Final Report for AAA-FTS Rating Project

MIT AgeLab Technical Report: 2013-27C

Proposed System for the Objective Evaluation of the Safety Benefits of Technologies and Initial Rating Values

Bruce Mehler, Bryan Reimer, Martin Lavallière, Jonathan Dobres, & Joseph F. Coughlin

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The AAA Foundation for Traffic Safety tasked the MIT AgeLab with developing a data-driven system for rating new in-vehicle technologies, analogous to NCAP crashworthiness, but extended to scalar evaluations of the objective safety benefits of emerging safety technologies (e.g., adaptive headlights, back-up cameras, lane-departure warning). Such a system was envisioned as having the potential to educate and guide consumers towards more confident and strategic purchasing decisions that may enhance automotive safety. Moreover, an evaluation of the status and extent of existing data on these safety systems was seen as a way of identifying possible research gaps in the present state of knowledge.

This report provides an overview of key project activities and observations made to date. It then details the concepts and methods upon which the proposed rating system is based. The system is further developed by applying it to the rating of a set of seven safety relevant technologies. The resulting ratings and documentation concerning the data used in making the ratings provide insight into the current status of our understanding of the actual safety benefits of the technologies. These initial ratings also provide a means of evaluating the extent to which the current scaling methodology and values appear to meet the project objectives. Possible reasons for considering adjustment of present scaling values and other rating relevant issues are discussed. Extensive background material and supporting documentation is provided in appendices and as associated documents.

Lead Project Contact: Bryan Reimer, Ph.D.

Massachusetts Institute of Technology > AgeLab > 77 Massachusetts Ave, E40-291, Cambridge, MA 02139
Phone: 617.452.2177 > fax: 617.258.7570 > reimer@mit.edu > agelab.mit.edu

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Executive Overview

The AAA Foundation for Traffic Safety tasked the MIT AgeLab with developing a data-driven system for rating the effectiveness of new in-vehicle technologies intended to improve driver safety. Such a system was envisioned as having the potential to educate and guide consumers towards more confident and strategic purchasing decisions, ideally encouraging adoption of technologies showing demonstrated safety benefit. Further, an evaluation of the status and extent of existing data was seen as a way of identifying research gaps in the present state of knowledge about these safety systems. It should be made clear that the focus of the project based on the mandate given to the MIT AgeLab was on given technologies as a class, not on a rating review of individual vehicle model implementations. Development of the rating system and identification of data was undertaken in consultation with identified academic, industrial, consumer, NGO, and governmental experts as well as with representatives of a majority of the major automotive manufacturers. Almost universal endorsement of the importance of this undertaking was voiced.

A top level rating structure has been developed that independently considers safety benefit potential and objectively demonstrated benefit. The latter values are often found to be lower than theoretical expectations. Factors that may be relevant to understanding why such differences appear have been identified as part of the overall project. The emphasis on ratings based on observed benefit for actual drivers under real-world conditions is a key aspect of why this system complements, rather than competes with, ratings developed by IIHS and NCAP which focus largely on controlled test track evaluations of engineered capability. In addition, the rating structure assesses benefit relative to overall crash, injury, and fatality rates – and in relation to the specific scenario / crash event type that a given technology is intended to address. This allows consumers to consider a technology relevant to their particular driving needs.

A total of seven technologies have been reviewed to date – two reference technologies (Electronic Stability Control and Adaptive Cruise Control) and five emergent safety technologies (Adaptive Headlights, Back-Up Cameras, Forward Collision Warning, Forward Collision Mitigation, and Lane Departure Warning). A major finding of the project so far has been that only relatively limited data is available upon which to objectively rate the real-world performance of most of these safety systems. A number of experts and industry representatives expressed some surprise at both the divergence between theoretical and observed benefit and the relative scarcity of data upon which to make objective assessments, while others were quite aware of these issues and the need for the development of objective data on real-world performance. This undertaking appears to have already succeeded in one of its goals by stimulating substantive constructive discussion and engagement within the research and industry based safety communities.

The report begins with a review of the original project objectives and an overview of key activities undertaken during the course of the project. Selected observations on the development of the proposed rating system follow, including a brief discussion of the evolving view of rating factors and concepts of scaling that were considered as the project developed. The issue of rating a technology class in contrast to rating specific vehicle implementations is summarized. Key concepts in the proposed rating system are then presented. In particular, the concepts of projected vs. demonstrated benefit and overall safety benefit vs. scenario specific benefit. A proposed approach to scaling ratings is presented. Detailed reviews of available data on each of the technologies were developed as a core component of the project and used to identify values to rate the technologies. The benefit values extracted from the reviews to assign ratings to each technology class are described. To appreciate the full context from which the ratings are drawn, readers are encouraged to see the more extensive technology review summaries provided in Appendix C. These reviews not only consider the issue of evaluating technology effectiveness, but also address topics including consumer awareness and trust, mobility significance, technology penetration, frequency of use, training and educational issues associated with the technologies, behavioral adaptation, demands placed upon the driver, vehicle type considerations, limitations and failure conditions, and differences between technology implementations. Several approaches to summarizing the ratings in a matrix format are presented. These are intended to be conceptual in nature rather than necessarily representing exact design format recommendations.

The report then presents a number of observations arising out of the work on the project. As already noted, a major point of discussion is the issue of the relatively limited body of objective data that is available to advise not only the consumer, but also the wider public and automotive industry on how these emerging safety technologies are actually performing. Also emphasized is the point that what is presented in this report is a proposed rating system; it is intended to encourage discussion and consideration of important issues related to the better understanding of safety technologies. The extent to which the approach and values proposed here are further developed and updated to keep pace with rapidly evolving technologies and increased scientific evaluation of their performance is seen as an open question. An extended consideration of limitations and points to be kept in mind follows. Comments and critiques from industry reviewers and various Advisory Panel members are recognized and integrated in this important section. Finally, we acknowledge the significant contributions of many individuals and groups to this project, while emphasizing that the conclusions expressed in this report are the responsibility of the authors and do not necessarily represent the opinions or formal positions of those contributors. With this in mind, we would like to extend our sincere appreciation to everyone who commented on or otherwise contributed to this undertaking and, in particular, to AAA-FTS for initiating and supporting the development of this work.

Project Objectives

This project was initiated in response to an RFP issued by the AAA Foundation for Traffic Safety (AAA-FTS) entitled *Effectiveness and Efficacy of Technologies to Reduce Older Driver Crashes*. Following discussions with the Foundation's R&D Committee, it was decided to expand the scope of the project to consider drivers across the lifespan.

The stated purpose of the RFP was to support research to identify and develop objective measures that could be used to construct a rating system to compare and contrast the effectiveness of a wide range of relatively new in-vehicle technologies that are relevant to enhancing driver safety. At the initiation of the project, we stated that we believed that this undertaking has the potential to provide a useful tool to aid consumers in making informed decisions about the purchase and use of safety systems. It was also seen as an opportunity to stimulate discussion and possible action within the safety research and manufacturer communities relative to developing a more comprehensive approach to thinking about safety and methods for objectively evaluating new technologies. Our experience interacting with numerous safety research, automotive manufacturer, and technology supplier professionals over the course of the project suggests that it has already had some impact on the latter front.

Overview of Key Project Activities

The RFP that initiated this project was issued in the Fall of 2011, the MIT AgeLab submitted an initial proposal on November 1, 2011, and based on questions and other feedback from AAA-FTS staff, a revised proposal was submitted on December 12th. Key members of the MIT AgeLab research presented a vision for the project and answered questions at the AAA-FTS Research and Development Advisory Committee meeting February 2-3, 2012. A formal Statement of Work (SOW) agreement between MIT and AAA-FTS was developed over the next several months. An overview of the flow of the project is provided through the listing of key project activity points below. (Regular phone conversations with AAA_FTS staff are not included in the listing.)

- **June 2012** - An agreement was signed and formal work on the project was initiated. Initial efforts focused on SOW tasks 1 and 2: review of potential factors for inclusion in a rating system and a review of relevant rating methodologies.
- **August 10, 2012** - A project planning and review meeting was held at MIT AgeLab with Jurek Grabowski of AAA-FTS. Among the topics covered were: the presentation of a white paper considering our review of rating methodologies (task 2) titled, *How Rating Scales Summarize Consumer Information*; a discussion of the process of factor identification and possible technologies to be considered; discussion concerning the creating of a panel of experts; and discussion concerning notification of industry about the project and the development of information sessions to encourage active industry engagement in the project.
- **October 4, 2012** – Project leads Bryan Reimer and Bruce Mehler met with Peter Kissinger and Jurek Grabowski at the AAA-FTS office in Washington D.C. Among the items covered were the MIT AgeLab's presentation of a second white paper, *Defining an In-Vehicle Technology Rating Scale in Terms of Safety, Convenience, and Comfort*. This

paper presented the concept of developing safety ratings within a broader context of a Three-Domain Model of vehicle technologies consisting of safety, comfort, and convenience features. The implications of this model for the range of factors to be considered in the rating of technologies were discussed along with further discussion on the formation of the expert panel.

- **November 1, 2012** – The task 3 deliverable, a progress report on the project was provided to AAA-FTS. Development of the factor list continued.
- **November – December 2012** – Interviews were conducted with safety experts, academics, and industry professionals to solicit input on the identification of factors that might ideally be considered in evaluating the effectiveness and overall benefit of safety technologies. Details on the individuals consulted and selected materials are provided in Appendix E. Common themes in most of the discussions were agreement that the project being undertaken by MIT AgeLab and AAA-FTS was important for both the consumer and the industry, that the it was a highly challenging task to identify an objective method of developing ratings, and a concern that only very limited objective data might be available to base ratings upon. A report on the first 8 interviews and resulting refinements in our listing of potential factors to consider in technology ratings (*Conceptualization of a Technology Safety Benefit Ratings System: Initial Conversations with Select Experts*) was sent to AAA-FTS on December 2. This document was updated on December 14th.
- **January 17, 2013** – Industry briefing before the Alliance of Automotive Manufacturers in Washington D.C. on the project to solicit input and cooperation in identifying relevant data on safety technologies. (This organization represents BMW, Chrysler, Ford, General Motors, Jaguar Land Rover, Mazda, Mercedes-Benz, Mitsubishi, Porsche, Toyota, Volkswagen, and Volvo.) Briefing slides used in this presentation are reproduced in Appendix F.
- **February 1, 2013** – Industry briefing before the Association of Global Automakers in Washington D.C. on the project to solicit input and cooperation in identifying relevant data on safety technologies. (This organization represents Aston Martin, Ferrari, Honda, Hyundai, Isuzu, Kia, Maserati, McLaren, Nissan, Subaru, Suzuki, and Toyota.)
- **March 5, 2013** – Follow-up teleconference with industry representatives interested in learning more about the project (see Appendix G for invitation letter). Briefing materials were provided on the project and then current conceptions for the rating system. Initial feedback was provided by a number of participants. Representatives of the following companies took part: Nissan, BMW, Mitsubishi, Toyota, Hyundai, Honda, Volvo, Ford, and Daimler.
- **March 19, 2013** – Briefing and project review at AAA-FTS offices in Washington D.C. Considerable discussion concerning initial proposed approach to calculating technology ratings. Presentation of concept for developing consumer oriented educational information.
- **April 5, 2013** – Second teleconference with industry representatives (see Appendix G for invitation letter). Content included: discussion of proposed approach for calculating

technology ratings, proposed consumer focused technology explanations, review of Electronic Stability Control (ESC) as an example safety technology, discussion of what factors should be added in the consideration of theoretical limits of technologies and to the list of human factors considerations, review of the list of proposed technologies to be included in the initial ratings, and a request for information and supporting materials that may be useful in rating and explaining selected technologies.

- **April – May 2013** – Formal invitations and supporting materials on the project were sent to prospective Advisory Panel members. The panel was finalized and a date and location for the initial panel meeting arranged. Formal technology rating forms were developed and sent to industry representatives to solicit specific input on what was and was not known about the performance of various safety related technologies (see Appendix G for relevant materials). Example educational support and other materials were also sent to elicit comment and feedback. Efforts by MIT AgeLab staff to identify objective data sources and other relevant research and supporting materials continued. Potentially useful information was gathered into "notebooks" on each technology and selected information and data summarized in "Technology Review sheets" on each technology.
- **July 19, 2013** – In person Advisory Panel meeting at AAA-FTS offices in Washington D.C. Content included presentation of an overview of the project vision, presentation of a strategy for a comprehensive vehicle safety technology rating system and supporting educational material, discussion of the overall concept, review and discussion of the components of the proposed system, consideration of initial technologies under consideration for inclusion in initial ratings, and discussion of collaborative efforts to engage industry input and support for the project. One of the ideas that emerged from the meeting was that we shift emphasis somewhat from a strictly technology focus to more of a "scenario" focus in the rating system. In terms of defining and describing the capabilities of a technology, a scenario framing was seen as potentially playing an important role in providing the consumer with an understanding of the situations (scenarios) that a technology is intended to address.
- **June – October** – Continued focused efforts by MIT AgeLab staff to identify objective data sources and other relevant research and supporting materials. Working copies of technology notebooks and associated Technology Review sheets updated. Feedback received from industry representatives, project collaborators, and invited reviewers in response to technology rating forms and other requests were integrated into technology notebooks using coded reference to industry sources to maintain appropriate anonymity. (Note any data for direct inclusion in the rating processes required citation to a publically available source.)
- **October 9, 2013** – Teleconference with the Advisory Panel. The conference began with short presentations of related efforts. First, Adrian Lund of IIHS provided a briefing on his organizations recent release of ratings of front crash prevention technologies based on structured test track evaluations. David Nguyan of AAA spoke briefly on some of the technology testing recently conducted by AAA. A full briefing on an updated rating system concept including rating components, supporting consumer educational material, and the issue of research gaps was presented. Extensive comment was obtained,

particularly focused on a recommendation that the proposed top level rating methodology attempted to provide more detail and nuance than many consumers would be inclined to interpret.

- **November 12, 2013** – Teleconference with the Advisory Panel to review and discuss a revision of the rating system concept developed in response to feedback obtained during the previous conference call and from conversations and e-mail exchanges with individual panel members.
- **December 16, 2013** – Final teleconference with the Advisory Panel prior to the development of this report. The goal of the teleconference was to provide an update on the development of the rating system concept along with draft ratings for seven technologies. Input and critique was solicited from the panel. A number of minor adjustments, particularly to text associated with the top level matrix presentation were made as result of panel member input. Exchanges with AAA-FTS staff during and following the teleconference led to the drafting of a number of variations in format for presenting the top level matrix, several of which are included in this document.
- **December 18, 2013** – Final teleconference with industry representatives to provide an update on the development of the rating system concept along with draft ratings for seven technologies. A primary goal of the teleconference was to solicit additional input prior to the finalization of the current report.
- **December 31, 2013** – The initial version of this report was submitted as an internal project report to AAA-FTS for review and comment.
- **January 12, 2014** – An expanded version of this report was submitted to AAA-FTS.
- **March 26, 2014** – A draft revision of this report was prepared for review and comment by the Advisory Panel and AAA-FTS.
- **April 3, 2014** – The draft revision of this report was discussed with the Advisory Panel via telephone conference. Panel members were encouraged to continue to provide additional feedback as desired as the final revision was prepared.
- **April – May, 2014** – Feedback via e-mail, telephone, and in-person conversations was obtained and considered in preparing the final version of the report. During this process, a limited amount of additional data was identified and clarification concerning the interpretation of some of the available IIHS data that led to minor adjustments in the ratings.
- **June** – AAA-FTS circulated the report for additional review and it was refined further taking this feedback into consideration.

Selected Observations on the Development of a Rating System

Of Factors and Scaling: An Evolving View

A major focus in the RFP was on the identification of factors relevant to understanding the effectiveness of various technologies in terms of enhancing safety. Emphasis was also placed on developing ratings derived primarily from unbiased objective measures. The vision called for reporting the ratings in the form of a matrix showing how a technology was rated, and envisioned the matrix as a tool that could be used to inform consumers on the value and usefulness of various in-vehicle safety technologies. The RFP included the following list as illustrative examples of what might be considered as factors:

- Estimates of the number of crashes/injuries/fatalities reduced based on previously published research or new estimates developed
- Cognitive workload measures
- Driving performance as measured by a simulator and/or instrumented car
- Efficacy of the technology
- Self-reported use of the technology (e.g. deactivation or use of "bypass" feature)

Consequently, we defined task 1 of the project to be a comprehensive review of potential factors for inclusion in a rating system. The review was to take into consideration advantages and disadvantages of each factor based upon a synthesis of the scientific literature, public availability of objective data, feasibility of primary data collection where needed, potential for consumer understanding and impact factors on driver safety. A great deal of thought went into developing an initial listing of potential factors and these were reviewed and refined over the course of the project, as highlighted in the outline of project activities, through extensive discussions with selected experts, industry representatives, and with the Advisory Panel. Aspects of this process can be seen in various materials reproduced in the Appendices.

