promote the enactment of ASE laws, and to support the use of ASE (AASHTO 2004). In 2006, the AASHTO Standing Committee on Highway Traffic Safety (SCOHTS) adopted a policy resolution to further support automated traffic law enforcement, including ASE. Citing the high percentage of crashes involving traffic law violations, the limited resources and staffing difficulties of law enforcement agencies, and the demonstrated effectiveness of automated enforcement in reducing deaths and injuries, SCOHTS encouraged "a top-down leadership approach by the executive and legislative branches of the federal government to implement automated enforcement throughout the country," including incentives for states to enact enabling legislation (AASHTO 2006).

The IACP, in a 2007 resolution, cited some of the same reasons as AASHTO in calling for the use of ASE in high-crash locations in conjunction with in-person traffic enforcement (IACP 2007). The IACP also included ASE as an effective enforcement strategy in its *Traffic Safety Strategies for Law Enforcement* guide (IACP 2003).

The National Association of City Transportation Officials, in its 2016 policy document, noted that automated traffic enforcement "is a crucial tool in preventing crashes that result in serious injuries and fatalities," called for the federal government to allow states to use federal-aid grant funds for automated traffic enforcement, and encouraged states to authorize the use of ASE (NACTO 2016).

The positions of these national associations are in line with the statements made during stakeholder interviews the NTSB conducted for this study. Nearly all of the representatives from state and local transportation departments expressed a positive view of their ASE programs (for those with active programs) or a desire to use ASE (for those without ASE programs). Opinions from officers were more varied. Several officers mentioned the benefits of in-person traffic stops, including the ability to discover other illegal behaviors and outstanding warrants, the ability to apply discretion and take into account mitigating factors, and the opportunity to educate drivers about traffic laws and the risks of speeding. However, only officers in communities without active ASE programs mentioned the benefits of in-person traffic stops as reasons for not implementing ASE. The NTSB interviewed representatives of five law enforcement agencies operating ASE programs. With one exception, every law enforcement representative in a community with ASE expressed the view that their programs should be maintained or expanded, and stated that they did not see ASE as limiting their ability to conduct in-person speed enforcement.[55]

[55] The ASE program in question (which has since been discontinued) operated in about six school zones throughout a county, with two mobile vans that rotated among the schools on a daily basis. The officer responsible for the program indicated that the daily process of moving, configuring, and removing the mobile units was too time consuming for his small force of seven officers, given their other required duties in addition to traffic enforcement.

Driver surveys have shown that public support varies depending on the roadway environment for which ASE is used and driver characteristics. In a nationally representative survey conducted by the AAA Foundation for Traffic Safety in 2015, 35% of respondents stated they supported ASE on freeways, 41% supported ASE in urban areas, 45% supported it on residential streets, and 56% supported it in school zones. These figures have not changed substantially since 2012, when the AAA Foundation started surveying drivers about this topic (AAA Foundation for Traffic Safety 2016).[56] Also, in a 2009 national public opinion survey conducted by the University of Minnesota, 64% of respondents said they were very or somewhat supportive of ASE in general. When asked about particular locations for ASE, support was higher for roads near schools (87%), roads where many people have died (81%), and roads where many people violate speed limits (75%). However, support for ASE on all roads was lower (43%). ASE support was also higher among women and older drivers, which are groups that are less likely than males and younger drivers to be involved in speeding-related fatal crashes. In addition, 73% of all survey respondents said that ASE would be an effective way to improve road safety (Munnich and Loveland 2011).

Several studies have shown maintained or increased public support for ASE after program implementation (Retting 2003). In Montgomery County, Maryland, a survey taken 6 months before the county's ASE program began in 2007 showed that 58% of drivers were in favor of ASE on residential streets. This level of support has been sustained, with followup surveys taken 6 months after the program began and again in 2014, showing 62% of drivers supporting the program (Retting, Farmer, and McCartt 2008; Hu and McCartt 2016). Surveys of drivers in Scottsdale, Arizona, in 2005 and 2006, showed that the percentage of drivers favoring ASE increased from 62% before an ASE program began to 77% after 8 months of operation (Retting, Kyrychenko, and McCartt 2008).

Although most ASE public opinion surveys the NTSB reviewed were directed to drivers, non-drivers are also affected by speeding, especially in urban areas with large numbers of pedestrians and bicyclists. A 2012 survey of District of Columbia residents found support for ASE even higher among non-drivers (90% support) than drivers (71% support) (Cicchino, Wells, and McCartt 2014).

3.3.4 Enabling Legislation

Table 7 shows, as of August 2016, the number of states with laws authorizing or prohibiting ASE, and whether these states have active ASE programs operating within the state.[57] Of the 14 states with ASE programs, most of these programs are operating with state legislation explicitly authorizing the use of ASE; very few ASE programs operate in states where laws are silent on the topic. This indicates that state-level enabling legislation is an important criterion for local communities to implement ASE programs.

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[56] It should be noted that the ASE survey questions specifically asked about citing vehicle drivers, an increasingly rare practice since newer ASE programs issue a fine to the vehicle owner. Survey respondents were asked if they support strongly, support somewhat, oppose somewhat, or oppose strongly "using cameras to automatically ticket drivers who drive more than 10 mph over the speed limit" on freeways, residential streets, urban areas, and school zones.

[57] Appendix E provides a complete summary of ASE laws by state.

Table 7. ASE state laws and active programs as of April 2017

	States Authorizing ASE	States Authorizing ASE with Restrictions	States without ASE Laws	States Prohibiting ASE	Total
States with ASE Programs	0[a]	10	4	0	14
States without ASE Programs	0	5	24	7	36
Total	**0**	**15**	**28**	**7**	**50**

Source: GHSA and IIHS
[a] The District of Columbia allows ASE throughout its jurisdiction and operates an ASE program.

The importance of state-level ASE-enabling legislation is supported by interviews the NTSB conducted with state and local transportation departments. Representatives from every state and local transportation department in a state without ASE-enabling legislation mentioned that they would like to implement an ASE program, but they were unwilling to do so without laws in place authorizing its use. The most common reason given for not implementing ASE programs without enabling legislation was that the citations issued by such a program, or the program itself, would be subject to significant legal challenges. For example, several Texas counties operated ASE programs only in unincorporated areas because state law prohibits ASE within Texas municipalities. As of April 2017, these programs have all been discontinued, and the law enforcement agency responsible for administering one such program reported a 50% dismissal rate for all ASE citations challenged in court.

However, even among the states with ASE-enabling legislation, significant restrictions on its use often prevent ASE from effectively reducing speeding-related deaths and injuries in these states. In the 15 states (and the District of Columbia) that authorize ASE, every state places some limitations on the specific municipalities or roadway environments in which ASE can be used; only the District of Columbia allows ASE throughout its jurisdiction. Several states limit the use of ASE to school zones, work zones, roads adjacent to parks, or some combination of these. Other states limit ASE programs to particular cities. For example, outside of school zones, the state of Washington effectively limits ASE to a single camera in the city of Tacoma.[58] Further, five states require that an officer or government employee be present at the time when the ASE unit captures the speeding violation.

Although it may be easier to garner community and legislative support for the use of ASE in locations such as school zones, those are generally not the locations most at risk for speeding-related deaths and injuries. For example, FARS data show that only seven US speeding-related fatalities occurred in school zones in 2014. The NTSB interviewed representatives from several agencies with active ASE programs who stated that the locations where ASE was authorized did not adequately address the speeding-related crash hot spots in their

[58] Any city "west of the Cascade mountains with a population of more than one hundred ninety-five thousand located in a county with a population of fewer than one million five hundred thousand" may operate a single ASE camera, and the specific site "must have first been authorized by the Washington state legislature as a pilot project for at least one full year" (see Revised Code of Washington 46.63.170).

communities, and that they would like the ability to place ASE equipment at the locations most susceptible to speeding-related crashes. The NTSB concludes that the lack of state-level ASE-enabling legislation, and restrictions on the use of ASE in states where legislation exists, have led to underuse of this effective speeding countermeasure. However, the NTSB acknowledges that some restrictions on ASE operations (such as the Maryland prohibition against paying vendors on a per-citation basis) may reflect best practices and are intended to increase public acceptance of ASE without limiting its safety benefits. Therefore, the NTSB recommends that the seven states prohibiting ASE amend current laws to authorize state and local agencies to use ASE.[59] The NTSB further recommends that the 28 states without ASE laws authorize state and local agencies to use ASE.[60] Finally, the NTSB recommends that the 15 states with ASE restrictions amend current laws to remove operational and location restrictions on the use of ASE, except where such restrictions are necessary to align with best practices.[61]

3.3.5 Best Practices

At the federal level, the primary source of best practices for establishing, operating, and evaluating ASE programs is the *Speed Enforcement Camera Systems Operational Guidelines* (FHWA and NHTSA 2008). These guidelines are designed to be a resource for "program managers, administrators, law enforcement, traffic engineers, program evaluators, and other individuals responsible for the planning and operation of the program" and contain best practices in over 40 topic areas related to ASE, such as legal authorities, site selection, marketing, operator training, equipment maintenance, violation processing and adjudication, and program evaluation.

However, NHTSA has found that these guidelines are neither well known, nor well adhered to, by ASE program managers. In 2011, NHTSA conducted a survey of all 107 communities identified at that time as current or recent operators of ASE programs (Miller and others 2016). The objectives of the study were to determine how aligned the ASE programs were with the federal guidelines. However, 63% of the survey respondents indicated that they were not even aware of the federal ASE guidelines.[62]

To determine these programs' degree of alignment to the guidelines, survey questions were developed for 35 topic areas in which the guidelines provided "clear guidance terms such as 'shall,' 'should,' 'critical,' and 'must.'" In only 7 of the 35 areas did 80% or more of the surveyed

[59] These seven states are Maine, Mississippi, New Hampshire, New Jersey, Texas, West Virginia, and Wisconsin. See appendix E.