It gradually became clear over the course of the project that the identification of factors that are relevant to understanding the effectiveness and overall safety benefit associated with a given technology and the development of a consumer oriented method of objectively rating the safety benefit of a given technology are, in fact, best considered as somewhat distinct undertakings. Factors such as technical limitations of the basic technology, usability / understandability of the technology, behavioral adaptation, added cognitive demand / confusion associated with technology implementations, etc. are all important factors to be taken into consideration at the technical design, integration, and evaluation levels by professionals involved in assessing given technologies. However, the construction of a rating matrix or matrices that take into consideration all such potentially meaningful factors rapidly become quite complex; this complexity would be difficult for a typical consumer to follow. Moreover, it has become quite evident in our search of data sources that many of the cells in such a matrix would be found to be empty due to a lack of appropriate data. Where data do exist, it is often difficult to integrate values / findings across cells since available data is often specific to different implementations of a given technology type – thus not being directly comparable. These, and other considerations, make it functionally impractical, if not impossible, to develop objectively defined, well scaled, ratings of overall safety benefit directly from such an underlying factor matrix. On the other hand, the typical consumer is likely to be less concerned with what the underlying factors are that might explain why a given technology offers more or less benefit than they are with being provided with some understanding of what the relative level of benefit appears to be.

This has led us to view the project as developing two different types of evaluation. The "top level" rating system is intended to be consumer oriented and focuses on available objective data on the safety benefit of a given technology. At this level, the operative question is "what is the relative safety benefit?" as opposed to focusing on what might account for the apparent level of benefit. The majority of the main body of this report is directed at detailing a proposed method for making such a top level rating of safety benefit that can be presented to the consumer.

The second type of evaluation considers the underlying factors that may account for the apparent level of safety benefit associated with a given type of technology. Often this takes the form of trying to understand why observed benefits are not as high as might be expected on the basis of the theoretical potential of a safety feature. As presented in more detail in several of the appendices of this report, factors that may account for such discrepancies can range from technical limitations in sensor technology to implementation details to human interface and interaction considerations. The background "Technology Review sheets" developed for each technology during the course of the project identify available information, hypotheses, research, and data that may bear on apparent effectiveness. Considering content across these Technology Review sheets effectively forms an underlying matrix of potential impact factors by technology.

Rating a Technology Class vs. Specific Vehicle Implementations

Early in the course of the project there was extensive discussion around whether the focus of the ratings should be on what would in essence be comparative safety benefit ratings of different technology types (e.g. lane departure warnings vs. adaptive headlights) or on specific implementations of a technology (e.g. lane departure warnings on model x vs. model y). While we consider the question of to what extent and how specific implementations of a given technology type vary in effectiveness to be of significant interest, a number of considerations led to the decision to focus for the present on a broad rating evaluation comparing different technology types. These considerations included:

- The directive in the RFP to rate across a range of technologies (possible examples suggested included back-up cameras, intelligent cruise control / adaptive cruise control, lane-departure warning, adaptive headlights). In-depth consideration both within a technology class and across multiple technology types was not practical within the time frame and resources of the current phase of the project. It was decided that once a base rating of relevant safety systems was established, this would provide a good foundation for future work examining whether and to what extent different implementations vary in effectiveness.
- Extensive model by model specific evaluations were clearly outside the scope of the project in terms of time frame and resources. Moreover, the National Highway Transportation Safety Administration's (NHTSA) expanding New Car Assessment Program (NCAP) provides the consumer with a resource listing for obtaining information

on whether various vehicle models do or do not offer selected safety technologies that meet a minimum level of performance. The Insurance Institute for Highway Safety (IIHS) has recently expanded their testing programs to begin to consider model specific performance of safety technologies, beginning with scenario specific test track evaluations of forward collision braking / mitigation systems. It was concluded that developing this project in ways that complement rather than attempt to duplicate these undertakings was in order.

- From a conceptual standpoint, the most appropriate assessment of actual safety benefit would be based on epidemiological data examining the extent to which a given technology impacts crashes, injuries, and/or fatalities in the actual driving population. While the total number of adverse events per year is unacceptably high, the number of events per individual vehicle model, identifiable as being equipped with and without a given technology, is relatively low for purposes of calculating effect statistics. Thus, initial development of the rating system focusing more broadly on a class of technology rather than attempting to make evaluations across all models again seemed the most prudent starting point.

Considering the above, a reasonable question that might be asked is "How is this rating system going to help a consumer choose one car over another?". In brief, the answer is that the top level rating system is not intended as a car buying guide but rather is intended to serve as a technology buying guide. It is intended to assist the consumer in identifying safety technologies that they may wish to look for in their next vehicle or consider as options within specific vehicle models of interest to them. After a consumer identifies a safety technology of interest to them, resources such as NCAP listings and IIHS evaluations provide a means to obtain vehicle / model specific information. Again, this does not preclude continuing / expanding the project over time to delve deeper into features or implementation characteristics that objective data suggest impact the overall effectiveness of a type of technology.

Selected Materials Developed During the Course of the Project

A range of materials have been developed during the course of the project that AAA can utilize in crafting suitable mechanisms for sharing information and findings with its members and the general public. Key materials are identified below.

Factor Identification

Extensive consideration went into the identification of factors with potential relevance to evaluating the effectiveness of various safety technologies. Several interim documents developed during this process are reproduced in Appendix E. While a reduced grouping of factors was eventually employed in the development of the individual Technology Review sheets, some of the concepts and details considered in these interim documents may prove useful in future, further work on the evaluation of specific technologies. With this in mind, these selected materials are preserved in this report for reference purposes.

Research Notebooks

Our survey of the existing literature and data sources on selected safety technologies began with the development of research notebooks. These notebooks consist largely of "clippings" and notes collected on each technology along with a listing of sources of the material. Where particularly relevant, summaries of feedback received from industry representatives in response to technology rating forms and other requests were integrated into the notebooks using coded reference to industry sources to maintain appropriate anonymity. These notebooks should be considered as raw background material and not as formal documents; they are not intended for general release. They have been provided to AAA-FTS (as separate documents) since some of the source material may prove useful in other literature reviews undertaken by Foundation staff as well as providing additional context for where material was drawn.

The layout of the notebooks largely follows the long version of the technology information form (Appendix G) that was sent to industry sources who expressed a willingness to contribute to the information gathering process.

Technology Review sheets

The technology notebooks served as the starting source for the development of summary Technology Review sheets on each technology. The Technology Review sheets organize material into the following categories:

- *What is the technology?* – A brief description of the technology.
- *Crash Reduction/Prevention* – A summary of key findings relating to both estimated and observed reductions in events relevant to evaluating the safety benefit of the technology. These are the values that are considered in the consumer oriented, top level rating of safety benefit.
- *Consumer Awareness & Trust* – A summary of identified information on the extent to which consumers are aware of the technology, understand how it is intended to function, and the degree to which they trust / have confidence in the technology. Much of the data in this section is based on self-report surveys and should be interpreted within that context.
- *Mobility Significance* – This section was originally intended to capture data that might be particularly relevant to the extent to which the technology might enhance older driver mobility. At present, it is being used to capture information that might be relevant to the extent to which a technology appears to enhance the mobility of any individuals who might otherwise be limited in their driving due to age or other sources of limitation.
- *Other Benefits* – A section for capturing other benefit relevant information not otherwise covered.
- *Technology Penetration* – Considers the extent to which the technology is readily available and/or is present in the active vehicle fleet.
- *Frequency of Use* – Considers the extent to which drivers actually use a given technology if they need to actively engage the technology or if the option to turn the technology off is available.
- *Training and Education* – Some systems require little or no familiarity with the technology to derive benefit from them. Others have a steep learning curve for a user to become comfortable with them, but may become second nature once the user has

developed a good mental model of how they work. This section considers to what extent the user needs to learn how to use the system to derive benefit and whether there is any identified data on how long most users take to become comfortable with the technology.

- *Behavior Adaptation* – This refers to behavior changes resulting from the use of the technology that may impact its net safety gain.
- *Auditory / Visual / Haptic / and Cognitive Demand* – A technology may offer potential benefits while also placing certain demands on the driver before they can derive that benefit. Engaging a system may involve a degree of mental, visual, manipulative, or auditory workload. Attending to a warning may similarly require some amount of attention and resource allocation that may impact effectiveness or even introduce distraction into the driving situation. This section considers what data are available on the extent to which the technology places some level of demand on the driver in each of the listed domains.
- *Vehicle Type* – This section considers the extent to which a particular technology may be more relevant to a particular type of vehicle. For example, electronic stability control (ESC) has been found to have a much more significant impact on overall safety gains in vehicles that are inherently less stable due to high centers of gravity (e.g. many SUVs) than in vehicles that are inherently more stable.
- *Limitations / Failure Conditions* – This section considers conditions under which the technology will not operate, performance may degrade, or actual failure may occur (i.e. weather, speed, tolerance boundaries, etc.)
- *Differences between Implementations* – This section considers whether there are known major differences between implementations of this general class of "technology" that need to be considered in evaluating its effectiveness, understanding or using the technology.
- *References* – Sources of information and data incorporated into the technology review sheet as well as other key references consulted but not directly cited.

As noted above, the *Crash Reduction/Prevention* section lists the sources from which objective values have been drawn to rate the safety benefit of the technology. Other sections cover material that is relevant for developing educational support material for the consumer. Many of the sections highlight factors that are highly relevant for both system designers and applied researchers to consider in identifying areas and features that might be improved to derive further gains in overall safety benefit in a technology class or specific implementation. It can be readily noted in working through the Technology Review sheets that the availability of objective data on many of these factor areas is relatively sparse or missing altogether. Areas where relevant objective data appears to be limited or missing suggest areas of potential research needs. Due to the central nature of the Technology Review sheets to the project, copies of the current versions are included as appendices in this report.

The Technology Review sheets are seen as dynamic documents that should ideally be updated in an ongoing basis as additional research and associated data becomes available on the technology class and as implementations of the technology evolve. Current versions of the Technology Review sheets are reproduced in Appendix C.

<u>Educational Support Material</u>

The RFP that initiated this project did not specifically call for the development of educational support materials for the consumer on the selected technologies. The MIT AgeLab project leads elected to gather information and descriptions on each of the technologies that might prove useful to AAA-FTS and/or individual AAA clubs in developing such support material at a future date. There is no presumption on our part that the content provided need be presented in the same format as currently used in the sheets. The educational support material sheets include the following content sections:

- *What Is It?* – A short one to two paragraph description of what a technology is and the conditions under which it might be relevant. This is intended as a very brief, high level orientation to the technology.

The sections listed below represent a next level down description and elaboration of information on the technology, but again presented at a consumer oriented level.

- *Why Would I Use This Technology?* – This section generally expands somewhat on what the technology is, why it is relevant, and sometimes includes additional information on how and/or why it works.
- *What Do Drivers Think?* – This section generally highlights information on consumer satisfaction with the technology.
- *How Well Does It Work?* – This section addresses objective data on the expected potential and/or observed safety benefits of the technology. It is based on selected data drawn from the *Crash Reduction/Prevention* section of the technology review sheet.
- *Who Benefits Most?* – This section highlights relevant information on the type of drivers, driving conditions, or type of vehicles that may benefit the most from availability of this technology.
- *In What Situations Doesn't It Work*? - Similar to the *Limitations / Failure Conditions* section of the technology review sheet, but presented at a consumer level.
- *Mobility Significance* – Similar to the *Mobility Significance* section of the technology review sheet, but presented at a consumer level.
- *Not All Systems Are Alike* – Similar to the *Differences between Implementations* section of the technology review sheet, but presented at a consumer level.
- *Different Names, Same Idea* – A listing of alternate names that different manufacturers may use to describe their implementation(s) of a particular type of safety technology.

Key Concepts in Proposed Rating System

The next several sections detail essential concepts utilized in the proposed rating system and specify the proposed scaling for determining actual rating values.

- The proposed rating system is based on a 5 level scale similar to the familiar 5-star rating systems employed in a variety of consumer familiar contexts.
    - While we initially considered using the familiar "star" symbol, we do see some potential for confusion between the ratings developed here and other automotive relevant ratings systems (i.e. NHTSA 5-star safety ratings, IIHS ratings).
    - As a working model, we are currently employing a geometric diamond symbol. We make reference to diamond symbols throughout this document, recognizing that an alternate symbol may be substituted in the future.
    - This means that ratings will range on a scale from 1 (♦) to 5 (♦♦♦♦♦).
- The system is intended to provide an evaluation of a general class of technology, not to rate specific vehicle implementations.
    - The extent to which there is a significant difference in effectiveness across vehicle implementations or significance based on vehicle type [think of the benefit gain with ESC in SUVs vs. for vehicle frames that are inherently more stable to begin with] will be addressed in the deeper level educational / support information developed as part of the project.
- The rating for a given technology will reflect the high end of what "good" data indicates the probable benefit of the technology can currently provide (i.e. it will reflect the upper end of possible benefit).
    - Again, the intent is to assist the consumer in identifying potential benefits that may be associated with a technology to assist them in identifying technologies that they may wish to investigate further and encourage consideration in buying decisions that are relevant to their particular driving and life situation.

Projected vs. Demonstrated Benefit

It takes many years to develop objective data on the extent to which benefits are (or are not) observed with a given technology in the real-world. In the interim, it is important to provide consumers with some guidance on "new" technologies, for which epidemiological data are not yet available. We believe it is important to promote "projected safety benefit" while being "truthful" to the consumer regarding demonstrated value.

To represent the distinction between projected vs. demonstrated benefit, two forms of the diamond symbol have been proposed:

- Open diamond (◊) ratings representing best case estimates of projected or theoretical benefit based on simulation, test track, and/or experimental field data.

- Solid diamonds ratings (♦) representing best case estimates based on real-world demonstration of benefit drawing on field-operational tests, naturalistic data, and epidemiological and/or actuarial data.

There has been extensive discussion around whether the open vs. closed diamond symbolism is useful in making the distinction between projected/theoretical benefit and objectively demonstrated benefit in the driving population. A number of panel members have expressed concern that this distinction might be confusing for some consumers. The project leads continue to feel that this representation has conceptual value, but recognize that further work with communications experts and consumers would be required to resolve this question. In addition, as the rating of technologies in and out of the car continues to evolve, engagement with communications experts may also be useful in assessing if consumers might benefit from the eventual development of a more graphically complex, but information rich rating structure that could integrated further information about a technology's performance and limitations. For now, the open and closed symbol approach, with several alternate methods of representing this distinction in graphic presentation of the rating matrix concept, is presented later in this report.

Rating Types: Overall Safety Benefit & Scenario Specific

One of the challenges that we have spent significant time considering is how to best represent the safety benefit of one technology relative to another. In one sense, a technology that offers the potential to save the largest absolute number of lives should logically receive a higher rating than a technology that offers the potential to save a much smaller number of lives. On the other hand, what if the first technology is relevant to a large percentage of all possible crash events, but only actually works successfully in a modest percentage of those cases – while the second technology is designed to function in a much more limited number of situations, but is highly successful in presenting loss of life under those conditions. It thus seems "unfair" in a sense to down-rate the second technology relative to the first. This may particularly be the case if the scenario that the second technology is designed to mitigate or eliminate is of particular concern or relevance to a particular consumer or class of consumer.

This led to the proposal to rate technologies both in terms of **Overall Safety Benefit** (considering the maximum number of lives, injuries, or crash events) and in terms of benefit within **Specific Scenarios** the technology was designed to address. Thus, the top level rating matrix presented in this document includes ratings considering technologies from both perspectives.

Scaling Details

Ratings along the 5-diamond levels are based on a percentage of cases a particular technology has the potential to, or has been observed to, impact. The literature most frequently considers impact in terms of reduction in fatalities, frequency and/or severity of injuries, or in numbers of crash events.

We had at one time considered several approaches for calculating the relative value of a fatality vs. an injury vs. property damage associated with a crash. While there clearly is some value in such calculations for particular purposes, it soon became apparent that attempting to justify any such approach was likely to detract from the overall focus of the rating system and significantly added to both the complexity and actual validity of any calculations. We have therefore proposed treating each of the categories **Fatalities**, **Injuries**, and **Crashes** individually.

- Where percentage reduction values can be derived for any given category, it is considered in the evaluation.
- If percentage values are available in more than one category, the category showing the highest percentage benefit is used in the benefit level calculation. (This goes along with the recommendation by a number of Panel members that the best case evaluation for each technology be considered in the rating.)

In addition to the three primary categories, insurance claim related data is available for some technologies that may contribute additional objective data on real-world impact. Many of the values currently available for emerging safety technologies are based on relatively limited numbers of cases or can be difficult to interpret for a number of technical reasons. When such data is available, such as through analyses released by the Highway Loss Data Institute (HLDI), such data may be considered in estimates of the technology's impact. It has been suggested that insurance claims may be a more complete tally of crashes than the more traditional reliance on police reports in that this data can include events that are recorded by the police as well as events that are not. Similarly, a HLDI representative commented that estimated effects based on injury claims in their published reports are most likely a reasonable representation of the injury events. While the majority of such events would be expected to be reported to the police, the insurance data may again pick-up some that are not or that are missed by police on the scene.

Scaling Theoretical vs. Observed Benefits

As noted previously, early in a safety technology's deployment, little or no real-world actuarial data will be available to realistically evaluate the actual extent to which a technology is producing a real safety benefit. Generally, actual benefit is found to be somewhat lower than potential benefit due to a range of factors such as unexpected technical limitations, driver override of a technology, and behavioral adaption, among others. Since actual observed benefits are expected to be lower than early estimated benefits, the rating system requires a higher theoretically estimated percentage benefit value (◊) to obtain a given diamond level rating than to obtain the same rating based on observed real-world benefits (♦) (see Table 1).

Scaling Overall Benefit vs. Scenario Specific Benefits

Given the unacceptably high number of adverse events on the nation's roadways, even a relatively modest percentage reduction in total events is quite meaningful. Estimated annual crashes involving passenger vehicles per year derived from the period 2004-2008 averaged 5,825,000 crashes, 698,000 nonfatal injury crashes, and 33,035 fatal crashes (Jermakian, 2011). On the other hand, if a technology is designed to address a specific event scenario, a somewhat higher percentage impact would be expected to obtain an equivalent scenario specific benefit rating (see Table 1).

Proposed Scaling Values

Table 1. Conceptual Approach to Scaling for Overall Safety & Scenario Specific Benefits

	Overall Benefit		Scenario Specific	
	Theory, Sim., TT	FOT / Actuarial	Theory, Sim., TT.	FOT / Actuarial
Level 1	1 to 6%	1 to 5%	1 to 12%	1 to 10%
Level 2	7 to 14%	6 to 11%	13 to 28%	11 to 22%
Level 3	15 to 25%	12 to 19%	29 to 50%	23 to 38%
Level 4	26 to 40%	20 to 30%	51 to 80%	39 to 60%
Level 5	=> 41%	=> 31%	=> 81%	=> 61%

Sim. = Simulation, TT = Test Track evaluation, FOT = Field Operational Tests

The implications of the proposed scaling values presented above are best reviewed by considering how they translate into actual ratings of the technologies based on currently identified data. This is covered in the next section and in the proposed rating matrix that follows. (The rational structure for scaling is detailed in Appendix A.)

Extracted Values from Rating Sources

In each of the rating sections, we first consider the theoretical or best case estimate of the potential benefit of a particular technology. A best case estimate might be adjusted somewhat based upon "expert opinion" if multiple estimates are available and/or there are sound grounds for otherwise adjusting a value. In instances when reported values are adjusted, a rational for the adjustment is provided. (All such adjustments are fully open for input / suggestions / critique.) Based upon the resulting values, an overall potential benefit rating is assigned both for a specific scenario for which the technology is designed to address and a benefit rating relative to all vehicle related crash events.

Notes:

- All crash reduction estimates are based on estimated impact on anticipated rates in the United States.
- The sources cited in the following sections represent highlighted values used to determine a best case rating for each technology. The full set of references considered in developing the ratings are provided in the individual *Technology Review sheets*.

Reference Technologies

Two technologies were considered as part of this rating system project largely to provide reference points for the development of the rating scale. These are Electronic Stability Control (ESC) and Adaptive Cruise Control (ACC) (sometimes referred to as intelligent cruise control and other related terms).

As detailed more fully in other portions of the deliverables for this project, ESC represents a fairly mature class of technology for which a reasonably robust body of real-world data exists on which to objectively evaluate the real-world safety benefits. These benefits have been deemed sufficiently substantive that NHTSA established Federal Motor Vehicle Safety Standard No. 126 to require ESC systems on all new production passenger vehicles, trucks, and buses with gross vehicle weight ratings of 10,000 lbs. or less by September 1, 2012. As documented in the ESC section, this technology has been established as providing a high safety benefit both for the specific scenarios for which it was designed, as well as impacting a substantial percentage of the overall risk associated with motor vehicle travel. Consequently, it was seen as a technology that should represent a top level rating both at the scenario specific level and a top level rating in terms of overall safety benefits.

At the other end of the continuum, ACC is seen as a technology that was developed largely as a convenience feature that has been considered as offering some modest potential safety benefit under limited circumstances. Thus, while ACC might be seen as offering relatively high value as a convenience feature, its relative rating as a safety technology might reasonably be expected to fall at the lower end of a safety benefit scale.

Electronic Stability Control (ESC)

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦♦♦♦♦	♦♦♦♦♦

*See individual **Technology Reviews** in **Appendix C** for full listing of data sources considered, including extracted values and full citations. While the term, ESC, is well established in the literature, a variety of manufacturer specific names are used for the technology class; these include: Vehicle Stability Assist, Vehicle Dynamic Control, Electronic Stability Program, Dynamic Stability Control, StabiliTrak, AdvanceTrac, etc.*

A substantive body of research is available to assess both the potential and demonstrated real-world benefit of ESC technology and this is a primary reason for including ESC as a reference point in the proposed rating system. See the ESC *Technology Review* in *Appendix C* for citation details and an extended overview of available data. In one representative study, an Insurance Institute for Highway Safety (IIHS) report (Farmer, 2010) based on ten years of data in the Fatality Analysis Reporting System (FARS) found an overall reduced fatal crash involvement risk of 33% for ESC equipped vehicles. This would translate into a 5 solid diamond rating in the Overall Benefit category using the proposed scaling values presented earlier in Table 1. In cases where the objectively demonstrated benefit of a technology is already at the highest ranking on the scale, this in effect provides the most meaningful evaluation of “potential” and the 5 open diamond ranking is assigned as well.

As presented in the ESC *Technology Review*, ratings for various Scenario Specific benefits of ESC technology range from 56 to 90% in the fatalities reduction category depending upon the vehicle type considered. Objective data is available for injury reduction at 70% and crash rate reduction at the 72% level have been reported. These values place the Scenario Specific rating for ESC at the 5 solid diamond rating level.

Adaptive Cruise Control (ACC)

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊	◊◊
Benefit Currently Documented	♦	♦♦

See individual ***Technology Reviews*** *in* ***Appendix C*** *for full listing of data sources considered, including extracted values and full citations. In addition to Adaptive Cruise Control, other brand oriented terms, such as Autonomous Cruise Control and Intelligent Cruise Control.*

The one publically available report that was identified that provided an estimate of potential safety benefits of ACC was a NHTSA sponsored field operational test (FOT) (Koziol et al., 1999). The authors concluded that if such systems were fully deployed and utilized at the engagement rate seen in the FOT, it was estimated that the number of collisions on freeways for travel velocities above 40 km/h would be reduced by 17% for two specified scenarios (highway driving when vehicles are traveling over 40 km/h when an ACC equipped vehicle approached a slower vehicle traveling at a constant velocity and when a lead vehicle decelerated in front of an ACC equipped vehicle). This estimate would correspond to a reduction in the number of police-reported rear-end collisions by about 13,000 in 1996 and this was interpreted as indicating a fairly strong benefit compared to manual driving. However, as a percentage of total crashes of all types, this would correspond to less than 1%. These FOT based estimates appear to provide the only substantive values that are available to work from for current rating purposes. While providing a limited basis for estimating benefit, the values are based on FOT based evaluation and qualify for solid diamond rating under the proposed system. This translates into qualifying for 2 solid diamonds under the Scenario Specific rating and 1 solid diamond under the Overall Benefit category.

It was noted in the report that additional safety benefits might be expected from a reduction in other rear-end collisions involving cut-ins and lane changes and from use of ACC on roadways other than freeways; however, benefit estimates for these scenarios were not examined in the FOT. Drivers were found to engage the system for 6 % of the time on arterials and 11% on state highways, thus limiting the percentage of time during which potential benefits might be realized.

More recent work, such as studies carried out by IIHS, largely consider vehicles that frequently combine ACC with forward collision warning (FCW) and, increasingly, autobrake features. Personal communication with IIHS personnel indicates that they see it as difficult to isolate the effects of ACC from the other components of these systems in work going forward.

Primary Technologies

Adaptive Headlights

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊	◊◊◊◊◊
Benefit Currently Documented	♦	♦♦♦

*See individual **Technology Reviews** in **Appendix C** for full listing of data sources considered, including extracted values and full citations. Note that the term 'adaptive headlights' can be used to refer to a range of technologies. The term is used here to apply largely to headlights that adjust the angle of illumination taking into consideration steering, speed and elevation of the car. In addition to "adaptive headlights", these might also be referred to as "curve illuminating", "steerable headlights", etc.*

The potential benefit ratings for adaptive headlights are based largely on an IIHS analysis by Jermakian (2011). Considering scenarios related to improving visibility when negotiating curves in darkness or twilight, the study estimated that adaptive headlights have theoretical relevance to 90% of the crashes occur on curves at night, 91% for nonfatal injury crashes, and 88% for fatal crashes. This would translate into an overall maximum safety benefit potential across all event types of: 8% for fatalities, 4% for injuries, and 2% for crashes. While the estimates in the Jermakian study do include some adjustments for known limitations of then current systems, they still do largely represent theoretical maximum benefits. It seems most appropriate at this time to use these values in an open diamond configuration to represent system potential. Using the Scenario Specific injury benefit value of 91% reduction, a 5 open diamond rating can be applied. At the Overall Safety Benefit level, the 8% reduction in fatalities value translates into a 2 open diamond rating.

A Highway Loss Data Institute (HLDI) analysis looked at adaptive headlights offered by Acura, Mazda, Mercedes and Volvo and found that property damage liability claims fell in the 5 to 10% range for vehicles with adaptive headlights compared to vehicles without adaptive headlights (IIHS, 2012). This strongly suggests a real-world benefit being realized in vehicles equipped with this technology, although it is difficult to extrapolate this value into an objective percentage value for the fatalities, injuries, and crash categories. *For purposes of the Overall Benefit category, we are proposing treating this high-end 10% reduction in insurance claims value as a surrogate for one of the three standard categories (fatalities, injuries, and crashes). Discussions with IIHS (Lund, 2014) indicate that this number would best be translated into a high-end estimate of around a 2.5 to 5% reduction in overall crash events, i.e. there are on the order of two property damage liability claims for a crash event that involves two vehicles.* Using this value, this results in assigning a 1 solid diamond rating in the Overall Benefit category. *(It should be noted that the HLDI reports include estimates for reductions on collision claims which represent crashes resulting in damage to the insured vehicle that is not the fault of the driver of another vehicle.)*

It is an open question as to how best to translate the aforementioned values into a scenario specific rating since the insurance data is not necessarily limited to the events occurring on curved roadways and night driving. On the other hand, the apparent best case reduction estimates in the currently available insurance data are in the same general range of the total number of scenario specific events that might be anticipated. Therefore, for purposes of the current proposal, we have conservatively assigned a Scenario Specific rating of 3 solid diamonds. It may be appropriate to reconsider in the future whether the scenario rating for adaptive headlights should be expanded to consider twilight and nighttime driving in general as opposed to the more restrictive scenario of driving on curved roads in low-light and dark driving conditions.

Back-Up / Rear-View Cameras

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊	◊◊◊
Benefit Currently Documented	♦	♦♦

*See individual **Technology Reviews** in **Appendix C** for full listing of data sources considered, including extracted values and full citations.*

While providing a back-up camera to increase a driver's ability to see directly behind the vehicle is an intuitively appealing concept, relatively limited data is available on the extent to which such systems actually provide a net benefit. Across a series of experimental studies (Mazzae, 2008, 2010, 2013) reported that the use of back-up cameras reduced crashes in an unexpected collision trial by approximately 30%. Treating these experimental studies as providing a theoretical estimate of potential benefit, this would translate into a scenario specific rating of 3 open symbols.

Real-world performance data is similarly limited at this time. Two studies from the Highway Loss Data Institute (HLDI, 2011, 2012) consider initial data on the impact of the presence of back-up camera on insurance claims and damages. The data for Mercedes-Benz vehicles showed small and mixed findings across insurance claims and damages. The report concluded that the data showed no significant effect on any insurance coverage; however, this was considered a relatively weak analysis for injury effects involving pedestrians and it was stated that additional analyses were underway. The data for Mazda vehicles found that, contrary to expectations, there was an increase in collision frequency claims (3.1%), severity, and overall losses ($18), but a non-significant reduction in property damage / liability claims. Most relevant from a safety perspective, there was a reduction in the frequency of high severity bodily injury claims of 22.2%, although the overall frequency of bodily injury claims was down a non-statistically significant 3.1%.

If the 22% value for reduction high severity bodily injury for the aforementioned vehicle type in is used as a measure of real-world potential, then a rating of 2 solid diamonds could be applied under the Scenario Specific category, resulting in a combined rating of 2 solid and 3 open diamonds.

Note: It should again be emphasized that the relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities. It is also recognized that there is a particularly high emotional cost associated with this type of event. NHTSA (2014) estimates that 31% of all backup event fatalities involve children under 5 years of *age and another 26% are adults 70 years and older; these events often involve family members or other close associations. Societal pressure to do something about such events led to NHTSA issuing a final rule on March 31st of this year mandating rear visibility technology in all new vehicles under 10,000 pounds by May 2018.*

Forward Collision Warning (FCW)

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦	♦♦

*See individual **Technology Reviews** in **Appendix C** for full listing of data sources considered, including extracted values and full citations. (Forward Collision Mitigation (FCM) systems that actively brake the vehicle are considered separately; see next section.) The terms Crash Imminent Warning and Pre-Crash Warning are sometimes used to describe this technology class.*

The IIHS analysis by Jermakian (2011) again provides a comprehensive assessment of potential safety benefit for this technology. However, a significant drawback of this study for our purposes is that it considers together both forward collision warning (FCW) and forward collision mitigation (FCM) / autobraking systems. As a consequence, the theoretical potential ratings for FCW alone may be somewhat elevated based on this data. Keeping that in mind, Overall Benefit estimates for potential fatality reduction of 17% (5,633 cases out of 33,035), non-fatal injury reduction of 21% (146,000 cases out of 698,000), and crash rate reduction of 25% (1,453,000 cases out of 5,825,000). (Case counts are based on combining annual relevant front-rear crashes and relevant single vehicle crashes.) The later would translate into an open diamond theoretical potential rating at the 3 open diamond level.

In a field operational test, 66 drivers were evaluated for four weeks each. Based on the number of near-crash scenarios identified, the system was projected to reduce rear-end collision rates by 10 percent (Najm, Stearns, Howarth, Koopmann, & Hitz, 2006). If this limited data set is used as a best case estimate of existing real-world data, then this 10% reduction estimate would qualify for 1 solid diamond in the Scenario Specific rating category. IIHS has reported (Lund, 2013; 2014) that insurance data on property damage loss claims show a reduction of 5 to 7% for vehicles with FCW and suggest that this translates into a 10 to 15% reduction in rear crashes. Using this insurance data based estimate would increase the Scenario Specific rating category to 2 solid diamonds. Combining these values would produce an Overall Benefit rating of one solid diamond and 3 open diamonds and a Scenario Specific rating of two solid diamonds and 4 open diamonds. Taken together, this rating suggests moderate to high potential for the technology, but with well-established real-world demonstration of benefit due to limited available data at this time (see note below).

Note: As this report was being finalized, HLDI (2014) released a new bulletin evaluating insurance data on a forward collision warning (FCW) system paired with lane departure warning (LDW) technology in the Honda Accord. These data may provide grounds for *upgrading the demonstrated benefit rating of one or both of these technologies. We anticipate considering this new data in a future review.*

Forward Collision Mitigation (FCM) / Collision Imminent Braking (FCB) / Autobrake

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦♦	♦♦♦

See individual ***Technology Reviews*** *in* ***Appendix C*** *for full listing of data sources considered, including extracted values and full citations. In addition to the terms above, this technology class is sometimes identified by the following terms: Crash Imminent Braking, Autonomous Emergency Braking, Emergency Brake Assist, and Predictive brake Assist.*

As discussed in the previous section, the current theoretical overall potential benefit rating for forward collision mitigation (FCM) / collision imminent braking / autobraking technology is based largely on the same estimates developed for FCW (i.e. Jermakian, 2011), which translates into a 3 open diamond rating. However, we are proposing that the theoretical values for the scenario specific rating be increased from 4 open diamonds (51 to 80% reduction) to a 5 open diamond rating (>80%) due to recently released IIHS test track data (IIHS, 2013) demonstrating that some vehicle types under specified scenarios are able to avoid or mitigate front-to-rear crashes greater than 80% of the time.

As noted in the *Technology Review* in *Appendix C*, implementations of forward collision mitigation technologies may include forward collision warning (FCW) and brake assist technology that pre-primes the brake system in addition to actual autonomous braking capability. The present rating includes consideration of hybrid FCM systems that bundle FCW and/or brake assist technologies. This decision is largely pragmatic since most of the available real-world effectiveness data is based on such bundled technologies. It should be recognized that implementations that do not include warning and/or brake assist technologies may not provide the same level of benefit.

An insurance claims based study based on comparable Volvo models with and without a FCM system (Isaksson-Hellman & Lindman, 2012) reported a 23% reduction in crashes for the equipped vehicles. Based on current scaling, this would qualify as a best case, scenario specific objective rating of 3 solid diamonds. As a percentage of total crash events, this would translate into a reduction of approximately 6.6% based the proportions reported in Jermakian (2011); this would qualify as a best case estimate of 2 solid diamonds. IIHS (Lund, 2014) reports similar reductions for vehicles equipped with FCW and autobrake in property damage loss data appearing as a 10 to 15% reduction in claims, which is interpreted as translating into a 20 to 30% reduction in rear crashes.