[60] These 28 states are Alabama, Alaska, California, Connecticut, Delaware, Florida, Georgia, Hawaii, Idaho, Indiana, Iowa, Kansas, Kentucky, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Carolina, North Dakota, Oklahoma, Pennsylvania, South Dakota, Vermont, Virginia, and Wyoming. See appendix E.

[61] These 15 states are Arizona, Arkansas, Colorado, Illinois, Louisiana, Maryland, Nevada, New York, Ohio, Oregon, Rhode Island, South Carolina, Tennessee, Utah, and Washington. See appendix E.

[62] Survey respondents included representatives from current and recently discontinued ASE programs at the time the survey was conducted and representatives from programs that began before and after the ASE guidelines were published. Programs starting before the ASE guidelines were published in 2008 reported 7% higher awareness of the guidelines (34%) than those programs starting in 2008 or later (27%). The survey was mailed to the head of the agency responsible for ASE within each community. NHTSA stated that "it appears that most of the agency staff assigned to complete the survey had operational responsibilities and/or oversight for ASE" but "the person assigned to complete the survey may not have been involved when the program was first established" (Miller and others 2016).

programs align with the guidelines. Further, in 11 of these 35 areas, less than 40% of the surveyed ASE programs aligned with the guidelines. For example, 31% of ASE programs aligned with the guideline to treat speeding violations by government vehicles the same as violations by the general public, and 27% of ASE programs aligned with the guideline to establish a stakeholder committee to guide program development (Miller and others 2016).

The NHTSA survey acknowledges that some of the low alignment to federal ASE guidelines may be due to changes in technology and operations that the 2008 guidelines do not reflect. For example, the guidelines recommend that the vehicle driver be identified and cited. However, in accordance with state and local laws, most recently established ASE programs send citations to the vehicle owner, a practice which has been shown to be effective (Hu and McCartt 2016). In addition, the survey noted that the increased use of unstaffed mobile units—a technology not available when the guidelines were written—could affect how an ASE program is operated and perceived.

The NTSB concludes that federal guidelines for ASE programs do not reflect the latest technologies and operating practices and are not very effective because their existence is not well known among the ASE program administrators. The NTSB therefore recommends that the FHWA work with NHTSA to update the *Speed Enforcement Camera Systems Operational Guidelines* to reflect the latest ASE technologies and operating practices, and promote the updated guidelines among ASE program administrators.

3.3.6 Point-to-Point Enforcement

One particular ASE technology that is relatively new is point-to-point enforcement (also referred to as average speed enforcement or section control). The first use of point-to-point enforcement was in the Netherlands in 1997; since then, its use has spread to other European countries, Australia, and New Zealand, but such systems have not yet been implemented in the United States (Soole, Fleiter, and Watson 2012).

Point-to-point enforcement uses the times a vehicle passes two points to calculate an average speed over the length of road between the points. Continuous visual observation of a vehicle is not necessary over the entire section of roadway, as a time-synchronized camera system captures vehicle images at the section endpoints and then uses automatic license plate recognition technology to match the images and determine which vehicles exceeded the posted speed limit. Thus, point-to-point enforcement can be used on highway segments many miles long, with multiple measurement points as necessary.

Point-to-point enforcement technology is best suited for limited-access highways with few entry or exit points on the designated highway section, for which the designated section is the fastest route between the section endpoints. This is a road type for which ASE in general has not been used extensively in the United States, despite interstate highways and non-interstate freeways and expressways accounting for 17% of speeding-related fatalities in 2014 (NCSA 2016a).

Several benefits of point-to-point enforcement have been noted in relation to fixed or mobile ASE implementations. By enforcing the speed limit over a longer segment of roadway rather than at discrete points, drivers are encouraged to drive the speed limit over longer distances.

In addition, point-to-point enforcement avoids the problem of drivers slowing prior to a known ASE site and then resuming an excessive speed after passing the camera (Lahrmann and others 2016).

Although it has not been evaluated as extensively as other types of ASE, studies have shown that point-to-point enforcement provides safety benefits, including some advantages over fixed ASE units. A 2013 review of studies in Europe and Australia found that point-to-point enforcement generally reduces average speeds, 85th percentile speeds, speed variability, fatal crashes, and serious injury crashes (Soole, Watson, and Fleiter 2013). A 2014 review of 15 fixed ASE studies and 4 point-to-point enforcement studies found that point-to-point enforcement was slightly more effective in reducing crashes than fixed ASE, with fatal and serious injury crashes declining by 51% for fixed ASE and 56% for point-to-point enforcement (Høye 2014).

Based on the experience of implementing point-to-point enforcement in Europe, Australia, and New Zealand, Austroads (the association of Australian and New Zealand transportation agencies) has developed best practices for point-to-point enforcement, which address operational, technological, legislative, evidentiary, public education, evaluation, and privacy considerations (Soole, Fleiter, and Watson 2012). However, this guidance may not be completely appropriate in the United States, where point-to-point enforcement would potentially be subject to the same types of legal arguments that have been made against other types of automated enforcement. Best practices for point-to-point enforcement in the United States would help ensure that enforcement operations are conducted in a legally appropriate manner, but US federal guidelines for ASE do not include any information on point-to-point enforcement (FHWA and NHTSA 2008).

The NTSB concludes that point-to-point speed enforcement has been shown to be an effective speeding countermeasure internationally, but it is not currently used in the United States. Therefore, the NTSB recommends that the FHWA work with NHTSA to assess the effectiveness of point-to-point speed enforcement in the United States and, based on the results of that assessment, update the *Speed Enforcement Camera Systems Operational Guidelines*, as appropriate.

3.4 Intelligent Speed Adaptation

Intelligent speed adaptation (ISA) is a vehicle technology that studies have shown is effective at reducing speeding. ISA systems determine the speed limit in effect by comparing a vehicle's global positioning system (GPS) location against a database of posted speed limits and using onboard cameras to recognize speed limit signs (Goodwin and others 2015).

The European Commission defines three levels of ISA (European Commission 2015):

- **Open ISA**: An advisory system that issues visual or aural alerts to the driver when the speed limit is exceeded; the driver is responsible for slowing the vehicle.
- **Half-Open ISA**: A system that increases back pressure on the accelerator when the speed limit is exceeded, making it more difficult (but not impossible) to exceed the speed limit.
- **Closed ISA**: A system that electronically limits the speed of a vehicle, preventing drivers from exceeding the speed limit.

The primary advantage of ISA compared to conventional speed limiters (also known as speed governors) is that the limiting speed is the posted speed limit in effect at a particular location, rather than a single, fixed speed. Conventional speed limiters have been voluntarily used by US commercial truck and bus fleets for their safety and fuel efficiency benefits, and other countries have required their use on trucks and buses since the 1990s (NTSB 2012). However, because conventional speed limiters cannot prevent speeding in locations where the speed limit is lower than the governed speed, the NTSB has previously recommended that heavy vehicles, including trucks, buses, and motorcoaches, be equipped with advanced speed-limiting technology such as ISA (NTSB 2012; NTSB 2015).[63]

3.4.1 Current Passenger Vehicle Implementations

Many manufacturers offer Open ISA capabilities for the US passenger vehicle market. The earliest and most common implementations show the current speed limit on the vehicle's navigation display. Some of these systems also change the display when the speed limit is exceeded (for example, highlighting the speed limit in amber or red). More recently, manufacturers have started displaying these speed limit alerts within the driver's instrument cluster, or projecting the information onto the windshield on a head-up display. Third-party Open ISA systems are available for retrofit (Mobileye 2017). In addition, drivers may use portable electronic devices as their source of navigation and speed limit data. Increasingly, these devices can interface directly with passenger vehicles through capabilities such as Android Auto and Apple CarPlay (Google 2017; Apple 2017).

Examples of currently available US vehicle capabilities related to ISA include the following:

- On General Motors vehicles with a navigation system, the current GPS-derived speed limit can be displayed on the navigation display, within the instrument cluster, or on a head-up display if so equipped, but no warnings are issued when exceeding the limit. In addition, as part of General Motors' Teen Driver system, many General Motors vehicles can issue a visual warning and chime when a user-set speed (between 40 and 75 mph) is exceeded, and owners can also enable a speed limiter fixed to 85 mph (Chevrolet 2016).
- On Toyota vehicles with a navigation system, the current GPS-derived speed limit can be displayed on the navigation display or in the instrument cluster. Drivers can also enable a yellow caution indicator that is displayed in the instrument cluster when the speed limit is exceeded (Toyota Motor Sales 2016).
- Tesla vehicles equipped with the Autopilot driver assistance system include an ISA capability called Speed Assist (Tesla Motors 2016). Speed Assist uses sign detection and GPS data (where no signs are present) to determine the current speed limit. If the driver has enabled Speed Assist, a speed limit sign is displayed on the instrument panel whenever a speed limit can be determined; when the speed limit (plus or minus a driver-specified offset) is exceeded, this speed limit sign enlarges and a chime optionally sounds.[64] Speed Assist is also integrated with Tesla's Traffic-Aware Cruise Control; when the driver pulls

[63] NTSB Safety Recommendation H-12-21 to NHTSA is currently classified "Open—Acceptable Response."

[64] Instead of basing the speed alerts on the posted speed limit, a driver can also manually specify a fixed speed between 20 and 140 mph for alerting.

and holds the cruise control lever, the cruising speed will be set to the Speed Assist speed. However, changes in posted speed limits are not automatically followed; the driver must pull the cruise lever again for the cruising speed to match a new speed limit.

- On Ford and Lincoln vehicles equipped with the MyKey feature, drivers can activate a set of user-configured restricted driving modes when starting the vehicle with a MyKey. These modes include visual and aural warnings when a user-set speed is exceeded, and fixed speed limits of 65, 70, 75, or 80 mph, which are also accompanied by visual and aural warnings. Ford and Lincoln vehicles equipped with GPS can also display the current GPS-derived speed limit in the instrument cluster (Ford Motor Company 2016).
- Audi vehicles equipped with GPS, sign-detecting cameras, and adaptive cruise control include a capability called Predictive Control. When Predictive Control is activated, the adaptive cruise control will adjust the vehicle's speed to match the currently detected speed limit, and it will automatically accelerate or decelerate the vehicle when a new speed limit is detected (Audi 2017).