Lane Departure Warning (LDW)

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊◊	◊◊◊
Benefit Currently Documented	♦	♦

See individual ***Technology Reviews*** *in* ***Appendix C*** *for full listing of data sources considered, including extracted values and full citations. (Note: this review does not consider "lane keeping assist" / lane keeping mitigation technologies that adjust steering to actively assist in keeping the vehicle within lane boundaries.)*

An IIHS analysis by Jermakian (2011) provided independent estimates for the maximum potential reductions across lane departures resulting in four types of scenarios: single vehicle crashes, head-on crashes, sideswipes between vehicles moving in the same direction, and sideswipes between vehicles moving in the opposite direction. Combining these lane departure events into a single generic scenario of crashes associated with lane departures, annual reduction totals of 179,000 crashes (out of 5,825,000), 38,000 non-fatal injury crashes (out of 698,000), and 7529 fatal crashes (out of 33,035) translates into corresponding theoretical reductions of 3%, 5.4%, and 23% respectively in the Overall Benefit category. Using the 23% reduction value for fatal crashes, this translates into a 3 open diamond rating. At the scenario specific level, the highest substantive theoretical estimate that we have located is Jermakian's (2011) estimate indicating a possible 46% reduction in fatalities in lane departure associated head-on crashes. This also corresponds to 3 open diamonds in the Scenario Specific category.

Obtaining objective data on the extent to which LDW systems are providing real-world safety benefits has proven to be challenging. Extracting data from a field operational test of one specific system (Wilson, Stearns, Koopmann, & Yang, 2007) suggests possible reductions in scenario specific crashes in the range of 1-8%. The scenarios considered were more restrictive than the broader scenario categories considered by Jermakian (2011) and the high end 8% reduction might be considered an optimistic rating. If this value is applied, a 1 solid diamond rating could be assigned to the scenario category. This suggests a translation into an Overall Benefit level of at most 1 solid diamond at this time. Available actuarial data also suggest a modest, a best, assessment of LDW systems as a class at the current time. A recent assessment by IIHS (Lund, 2013) concluded that "Lane departure warning may have the potential to reduce fatal crashes, but so far no benefits from this feature have shown up in insurance data." The apparent discrepancies between theoretical estimates of LDW potential and presently available objective real-world data represents a case in point for the concept of a combined solid and open diamond rating system. Give the data identified to date, LDW would receive a rating of 1 solid and 3 open diamonds.

Note: As this report was being finalized, HLDI (2014) released a new bulletin evaluating insurance data on a forward collision warning (FCW) system paired with lane departure warning (LDW) technology in the Honda Accord. These data may provide grounds for upgrading the demonstrated benefit rating of one or both of these technologies. We anticipate considering this new data in a future review.

Conceptual Presentation of the Rating Matrix

As detailed in the previous sections, we have proposed an approach to rating safety technologies that is based on a number of key elements. These include:

- the use of a 1-5 scale that consumers are familiar with from everyday rating systems,
- distinguishing between projected / theoretical potential and demonstrated benefit of production level technologies under actual real-world driving conditions,
- and, consideration of the overall safety benefit of a given technology relative to all expected driving related crash, injury, or fatality events versus the safety benefit of the technology relative to the specific type of driving situation the technology has been designed to mitigate.

The latter two aspects of the proposed approach is seen as particularly important for supporting different types of "customers" in approaching the ratings in way that is important to them. Individuals who are drawn to early adoption of technologies based largely on potential or who are willing to pay a premium to maximize possible safety gains prior to the full development of actuarial data, will find the ratings of technology potential the most relevant. On the other hand, individuals who are more comfortable adopting technologies only after they are well established and have a clearly demonstrated level of gain, will be find the ratings based on demonstrated benefit most meaningful. Along another dimension, some individuals simply want everything reduced to a single consideration, i.e. what is going to have the "biggest" overall impact on risk? These types of consumers are likely going to be drawn to the "overall" benefit rating of the system. Conversely, a consumer who willing to take a deeper look at their own driving situation in deciding what technologies are most relevant to them may well find the "scenario specific" rating aspect of the proposed system most useful. There is a clear challenge in developing a presentation approach that supports the interests of each of these types of consumers in a concise and relatively easy to understand manner.

During the course of this project, a number of upper-level approaches to summarizing the results of the proposed rating system have been explored. Feedback from the panel and industry representatives has generally pushed for simplifying the presentation of the ratings. The authors agree that simple, clear communication of ratings is the ideal goal; further work may wish to investigate the consumer's ability to "digest" rating structures that comprehensively represent various perspectives that consumers may wish to consider when evaluating the technologies to determine personal priorities. The following pages present four variant methods of presenting the upper-level of the assessment matrix at a conceptual level. (These are referred to as "conceptual" in that they are primarily intended to represent the content to be presented to the consumer – not necessarily the exact graphical layout that might be used. It is assumed that consumer oriented graphic design experts may well significantly improve upon the conceptual layouts presented here. Furthermore, it has always been assumed that web enabled forms of the matrix might well provide point and click links to deeper levels of detail, etc.). Version A represents an approach currently favored by the project leads. It uses the open and closed diamond ratings to highlight the difference between the potential benefit and observed benefit ratings. Versions B and C merge the open and closed diamond ratings into an overlapped presentation so that open diamonds are only visible if theoretical benefit is rated as exceeding currently demonstrated benefit. Version D differentiates theoretical from demonstrated benefit but drops the use of open diamonds to highlight these different dimensions.

A. Top Level Matrix with Initial Ratings – Potential & Observed Benefit Scaled Separately

Overall Safety Benefit (across all event types)	**Electronic Stability Control**	**Backup Cameras**	**Adaptive Headlights**	**Lane Departure Warning**	**Adaptive Cruise Control**	**Forward Collision Warning**	**Forward Collision Braking**
Potential Benefit	◊◊◊◊◊	◊[a]	◊◊	◊◊◊	◊	◊◊◊	◊◊◊
Benefit Currently Documented	♦♦♦♦♦	♦	♦	♦	♦	♦	♦♦

Scenario Specific Benefit	Loss of Steering Control	Back-Up Event	Dark Curves	Lane Departure	Rear End Collision		
Potential Benefit	◊◊◊◊◊	◊◊◊	◊◊◊◊◊	◊◊◊	◊◊	◊◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦♦♦♦♦	♦♦	♦♦♦	♦	♦♦	♦♦	♦♦♦

Ratings are based on currently identified data and percentage cut-points as defined under the draft working model; these ratings may be adjusted prior to any public release as data evaluation and system structure is refined based upon on-going feedback from the Expert Panel and other contributing sources.

All ratings are on a 1 to 5 scale. Open diamond (◊) ratings represent best case estimates of projected or theoretical benefit based on simulation, test track, and/or experimental field data. Solid diamonds ratings (♦) represent best case estimates based on real-world demonstration of benefit drawing on field-operational tests, naturalistic data, epidemiological and/or actuarial data.

Loss of Steering Control - Skidding on slippery surfaces, loss of traction with unexpected or high speed turn

Back-Up Event - Pedestrian fatality, injury or non-injury crash when backing–up a vehicle

Dark Curves - Impact of improved visibility when attempting to negotiate curves in darkness or twilight

Lane Departure - Unintended drift out of lane or failure to use turn signal to warn other drivers

Rear End Collision - Front of your vehicle with rear of a lead vehicle

[a]The relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities.

B. Top Level Matrix with Initial Ratings – Combined Scaling with Scenario Detail

Technology / Rating Type	Electronic Stability Control	Backup Cameras	Adaptive Headlights	Lane Departure Warning	Adaptive Cruise Control	Forward Collision Warning	Forward Collision Braking
Overall Safety Benefit (across all event types)	♦♦♦♦♦	♦[1]	♦	♦◊◊	♦	♦◊◊	♦♦◊

SPECIFIC SENARIOS	Electronic Stability Control	Backup Cameras	Adaptive Headlights	Lane Departure Warning	Adaptive Cruise Control	Forward Collision Warning	Forward Collision Braking
Loss of Steering Control Skidding on slippery surfaces, loss of traction with unexpected or high speed turn	♦♦♦♦♦	-	-	-	-	-	-
Rear End Collision Front of your vehicle with rear of a lead vehicle	-	-	-	-	♦♦	♦♦◊◊	♦♦♦◊◊
Lane Departure Event Unintended drift out of lane / failure to use turn signal to warn others resulting in an event	-	-	-	♦◊◊	-		
Dark Curves – Impact of improved visibility when attempting to negotiate curves in darkness or twilight	-	-	♦♦♦◊◊	-	-	-	-
Back-up Event Pedestrian fatality, injury or non-injury crash when backing –up a vehicle.	-	♦♦◊	-	-	-	-	-

Ratings above are based on currently identified data and percentage cut-points as defined under the draft working model; these ratings may be adjusted prior to any public release as data evaluation and system structure is refined based upon on-going feedback from the Expert Panel and other contributing sources.

All ratings are on a 1 to 5 scale. Open diamond (◊) ratings represent best case estimates of projected or theoretical benefit based on simulation, test track, and/or experimental field data. Solid diamonds ratings (♦) represent best case estimates based on real-world demonstration of benefit drawing on field-operational tests, naturalistic data, epidemiological and/or actuarial data.

[1] The relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities.

C. Top Level Matrix with Initial Ratings – Combined Scaling of Potential & Observed Benefit

Technology

	Electronic Stability Control	**Backup Cameras**	**Adaptive Headlights**	**Lane Departure Warning**	**Adaptive Cruise Control**	**Forward Collision Warning**	**Forward Collision Braking**
Overall Safety Benefit[1] (across all event types)	♦♦♦♦♦	♦[a]	♦	♦◊◊	♦	♦◊◊	♦♦◊

	Loss of Steering Control	Back-Up Event	Dark Curves	Lane Departure	Rear End Collision		
Scenario Specific Benefit[1]	♦♦♦♦♦	♦♦◊	♦♦♦◊◊	♦◊◊	♦♦	♦♦◊◊	♦♦♦◊◊

Ratings are based on currently identified data and percentage cut-points as defined under the draft working model; these ratings may be adjusted prior to any public release as data evaluation and system structure is refined based upon on-going feedback from the Expert Panel and other contributing sources.

All ratings are on a 1 to 5 scale. Open diamond (◊) ratings represent best case estimates of projected or theoretical benefit based on simulation, test track, and/or experimental field data. Solid diamonds ratings (♦) represent best case estimates based on real-world demonstration of benefit drawing on field-operational tests, naturalistic data, epidemiological and/or actuarial data.

Loss of Steering Control - Skidding on slippery surfaces, loss of traction with unexpected or high speed turn

Back-Up Event - Pedestrian fatality, injury or non-injury crash when backing–up a vehicle

Dark Curves - Impact of improved visibility when attempting to negotiate curves in darkness or twilight

Lane Departure - Unintended drift out of lane or failure to use turn signal to warn other drivers

Rear End Collision - Front of your vehicle with rear of a lead vehicle

[1]Benefit ratings reflect best case evaluations of existing systems. Not all implementations may offer the same level of benefit. Consumers may wish to consult the U.S. Government NCAP ratings for vehicle models offering select technologies meeting minimum performance standards, Insurance Institute of Highways Safety (IIHS) ratings of individual vehicle models, or other vehicle specific ratings for technologies of interest.

[a]The relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities.

D. Top Level Matrix with Initial Ratings – Potential & Observed Benefit Scaled Separately (All Solid Diamonds)

Overall Safety Benefit (across all event types)	**Electronic Stability Control**	**Backup Cameras**	**Adaptive Headlights**	**Lane Departure Warning**	**Adaptive Cruise Control**	**Forward Collision Warning**	**Forward Collision Braking**
Potential Benefit	♦♦♦♦♦	♦[a]	♦♦	♦♦♦	♦	♦♦♦	♦♦♦
Benefit Currently Documented	♦♦♦♦♦	♦	♦	♦	♦	♦	♦♦

Scenario Specific Benefit	Loss of Steering Control	Back-Up Event	Dark Curves	Lane Departure	Rear End Collision		
Potential Benefit	♦♦♦♦♦	♦♦♦	♦♦♦♦♦	♦♦♦	♦♦	♦♦♦♦	♦♦♦♦♦
Benefit Currently Documented	♦♦♦♦♦	♦♦	♦♦♦	♦	♦♦	♦♦	♦♦♦

Ratings are based on currently identified data and percentage cut-points as defined under the draft working model; these ratings may be adjusted prior to any public release as data evaluation and system structure is refined based upon on-going feedback from the Expert Panel and other contributing sources.

All ratings are on a 1 to 5 scale.

Loss of Steering Control - Skidding on slippery surfaces, loss of traction with unexpected or high speed turn

Back-Up Event - Pedestrian fatality, injury or non-injury crash when backing–up a vehicle

Dark Curves - Impact of improved visibility when attempting to negotiate curves in darkness or twilight

Lane Departure - Unintended drift out of lane or failure to use turn signal to warn other drivers

Rear End Collision - Front of your vehicle with rear of a lead vehicle

[a]The relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities.

Initial Observations

Availability of Objective Data

It is quite clear that dramatic advances have been made in passive safety as evidenced in both crash test results and in observed increases in driver and passenger survivability when vehicles crash in the real-world. As gains continue to be made in the passive safety domain, the industry is increasingly making investments in developing and marketing technologies that are intended to warn us of potential conflict situations, support our situational awareness of conditions around our vehicles, and even actively take limited control of the vehicle in apparent emergency situations. These are laudable investments and are ones that appear to offer great potential.

At the same time, perhaps the most concrete finding of this project to date is the observation of how relatively little objective data is available upon which to evaluate the real-world effectiveness of many of this new class of safety technologies that are appearing at car dealerships and on our highways. Of the technologies considered in this report, only electronic stability control (ESC) can be classified as a technology for which we have sufficient real-world performance data from which to make a solid evaluation of its effectiveness, and that data clearly indicates a solid and substantial safety benefit. However, that is not to say that the underlying sensing and actuating technology of the other, newer systems have not undergone extensive research and development testing; there is reason to believe that extensive development and functional test level work goes into determining the basic technical capacities and limitations of individual components and basic system level function. The impression that comes from talking in-depth with individuals within the automotive industry is largely one of significant dedication to finding ways to make vehicles safer. At the same time, until a new technology is available and in use by the general public, it is striking to realize the extent to which how relatively little can be established about how these systems actually perform outside of the laboratory or test track.

In some ways, this is not surprising. In contrast with advances in structural materials and engineered crumple zones, the effectiveness of many of these new safety technologies is likely to be dependent in part on how drivers interact, or fail to interact, with them. Comprehensive real-world testing / assessment of driver behavior is, in many ways, more complex and challenging. During the extensive interviews conducted as part of this project, a number of individuals from OEMs and tier one technology manufacturers made quite candid comments about where they look to for information on how these systems actually fare in the vehicle fleet. Beyond subjective customer surveys that they conduct or commission, the industry largely looks to governmental agencies and organizations such IIHS / HLDI for the collection and analysis of crash and other event relevant data. We have found that the available data and analyses relevant to these newer technologies are even sparser than we anticipated going into this project. Other objective data from relatively real-world assessments such a field operational testing studies employing production level systems are also quite limited, as are relevant naturalistic studies. Consequently, the ratings presented in this initial assessment are based on a quite limited set of observed benefit data for all of the technologies relative to what is known about the performance of ESC.

In addition to our being stuck by the limited availability of objective real-world performance data, many representatives from industry, academics, and individuals from NGOs and other organizations that we spoke with were similarly surprised that more data could not be identified to provide objective demonstration of real-world performance. In reviews of various versions of the Technical Review sheets, a number of the aforementioned individuals frequently commented that they were sure that there must be a study on "x" or that organization "y" had data on such and such. Yet when asked for citations, few were typically found. Similarly, inquires to the organizations in question generally failed to turn-up additional data. On the other hand, it should be noted that the experts that we questioned that came from epidemiological and database analysis backgrounds, particularly those that had in the past worked with governmental agencies charged with compiling such information, tended to be less surprised by the difficulty locating good data sources to use in the ratings.

While the finding that available data is currently quite limited is problematic in one sense, the way in which this was determined could in itself represent a constructive product of this phase of the project. As outlined in the introduction, and documented more fully in several of the appendices to this report, the search for available data involved a wide cross-section of professionals from the safety research, manufacturer and tier one supplier, academic, NGO, and governmental communities. Early discussions with identified experts, presentations before the Alliance of Automotive Manufacturers and the Association of Global Automakers, multiple broadly attended and industry wide teleconferences, numerous follow-up conversations, and the Advisory Panel meetings, all engaged a significant number of key domain professionals in far ranging consideration of these issues. This process thus stimulated discussion and encouraged thought within the safety research and manufacturer communities relative to developing a more comprehensive approach to thinking about safety and methods for objectively evaluating new technologies. We believe that continuing these discussions through expansion of the rating project to consider additional technologies, refinement of existing ratings, and staged and strategic disclosure of findings may further build upon this AAA-FTS initiative.

Current Scaling

As discussed earlier, the present scaling structure focuses on the concept of safety benefit in terms of reductions in crashes, injuries, and/or fatalities. ESC was selected as a reference technology that has sufficient penetration and history in the vehicle fleet to be used as an example of a highly beneficial technology that should reasonably score at the top rating level of the scale. The threshold for a top level rating was set somewhat lower than the observed impact values for ESC. The remaining levels were scaled downward from that point using a rational scaling structure. The scaling is further structured so that higher impact values are required for theoretical estimates of safety potential than for actual observed impact in real-world data. Similarly, higher impact values are required when a technology is considered in terms of the specific scenario it was designed to work under as opposed to its impact relative to the total universe of crashes, injuries, and fatalities.

Using the initial set of scaling values, ESC ranks at the 5 diamond level in terms of Overall Safety Benefit (both theoretical and observed) and at the 5 diamond level in Scenario Specific Benefit (both theoretical and observed). Most of the other technologies considered rank relatively highly (3 to 5 diamonds) in terms of potential benefit within the scenario they were designed to impact (i.e. adaptive headlights, lane departure warning, forward collision warning, and forward collision braking). Only adaptive cruise control (ACC) ranks somewhat modestly in terms of potential benefit within its relevant scenario (rear end collision) and this is a function of

ACC only being operational for a limited percentage of the time when it might potentially have a safety benefit (i.e. it is an option that a driver must actively engage). This result is reasonable when it is considered that ACC was designed primarily as a comfort or convenience system and any safety advantages are really secondary benefits.

The scenario specific safety potential ratings for back-up cameras and lane departure warning systems do not obtain higher scores because of observed limitations of how drivers interact with these systems (see *Technology Reviews* for specific citations). Both experimental studies and surveys indicate that drivers frequently fail to actually use their back-up cameras and many often fail to notice objects in the back-up path even when orienting to the camera. These factors thus limit the theoretical gain expected from simply purchasing such a system. Lane departure warning systems are limited by the availability of visible lane markings and other technical considerations and there is evidence that many drivers ignore or turn-off lane departure warning systems, again lowering the gain that might theoretically be expected of the technology. In addition, simulation data suggest that implementation differences – finding the right balance between warning drivers too early of a potential lane excursion (and risking driver frustration) and warning too late to have a significant reduction in actual risk – may play an important role in the real-world effectiveness of such systems. Similarly, the way in which warnings are delivered – auditory, haptic, etc. – may well merit significant investigation to assist in better understanding what appears to be something of a discrepancy between theoretical potential and observed actual benefits in clearly limited available real-world data. Future enhancements of these technologies may result in grounds for reevaluating this level of theoretical expectation. From a scenario specific potential benefit expectation, the scaling across the seven rated technologies appears fairly reasonable.

In terms of overall observed safety benefit, ESC is rated at 5 diamonds. Of the remaining six technologies, one (forward collision mitigation / autobraking) presently is ranked at 2 diamonds and the others all at 1 diamond. In terms of scenario specific benefits, of the remaining six technologies, two are rated at the 3 diamond level (Adaptive Headlights and Forward Collision Mitigation / Braking), three at the 2 diamond level (back-up cameras, adaptive cruise control, and forward collision warning) and one at the 1 diamond level (lane departure warning). It must be kept in mind that differences between potential benefit and observed benefit may in some or all cases be due to limitations in current system implementations. Careful review of the factors that might impact system effectiveness is clearly called for when differences appear between expected and observed ratings. Potential sources of explanation for some of the differences are identified in the relevant *Technology Reviews* in *Appendix C*. Targeted research on why apparent benefit is so modest seems particularly appropriate in technologies such as lane departure warning systems and back-up cameras. Adaptive headlights, forward collision warning and forward collision braking values may be relatively moderate at this time due in part to limited data availability; however, this strengthens the argument for why such real-world data collection is needed as adoption of some of these systems is being actively encouraged both by the automotive industry and government entities.

Given the issues just covered, the current observed benefit rating levels are not unreasonable, but it also seems appropriate to consider the present scaling as quite open for review. Initial responses from the Advisory Panel and industry representatives at our most recent briefings suggest that the scaling for observed data seems reasonable based on the logical structure of the scale and the relative deficit of objective data. We will continue to review the proposed scaling cut-points now that values from the technology review have been applied to the scale and as we continue to receive comments and suggestion from Advisory Panel members and industry representatives.

Limitations / Points to Keep in Mind

While significant effort has been made to present a set of ratings that realistically represent the current state of knowledge concerning the safety benefit of the technologies considered, we, in many ways, see this as a proposal for a rating system. That is to say, it organizes available information in a way that allows for serious review and discussion around what is currently known and not known about these emerging safety technologies. By presenting a rationale for how technologies might be rated, summarizing the data that was identified as being available to base ratings upon, and proposing an initial set of scaling values to use for making ratings, interested parties have something concrete to which to react. Since the charge for this project was to focus on data rather than opinion, individuals or entities that feel particular technologies are either under or overrated relative to others are encouraged to identify data that can be used to justify adjusting the current proposed ratings. As noted elsewhere, we particularly see the apparent discrepancies between theoretically projected benefit and observed benefit as a means to potentially focus attention on and motivate the investment in additional work to better understand why such apparent discrepancies appear. Some of the FOT and more naturalistic observational work that we believe is needed to better understand these issues is beyond the scope of what individual OEMs and Tier I equipment suppliers can realistically be expected to carry out on their own. We are hopeful that one potential outcome of this project is the encouragement of further collaborative efforts by various stakeholders to undertake additional work in this area. In summary, a number of points should be kept in mind when reviewing this report that are elaborated below. In addition, a number of comments and critiques from industry reviewers and various panel members are also recognized here:

- As discussed throughout this report, with the exception of ESC, the primary limitation in rating the technologies considered here is the relatively limited data available on how each technology performs under real-world driving conditions. While most of the technologies appear to have significant safety potential, for the most part, we know relatively little about how drivers interact with many of these technologies on a daily basis and how that may influence their ultimate performance. More work is needed in this area.
- Following the original submission of this report to AAA-FTS, the University of Michigan Transportation Research Institute (Blower, 2014) released a literature review covering some of the same technologies considered here (e.g. ESC, FCW, FCM, and LDW). Generally consistent with our conclusions, the report states that the technologies were "estimated to be substantially effective in reducing their target crash types". However, it was noted that most studies relied on simulation or limited field operational tests. Other than for ESC, it was stated that "available crash data cannot yet support evaluation of the actual crash experience of the technologies". While we believe that some of the insurance based claim data on crashes and property damage reviewed in our report show an

advance in the state of knowledge somewhat beyond what was considered in the UMTRI report, our substantive views are similar.

- In line with the statements above, representatives of several OEMs expressed their opinion that the data at this point does not seem robust enough to support "even a general rating" of most of these technologies. However, they also emphasized that the information brought together in this report on the technologies and the status of the data is useful. Other representatives commented that the overall ratings appeared reasonable given the data currently available.
    - Noting the exception of ESC, one representative passed on the recommended that, in terms of presentation to consumers, it might be better to wait until further data is collected to reflect accurate safety benefits of these advanced technologies.
    - One OEM expanded on this by stating: "The highest priority should be educating consumers (before rating) about functionalities of safety technologies to avoid over reliance and/or misunderstanding as well as to improve acceptance".
    - As seen in the case of systems that combine elements of ACC, FCW, and FCM/Autobraking, integrated safety systems are becoming the trend in the industry. It was suggested that it is more ideal to evaluate comprehensive safety rather than individual safety technologies.
- Representatives of an industry group commented that the work to date produced by the project represented a good start for further educating consumers on the different technologies.
    - It was suggested that there might be some value in expanding the adaptive headlight review to include automatic high beam control in addition to steerable headlights. This would allow expansion of the seneareo considered from "driving around curves at night" to "night driving".
- The initial ratings provided as part of this proposed rating system represent a "snap-shot" in time and are in some instances based upon "dated" data that represents the best available information. As more data ideally becomes available, it may justify a change in the rating of that technology. Consequently, any rating system should ideally be viewed as dynamic and updated on a periodic basis to provide the most meaningful representation of a system's benefit.
- Just as more data on system performance accumulates over time, technologies continue to be refined and improved, such that a technology class that is given a modest rating today, may offer a significantly enhanced safety benefit in next year's model. This also argues for periodic updating of any rating system.
- It is very important to recognize that different implementations of a class of technology may vary widely in their overall effectiveness and the specific scenarios for which they are optimized. Some of this information is noted in the ***Technology Reviews*** in Appendix C and consumer oriented support material drafted as part of this project. Nonetheless, this highlights one of the challenges in providing broad guidance on the potential of a technology class versus providing ratings of specific vehicle models.

- A representative of one OEM specifically advised that they felt it was most appropriate for the project to be considering generic technologies as a class type as opposed to attempting to evaluate how each manufacturer implemented a technology.
- Another OEM representative noted as a challenge for the rating system the example that ACC based on a single radar would operate over a smaller speed range than ACC based on multiple sensors (radars and/or cameras) that operate over the full speed range of the vehicle. As the system stands now, preference is given to data representing "best in class" performance.
  - This highlights the importance of providing supporting information along with the upper level ratings that makes clear that such implementation differences can exist.

- The current rating approach weights all event types equivalently. One consequence of this is the relatively modest ranking assigned to back-up cameras in terms of *Overall Safety Benefit*. This is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities. At the same time, it is recognized that there is a particularly high emotional cost associated with this type of event. NHTSA (2014) estimates that 31% of all backup event fatalities involve children under 5 years of age and another 26% are adults 70 years and older; these events often involve family members or other close associations. Societal pressure to do something about such events contributed to NHTSA recently issuing a final rule (on March 31st) mandating rear visibility technology in all new vehicles under 10,000 pounds by May 2018. This type of value assignment is most likely best done outside of the proposed rating system and left to the judgment of societal and/or personal evaluation of the personal significance of particular type of scenario. This is one of the reasons for incorporating both overall benefit and scenario specific objective ratings in the rating system.
- The question was raised by industry representatives as to whether ESC and back-up cameras should be included in the review as ESC is mandated for all vehicles produced from 2012 forward and rear-view visualization was recently (March 31, 2014) mandated for model years 2018 forward.
  - ESC was specifically included in the initial rating system for scaling purposes as a reference point for a technology that clearly qualified for a top level rating. Keeping ESC in the ratings might have value in encouraging owners of older cars without ESC to consider "upgrading" to derive a clear safety value. It has also been suggested that this might help inform used car shoppers to only consider older cars that include the technology. Nonetheless, it is a reasonable point to be reviewed as to whether inclusion of ESC should be carried forward.
  - As noted, the mandate for back-up visualization technology was issued after this report was essentially completed. Nonetheless, including back-up cameras in the current ratings does provide heuristic value in several areas. For one, it highlights the distinction between purely statistical ratings of significance in terms of

absolute numbers of events versus the apparent societal / emotional rating of a particular class of adverse scenario. Furthermore, the observations that the estimated scenario specific benefit for the technology class is currently less than 5 diamonds and that the currently demonstrated benefit of back-up camera systems is less than the theoretical potential, both highlight that there seem to be gaps in the full realization of this technological concept. This should encourage a closer look at how this class of technology might be further improved. In other words, the fact that a mandate has now been issued to implement technology to address back-up events does not mean that the push to solve this problem should necessarily be considered over. Further improvement in existing technology implementations appears to be needed and including back-up cameras in the rating system may have utility in contributing to the discussion around what remains to be done.

- A concern was expressed by one OEM that the project report did not provide a complete description of the database search and the search commands used in the review, and suggested that this limited the ability to update the ratings as additional real-world data is collected. While we believe that the search employed to develop the current review was quite extensive and well supplemented by requests to experts from a wide range of disciplines, as well as OEM and Tier One representatives, we agree that systematic documentation of search terms and databases employed would be useful in any further development of the project. This firm also stated that they understood "the limitation in publicly available data to show actual benefits or potential benefits for specific technologies and in particular the difficulties when comparing systems of different designs and performance characteristics in addressing a specific scenario. However, studies do exist and the MIT team has been successful in gathering extensive information on the technologies in question…".
- In early conceptions of the rating system, we proposed including a range factor within the rating of each technology class to indicate the extent to which variation in effective benefit was present. This was dropped from the proposal put forth here for two reasons. First, a number of members of the Advisory Panel and others consulted on the project expressed the strong opinion that this presented too much detail in the upper-level rating information and was likely to confuse consumers. Second, a number of individuals also strongly argued for the upper-level ratings to reflect the safety benefit of "best in class" systems. The intent here is to "err" on the side of encouraging serious consideration of technologies with the potential to increase safety.
- One automotive manufacturer noted for its investment in advanced safety technologies expressed the concern that a more mature technology may show an apparent advantage in the ratings over a newer technology as data on the newer technology will initially be limited. The comment further observed that given the time lag in studies and results on deployed systems, this might have a negative effect in terms of promotion and acceptance, rather than helping to improve customer adoption rate of the technology. This does seem to be a logical concern. One of the reasons for including a rating of theoretical benefit in the system is to provide a best case estimate of potential while deployment data

is sparse. Interestingly enough, one of the newest technologies, forward collision braking, does come out with a higher currently documented benefit rating than all of the other, more established technologies except for ESC. However, this higher demonstrated benefit rating is traceable to a single recent study that was not included in the first draft ratings. This highlights the importance of early studies of real-world behavior to advance confidence in new technologies.

- A number of contributors/reviewers have continued to express concern over our proposed dual rating of estimated safety benefit vs. observed demonstrated benefit in real-world conditions. There seems to be general agreement around the validity and importance of the distinction, but concern that this may be confusing for some consumers. The authors feel strongly that this distinction is important for a number of reasons, many of which are enumerated in this report, but take the issue of possible confusion quite seriously. It is likely that the proposed system would benefit from further creative input on possible alternative methods of presenting this information to the general public. Along the same lines, focus group testing is also suggested to assess the extent to which a generic technology rating (the focus of this effort) contributes to the education of consumers on the range of capabilities of technologies that may wish to purchase.

It is clear that distilling the assessment of the potential benefit a particular technology down to a meaningful and appropriate single rating value is challenging and, in some ways, questionable. The proposed rating system represents an attempt to take into account, at a minimum, a number of important concepts such as percentage reduction across all crash events vs. percentage reduction with the specific scenario that a given technology was developed to address. Nonetheless, we believe that the concepts and information developed and drawn together so far over the course of this project make a constructive contribution to efforts to better understand the status of these technologies. At a minimum, the initiation of this project by AAA-FTS has stimulated significant discussion and constructive exchange between a broad cross-section of stakeholders concerned with driving safety.

Next Steps

A separate document, *Evaluating Technologies Relevant to the Enhancement of Driver Safety: A Vision beyond Phase I*, was prepared at the request of AAA-FTS staff concerning our thoughts regarding possible next steps in the project.

As detailed there, the project was initiated with the vision that it would extend beyond the initial phase of rating a minimum of five technologies. As originally conceived, the intent was to continue adding technologies to the matrix to cover a wider range of relevant technologies. If this rating process and the information and materials developed prove useful, the next logical step would be to periodically update the rating of technologies as they evolve and as improved data becomes available. Two possible approaches to continuing this vision were proposed. The more extensive recommendation suggested that the project be continued to add additional safety technologies to the existing ratings. A possible second round of ratings might consider:

- Blind spot detection

- Lane departure mitigation / lane keeping assist
- Fatigue detection
- Back-up proximity detection sensors
- Pedestrian collision mitigation systems

Collecting relevant data on additional technologies, such as those listed above, and applying the obtained findings to the rating system would have both intrinsic informational value and would contribute to better evaluating whether the current scaling levels serve their intended purpose or should be adjusted.

The process of identifying available data on each of the technologies and the development of the associated Technology Review sheets represents a substantive investment in both conceptual thinking about relevant evaluation factors and applied research review. With this investment in place, it is worth considering the possible development of a series of formal review papers on each of the safety technologies. Such papers could form the basis of formal academic review papers that would be submitted to academic journals. It was also suggested that these efforts could be further adapted / developed into periodic Foundation / AAA publications on selected safety technologies. Such an undertaking by AAA-FTS and/or other organizations would further leverage the investment the AAA-FTS has already made in this work.

Acknowledgements & Responsibility Statement

A number of people have contributed significant time, thought, and experience during the development of this project ranging from early discussions about factors that might be important in better understanding the real-world effectiveness of emerging safety technologies, to the identification of relevant information, and the consideration of how available data might be scaled and presented in an manner that is both understandable and which constructively contributes to a dialog around the further enhancement of driving safety. These individuals represent a cross-section of perspectives ranging from industry experts, academic researchers, safety advocates, current and former government employees with expertise in the area, and so on. Many of these contributions were provided on personal time. While all input was taken seriously and considered in the development of this report, it was ultimately taken as advisory. Final decisions about what was included in this report, the language used, and conclusions expressed are the responsibility of the authors and do not necessarily represent the opinions or formal positions of any of the contributors mentioned, the organizations they are affiliated with, AAA-FTS, or individual AAA Clubs. With the aforementioned in mind, the authors would like to extend their sincere appreciation to everyone who commented on or otherwise contributed to this undertaking and, in particular, to AAA-FTS for initiating and supporting the development of this work.

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The following is a combined listing of references cited in the main body of the report and the accompanying appendices.

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Appendix A: Rational Scaling Structure for Level Scaling

The table below presents the scaling structure used for the current rating levels used in the proposed system. See main text for details.