These features are often marketed toward teen drivers and their parents. Automobile manufacturers typically only make these features available for a subset of their models, and the purchase of certain option packages (such as those that include a GPS navigation system) may be required.

The systems offered by automobile manufacturers in the United States do not yet meet the definitions of Half-Open or Closed ISA. However, third-party products are available for retrofit (Speedshield Technologies 2012). In addition, Half-Open ISA capabilities are offered by automobile manufacturers in other countries. For example, since 2015, the Ford S-Max has been sold in Europe with an optional Intelligent Speed Limiter. When activated by the driver using controls on the steering wheel, the vehicle is limited to speed limits detected via sign recognition.[65] If the driver fully depresses the accelerator, the speed limiter will turn off until the vehicle speed is again below the speed limit (Ford Motor Company 2015).

3.4.2 Effectiveness

ISA has been studied extensively internationally, and to a lesser degree in the United States (Blomberg and others 2015; De Leonardis, Huey, and Robinson 2014; Regan and others 2006; Várhelyi and others 2004). These studies have generally found ISA to be effective in reducing speeding.

For example, in a 2014 NHTSA study, 78 "chronic speeders" in Maryland drove with an Open ISA system for 4 weeks (De Leonardis, Huey, and Robinson 2014).[66] The mean percentage of each trip that study participants drove over 8 mph above the posted speed limit decreased from 18% to 13% when the Open ISA system was used.

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[65] The driver can also specify an offset above or below the speed limit, so that the Intelligent Speed Limiter will, for example, limit the vehicle speed to the posted speed limit plus 5 mph.

[66] Study participants had received at least three speeding violations in the 3 years before the study.

In Lund, Sweden, 284 vehicles were equipped with a Half-Open ISA system for 5 to 11 months in 2000 (Várhelyi and others 2004). ISA usage resulted in statistically significant changes in mean speeds (decreasing between 0.9 and 3.7 kilometers per hour (km/h)) on four of the six road types examined in the study.[67] Eighty-fifth percentile speeds on these road types decreased between 1.0 and 7.6 km/h, and speed variance also decreased.

In a study published by NHTSA in 2015, a Half-Open ISA system was tested with 18- to 24-year-olds in Kalamazoo, Michigan, using a fixed course of six road segments with different speed limits (Blomberg and others 2015). The Half-Open ISA system showed statistically significant reductions in both speeding 5 or more mph over the speed limit and speed variance for five of the six segments.[68] The NTSB concludes that ISA is an effective vehicle technology to reduce speeding.

3.4.3 Stakeholder Perceptions

Most of the automobile manufacturers the NTSB interviewed for this study did not collect usage data for their Open ISA implementations. However, one manufacturer that offers an Open ISA system with visual warnings as a standard feature (defaulted to be active) reported that 3% of vehicle owners disable the feature. Another automobile manufacturer noted that a primary motivation for developing its Open ISA system capability was customer interest.

When asked about equipping vehicles with more restrictive Half-Open or Closed ISA systems, the automobile manufacturers interviewed for this study all indicated that it was technically feasible. However, they also expressed several concerns, including limitations of sign-detection cameras and speed limit databases, a desire to retain the ability to exceed the speed limit in emergency situations, and the need to support customers who operate their vehicles off public roads (for example, people who use their vehicles for racing).

3.4.4 Performance and Equipage

The effectiveness of a particular ISA system depends on its underlying speed limit detection technology. For those systems that rely on GPS maps, the speed limit data must be complete, accurate, and timely. However, many vehicle map databases are updated infrequently and typically require owners to take action to purchase updated data. For example, navigation maps for Honda vehicles are typically updated once per year, and these updates cost about $150 (HERE 2016). Although the automobile manufacturers interviewed for this study could not provide quantitative data, they all estimated that the number of vehicle owners regularly purchasing map updates is quite low.

For those systems that rely on sign-detecting cameras, performance is dependent on weather conditions, lighting conditions, obstructions (such as vegetation or other vehicles), speed limit sign format, and sign placement. However, the impact of these factors on the performance of

[67] The four road types with statistically significant changes were arterials with speed limits between 50 and 70 km/h, and a "main street" with a speed limit of 50 km/h. The remaining two road types (a "main street, mixed traffic" with a 50 km/h speed limit and a "central street" with a 30 km/h speed limit) did not show significant differences between ISA-active and inactive test conditions.

[68] Traffic congestion on the sixth segment limited the opportunities to speed.

ISA systems is difficult to quantitatively assess, because ISA performance standards do not exist. Most manufacturers only provide a list of qualitative ISA performance disclaimers in their owner's manuals. For example, the Tesla Model S owner's manual states that owners should "not rely on Speed Assist to determine the appropriate speed limit" (Tesla Motors 2016).

Finally, ISA must actively be used to be effective. Several studies that measured driving behavior before, during, and after the ISA test phase have found that speeding reverts to (or close to) pre-ISA levels once the system is turned off (Blomberg and others 2015; De Leonardis, Huey, and Robinson 2014). In addition, several subjects in a Half-Open ISA study were able to speed by pushing harder on the accelerator pedal, accelerating beyond the speed limit, and then coasting above the speed limit (Blomberg and others 2015). These observations highlight the importance of defaulting any passenger vehicle ISA implementations to be activated/on and of limiting the ability of drivers to disable or defeat the system.

One way to incentivize manufacturers to include advanced safety capabilities that satisfy minimum performance standards in their vehicles is through crash testing and safety rating programs. In the United States, these include NHTSA's New Car Assessment Program (NCAP) (NHTSA 2016b) and the IIHS "Top Safety Pick" awards (IIHS 2016b).

The European NCAP includes ISA as a rating factor and provides test protocols for evaluating a manufacturer's ISA implementation (Euro NCAP 2015). However, ISA is not incorporated into the US NCAP. One automobile manufacturer interviewed for this study stated that the inclusion of ISA in the European NCAP was a primary reason why an ISA capability was developed for its vehicles sold in Europe. In addition, safety ratings programs like the NCAP have been shown to increase sales of high-rated vehicles relative to lower-rated vehicles (IIHS 2013). The NTSB concludes that new car safety ratings are effective in incentivizing consumers to purchase passenger vehicles with advanced safety systems. The NTSB therefore recommends that NHTSA incentivize passenger vehicle manufacturers and consumers to adopt ISA systems by, for example, including ISA in the NCAP.

3.5 National Leadership

In interviews the NTSB conducted, national, state, and local traffic safety stakeholders repeatedly mentioned that—unlike other crash factors such as alcohol impairment or unbelted occupants—speeding has few negative social consequences associated with it, and it does not have a leader campaigning to increase public awareness about the issue at the national level. Stakeholders further stated that they thought the dangers of speeding are not well-publicized, that society therefore underappreciates the risks of speeding, and that the resulting complacency among drivers has led to speeding becoming a common behavior even though surveys indicate that drivers generally disapprove of other drivers speeding. Stakeholders also expressed the belief that, to gradually change public perceptions of speeding, a coordinated effort among safety advocacy groups, with strong leadership from the federal government, is needed. This section describes several ways that national organizations can take a greater leadership role in addressing speeding.

3.5.1 Traffic Safety Campaigns and Public Awareness

Traffic safety campaigns use communications and outreach to increase public awareness of a traffic safety topic. When campaigns also include increased enforcement, they have been shown to be highly effective countermeasures for several traffic safety issues, such as impaired driving and occupant protection (Goodwin and others 2015). For example, a key component of the NHTSA-coordinated campaign to increase seat belt usage is “Click It or Ticket,” an annual, 2-week enforcement mobilization that has been conducted nationally since 2003 (Hinch, Solomon, and Tison 2014).

NHTSA has stated that traffic safety campaigns for speeding show promise; however, the safety benefits have varied greatly among campaigns that have been studied (Goodwin and others 2015). For example, pilot tests of two campaigns in Peoria and Phoenix, Arizona, showed 17 and 31% increases, respectively, in the proportion of drivers complying with the posted speed limit, and 14 and 29% decreases, respectively, in the proportion of drivers exceeding the speed limit by 7 mph or more (Blomberg and Cleven 2006). Also, a 4-week trial of increased speeding enforcement in London in 2008 found that 85th percentile speeds decreased by 1.9 mph on the targeted section of roadway, and 1.1 mph at nearby sites not subject to increased enforcement. There were also greater reductions at those sites where pre-trial mean speeds were highest, and the reductions persisted for 2 weeks after the trial concluded (Walter, Broughton, and Knowles 2011). In contrast, a study of two 6-month campaigns focusing on aggressive driving in Tucson, Arizona, and Marion County, Indiana, found that the proportion of crashes related to aggressive driving decreased by 8% during the Tucson campaign but increased by 6% during the Marion County campaign (Stuster 2004).

The varying benefits of these traffic safety campaigns for speeding can be explained by two factors: inconsistent implementations and low levels of awareness of the campaigns among drivers. For example, the Marion County campaign relied on overtime hours by 42 officers from six different law enforcement agencies, operating on average 1 out of every 3 days, whereas the Tucson campaign used two full-time and two part-time officers who operated almost every day. These two campaigns also differed in their relative expenditures for labor, equipment, and publicity, and in their focus on single or multiple traffic violations. In a survey conducted after the Peoria and Phoenix campaigns, 26% of neighborhood residents mentioned the campaigns’ “Heed the Speed” slogan. In contrast, a 2012 survey of the long-running national occupant protection campaign found that 85% of respondents were aware of its “Click It or Ticket” slogan (Hinch, Solomon, and Tison 2014).

Research has shown that the communications component of a traffic safety campaign increases safety benefits. One review of 67 studies on traffic safety campaigns in 12 countries found that public information and education reduced crashes by 9% on average (Phillips, Ulleberg, and Vaa 2011). A study of an ASE program in North Carolina likewise found that 8 to 9% of the crash reduction effects were due to media coverage of the program (Moon and Hummer 2010). These results highlight the importance of public media efforts to the success of traffic safety campaigns.

NHTSA, through its Traffic Safety Marketing (TSM) group, provides marketing materials and advice for states to use in developing traffic safety campaigns, and coordinates national traffic safety events (NHTSA 2016c). Table 8 shows the traffic safety events that NHTSA sponsored in 2016, including three national enforcement mobilizations, which addressed distraction, occupant protection, and alcohol impairment. None of the events addressed speeding.

Table 8. 2016 NHTSA Traffic Safety Marketing events

Event Type	Date(s)	Description (Slogan)
Official Month	April	National Distracted Driving Awareness Month Bicycle Safety Month
	May	Motorcycle Safety Awareness Month
	July	Vehicle Theft Prevention Month
	August	Back to School Safety Month
Official Week	May 29-June 4	Tire Safety Week
	September 18-24	Child Passenger Safety Week
	October 16-22	National Teen Driver Safety Week
National Enforcement Mobilization	April 8-13	Distracted Driving (*U Drive. U Text. U Pay.*)
	May 16-30	Occupant Protection (*Click It or Ticket*)
	August 17-September 5	Impaired Driving (*Drive Sober or Get Pulled Over*)
Holiday with Traffic Safety Emphasis	Super Bowl, St. Patrick's Day, Cinco de Mayo, Fourth of July, Halloween, Holiday Season (November 25-Jan 1)	Impaired Driving
	Thanksgiving	Occupant Protection

Although NHTSA does not currently coordinate any national activities related to speeding, TSM does make available marketing materials that state and local agencies can use in their own campaigns, using the slogans "Stop Speeding Before It Stops You" and "Obey the Sign or Pay the Fine" (NHTSA 2016c). However, in the absence of a national speeding campaign, there is incomplete participation among states, and little consistency among the individual state campaigns. A 2011 study found that 32 states funded public awareness efforts for speeding; 25 of these states reported using a total of 30 different campaign slogans, and 8 states used the NHTSA slogans (GHSA 2012). In contrast, all 50 states participate in the national occupant protection campaign, and they all use the campaign's "Click It or Ticket" slogan.

Participation in the NHTSA-coordinated, national traffic safety campaigns is high because states are required to participate in order to receive some federal highway safety grant funds. For example, under the Highway Safety Program, each state must "provide satisfactory assurances" that the state will implement all "national law enforcement mobilizations and high-visibility law enforcement mobilizations coordinated by the Secretary" of Transportation (23 *USC* section 402). In addition, a state is only eligible to receive National Priority Safety Programs occupant protection grants if it "participates in the Click It or Ticket national mobilization" (23 *USC* section 405).

During NTSB interviews with stakeholders, including safety advocates, state transportation officials, and officers, the lack of a national traffic safety campaign was cited as a key issue hindering the effective implementation of speeding prevention programs in the United States. The GHSA has also called for NHTSA to “sponsor a national high visibility enforcement campaign and support public awareness efforts to address the issues of speed and aggressive driving” (GHSA 2012). The NTSB concludes that traffic safety campaigns that include highly publicized, increased enforcement can be an effective speeding countermeasure, but their inconsistent and infrequent use by states hinders their effectiveness.

Despite the lack of a national speeding campaign, recently developed national efforts to achieve zero US traffic fatalities (called Vision Zero or Toward Zero Deaths) recognize the impact of speeding on traffic safety. For example, the Toward Zero Deaths Steering Committee consists of eight “organizations and agencies that own, operate, enforce and maintain our nation’s roads” with technical support from the FHWA, the FMCSA, and NHTSA.[69] The committee has developed *Toward Zero Deaths: A National Strategy on Highway Safety*, which identifies six strategies to move toward safer drivers and passengers: increasing seat belt use, reducing speeding-related fatalities, reducing impaired driving, reducing driver distraction, increasing the safety of teen drivers, and increasing the safety of older drivers (The Toward Zero Deaths Steering Committee 2014). Except for the topics of speeding and older drivers, all of these strategies have NHTSA-coordinated traffic safety events. The international traffic safety community has also recognized speeding as an important problem to address. For example, speeding is included in the United Nations’ *Global Plan for the Decade of Action for Road Safety 2011-2020*, and the Fourth United Nations Global Road Safety Week (May 8-14, 2017) focused on speed management (WHO 2011; WHO 2017). However, this level of importance is not reflected in the schedule of national traffic safety events coordinated by NHTSA. The NTSB concludes that the current level of emphasis on speeding as a national traffic safety issue is lower than warranted and insufficient to achieve the goal of zero traffic fatalities in the United States.

In October 2016, NHTSA, along with the FHWA and FMCSA, joined the National Safety Council (NSC) to launch the “Road to Zero” initiative and coalition (NHTSA 2016d). The purpose of the initiative is “to eliminate traffic fatalities within 30 years” (National Safety Council 2017). This growing coalition has over 200 members with a steering committee that includes the three aforementioned DOT agencies, the NSC, AASHTO, Mothers Against Drunk Driving (MADD), and others. All of these organizations have their own diverse initiatives and programs to increase traffic safety in the United States. Also, safety advocacy organizations have had success in developing, launching, and implementing nationwide public awareness, education, and media efforts. Therefore, the NTSB recommends that NHTSA collaborate with other traffic safety stakeholders to develop and implement an ongoing program to increase public awareness of speeding as a national traffic safety issue. The program should include, but not be limited to, initiating an annual enforcement mobilization directed at speeding drivers.

[69] The eight organizations on the Toward Zero Deaths Steering Committee are the American Association of Motor Vehicle Administrators, AASHTO, the Commercial Vehicle Safety Alliance, the GHSA, the IACP, the National Association of County Engineers, the National Association of State Emergency Medical Service Officials, and the National Local Technical Assistance Program Association.

3.5.2 Funding for Speed Management Programs

Another way to increase public awareness of speeding as a traffic safety issue is by providing states incentives to be more engaged in addressing speeding. As discussed in section 2.7, the three primary federal-aid programs for traffic safety are the Highway Safety Improvement Program, Highway Safety Program, and National Priority Safety Programs. The latter two both fund non-engineering (that is, behavioral) countermeasures, but their funding methods differ in several important ways. Highway Safety Program grants are allocated based on the population and road miles in each state, and these funds can be spent on any of 10 different focus areas (of which speeding is one) according to a state's Highway Safety Plan. It is not possible to determine, at the national level, how these grants are designated for speeding. In contrast, National Priority Safety Programs funds are directed toward seven different priority areas, the funding level for each priority area (rather than the overall total) is established by Congress, and each priority area has specific eligibility requirements that incentivize states to conduct particular traffic safety activities.[70] Speeding is not one of the seven priority areas. Table 9 shows how funds for these programs were allocated in fiscal year 2016.

Table 9. Federal funds allocated to states for behavioral traffic safety programs, fiscal year 2016

Program	Focus/Priority Area	Allocated Funds[b]	
		Amount ($)	%
Highway Safety Program	(All Grants)	260,034,506	44.8
National Priority Safety Programs	Impaired Driving[a]	231,558,630	39.9
	Occupant Protection	43,136,833	7.4
	State Traffic Safety Information System Improvements	39,016,291	6.7
	Motorcycle Safety	4,075,075	0.7
	Distracted Driving	2,334,950	0.4
	Graduated Driver Licensing	0	0.0
	Nonmotorized Safety[c]	n/a	n/a
Total		**$580,156,285**	**100.0**

Source: GHSA
[a] Includes open container (23 *CFR* Part 154) and repeat offender (23 *CFR* Part 164) funds.
[b] Excludes Puerto Rico, Guam, American Samoa, US Virgin Islands, and Indian Nations.
[c] Nonmotorized Safety was added as a priority area with the passage of the FAST Act in 2015, and Nonmotorized Safety grants were first awarded in fiscal year 2017.

[70] For example, to receive occupant protection funds, all states must meet certain criteria, including participating in the "Click It or Ticket" national campaign. However, states with lower rates of seat belt use must meet additional criteria and their use of the funds is restricted to particular activities involving enforcement, child safety seats, and information systems (23 *CFR* Part 405). Thereby, National Priority Safety Program grants encourage states with lower safety performance to take specific actions to improve their outcomes in each priority area.

The Highway Safety Program allows states significant leeway to spend funds according to their particular traffic safety priorities, including speeding; it does not provide a means to encourage states to focus on national priorities. In contrast, National Priority Safety Program grants are specifically designed to encourage states to focus additional traffic safety efforts in areas of national importance, but these funds currently cannot be used for speed management. The NTSB concludes that current federal-aid programs do not require or incentivize states to fund speed management activities at a level commensurate with the national impact of speeding on fatalities and injuries. Thus, the NTSB recommends that NHTSA establish a program to incentivize state and local speed management activities.

3.5.3 DOT Cross-Agency Coordination

In 2005, the DOT Speed Management Team produced a strategic plan to reduce speeding-related fatalities; that plan was updated in 2014 (DOT 2005; DOT 2014). The 2014 Speed Management Program Plan includes 71 planned actions to be completed within 5 years in the areas of data and data-driven approaches, research and evaluation, technology, enforcement and adjudication, engineering, and education and communications. Twenty-nine of the actions are in "priority areas that warrant immediate, more focused attention," and 22 of the actions are carryovers from the 2005 plan (DOT 2014).

The focus areas in the Speed Management Program Plan address several of the same safety issues identified in this study, and the planned actions complement the recommendations the NTSB makes as a result. For example, actions related to ASE include developing a model contract for states and municipalities to use when working with a vendor, and identifying "practices that contribute to public acceptance and reinforce fairness" of ASE (DOT 2014). Additionally, actions related to a national traffic safety campaign for speeding include evaluating the existing communications materials, developing new creative concepts, and launching a new communications campaign.