Actual Scenario	min.	max.	range	scaling
Level 1	1	10	9	
Level 2	11	22	11	2
Level 3	23	38	15	4
Level 4	39	60	21	6
Level 5	61+			

Actual Overall	min.	max.	range	scaling
Level 1	1	5	4	
Level 2	6	11	5	1
Level 3	12	19	7	2
Level 4	20	30	10	3
Level 5	31+			

Theory Scenario	min.	max.	range	scaling
Level 1	1	12	11	
Level 2	13	28	15	4
Level 3	29	50	21	6
Level 4	51	80	29	8
Level 5	81+			

Theory Overall	min.	max.	range	scaling
Level 1	1	6	5	
Level 2	7	14	7	2
Level 3	15	25	10	3
Level 4	26	40	14	4
Level 5	41+			

Appendix B: Advisory Panel

A panel of experts was convened to provide critique and input on all aspects of the rating system and data being considered for rating purposes. The group initially assembled in Washington DC on July 19th 2013 and continued discussions over five conference calls (October, November and December 2013, and March 2014). Numerous panel members provided directed comments via personal emails and conversations independent from the panel meetings. Input from this group provided pivotal feedback on various revisions to the rating system, review of the overall methodology selected for rating and detailed feedback on the Technology Review sheets assembled for each technology.

The current materials were developed taking into account feedback from panel members, but the content and interpretation should not be seen as a necessarily representative of any individual member's opinion or of organizations with which they are affiliated.

Chair

Joseph Coughlin - Director MIT AgeLab & New England University Transportation Center

Members

Academic Research

- Dan McGehee - Director of the Human Factors and Vehicle Safety Research Division at the University of Iowa Public Policy Center
- Jim Sayer - Research Scientist in the Human Factors Group at the University of Michigan Transportation Research Institute

Automotive Industry

- Mike Cammisa - Director, Safety - Global Automakers
- Scott Schmidt - Senior Director, Safety & Regulatory Affairs - Alliance of Automobile Manufacturers

Government Agency

- Jennifer Dang – Chief of NHTSA's New Car Assessment Program (NCAP)
- Erin Sauber-Schatz - Acting Team Lead/Epidemiologist Transportation Safety Team Division of Unintentional Injury Prevention National Center for Injury Prevention and Control, CDC

Insurance industry

- Adrian Lund - President of the Insurance Institute for Highway Safety and the affiliated Highway Loss Data Institute

Other Specialists

- Joseph Carra - NHTSA Retired

Consumer Safety Advocate

- Paul Santos - Santos Family Foundation

Representatives of the "Consumer"

- Jake Nelson - Director of Traffic Safety Advocacy & Research for AAA
- David Nguyen - Manager, Automotive Engineering AAA National Office

Observers

- Jurek Grabowski - Director of Research AAA Foundation for Traffic Safety
- Peter Kissinger - President & CEO AAA Foundation for Traffic Safety

Appendix C – Technology Review sheets

In their current form, the Technology Review sheets are intended for internal reference. They identify relevant objective data collected on the safety benefit of each of the technologies. Information relevant to factors that may impact effectiveness is also identified. Note that some of the latter material includes listings of concerns or possible issues raised in either the research field or by industry sources. Similarly, industry comments on driver responsibility have been noted in a number of limitations entries. If an entry does not include a source citation, then it should be taken as opinion or hypothesis as opposed to necessarily being data based.

In addition to significant input from a number of OEM representatives, Advisory Panel members, and other advisors already mentioned, we would like to express our appreciation to Richard Young who commented extensively on early versions of several of the technology reviews. However, as noted elsewhere, responsibility for the summarization presented remains with the authors of this report. Identification of additional relevant data and studies, corrections, and constructive input and comment on the technology review summaries is welcome and encouraged as we anticipate further update and refinement of these summaries.

Electronic Stability Control (ESC)

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊◊◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦♦♦♦♦	♦♦♦♦♦

What is the technology?

- Electronic Stability Control (ESC) is designed to help a driver maintain or regain control of the vehicle in difficult driving situations, such as during unexpected turns or while negotiating icy roads. ESC systems continuously monitor actual vehicle motion (tire movement) and driver's intention (steering wheel activity) to sense a loss of traction or slippage. In such situations, ESC systems apply brakes independently to each wheel to counter oversteer and understeer conditions.
    - Some ESC systems adjust tire suspension and can reduce engine power until control is regained.
- ESC is a level 1 vehicle automation system (Function-Specific Automation) (NHTSA, 2013).

Crash Reduction/Prevention

- An Insurance Institute for Highway Safety (IIHS) report (C. Farmer, 2004) based on an analysis of the Fatality Analysis Reporting System (FARS) for all fatal crashes in the United States over 3 years (2001–2003) found that:
    - ESC was found to have reduced single-vehicle fatal crash involvement risk by 56 percent (C.I. 39–68).
    - This translates to an estimated 34 percent reduction in overall fatal crash involvement risk (C.I. 21–45)(C. Farmer, 2004).
- In a follow-up analysis considering a ten year period, Farmer (C. M. Farmer, 2010) reported somewhat smaller effectiveness values while providing a number of explanations for this decline. The updated summary finds a reduced fatal crash involvement risk of 33%:
    - 20% for multiple-vehicle crashes and 49% for single vehicle crashes.
    - Effectiveness estimates were 30% for cars and 35% for SUV's, although these differences were not statistically significant.
- Using data from the NASS General Estimates System (GES) for Sport utility vehicles, Green and Woodrooffe (2006) showed that the odds of a loss-of-control crash for sport utility vehicles equipped with ESC was reduced by 70.3%.
    - Both genders and all age groups benefited equally from the system.
    - With respect to driver age, the maximum percentage reduction of 73.6% occurred at age 27.

- Fergusson (2007), in a 2003 to 2006 literature review, found that the overwhelming majority of real-world crash studies find ESC to be highly effective in reducing single-vehicle crashes in cars and SUVs. Single vehicle crash risk was reduced by 33-35% for standard passenger vehicles and 56-67% for SUV's. Additional breakdowns:
    - Fatal single-vehicle crashes involving small cars were reduced by about 30–50% and SUVs by 50–70%.
    - Fatal rollover crashes were estimated to be about 70–90% lower with ESC regardless of vehicle type.
    - A number of studies found improved effectiveness in reducing crashes when road conditions are slippery.
    - ESC does not reduce the overall occurrence of multi-vehicle crashes, but does reduce the number of fatal multi-vehicle crashes by 17-38%.
- Erke (2008) summarized the effects of ESC from a number of studies in a meta-analysis:
    - Large reductions of single vehicle crashes were found (-49%; 95% confidence interval -55% to -42%), and smaller but still statistically significant reductions of head-on collisions (-13%; 95% confidence interval -17% to -8%).
    - Multi-vehicle fatal crashes are also reduced (-32%; 95% confidence interval -43% to -20%).
    - However, the studies vary in their effect size estimates, especially for single vehicle crashes. Results of studies on single vehicle crashes produce larger effect size estimates than are expected based on the total number of crashes that could be affected by ESC, suggesting an upward bias in the 49% single vehicle crash reduction estimate. Unspecified properties of the vehicles, time trends, and driver behavior may have biased the single vehicle effect estimates too high.
- Based on statistical analyses of the Fatality Analysis Reporting System (FARS) and National Automotive Sampling System Crashworthiness Data System (NASS CDS) data from 1997 to 2009, ESC has the potential to prevent 72% of car rollovers and 64% of SUV rollovers that would otherwise occur in single-vehicle crashes (Sivinski, 2011).
- ESC is effective for single-vehicle crashes (18.6% effectiveness across all crash severities, 49.3% effectiveness for injury crashes) (Chouinard & Lecuyer, 2011). The results of the study also show that ESC is effective in Canadian weather conditions (i.e. on ice, snow and slush). The effectiveness of ESC on roads covered with ice, snow and slush is 51.1% across all severities and 71.1% for injury crashes.
- According to Insurance Institute for Highway Safety and the U.S. National Highway Traffic Safety Administration, one-third of fatal collisions could be prevented by the use of the ESC (Dang, 2004; IIHS, 2012).
- ESC has been shown to be effective in different weather conditions (i.e. on ice, snow and slush)(Chouinard & Lecuyer, 2011).

Consumer Awareness & Trust

- Rudin-Brown et al. (2009) conducted two separate telephone surveys evaluating Canadian drivers' perceptions and awareness of ESC. The first surveyed 500 randomly selected owners of passenger vehicles. The second survey contacted 1,017 owners of 2006-2008 ESC-equipped passenger vehicles.
    - Results indicated that awareness of ESC was low. When prompted to identify vehicle safety features, only 1% of the people surveyed mentioned ESC, or a branded equivalent. Out of the first 500 surveyed, sixty percent of drivers had never heard of ESC, and less than 5% were aware that they own a vehicle equipped with ESC.
    - While ESC drivers were much more likely than drivers of other vehicles to be aware of ESC (77% vs. 39%) and whether their own vehicle was ESC-equipped (63% vs. 8%), 23% had never heard of it.
    - Ninety percent of drivers who knew that their vehicle was equipped with ESC believed that ESC had made it safer to drive, and reported being confident that ESC would work in an emergency.
    - Twenty-three percent of ESC owners who knew their vehicle was equipped with ESC reported noticing long-lasting changes in their driving behavior since they began driving the vehicle.
- In a recent survey conducted by Traffic Injury Research Foundation (TIRF), a total of 2,506 Canadians completed a poll on major available safety technologies (832 over the phone and 1,674 online)(Robertson, Vanlaar, Marcoux, & McAteer, 2012).
    - The results showed that only 31.4% of them were familiar with ESC (Female: 20.3%, Male: 44.2%).
    - 41% of the drivers said that ESC could make them a better driver (Female: 37.5%, Male: 44.9%).
    - 65.5% of male drivers perceived easiness of use of ESC whereas female drivers reported a 49.4% of perceived easiness (total: 56.9%).
    - 59.5% of drivers reported they would use ESC in the future (intention to use) (Female: 53.7%, Male: 66.2%).

Mobility Significance

- No substantive research has been identified to date that examined the mobility significance of ESC systems.

Other Benefits

- None identified

Technology Penetration

- In the US, regulation FMVSS No. 126 (Electronic Stability Control Systems Indicative Test for Compliance) requires that all cars be manufactured with ESC technology by 2012. This regulation has been proposed as a GTR (Global Technical Regulation) (National Highway Traffic Safety Administration, 2007).
- The only way to get ESC is to buy a new or used vehicle that is equipped with ESC. It cannot be installed as an add-on package.

Frequency of Use

- Rudin-Brown et al. (2009) conducted two separate telephone surveys evaluating Canadian drivers' perceptions and awareness of ESC. The first surveyed 500 randomly selected owners of passenger vehicles. The second survey contacted 1,017 owners of 2006-2008 ESC-equipped passenger vehicles.
  - ESC is automatically "on" whenever the engine is started. In some models, ESC can be turned off by the driver. If so, a telltale lamp will normally illuminate on the instrument cluster. However, the system will automatically be turned back on at the next ignition. The owner's manual should be consulted to learn how ESC works for a given vehicle.
  - The survey did not report how frequently drivers may have turned off the ESC system.

Training and Education

- No formal studies were identified that examined the impact training/education on drivers' interaction with ESC.
- Consistent with Thatcham's statement (Thatcham, 2013), in order to allow the full intended safety benefits of ESC to reach consumers, vehicle manufacturers are encouraged to market ESC-equipped vehicles in a responsible, safe, and realistic manner.
  - Driver training and safety organizations are also encouraged to provide balanced educational information regarding ESC to their students (Thatcham, 2013).

Behavior Adaptation

- Although past and emerging research indicates that ESC is effective in reducing crash rates and saving lives, and its inclusion in all vehicle platforms is encouraged, it may be speculated that some drivers may develop an over-reliance on ESC that could offset or reduce its overall effectiveness, a phenomenon known as 'behavioral adaptation' (Thatcham, 2013).
  - While potential changes in driver behavior are of concern, ESC's proven effectiveness in reducing the likelihood of being involved in a serious crash outweighs any potential increases in unsafe driving due to behavioral adaptation (C.M. Rudin-Brown, Burns, Jenkins, Whitehead, & LeBlond, 2008).

Auditory Demand

- Some ESC systems utilize a sharp alarm sound, but the effects of different alarm types on the driver and any resulting impact on the effectiveness of ESC have not been studied.

Visual Demand

- Some ESC systems utilize a visual alarm, but the effects of different alarm types on the driver and any resulting impact on the effectiveness of ESC have not been studied.

Haptic Demand

- In this review, no information was found that indicated that haptic warning signals for ESC were used by any vehicle manufacturer.

Cognitive Demand

- The system activates only in situations where the driver is highly likely to be taxed by the demands of maintaining vehicular control. No research has been identified that examines the specific cognitive effects of ESC.
    - It might be hypothesized that ESC engagement could reduce cognitive demand, because it reduces the loss of vehicle control which arguably is a high cognitive demand event. However, this suggestion should be evaluated rather than assumed.

Vehicle Type

- In a meta-analysis conducted by Hoye (2011), ESC was often found to be more effective in Sports Utility Vehicles (SUVs) than in passenger vehicles. This is likely due to many SUV designs having significantly higher centers of gravity than typical passenger vehicles and are, as a consequence, inherently less stable in turning conditions. Such vehicle designs thus show greater percentage improvement with the addition of ESC.
- Since ESC is embedded differently in every vehicle, some sportier models allow more wheel spin and sliding, while still maintaining control. This may influence ESC efficiency, but no studies to date have separated out these effects (Ferguson, 2007).
- On some four-wheel drive vehicles, ESC will turn off when you shift to the low range of four-wheel drive. A dashboard light or message is typically provided to indicate to the driver when this occurs (C.M. Rudin-Brown et al., 2008).

Limitations / Failure Conditions

- ESC systems are not optimized for operation in contact with loose surfaces such as gravel, soft snow, and mud. Some vehicles provide an override switch or other mechanism for disengaging the ESC system if a driver experiences difficulty maneuvering under such conditions.
- This technology does not and cannot change the laws of physics. If a vehicle is traveling too fast for road conditions or is not maintained properly (ex. tires and brakes), an ESC equipped vehicle can still lose control.

Differences between Implementations

- Consumers should be made aware that ESC performance can vary between vehicle models (i.e. lateral displacement of the vehicle, angle maintenance). (Thatcham, 2013).
  - Each ESC system is tuned by the manufacturer to work with the chassis dynamics of each vehicle to provide safety benefits while balancing intentional handling characteristics of a particular brand. Individual model tuning may provide more advantage in one loss of control scenario and less in another.
  - It is also worth noting that vehicle models that crashed more frequently before ESC was introduced are generally the models that have shown the greatest reduction in crashes after ESC was added.

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Adaptive (Automatic) Cruise Control (ACC)

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊	◊◊
Benefit Currently Documented	♦	♦♦

What is the technology?

- Automatic Cruise Control (ACC) uses distance sensing technology that automatically slows down and speeds up the vehicle to maintain a constant distance between the vehicle and the vehicle directly ahead.
- ACC differs from previous cruise control systems that could only maintain the vehicle's current speed, without taking the speed of other vehicles into account. It still allows a driver to maintain a set speed when no other vehicles are nearby, but if a vehicle is sensed in the forward view by ACC, it can maintain a set time headway to the forward vehicle.
- If the forward vehicle picks up speed, the automatic cruise control system will increase the speed of the vehicle such that the set headway gap is maintained up until the vehicle reaches the programed cruise speed set by the driver. In many vehicles the ACC will not automatically accelerate the vehicle if the vehicle slows below some threshold level.
- Automatic cruise control will not perform emergency braking. ACC will only perform moderate braking. For emergency braking a separate AEB system is required.
- Automatic Cruise Control is a level 1 vehicle automation system (Function-Specific Automation) (NHTSA, 2013).

Crash Reduction/Prevention

- The one publically available report that was identified that provided an estimate of potential safety benefits of ACC was a NHTSA sponsored FOT (Koziol et al., 1999). The authors concluded that if such systems were fully deployed and utilized at the engagement rate seen in the FOT, it was estimated that the number of collisions on freeways for travel velocities above 40 km/h would be reduced by 17% for two specified scenarios. This estimate would correspond to a reduction in the number of police-reported rear-end collisions by about 13,000 in 1996 and this was interpreted as indicating a fairly strong benefit compared to manual driving. However, as a percentage of total crashes of all types, this would correspond to less than 1%.
    - Scenario 1 – when an ACC equipped vehicle approached a slower vehicle traveling at a constant velocity
    - Scenario 2 – when a lead vehicle decelerated in front of an ACC equipped vehicle.
    - It was noted that additional safety benefits would be expected from a reduction in other rear-end collisions involving cut-ins and lane changes and from use of ACC on roadways other than freeways; however, benefit estimates for these scenarios

were not examined in the FOT. Drivers were found to engage the system for 6 % of the time on arterials and 11% on state highways.

- A senior staff member at IIHS confirmed in personal communication (12/2013) that they were not aware of any other theoretical estimates of crash prevention or mitigation benefits of ACC or any reports that measured benefits for ACC isolated from other, related safety features. Since more recent IIHS work has considered vehicles that frequently combine ACC with forward collision warning (FCW) and, increasingly, autobrake features, it is seen as difficult to isolate the effects of the component systems.