However, progress on the Speed Management Program Plan actions has been slow. Table 10 shows the status of the 71 planned actions as of December 2016, which members of the Speed Management Team manually compiled in response to the NTSB's request. Halfway through the 5-year plan timeline, 8 of the 71 planned actions have been completed, 35 are ongoing, 25 have yet to start, and 3 actions have been discontinued due to the MAP-21 prohibition on using federal grant funds for ASE.

Table 10. Status of DOT Speed Management Program Plan actions as of December 2016

Status	All Actions		Priority Actions	
	Number	%	Number	%
Discontinued	3	4.2	0	0.0
Pending	25	35.2	7	24.1
Ongoing	35	49.3	18	62.1
Completed	8	11.3	4	13.8
Total	**71**	**100.0**	**29**	**100.0**

Source: DOT Speed Management Team

Members of the DOT Speed Management Team stated that there is no one responsible for tracking the overall progress of the planned actions or ensuring that they are incorporated into DOT agency work plans. Therefore, the NTSB concludes that the DOT Speed Management Program Plan identifies important actions to reduce speeding-related fatalities, but the DOT has not tracked or ensured the timely implementation of these actions. Consequently, the NTSB recommends that the DOT complete the actions called for in its 2014 Speed Management Program Plan, and periodically publish status reports on the progress it has made.

4 Conclusions

4.1 Findings

1. Speed increases the likelihood of serious and fatal crash involvement, although the exact relationship is complex due to many factors.

2. Speed increases the injury severity of a crash.

3. Drivers report understanding that speeding is a threat to safety but acknowledge it is a common driving behavior in the United States.

4. The *Manual on Uniform Traffic Control Devices* guidance for setting speed limits in speed zones is based on the 85th percentile speed, but there is not strong evidence that, within a given traffic flow, the 85th percentile speed equates to the speed with the lowest crash involvement rate on all road types.

5. Unintended consequences of the reliance on using the 85th percentile speed for changing speed limits in speed zones include higher operating speeds and new, higher 85th percentile speeds in the speed zones, and an increase in operating speeds outside the speed zones.

6. Expert systems such as USLIMITS2 can improve the setting of speed limits by allowing traffic engineers to systematically incorporate crash statistics and other factors in addition to the 85th percentile speed, and to validate their engineering studies.

7. The safe system approach to setting speed limits in urban areas is an improvement over conventional approaches because it considers the vulnerability of all road users.

8. Speeding-related performance measures are needed to determine the effectiveness of data-driven, high-visibility enforcement programs and to communicate the value of these programs to law enforcement officers and the public.

9. The involvement of speeding passenger vehicles in fatal crashes is underestimated.

10. The lack of consistent law enforcement reporting of speeding-related crashes hinders the effective implementation of data-driven speed enforcement programs.

11. Automated speed enforcement is an effective countermeasure to reduce speeding-related crashes, fatalities, and injuries.

12. The lack of state-level automated speed enforcement (ASE) enabling legislation, and restrictions on the use of ASE in states where legislation exists, have led to underuse of this effective speeding countermeasure.

13. Federal guidelines for automated speed enforcement (ASE) programs do not reflect the latest technologies and operating practices and are not very effective because their existence is not well known among the ASE program administrators.

14. Point-to-point speed enforcement has been shown to be an effective speeding countermeasure internationally, but it is not currently used in the United States.

15. Intelligent speed adaptation is an effective vehicle technology to reduce speeding.

16. New car safety ratings are effective in incentivizing consumers to purchase passenger vehicles with advanced safety systems.

17. Traffic safety campaigns that include highly publicized, increased enforcement can be an effective speeding countermeasure, but their inconsistent and infrequent use by states hinders their effectiveness.

18. The current level of emphasis on speeding as a national traffic safety issue is lower than warranted and insufficient to achieve the goal of zero traffic fatalities in the United States.

19. Current federal-aid programs do not require or incentivize states to fund speed management activities at a level commensurate with the national impact of speeding on fatalities and injuries.

20. The US Department of Transportation (DOT) Speed Management Program Plan identifies important actions to reduce speeding-related fatalities, but the DOT has not tracked or ensured the timely implementation of these actions.

5 Recommendations

As a result of this safety study, the National Transportation Safety Board makes the following safety recommendations:

To the US Department of Transportation:

Complete the actions called for in your 2014 Speed Management Program Plan, and periodically publish status reports on the progress you have made. (H-17-18)

To the National Highway Traffic Safety Administration:

Identify speeding-related performance measures to be used by local law enforcement agencies, including—but not limited to—the numbers and locations of speeding-related crashes of different injury severity levels, speeding citations, and warnings, and establish a consistent method for evaluating data-driven, high-visibility enforcement programs to reduce speeding. Disseminate the performance measures and evaluation method to local law enforcement agencies. (H-17-19)

Identify best practices for communicating with law enforcement officers and the public about the effectiveness of data-driven, high-visibility enforcement programs to reduce speeding, and disseminate the best practices to local law enforcement agencies. (H-17-20)

Work with the Governors Highway Safety Association, the International Association of Chiefs of Police, and the National Sheriffs' Association to develop and implement a program to increase the adoption of speeding-related Model Minimum Uniform Crash Criteria Guideline data elements and improve consistency in law enforcement reporting of speeding-related crashes. (H-17-21)

Work with the Federal Highway Administration to update the Speed Enforcement Camera Systems Operational Guidelines to reflect the latest automated speed enforcement (ASE) technologies and operating practices, and promote the updated guidelines among ASE program administrators. (H-17-22)

Work with the Federal Highway Administration to assess the effectiveness of point-to-point speed enforcement in the United States and, based on the results of that assessment, update the Speed Enforcement Camera Systems Operational Guidelines, as appropriate. (H-17-23)

Incentivize passenger vehicle manufacturers and consumers to adopt intelligent speed adaptation (ISA) systems by, for example, including ISA in the New Car Assessment Program. (H-17-24)

Collaborate with other traffic safety stakeholders to develop and implement an ongoing program to increase public awareness of speeding as a national traffic safety issue. The program should include, but not be limited to, initiating an annual enforcement mobilization directed at speeding drivers. (H-17-25)

Establish a program to incentivize state and local speed management activities. (H-17-26)

To the Federal Highway Administration:

Revise Section 2B.13 of the Manual on Uniform Traffic Control Devices so that the factors currently listed as optional for all engineering studies are required, require that an expert system such as USLIMITS2 be used as a validation tool, and remove the guidance that speed limits in speed zones should be within 5 mph of the 85th percentile speed. (H-17-27)

Revise Section 2B.13 of the Manual on Uniform Traffic Control Devices to, at a minimum, incorporate the safe system approach for urban roads to strengthen protection for vulnerable road users. (H-17-28)

Work with the National Highway Traffic Safety Administration to update the Speed Enforcement Camera Systems Operational Guidelines to reflect the latest automated speed enforcement (ASE) technologies and operating practices, and promote the updated guidelines among ASE program administrators. (H-17-29)

Work with the National Highway Traffic Safety Administration to assess the effectiveness of point-to-point speed enforcement in the United States and, based on the results of that assessment, update the Speed Enforcement Camera Systems Operational Guidelines, as appropriate. (H-17-30)

To the seven states prohibiting automated speed enforcement:

Amend current laws to authorize state and local agencies to use automated speed enforcement. (H-17-31)

To the 28 states without automated speed enforcement laws:

Authorize state and local agencies to use automated speed enforcement. (H-17-32)

To the 15 states with automated speed enforcement restrictions:

Amend current laws to remove operational and location restrictions on the use of automated speed enforcement, except where such restrictions are necessary to align with best practices. (H-17-33)

To the Governors Highway Safety Association:

Work with the National Highway Traffic Safety Administration, the International Association of Chiefs of Police, and the National Sheriffs' Association to develop and implement a program to increase the adoption of speeding-related Model Minimum Uniform Crash Criteria Guideline data elements and improve consistency in law enforcement reporting of speeding-related crashes. (H-17-34)

To the International Association of Chiefs of Police:

Work with the National Highway Traffic Safety Administration, the Governors Highway Safety Association, and the National Sheriffs' Association to develop and implement a program to increase the adoption of speeding-related Model Minimum Uniform Crash Criteria Guideline data elements and improve consistency in law enforcement reporting of speeding-related crashes. (H-17-35)

To the National Sheriffs' Association:

Work with the National Highway Traffic Safety Administration, the Governors Highway Safety Association, and the International Association of Chiefs of Police to develop and implement a program to increase the adoption of speeding-related Model Minimum Uniform Crash Criteria Guideline data elements and improve consistency in law enforcement reporting of speeding-related crashes. (H-17-36)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT, III
Acting Chairman

CHRISTOPHER A. HART
Member

EARL F. WEENER
Member

T. BELLA DINH-ZARR
Member

Adopted: July 25, 2017

Board Member Statement

Member T. Bella Dinh-Zarr filed the following statement on August 1, 2017, concurring in part and dissenting in part:

Speeding has long been an important but difficult safety issue to address. This publication is the first study on speeding undertaken by the NTSB in our 50-year history. I commend staff for proposing and completing this study and for their careful analysis of current research. As staff explained in response to my questions during the Board Meeting, this study was meant to cover certain aspects of speeding and certain solutions. Nevertheless, although it does not appear in the Executive Summary and Conclusions, it is important to underscore that the full report does briefly review two topics of great interest and importance: road design and vulnerable road users. I would like to further discuss these issues and their importance to speeding and to preventing speeding-related deaths and injuries.

Road design is integral to the analysis of speeding and, while the report focuses on countermeasures that staff considered less widely accepted, it is important to note that road design to address speed-related crashes is not yet widely *implemented*, but should be. Some states (and other types of jurisdictions such as cities and counties) are already addressing speed-related crashes using road design, by using FARS data related to infrastructure and other data-driven measures. Other states can learn from them. Some states, as I have seen first-hand, are already including speed as an emphasis area in their Strategic Highway Safety Plans (SHSP). Some jurisdictions are using AASHTO's Green Book and other design manuals and some jurisdictions are using road design features that enhance compliance for lower speed limits rather than simply lowering speed limits. Federal government agencies can, and should, be given the ability to foster these types of best practices in which jurisdictions take a systemic approach to identifying locations prone to speeding-related crashes and correcting them in the manner they have determined is most effective using data.

Although this report focuses on passenger vehicles, current discussions about speeding must necessarily include people who walk and bike. The safe systems approach discussed in the report incorporates the needs of all road users, especially vulnerable ones. It is widely acknowledged among road safety professionals that interventions that prevent the deaths of the most vulnerable road users will benefit *all* road users. Some states and other jurisdictions have acknowledged this safety tenet by including pedestrians and cyclists in their SHSPs. Other jurisdictions should be encouraged to follow these best practice examples.

Overall, it is important to recognize that states, cities, and other jurisdictions already may be addressing speed in effective ways – even if we were not able to include it in our report due to the focus. Automated speed enforcement (ASE) was covered thoroughly in the report and three different recommendations were made to states, depending on the status of their laws related to ASE. I proposed, and still strongly believe, that combining the 3 recommendations into one recommendation to all 50 states and D.C. to examine current laws and implement ASE "to the fullest extent possible" would allow each state to advance ASE and safety most effectively, rather than focusing simply on reducing the prohibitions to ASE. By allowing states the freedom to be creative in implementing an effective technology (such as ASE), we are giving states a proven safety tool rather than prescriptively telling states how to use it. States (and other jurisdictions) know their communities best and our safety recommendations should give them the information and the freedom to advance safety in the manner they choose.

Appendixes

Appendix A: Speeding-Related National Transportation Safety Board Investigations

Table A-1 lists 49 National Transportation Safety Board (NTSB) major highway investigations in which speeding or speed was found to be a safety issue, or a causal or contributing factor.

Table A-1. Speeding-related NTSB major highway investigations

Date	Location	Description	Report Number
6/25/2015	Chattanooga, TN	Multivehicle Work Zone Crash on Interstate 75	HAR-16/01
6/7/2014	Cranbury, NJ	Multivehicle Work Zone Crash on Interstate 95	HAR-15/02
2/16/2012	Chesterfield, NJ	School Bus and Truck Collision at Intersection	HAR-13/01
3/12/2011	New York City, NY	Motorcoach Run-Off-the-Road and Collision with Vertical Highway Signpost, Interstate 95 Southbound	HAR-12/01
1/6/2008	Mexican Hat, UT	Motorcoach Rollover	HAR-09/01
10/1/2003	Hampshire, IL	Multivehicle Collision on Interstate 90, Hampshire-Marengo Toll Plaza	HAR-06/03
5/1/2003	Linden, NJ	Passenger Vehicle Median Crossover and Head-On with Another Passenger Vehicle	HAR-06/02
2/14/2003	Hewitt, TX	Motorcoach Median Crossover and Collision with Sport Utility Vehicle	HAR-05/02
1/17/2003	Fairfield, CT	Multiple Vehicle Collision on Interstate 95	HAR-05/03
2/1/2002	Largo, MD	Ford Explorer Sport Collision with Ford Windstar Minivan and Jeep Grand Cherokee on Interstate 95/495	HAR-03/02
10/13/2001	Omaha, NE	School Bus Run-Off-Bridge Accident	HAR-04/01
2/12/1997	Slinger, WI	Multiple Vehicle Crossover Accident	HAR-98/01
1/9/1995	Menifee, AR	Multiple Vehicle Collision with Fire During Fog near Milepost 118 on Interstate 40	HAR-95/03
12/11/1990	Calhoun, TN	Multiple-Vehicle Collisions and Fire During Limited Visibility on Interstate 75	HAR-92/02
7/26/1990	Sutton, WV	Multiple Vehicle Collision and Fire in a Work Zone on Interstate Highway 79	HAR-91/01
11/19/1988	Nashville, TN	Greyhound Lines, Inc., Intercity Bus Loss of Control and Overturn Interstate Highway 95	HAR-89/03
5/4/1987	Beaumont, TX	Tractor-Semitrailer/Intercity Bus Head-On Collision, Interstate 10	HAR-88/01
9/29/1986	Carney's Point, NJ	Charter Bus/Tractor-Semitrailer Rear-End Collision	HAR-87/03
7/14/1986	Brinkley, AR	Trailways Lines, Inc., Intercity Bus Collision with Rising Fast Trucking Company, Inc., Interstate Highway 40	HAR-87/05
5/30/1986	Walker, CA	Intercity Tour Bus Loss of Control and Rollover Into the West Walker River	HAR-87/04

Date	Location	Description	Report Number
11/11/1985	St. Louis County, MO	Schoolbus Loss of Control and Collision with Guard Rail and Sign Pillar, US Highway 70 near Lucas and Hunt Road	HAR-87/02
8/25/1985	Frederick, MD	Intercity Bus Loss of Control and Collision with Bridge Rail on Interstate 70	HAR-87/01
6/21/1985	Van Buren, AR	Tractor-Semitrailer/Station Wagon Runaway, Collision, and Fire	HAR-86/03
11/30/1983	Livingston, TX	Trailways Lines, Inc., Bus/E.A. Holder, Inc., Truck, Rear End Collision and Bus Run-Off-Bridge, US Route 59	HAR-84/04
4/5/1983	Holmesville, NY	Valley Supply Co. Truck Towing Farm Plow/Anchor Motor Freight Inc. Car Carrier Truck/New York State Association for Retarded Children Bus Collision and Fire, State Route 8	HAR-84/01
3/25/1983	Newport, AR	Jonesboro School District Schoolbus Run-Off-Road and Overturn, State Highway 214 at State Highway 18	HAR-83/03
2/28/1983	Ocala, FL	Multiple Vehicle Collisions and Fires Under Limited Visibility Conditions, Interstate Route 75	HAR-83/04
10/8/1982	Lemoore, CA	J.C. Sales, Inc., Tractor-Semi-Trailer/Calvary Baptist Church Van Collision, State Route 198 at 19th Avenue	HAR-83/02
4/7/1982	Oakland, CA	Multiple Vehicle Collisions and Fire, Caldecott Tunnel	HAR-83/01
11/14/1981	Canon City, UT	Pacific Intermountain Express Tractor Cargo Tank Semitrailer Eagle/F.B. Truck Lines, Inc., Tractor Lowboy Semitrailer Collision and Fire, US Route 50	HAR-82/03
2/18/1981	Frostburg, MD	Direct Transit Lines, Inc., Tractor-Semitrailer/Multiple Vehicle Collision and Fire, US Route 40	HAR-81/03
11/10/1980	San Bernardino, CA	Multiple Vehicle Collisions and Fire in Fog, Interstate 50	HAR-81/02
2/23/1980	Perry, OK	Head-On Collision of Auto and Pickup Truck, US Route 64	HAR-80/04
9/22/1979	Indiana, PA	Two-Vehicle Collision and Fire, US Route 422	HAR-80/03
8/22/1979	Laramie, WY	Multiple Vehicle Collision in a Construction Zone, US Interstate 80	HAR-80/01
6/8/1979	New York, NY	Multiple Vehicle Median Barrier Crossover and Collision, Grand Central Parkway	HAR-79/08
4/23/1979	Crofton, MD	Ford Courier Pickup Truck/Fixed Object Collision, Patuxent Road	HAR-79/06
11/11/1978	Alhambra, CA	Stationwagon Penetration of Bridgerail, I-10	HAR-79/05
8/22/1978	Littleton, NH	Ross Ambulance Service, Ambulance Overturn, State Route 116	HAR-79/04
9/25/1977	St. Louis, MO	Gateway Transportation Company, Inc., Tractor-Semitrailer Penetration of Median Barrier and Collision with Automobile, I-70	HAR-79/03
9/24/1977	Beattyville, KY	Usher Transport, Inc., Tractor-Cargo-Tank-Semitrailer Overturn and Fire, State Route 11	HAR-78/04
5/11/1976	Houston, TX	Transport Company of Texas, Tractor Semitrailer (Tank) Collision with Bridge Column and Sudden Dispersal of Anhydrous Ammonia Cargo	HAR-77/01

Date	Location	Description	Report Number
12/4/1975	Seattle, WA	Union Oil Company of California, Tank Truck and Full Trailer Overturn and Fire	HAR-76/07
6/6/1975	Hamilton, GA	Collision of Hubert Roten Trucking Company Truck and Skinner Corporation Bus	HAR-76/05
2/28/1975	Corona, CA	Multiple Vehicle Collisions in Fog	HAR-75/07
7/11/1970	San Francisco, CA	Two Car Collision, Southern Approach to Golden Gate Bridge	HAR-71/05
11/29/1969	New Jersey Turnpike, NJ	Multiple Vehicle Collisions Under Fog Conditions, Followed by Fires	HAR-71/03
11/24/1969	Petersburg, IN	Interstate Bus/Automobile Collision and Rollover on Indiana Route 57	HAR-71/04
8/12/1967	Joliet, IL	Motor Carrier Highway Accident	HAR-1967

Appendix B: Road Function Classifications

This appendix summarizes the Federal Highway Administration guidance on road function classification for arterial, collector, and local roads, and provides the corresponding attributes of the "road_fnc" data element in the Fatality Analysis Reporting System (FARS) database (FHWA 2013; NHTSA 2015a).

Arterials

Arterials are roadways that provide a high level of mobility, primarily serve long-distance travel, are typically designed as either access-controlled or partially access-controlled, and have higher posted speed limits than most other types of roads. Principal arterials and minor arterials are subcategories of arterials.

Principal arterials include interstates (which are access-controlled), other freeways and expressways (which look very similar to interstates and are also access-controlled), and other principal arterials (which are unlike interstates and other freeways and expressways in that abutting land uses can be served directly). Table B-1 shows roadway characteristics and FARS attributes of principal arterials by land use.