Consumer Awareness & Trust

- In a recent survey conducted by Eichelberger and McCartt (2012), Volvo drivers were asked whether they would want specific technologies that they currently possess in their next vehicle. Ninety-three percent reported they would want ACC again.
    - Moreover, 49% mentioned that the technology relieved stress while driving.
- Numerous studies have shown that ACC is well received among adopters primarily because of its perceived convenience and improved safety. However, despite increased usage of ACC while driving, few drivers who own such a system fully understood how the system operated and overestimated the effectiveness of ACC in situations in which it does not work appropriately (Hoedemaeker & Brookhuis, 1998; Jenness, Lerner, Mazor, Osberg, & Tefft, 2008; Llaneras, 2006).
- In a survey conducted by the Automobile Club of Southern California (AAA-FTS, 2008a; Jenness et al., 2008), 370 owners of ACC (out of a total of 1,659 responses from the initial mailed surveys) responded to a questionnaire:
    - Most respondents who have ACC appeared to be satisfied with their systems because the majority of them reported that they would want to purchase ACC again (76%).
    - Although most ACC owners would want to get their system again, many (72%) were not aware of manufacturers' warnings about system limitations.
    - Nearly half of the respondents agreed that using ACC relieves them of stress when driving.
    - Sixteen percent of respondents said that they were "always," "frequently," or "sometimes" confused about whether their ACC system or conventional cruise control system was operating.

Mobility Significance

- No substantive research has been identified that specifically examined the mobility impact of ACC.
    - ACC is conceptually most beneficial for people who primarily drive on highways. An advantage over earlier generation fixed-speed cruise control systems is the ability to function under conditions where traffic speed varies such as conditions of traffic congestion.

Other Benefits

- ACC is estimated to have benefits related to reduced congestion and improved fuel economy due to smoother traffic flow (Marsden, McDonald & Brackstone, 2001).

Technology Penetration

- ACC is primarily available on luxury cars either as standard or optional equipment. However, as more vehicle makes and models begin to feature ACC as either optional or standard features, the price of the system is likely to decline.
- The system has been available in the United States since 2001.

Frequency of Use

- No substantive data was identified on the actual frequency of use of ACC in vehicles so equipped.
- Most systems require the driver to turn on ACC, just as with conventional cruise control. It is not on by default.
- In a recent survey conducted by Eichelberger and McCartt (2012), Volvo drivers were asked whether they use ACC on freeways, expressways, or other high-speed roads.
    - Fifty-one percent reported always using it, while 23% and 5% reported using it sometimes or rarely, respectively.
    - Among those who used ACC, 55% also reported adjusting the gap between the vehicles from the default settings (to either longer (22%) or shorter (33%) following headway time). Whereas 36% never changed the pre-set headway time.

Training and Education

- No formal studies were identified that examined the impact of training/education on the usage of ACC.
- In a survey conducted by the Automobile Club of Southern California (AAA-FTS, 2008a; Jenness et al., 2008), 370 owners of ACC (out of a total of 1,659 responses from the initial mailed surveys) responded to a questionnaire:
    - The most frequently cited method for learning how to use ACC were the vehicle owner's manual and "on-road experience." On-road experience was the only learning method selected by 15.5 percent of respondents.

Behavior Adaptation

- In a test-track study, Rudin-Brown and Parker (2004) assessed whether ACC induces behavioral "adaptation" or over-compensation in drivers in three counterbalanced conditions: No ACC (self-maintained average headway of 2 s), ACC-Short (headway of 1.4 s) and ACC-Long (headway of 2.4 s).
    - Use of ACC resulted in significantly more lane position variability, an effect that was also more pronounced in high sensation-seekers.

  - Driver trust in ACC increased significantly after using the system in this experiment, and these ratings did not change despite a simulated failure of the ACC system during the ACC-Long condition.

- In a simulator study, Xiong et al. (2012) showed that conservative drivers tend to stay farther from the lead vehicle as compared to risky and moderately risky drivers. Risky drivers tended to respond later to critical events and had more ACC warnings.

- In a recent survey conducted by Eichelberger and McCartt (2012), Volvo drivers were asked whether they followed vehicles more or less closely when using ACC. Three percent reported that they followed vehicles more closely, 46 percent followed less closely, and 49 percent reported no change. When asked whether they looked away from the road when using ACC, 4 percent of drivers said they tended to look away from the road more often, 5 percent tended to look away less often, and 90 percent reported no change.

- In a survey conducted by the Automobile Club of Southern California (AAA-FTS, 2008a; Jenness et al., 2008), 370 owners of ACC (out of a total of 1,659 responses from the initial mailed surveys) responded to a questionnaire:
  - Eleven percent of respondents said they usually have their ACC set to the shortest gap (following distance) and 24 percent said that they usually use the longest gap setting.
  - Many ACC owners were not aware of the limitations of their system and overestimate its effectiveness at helping them to avoid collisions. In fact, 72 percent of respondents said that they were not aware of any manufacturer's warnings or limitations about their ACC system.
  - Thirty-eight percent of ACC owners thought that using ACC made them safer drivers than using only conventional cruise control and 7 percent thought that it made them less safe. A majority (54 percent) thought that using ACC made them neither more nor less safe.
  - 12 respondents (3.7%) reported having a collision or "close call" while driving another vehicle equipped with conventional cruise control because they expected the vehicle they were driving to automatically slow down.

Auditory Demand

- Some ACC systems provide an auditory alarm if the driver needs to take action or if the system is disabled. However, no substantive research specifically considering auditory demand associated with ACC use has been identified to date.
  - "The ACC will automatically disengage and send an audio alert of termination at a speed of 40.3 km/h or lower. When the leading vehicle brakes hard and the required deceleration rate exceeds the ACC maximum rate (0.3 g), an audio alert of deceleration limit exceedance is also sent."(Xiong et al., 2012)

Visual Demand

- No substantive research was identified that examined the impact of ACC on visual.

Haptic Demand

- No substantive research was identified that examined the impact of ACC on haptic demand.

Cognitive Demand

- No substantive research was identified that examined the impact of ACC on cognitive demand.

Vehicle Type

- No substantive research was identified that examined the impact of vehicle type on the usability or effectiveness of ACC.

Limitations / Failure Conditions

- ACC only responds to changes in the speed of the forward vehicle. It is not intended to respond to people, animals, stationary obstacles, stopped/parked vehicles on the road, or oncoming and crossing traffic.
- An AAA-FTS assessment (AAA-FTS, 2008b) of results from a survey covering ACC saw benefit potential in the technology, but also raised the concern that many drivers are not aware of the limitations of systems.
    - Misunderstandings identified in the survey included the incorrect assumption that ACC technology would help avoid a collision with a stopped vehicle.
- Some vision based systems can be hindered by rain, fog, and darkness. Also obstruction of the windshield by ice/frost, snow, or dirt can impair sensor function.
- Radar based systems can also be obstructed by snow/ice or dirt/mud which might block the sensor. ACC may not respond well to dirty vehicles that do not reflect enough light or in poor weather conditions.

Differences between Implementations

- Major differences between implementations were not identified during the course of the review (however, this question was not researched in depth).
- Some systems include a lead vehicle graphic in the instrument cluster (or other indicator) to indicate the status of the system. If the indicator is not illuminated, this indicates that the system is not detecting a vehicle in front. This can be useful in indicating to the driver whether the system is functioning properly; if a lead vehicle is present and the indicator is "off", this provides a cue that the sensor may be damaged or obscured due to dirt or other sources.

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Adaptive Headlights

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊	◊◊◊◊◊
Benefit Currently Documented	♦	♦♦♦

What is the technology?

- Adaptive headlights adjust their direction and intensity to provide additional illumination on curves, turns, and hills and to highlight potential hazards.
- Adaptive headlights (adaptive front lighting systems) are lighting devices that adjust the characteristics of the headlight beams to different situations, based upon the steering of the driver. These can apply to either the low beam or high-beam setting.
- Adaptive headlights are a level 0 vehicle automation system (No-Automation) (NHTSA, 2013).

Crash Reduction/Prevention

- An Insurance Institute for Highway Safety (IIHS) study estimated that adaptive headlights have the potential to prevent up to 142,000 crashes per year associated with poor visibility negotiating dark curves (Jermakian, 2011).
  - Estimating the significance of this technology on scenarios related to improving visibility when negotiating curves in darkness or twilight, the study estimated that adaptive headlights have theoretical relevance to 90% of the crashes that occur on curves at night - 91% for nonfatal injury crashes and 88% for fatal crashes.
  - These situations for which there may be potential benefits represent 2% of all crashes, 4% of nonfatal injury crashes, and 8% of fatal crashes.
- The Highway Loss Data Institute (HLDI) looked at adaptive headlights offered by Acura, Mazda, Mercedes and Volvo and found that property damage liability claims fell up to 10% for vehicles with adaptive headlights compared to vehicles without adaptive headlights (IIHS, 2012). Discussions with IIHS (Lund, 2014) indicate that this number would best be translated into a high-end estimate of around a 2.5 to 5% reduction in overall crash events, i.e. there are on the order of two property damage liability claims for a crash event that involves two vehicles. These findings highlight some of the complexity of interpreting insurance data because the IIHS reports also show that:
  - Adaptive headlights do not seem to be associated with a statistically significant reduction in insurance collision claims for Acura, Mercedes and Volvo, the kind of claim that would result from a single-vehicle crash (with the possible exception of Mazda).
  - However, vehicles with adaptive headlights are responsible for fewer crashes with other vehicles, as indicated by a reduction in property damage liability claims and in claims for injuries in other vehicles (IIHS, 2012; Lund, 2013).

- It's possible that differences between the adaptive headlights and conventional headlights—for example, brightness or beam pattern—may have played a role in reducing crashes with other vehicles.

Consumer Awareness & Trust

- A recent survey of 2,506 Canadians on major available safety technologies (Robertson, Vanlaar, Marcoux, & McAteer, 2012) found that:
  - Only 30.6% of those surveyed were familiar with adaptive headlights (Female: 24.1%, Male: 37.7%).
  - Of those surveyed who were familiar with adaptive headlights, 59.6% agreed that the safety feature offered more protection to passengers in the event of a collision, whereas only 40.5% of those who were not familiar agreed.
- In a study conducted by Sullivan, Flannagan, & Schoettle (2002), participants were not aware of the bending feature of a prototype system of adaptive headlights. Even when asked leading questions by the researcher, participants were not very aware of the bending feature.
- A survey was conducted by the Automobile Club of Southern California with customers (1,117 respondents) who own vehicles that may have high-intensity discharge (HID) headlights or directionally adaptive headlights (Jenness, Lerner, Mazor, Osberg, & Tefft, 2008). The results showed that :
  - Drivers do not necessarily know what type of light source their headlights use. For example, 18 percent of survey respondents did not know whether they had HID headlights and 20 percent did not know whether they had adaptive headlights. Women were more likely than men to say that they didn't know, and older respondents were more likely than younger respondents to say that they didn't know.

Mobility Significance

- Braitman et al. (2010) found that drivers using adaptive headlights reported they were more likely to drive at night.
- In terms of expected impact:
  - Adaptive headlights are expected to be beneficial on moderate- to high-speed roads that are curved and dark. This technology should logically allow drivers with reduced night vision (common in older drivers) to expand the hours in which he/she would feel comfortable driving with the increased visibility provided by adaptive headlights.
  - Adaptive headlights should logically benefit other motorists on the road. For example, when turning around a bend in low-light conditions, standard headlights will temporarily point directly at oncoming traffic, causing glare to oncoming drivers.

- Unlike standard headlights, adaptive headlights are designed to point more at the road rather than the other driver, thereby reducing the likelihood that oncoming motorists experience glare from the headlights of others (TIRF, 2013).
- However, effects of reduced glare are not always consistent across all curve/ turn types)(McLaughlin, Hankey, Green, & Larsen, 2004a).

Other Benefits

- Adaptive headlights have been reported to increase the visibility of pedestrians on unlit curves by 14 percent (Sivak, Flannagan, Traube, Aoki, & Sayer, 1994).
  - Other studies have shown similar results (McLaughlin, Hankey, Green, & Larsen, 2004b). However, it is reported that different implementations might differ in detection distances depending on the curve and turn scenarios (ex. Left vs. right curves and radius of the curves).

Technology Penetration

- Adaptive headlights are primarily available on luxury cars in today's market either as an option or standard. The systems have already begun to appear in modestly priced vehicles (e.g., Mazda 3). They are also available as an aftermarket system. However, as more vehicle makes and models begin to feature adaptive headlights as either optional or standard features, the price of the system is likely to decrease.

Frequency of Use

- No substantive research was identified on the frequency of use of Adaptive Headlights by customers who have that feature on their vehicles.
- Most systems require the driver to turn the light switch to the automatic setting to make this feature available.
- Adaptive headlights automatically disengage when a vehicle is stationary or moving in reverse, so drivers do not need to be concerned about having to turn the feature on and off.
  - That being said, the driver can still turn off the adaptive headlight feature in most systems by moving the lighting switch from AUTO to OFF. There is also typically an adaptive headlight indicator light on the vehicle's dashboard to remind the driver of whether the system is active.
  - For more detailed instructions about turning adaptive headlights on or off, drivers may consult the owner's manual of their vehicles (TIRF, 2013).

Training and Education

- No formal studies were identified that examined the impact of training/education on the usage of Adaptive Headlights.

Behavior Adaptation

- A survey was conducted by the Automobile Club of Southern California with customers (1,117 respondents) who own vehicles that may have high-intensity discharge (HID) headlights or directionally adaptive headlights (Jenness et al., 2008). The results showed that :
  - Nearly a quarter of both older and younger respondents with HID headlights said they are willing to drive faster with their headlights as compared to conventional headlights, and when asked how their driving behavior would change if their HID headlights were replaced with conventional headlights, nearly 18 percent of respondents said they would drive more slowly at night.
- Braitman et al. (2010) found that drivers using adaptive headlights reported they were more likely to drive at night and at higher speeds; whether this translates into any increased risk has not been established.
  - Research on reflector posts, raised pavement markers, and other roadway markings on curves has shown that drivers sometimes increase their speeds when visibility is improved (Zador, Stein, Wright, & Hall, 1987)
- It has been suggested that drivers who put "too much faith" in these systems may be less observant or drive more aggressively (Braitman, McCartt, Zuby & Singer, 2009).

Auditory Demand

- There is no a priori reason to consider auditory demand associated with this technology.

Visual Demand

- No substantive research has been identified that examines the impact of adaptive headlights on visual roadway demand, though presumably the system would increase the amount of visual information while the driver is turning. However, this would be expected to have a beneficial effect, because in nighttime driving visual information is impoverished compared to daytime driving.

Haptic Demand

- There is no a priori reason to consider haptic demand associated with this technology.

Cognitive Demand

- There is no a priori reason to consider specific cognitive demand associated with this technology.

Vehicle Type

- Some systems can swivel the main beams left and right up to 15 degrees, depending on the vehicle's travel path (angle of the curve) and speed (Transport Canada, 2011). This swivel amount provides greater lighting to the road ahead.
- Some systems can automatically switch from high beam to low beam when an approaching vehicle is detected (Transport Canada, 2011).

- There are systems that can shine light 90-degrees in either direction when the vehicle is turning at an intersection. These systems usually use Bi-Xenon or High Intensity Discharge (HID) lights (Transport Canada, 2011).

Limitations / Failure Conditions

- While adaptive headlights can significantly increase a driver's range of visibility, this range still has limits. The system is not designed to alert drivers of nearby obstacles or potential road hazards (Robertson et al., 2012).
- Driving a vehicle equipped with adaptive headlights does not make speeding around corners any safer beyond providing improved illumination; drivers are urged to respect the posted speed limits and to reduce speed appropriately when going around curves (Robertson et al., 2012).

Differences between Implementations

- Major differences between implementations were not identified during the course of the review (however, this question was not researched in depth).

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Back-Up / Rear-View Cameras

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊	◊◊◊
Benefit Currently Documented	♦	♦♦

Note: The relatively modest ranking for Back-Up cameras in terms of Overall Safety Benefit is a result of the relatively low number of backup event related injuries and fatalities relative to the total number of driving related injuries and fatalities. It is also recognized that there is a particularly high emotional cost associated with this type of event. NHTSA (2014) estimates that 31% of all backup event fatalities involve children under 5 years of age and another 26% are adults 70 years and older; these events often involve family members or other close associations. Societal pressure to do something about such events led to NHTSA recently issuing a final rule on March 31st of this year mandating rear visibility technology in all new vehicles under 10,000 pounds by May 2018.

What is the technology?

- Back-Up Cameras allow the driver to view a video image of the area behind the rear bumper and see small objects that are not ordinarily visible with mirrors or looking over the shoulder.
  - The video is displayed either on a screen in the instrument panel or in a corner of the inside rearview mirror, and is automatically activated when the transmission is shifted into reverse.
- Back-Up Cameras are a level 0 vehicle automation system (No-Automation) (NHTSA, 2013).

Crash Reduction/Prevention

- Based on 2007 NiTS (Not-in-Traffic Surveillance) data, NHTSA estimated that 221 deaths and 14,000 injuries occur annually in non-traffic backover crashes. In addition, an average of 71 backover fatalities and 4,000 backover injuries are reported each year on public roadways (NHTSA, 2008), resulting in a combined total of 292 deaths and 18,000 injuries.
  - 103 of these estimated 292 annual deaths involved children younger than 5, and 76 deaths involved people 70 and older. About 2,000 of the 18,000 injuries that occur every year from backover crashes involve children younger than 5, and 3,000 involve people 70 and older.
  - These figures likely underestimate the frequency of backover crashes, as their lower severity makes them less likely to be reported (i.e. little property damage, minor injuries).
- NHTSA (2010) released proposed rules in the Federal Register that estimated that annual fatalities occurring from backing crashes could be reduced from 207 to 112 (46% reduction) if all vehicles were equipped with rearview video technology. The estimate for reduction in annual injuries was from 15446 to 8374 (46%).