Table B-1. Roadway characteristics and FARS attributes for principal arterials, by land use

Principal Arterials	**Land Use**	
	Urban	**Rural**
Roadway Characteristics	• Serve major activity centers, highest traffic volume corridors and longest trip demands • Carry high proportion of total urban travel on minimum of mileage • Interconnect and provide continuity for major rural corridors to accommodate trips entering and leaving urban area and movements through the urban area • Serve demand for intra-area travel between the central business district and outlying residential areas	• Serve corridor movements having trip length and travel density characteristics indicative of substantial statewide or interstate travel • Connect all or nearly all urbanized areas and a large majority of urban clusters with 25,000 and over population • Provide an integrated network of continuous routes without stub connections (that is, dead ends)
FARS "road_fnc" Attributes	• Interstates (11) • Other freeways and expressways (12) • Other principal arterials (13)	• Interstates (1) • Other principal arterials (2)

Minor arterials provide service for trips of moderate length, serve geographic areas that are smaller than their principal arterial counterparts, and offer connectivity to the principal arterial system. Table B-2 shows roadway characteristics and FARS attributes of minor arterials by land use.

Table B-2. Roadway characteristics and FARS attributes for minor arterials, by land use

Minor Arterials	**Land Use**	
	Urban	**Rural**
Roadway Characteristics	• Interconnect and augment the higher-level arterials • Serve trips of moderate length at a somewhat lower level of travel mobility than principal arterials • Distribute traffic to smaller geographic areas than those served by higher-level arterials • Provide more land access than principal arterials without penetrating identifiable neighborhoods • Provide urban connections for rural collectors	• Link cities and larger towns (and other major destinations such as resorts capable of attracting travel over long distances) and form an integrated network providing interstate and inter-county service • Be spaced at intervals, consistent with population density, so that all developed areas within the state are within a reasonable distance of an arterial roadway • Provide service to corridors with trip lengths and travel density greater than those served by rural collectors and local roads and with relatively high travel speeds and minimum interference to through movement
FARS "road_fnc" Attributes	• Minor arterial (14)	• Minor arterial (3)

Collectors

Collectors provide a balanced blend of mobility and access; collect traffic from local roads; connect traffic to arterial roadways; and provide traffic circulation within residential neighborhoods and commercial, industrial, and civic districts. Major collectors and minor collectors are subcategories of collectors. Table B-3 shows roadway characteristics and FARS attributes for major collectors by land use. Table B-4 shows roadway characteristics and FARS attributes for minor collectors by land use.

Table B-3. Roadway characteristics and FARS attributes for major collectors, by land use

Major Collectors	Land Use	
	Urban	**Rural**
Roadway Characteristics	• Serve both land access and traffic circulation in higher density residential, and commercial/industrial areas • Penetrate residential neighborhoods, often for significant distances • Distribute and channel trips between local roads and arterials, usually over a distance of greater than three-quarters of a mile • Operating characteristics include higher speeds and more signalized intersections	• Provide service to any county seat not on an arterial route, to the larger towns not directly served by the higher systems and to other traffic generators of equivalent intra-county importance such as consolidated schools, shipping points, county parks, and important mining and agricultural areas • Link these places with nearby larger towns and cities or with arterial routes • Serve the most important intra-county travel corridors
FARS "road_fnc" Attributes	• Collector (15)	• Major collector (4)

Table B-4. Roadway characteristics and FARS attributes for minor collectors, by land use

Minor Collectors	Land Use	
	Urban	**Rural**
Roadway Characteristics	• Serve both land access and traffic circulation in lower density residential and commercial/industrial areas • Penetrate residential neighborhoods, often only for a short distance • Distribute and channel trips between local roads and arterials, usually over a distance of less than three-quarters of a mile • Operating characteristics include lower speeds and fewer signalized intersections	• Be spaced at intervals, consistent with population density, to collect traffic from local roads and bring all developed areas within reasonable distance of a collector • Provide service to smaller communities not served by a higher-class facility • Link locally important traffic generators with their rural hinterlands
FARS "road_fnc" Attributes	• Collector (15)	• Minor collector (5)

Locals

Local roadways provide a high level of accessibility and direct access to multiple properties. They are lined with intersecting access points and constitute the mileage not classified as part of the arterial or collector systems. Speed limits on local roads are kept low to promote safe traffic operations. Table B-5 shows roadway characteristics and FARS attributes of locals, by land use.

Table B-5. Roadway characteristics and FARS attributes of locals, by land use

Locals	Land Use	
	Urban	**Rural**
Roadway Characteristics	• Provide direct access to adjacent land • Provide access to higher systems • Carry no through traffic movement	• Serve primarily to provide access to adjacent land • Provide service to travel over short distances as compared to higher classification categories
FARS "road_fnc" Attributes	• Local road and street (16)	• Local road and street (6)

Appendix C: *Manual on Uniform Traffic Control Devices* Speed Limit Guidance

This appendix includes Section 2B.13 of the *Manual on Uniform Traffic Control Devices*, which serves as the standard for setting speed limits in speed zones (FHWA 2012a).

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02 Highway agencies may develop and apply criteria for determining the applicability of In-Street Pedestrian Crossing signs.

Standard:

03 **If used, the In-Street Pedestrian Crossing sign shall be placed in the roadway at the crosswalk location on the center line, on a lane line, or on a median island. The In-Street Pedestrian Crossing sign shall not be post-mounted on the left-hand or right-hand side of the roadway.**

04 **If used, the Overhead Pedestrian Crossing sign shall be placed over the roadway at the crosswalk location.**

05 **An In-Street or Overhead Pedestrian Crossing sign shall not be placed in advance of the crosswalk to educate road users about the State law prior to reaching the crosswalk, nor shall it be installed as an educational display that is not near any crosswalk.**

Guidance:

06 *If an island (see Chapter 3I) is available, the In-Street Pedestrian Crossing sign, if used, should be placed on the island.*

Option:

07 If a Pedestrian Crossing (W11-2) warning sign is used in combination with an In-Street or an Overhead Pedestrian Crossing sign, the W11-2 sign with a diagonal downward pointing arrow (W16-7P) plaque may be post-mounted on the right-hand side of the roadway at the crosswalk location.

Standard:

08 **The In-Street Pedestrian Crossing sign and the Overhead Pedestrian Crossing sign shall not be used at signalized locations.**

09 **The STOP FOR legend shall only be used in States where the State law specifically requires that a driver must stop for a pedestrian in a crosswalk.**

10 **The In-Street Pedestrian Crossing sign shall have a black legend (except for the red STOP or YIELD sign symbols) and border on a white background, surrounded by an outer yellow or fluorescent yellow-green background area (see Figure 2B-2). The Overhead Pedestrian Crossing sign shall have a black legend and border on a yellow or fluorescent yellow-green background at the top of the sign and a black legend and border on a white background at the bottom of the sign (see Figure 2B-2).**

11 **Unless the In-Street Pedestrian Crossing sign is placed on a physical island, the sign support shall be designed to bend over and then bounce back to its normal vertical position when struck by a vehicle.**

Support:

12 The Provisions of Section 2A.18 concerning mounting height are not applicable for the In-Street Pedestrian Crossing sign.

Standard:

13 **The top of an In-Street Pedestrian Crossing sign shall be a maximum of 4 feet above the pavement surface. The top of an In-Street Pedestrian Crossing sign placed in an island shall be a maximum of 4 feet above the island surface.**

Option:

14 The In-Street Pedestrian Crossing sign may be used seasonably to prevent damage in winter because of plowing operations, and may be removed at night if the pedestrian activity at night is minimal.

15 In-Street Pedestrian Crossing signs, Overhead Pedestrian Crossing signs, and Yield Here To (Stop Here For) Pedestrians signs may be used together at the same crosswalk.

Section 2B.13 Speed Limit Sign (R2-1)

Standard:

01 **Speed zones (other than statutory speed limits) shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall include an analysis of the current speed distribution of free-flowing vehicles.**

02 **The Speed Limit (R2-1) sign (see Figure 2B-3) shall display the limit established by law, ordinance, regulation, or as adopted by the authorized agency based on the engineering study. The speed limits displayed shall be in multiples of 5 mph.**

03 **Speed Limit (R2-1) signs, indicating speed limits for which posting is required by law, shall be located at the points of change from one speed limit to another.**

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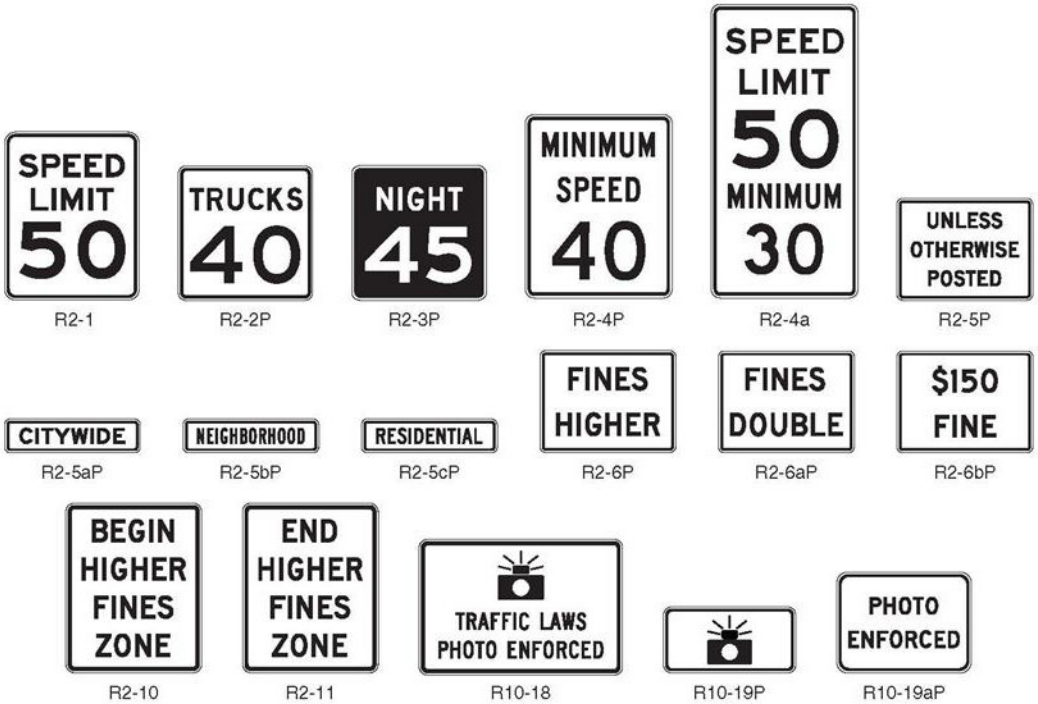
Figure 2B-3. Speed Limit and Photo Enforcement Signs and Plaques



04 **At the downstream end of the section to which a speed limit applies, a Speed Limit sign showing the next speed limit shall be installed. Additional Speed Limit signs shall be installed beyond major intersections and at other locations where it is necessary to remind road users of the speed limit that is applicable.**

05 **Speed Limit signs indicating the statutory speed limits shall be installed at entrances to the State and, where appropriate, at jurisdictional boundaries in urban areas.**

Support:

06 In general, the maximum speed limits applicable to rural and urban roads are established:

A. Statutorily – a maximum speed limit applicable to a particular class of road, such as freeways or city streets, that is established by State law; or
B. As altered speed zones – based on engineering studies.

07 State statutory limits might restrict the maximum speed limit that can be established on a particular road, notwithstanding what an engineering study might indicate.

Option:

08 If a jurisdiction has a policy of installing Speed Limit signs in accordance with statutory requirements only on the streets that enter a city, neighborhood, or residential area to indicate the speed limit that is applicable to the entire city, neighborhood, or residential area unless otherwise posted, a CITYWIDE (R2-5aP), NEIGHBORHOOD (R2-5bP), or RESIDENTIAL (R2-5cP) plaque may be mounted above the Speed Limit sign and an UNLESS OTHERWISE POSTED (R2-5P) plaque may be mounted below the Speed Limit sign (see Figure 2B-3).

Guidance:

09 *A Reduced Speed Limit Ahead (W3-5 or W3-5a) sign (see Section 2C.38) should be used to inform road users of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgment indicates the need for advance notice to comply with the posted speed limit ahead.*

10 *States and local agencies should conduct engineering studies to reevaluate non-statutory speed limits on segments of their roadways that have undergone significant changes since the last review, such as the addition or elimination of parking or driveways, changes in the number of travel lanes, changes in the configuration of bicycle lanes, changes in traffic control signal coordination, or significant changes in traffic volumes.*

11 *No more than three speed limits should be displayed on any one Speed Limit sign or assembly.*

12 *When a speed limit within a speed zone is posted, it should be within 5 mph of the 85th-percentile speed of free-flowing traffic.*

13 *Speed studies for signalized intersection approaches should be taken outside the influence area of the traffic control signal, which is generally considered to be approximately 1/2 mile, to avoid obtaining skewed results for the 85th-percentile speed.*

Support:

14 Advance warning signs and other traffic control devices to attract the motorist's attention to a signalized intersection are usually more effective than a reduced speed limit zone.

Guidance:

15 *An advisory speed plaque (see Section 2C.08) mounted below a warning sign should be used to warn road users of an advisory speed for a roadway condition. A Speed Limit sign should not be used for this situation.*

Option:

16 Other factors that may be considered when establishing or reevaluating speed limits are the following:

A. Road characteristics, shoulder condition, grade, alignment, and sight distance;
B. The pace;
C. Roadside development and environment;
D. Parking practices and pedestrian activity; and
E. Reported crash experience for at least a 12-month period.

17 Two types of Speed Limit signs may be used: one to designate passenger car speeds, including any nighttime information or minimum speed limit that might apply; and the other to show any special speed limits for trucks and other vehicles.

18 A changeable message sign that changes the speed limit for traffic and ambient conditions may be installed provided that the appropriate speed limit is displayed at the proper times.

19 A changeable message sign that displays to approaching drivers the speed at which they are traveling may be installed in conjunction with a Speed Limit sign.

Guidance:

20 *If a changeable message sign displaying approach speeds is installed, the legend YOUR SPEED XX MPH or such similar legend should be displayed. The color of the changeable message legend should be a yellow legend on a black background or the reverse of these colors.*

Support:

21 Advisory Speed signs and plaques are discussed in Sections 2C.08 and 2C.14. Temporary Traffic Control Zone Speed signs are discussed in Part 6. The WORK ZONE (G20-5aP) plaque intended for installation above a Speed Limit sign is discussed in Section 6F.12. School Speed Limit signs are discussed in Section 7B.15.

Section 2B.14 Truck Speed Limit Plaque (R2-2P)

Standard:

01 **Where a special speed limit applies to trucks or other vehicles, the legend TRUCKS XX or such similar legend shall be displayed below the legend Speed Limit XX on the same sign or on a separate R2-2P plaque (see Figure 2B-3) below the standard legend.**

Section 2B.15 Night Speed Limit Plaque (R2-3P)

Standard:

01 **Where different speed limits are prescribed for day and night, both limits shall be posted.**

Appendix D: Speeding Categories

This appendix lists the attributes of the "speeding related" data element in the *Model Minimum Uniform Crash Criteria* (*MMUCC*) *Guideline* and the corresponding attributes of the "speedrel" data element in the Fatality Analysis Reporting System (FARS) database. The *MMUCC Guideline* and FARS definitions for speeding are both based on the determination of officers, with the *MMUCC Guideline* stating that these categories are an "indication of whether the investigating officer suspects that the driver involved in the crash was speeding based on verbal or physical evidence and not on speculation alone," and FARS documentation stating that each category "records whether the driver's speed was related to the crash as indicated by law enforcement" (GHSA and NHTSA 2012; NHTSA 2015a). See table D-1.

Table D-1. Speeding categories in *MMUCC Guideline* and FARS database

Speeding Category	***MMUCC Guideline* "speeding related" Data Element**		**FARS "speedrel" Data Element**
	Attribute	**Definition**	**Attribute**
Not Speeding	No	(none)	No
Exceeding Speed Limit	Exceeded Speed Limit	When a motor vehicle is traveling above the posted/statutory speed limit on certain designated roadways or by certain types of vehicles (for example, for trucks, buses, motorcycles, on bridge, at night, in school zone, and so on)	Yes, Exceeded Speed Limit
Too Fast for Conditions	Too Fast for Conditions	Traveling at a speed that was unsafe for the road, weather, traffic or other environmental conditions at the time	Yes, Too Fast for Conditions
Racing	Racing	When two or more motor vehicles are engaged in a speed-related competition on the trafficway	Yes, Racing
Speeding of Unspecific Type	n/a	n/a	Yes, Specifics Unknown
No Driver Information	n/a	n/a	No Driver Present / Unknown if Driver Present
Unknown if Speeding	Unknown	(none)	Unknown

Appendix E: State Laws Regarding Automated Speed Enforcement

Table E-1 summarizes state laws regarding automated speed enforcement (ASE) and notes whether any ASE programs are active in each state (IIHS 2016a). The District of Columbia allows ASE throughout its jurisdiction and operates an ASE program.

Table E-1. ASE state laws and active programs, April 2017

State	ASE State Law	Active ASE Programs	Notes
Alabama	No state law	Yes	
Alaska	No state law	No	
Arizona	Allowed with restrictions	Yes	Prohibited on state highways; contractors must be licensed as private investigators.
Arkansas	Allowed with restrictions	No	Officer must be present and citation issued at time of violation
California	No state law	No	
Colorado	Allowed with restrictions	Yes	Restricted to construction and school zones, residential areas, and streets that border a municipal park; officer or government employee must be present at time of violation.
Connecticut	No state law	No	
Delaware	No state law	No	
Florida	No state law	No	
Georgia	No state law	No	
Hawaii	No state law	No	
Idaho	No state law	No	
Illinois	Allowed with restrictions	Yes	Restricted to construction zones; allowed in school zones and park districts in municipalities with a population of 1,000,000 or more
Indiana	No state law	No	
Iowa	No state law	Yes	
Kansas	No state law	No	
Kentucky	No state law	No	
Louisiana	Allowed with restrictions	Yes	Restricted to specified jurisdictions and interstate work zones
Maine	Prohibited	No	
Maryland	Allowed with restrictions	Yes	Restricted to school zones, work zones on expressways or controlled access highways, and Montgomery County residential areas
Massachusetts	No state law	No	
Michigan	No state law	No	
Minnesota	No state law	No	
Mississippi	Prohibited	No	
Missouri	No state law	Yes	

State	ASE State Law	Active ASE Programs	Notes
Montana	No state law	No	
Nebraska	No state law	No	
Nevada	Allowed with restrictions	No	Equipment must be hand-held by officer or installed within law enforcement vehicle or facility
New Hampshire	Prohibited	No	
New Jersey	Prohibited	No	
New Mexico	No state law	Yes	
New York	Allowed with restrictions	Yes	Restricted to specified jurisdictions
North Carolina	No state law	No	
North Dakota	No state law	No	
Ohio	Allowed with restrictions	Yes	Officer must be present
Oklahoma	No state law	No	
Oregon	Allowed with restrictions	Yes	Restricted to specified jurisdictions, state highway construction zones, and Portland urban high crash corridors
Pennsylvania	No state law	No	
Rhode Island	Allowed with restrictions	No	Restricted to school zones
South Carolina	Allowed with restrictions	No	Restricted to use during declared states of emergency
South Dakota	No state law	No	
Tennessee	Allowed with restrictions	Yes	Restricted to school zones and s-curves inhibiting driver vision
Texas	Prohibited	No	
Utah	Allowed with restrictions	No	Restricted to school zones with speed limit of 30 mph or lower; officer must be present
Vermont	No state law	No	
Virginia	No state law	No	
Washington	Allowed with restrictions	Yes	Restricted to school zones and a single camera for any city west of the Cascade mountains with a population of more than 195,000 located in a county with a population of fewer than 1,500,000
West Virginia	Prohibited	No	
Wisconsin	Prohibited	No	
Wyoming	No state law	No	

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