- In experimental settings, Mazzae (Mazzae, 2008, 2010, 2013) found that the use of back-up cameras reduced crashes in an unexpected collision trial by approximately 30% across all three studies.
    - In a controlled, surprise collision event after 4 weeks of Backup Camera use, only 5 out of 13 drivers tested received a rear collision warning from the installed system, suggesting that these systems may not be universally reliable in all types of backing scenarios (Mazzae, 2008).
- An experimental IIHS research study (Kidd, Hagoski, Tucker, & Chiang, 2014) using an SUV and conducted with volunteers suggests that rearview camera systems would aid in preventing more backover crashes into pedestrians in a vehicle's rear blind zone than rear proximity (parking) warning sensors. Perhaps surprisingly, the research found that cameras alone worked better than the combination of both rearview camera and backup warning sensors.
- Data from the Highway Loss Data Institute (2012) considering an initial assessment of Mercedes vehicles with and without backup cameras showed small and mixed findings across insurance claims and damages. The report concluded that the data showed no significant effect on any insurance coverage; however, this was considered a relatively weak analysis for injury effects involving pedestrians and it was stated that additional analyses were underway. An initial analysis considering Mazda vehicles (HLDI, 2011) found that, contrary to expectations, there was an increase in collision frequency claims (3.1%), severity, and overall losses ($18), but a non-significant reduction in property damage / liability claims. Most relevant from a safety perspective, there was a reduction in the frequency of high severity bodily injury claims of 22.2%.

Consumer Awareness & Trust

- A survey conducted by the Automobile Club of Southern California on Sensor-Based Backing Systems and Rear-View Video Cameras showed that (Jenness, Lerner, Mazor, Osberg, & Tefft, 2007):
    - Most respondents (96%) found their camera to be easy or very easy to use when backing out of a driveway.
    - Approximately 36 percent of respondents agreed or strongly agreed with the statement that "the rear-view camera does not show the entire area behind my vehicle that I need to see when backing, in other words there is a blind spot."
    - Older respondents (aged 65 and older) were more likely than younger respondents (younger than 65) to say that they would want to get the system again.
    - Only 39 percent of rear-view camera owners reported that they were aware of "any warnings or limitations" about their system. The percentage of respondents who said that they were aware of warnings or limitations varied significantly by vehicle manufacturer. Also, a higher percentage of younger backing aid owners (26%) as compared to older owners (18%) were aware of system limitations.

- A survey of nearly 300 drivers who recently purchased vehicles (model years 2000-2004) with parking aids (proximity sensors or back-up cameras) for backing was conducted to assess their opinions and use of the devices (NHTSA, 2006).
    - Approximately 25% of the cars sampled were equipped with a rearview camera system.
    - Eighty percent of drivers thought the parking aid (back-up cameras + proximity sensors) would lower their likelihood of being involved in a backing-related crash, but a few drivers (11 percent) believed that the system might increase the likelihood.
    - Sixty-seven percent of owners believed that their parking aid system would provide warnings at any backing speed. However, most systems only operate at speeds less than 6 mph. Thus, while this survey indicates that many drivers like the systems and find them helpful, some drivers had beliefs that might lead to decreased safety in some circumstances.

Mobility Significance

- No substantive research was identified in the course of this review that specifically examined the impact of back-up cameras on mobility significance.
    - Conceptually, back-up cameras might be expected to be beneficial for drivers with physical limitations (such as inability to turn their heads sufficiently to look over the shoulder) that make inspections towards the rear of the car difficult. This generally becomes more of an issue as drivers age.
    - As was noted earlier, a AAA survey (Jenness, Lerner, Mazor, Osberg, & Tefft, 2007) found that Older respondents (aged 65 and older) who had experience with a vehicle with a back-up camera were more likely than younger respondents (younger than 65) to say that they would want this technology in their next car. This could be interpreted as indirect support the perceived utility of the technology and possible mobility relevance in older drivers.

Other Benefits

- None Identified.

Technology Penetration

- Back-Up Cameras are available for numerous new vehicles on the market today as an add-on option or a standard feature. They are also available as an aftermarket system. However, as more vehicle makes and models begin to feature Back-Up Cameras as either optional or standard features, the price of the system is likely to decline (NHTSA, 2006).
    - It is expected that back-up cameras will reach 42.4 million units by 2020, up from just 11.4 million units in 2012, with a compound annual growth rate CAGR) of 19.6 percent (IHS iSuppli's, 2013).

Frequency of Use

- Most systems automatically turn on the Back-Up Cameras when the car is put into reverse.
- No substantive data has been identified to date on the frequency of use for Back-Up Cameras.

Training and Education

- A review of relevant research indicated that factors such as prior experience with rearview cameras, expectations regarding the likelihood of an obstacle during backing, and the timing of glances to the camera images influence the use and subsequent benefits of these systems (Llaneras, Neurauter, & Green, 2011).
- A survey conducted by the Automobile Club of Southern California on Sensor-Based Backing Systems and Rear-View Video Cameras (Jenness et al., 2007) found that older drivers were more likely to have learned how to operate their systems from the owner's manual. (A higher percentage of younger respondents learned to use their systems from on-road experience and practice.)

Behavior Adaptation

- As reported in (Jenness et al., 2007), a survey conducted by the Automobile Club of Southern California on sensor-based backing systems and rear-view video cameras found that approximately 17 percent of rear-view camera owners admitted backing without checking their mirrors or turning to look out the rear window within the last two weeks. Younger system owners were more likely have done this than were older system owners.
    - It has been hypothesized by some that drivers who have systems that pair back-up cameras with a proximity warning alarms may be less careful than drivers who do not have these system when driving in reverse (e.g., not looking out for pedestrians or small children; using the mirrors less; making fewer shoulder checks; and driving in reverse with more speed than without the system) because they assume that the alarm will system will serve this function for them. (It should not be assumed that these same individuals would have appropriately completed these types of safety checks if their vehicles were not equipped with these technologies – further research on this question seems warranted.)
- As noted above, an experimental IIHS research study (Kidd, Hagoski, Tucker, & Chiang, 2014) found that back-up cameras alone worked better than the combination of both rearview camera and backup warning sensors.
    - IIHS researchers have suggested that the back-up sensors may have given drivers a false sense of security such that they paid less attention to the camera display. It was noted that slightly fewer drivers who had both systems operational looked at the camera display at least once than participants who had only the camera display. In addition, drivers with the combined system spent a smaller proportion of time looking at the display; however, these differences were not statistically significant and should be interpreted cautiously.

Auditory Demand

- There is no a priori reason to consider Back-Up Camera technology alone to be a source of added auditory demand.
  - Only systems that are paired with proximity sensor alarms, which typically issue auditory alarms when objects are detected, would impose an auditory demand on the driver.

Visual Demand

- Conceptually, a Back-up camera system might be considered as a technology that reduces some aspects of visual demand by possibly improving visibility directly behind the vehicle. At the same time, visual load might be considered to have been increased in some ways when there is an expectation that the driver should both make use of the camera display as well as continuing to visually inspect mirrors, looking over the shoulder to check behind the vehicle, etc. No objective data has been identified to date as part of this review that specifically addresses this issue.

Haptic Demand

- There is no a priori reason to consider Back-Up Camera technology alone to be a source of added haptic demand, since no haptic alarm is produced by systems on the market today.

Cognitive Demand

- No research data has been identified to date in the course of this review that specifically addresses the question of cognitive demand.

Vehicle Type

- More SUVs and pickup trucks than cars are involved in backover crashes (NHTSA, 2008).
  - SUVs and pickup trucks typically have bigger blind zones than cars because they sit higher off the ground, making it more difficult for drivers to see children and smaller objects near the rear of the vehicle (Mazzae & Barickman, 2009; Mazzae & Garrott, 2008).
- An analysis of driveway backovers involving children in Utah from 1998-2003 found that children were 53% more likely to be injured by a pickup truck than a car and 2.4 times more likely to be injured by a minivan, relative to the number of registered vehicles of each type (Pinkney et al., 2006).
  - Future studies should control not just for the number of registered vehicles for each type, but also for the fact that minivans are more likely to be owned by families with children.
- Data from the Highway Loss Data Institute (2011) show that Back-Up Cameras are infrequently installed in non-hybrid vehicles (19%), but are very common in hybrids (83%).

Limitations / Failure Conditions

- Hurwitz et al. (2010) evaluated the use of rearview cameras with sensor systems. Thirty-five drivers completed 16 parking trials. Only seven drivers looked at the camera image before backing. Of those who didn't, 46% looked at it after the sensor issued an audible warning.
    - This is a classic issue with some forms of support technology – while a technology such as a back-up camera offers the potential to aid the driver, the driver cannot benefit from this type of technology unless they make use of it.
- In a controlled, surprise collision event after 4 weeks of Backup Camera use, only 5 out of 13 drivers tested received a rear collision warning from the installed system, suggesting that these systems may not be universally reliable in all types of backing scenarios (Mazzae, 2008).
- Conditions such as rain, darkness, glare and/or dirt on the camera lens could make visibility more difficult than without such conditions.

Differences between Implementations

- Some systems offer interactive track lines on the video screen that turn along with the steering wheel to help direct your path.
    - Fixed guidelines: Show the actual path of the vehicle while reversing in a straight line, which can be helpful when backing into a parking space or aligning the vehicle with another object behind the vehicle.
    - Centerline: Helps align the center of the vehicle with an object (e.g. a trailer).
    - Active guidelines: Shows the intended path of the vehicle when reversing.
- Some systems are equipped with sensors such as radar or ultrasonic systems to warn the driver of objects behind the vehicle or of vehicles approaching from the sides.Some systems will even automatically apply the brakes to keep the vehicle from backing into or over an object.
- Mazzae (2010) found that a rear collision warning system was as effective in reducing crashes as a full camera system, and that the camera systems were most effective when embedded in the rearview mirror.
- In many vehicles, blind zones could be reduced through better vehicle designs that increase the directly viewable area (Hammond & Wade, 2005), that would be anticipated to increase safety even without a backup camera – although the issue remains that a driver had to actually look to benefit.
- Different systems may have different fields of view and induce differing amounts of optical distortion in the rearview image.
- Image quality may vary between systems, depending on the exact type of camera used (i.e. black and white vs. color camera, color depth, contrast and resolution).

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Forward Collision Warning (FCW)

Initial Ratings	**Overall**	**Scenario Specific**
Potential Overall Benefit	◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦	♦♦

What is the technology?

- Forward Collision Warning (FCW) is designed to warn drivers of possible hazards in front of their vehicles so that they can take braking or steering actions to avoid crashes or reduce the damage from unavoidable crashes. (Forward Collision Mitigation (FCM) systems that actively brake or steer the vehicle are considered separately.)
    - The system monitors the relative speed and following distance from the forward vehicle, or the distance to an unmoving object if it is estimated to be in the forward path of the vehicle. When the combination of speed and distances (i.e., the time headway or the time to collision) becomes critical, a signal (audible, haptic, visual, or some combination) is presented to alert the driver.
- The area in front of the car is monitored by a sensor (e.g., RADAR, LIDAR, and/or camera).
- Forward Collision Warning is a level 0 vehicle automation system (No-Automation)(NHTSA, 2013) .

Crash Reduction/Prevention

- Early simulator based research suggested that FCW can redirect the driver's attention to the road and improve reaction time (Lee, McGehee, Brown, & Reyes, 2002).
- In a mathematical simulation drawing on data from the National Automotive Sampling System Crashworthiness Data System (NASS CDS), Kusano and Gabler (2012) estimated a 3.2% rear-end crash prevention benefit for FCW.
    - Extending this analysis to possible injury reduction, the combined FCW technology alone was estimated to potentially prevent 29% of Abbreviated Injury Scale (AIS) injuries of category 2 or above.
    - Modeling using the German In-Depth Accident Study (GIDAS) database and effectiveness estimates based on reactions to a Bosch system by researches affiliated with the manufacturer (Georgi et al. 2009) estimated that FCW feature would translate into a safety benefit of a 38% reduction in rear-end crashes.
- In a simulation study (Yasuda et al. 2011) estimated that FCW could reduce rear-end crashes at a relative velocity of 20 km/hr by 30%.
- FCW has since been examined at least one field operational test (Najm, Stearns, Howarth, Koopmann, & Hitz, 2006). A prototype FCW system without automatic braking was field tested by 66 drivers for four weeks each. Based on the number of near-

crash scenarios identified, the system was projected to reduce rear-end collision rates by 10 percent.

- Property damage liability claim rates are lower than average for vehicles equipped with FCW (Lund, 2013). The same analyses found that vehicle models that also equipped with autonomous braking (forward collision mitigation) (i.e. Acura and Mercedes) are associated with even lower rates than the same vehicle models with only FCW.
    - IIHS has stated in follow-on discussions (Lund, 2014) that the available property damage loss data shows a reduction in claims for vehicles equipped with FCW in the range of 5 to 7%. IIHS estimates that this translates into a 10 to 15% reduction in rear crashes.

Consumer Awareness & Trust

- In a recent survey (Robertson, Vanlaar, Marcoux, & McAteer, 2012), 2,506 Canadians were polled on major available safety technologies (832 over the phone and 1,674 online).
    - The results showed that only 23.6% of the respondents were familiar with FCW (Female: 15.1%, Male: 32.6%).
    - 60.0% of drivers who were familiar with FCW said that FCW would be easy to use (Female: 54.1%, Male: 66.2%).
    - 46.5% of respondents considered FCW to be useful.
    - 66.3% of those surveyed mentioned that they would be willing to use FCW if it is already included in the car.
- In a large field study (Sayer et al., 2011), drivers rated the usefulness and satisfaction with FCW lowest among the subsystems evaluated.
    - Overall, drivers rated them neutral with regard to satisfaction, but recognized that they had some utility.
    - The brake pulse accompanying FCWs was the single system attribute that drivers disliked most.

Mobility Significance

- No substantive research was identified during the course of this review that explicitly considered the impact of FCW on mobility.
    - It might be hypothesized that safety technologies such as FCW that are intended to alert drivers of potentially dangerous situations may increase the confidence of individuals who are otherwise concerned about their ability to continue to drive safely due to aging or other factors; however, this needs to be objectively evaluated.

Other Benefits

- None Identified

Technology Penetration

- FCW is primarily available on luxury cars in the current U.S. vehicle fleet. However, as more vehicles begin to feature FCW as either optional or standard features, the price of the system is likely to decline and its market penetration increased.

Frequency of Use

- No substantive data has been identified to date on the frequency with which drivers with cars equipped with FCW drive with or without the technology active.
- Most FCW systems are on by default, and require drivers to deactivate them if they do not want to use them.

Training and Education

- No formal studies were identified that examined the impact of training/education on the usage of FCW.

Behavior Adaptation

- In a field study (Sayer et al., 2011) evaluating the impact of an integrated crash warning system found that drivers were slightly more likely to maintain shorter headways; more time was spent at time headways of one second or less with the integrated system in the treatment condition (24%) than in the baseline condition (21%).
    - Some have suggested that drivers who put too much faith in these systems may be less observant or drive more aggressively; however, additional research is indicated to determine whether this may or may not be a substantive behavioral pattern and whether safety net safety benefits are negatively impacted as a result.

Auditory Demand

- Many FCW systems issue an auditory alarm. However, no substantive research specifically considering auditory demand associated with FCW use has been identified to date.

Visual Demand

- FCW systems may include a visual indicator and/or alarm. However, no substantive research specifically considering visual demand associated with FCW use has been identified to date.

Haptic Demand

- Several of field trials have used systems that include haptic stimuli; however, no substantive research specifically considering haptic demand associated with FCW use has been identified to date.

Cognitive Demand

- No substantive research has been identified to date that specifically has considered the cognitive demand associated with FCW systems.

Vehicle Type

- No relevant data on vehicle type has been identified in to date; however, this question has not been a significant focus of the literature review at this point.

Limitations / Failure Conditions

- While a Forward Collision Warning system may provide assistance in directing a driver's attention to a potential collision event, drivers need to be aware that FCW technology still requires an appropriate response by the driver to avoid or mitigate the severity of a potential crash and that the technology is not designed to or able to warn of all potential crash situations. Drivers need to maintain an appropriate level of attention to the driving environment at all times even when driving with an FCW system active.
- Camera-based systems are less effective at night than radar-based systems and can be "blinded" by direct sun light (e.g., early sunrise and late sunset).
- The effectiveness of both radar and camera based systems can be compromised by snow/ice build-up in front of the sensors.

Differences between Implementations

- Some FCW implementations automatically prepare the brake system for rapid braking (prime the brakes) when an alarm is active. The system does not automatically activate the brakes but, if the brake pedal is pressed, full force braking is applied even if the brake pedal is lightly pressed.
    - The FCW's brake support can only help reduce the speed at which a collision occurs if the driver applies the vehicle's brakes. The brake pedal still must be pressed, as in a typical braking situation.
    - FCW is thus a warning only, and is to be distinguished from Forward Collision Mitigation, where the system may actually apply the brakes.

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Forward Collision Mitigation (FCM) / Collision Imminent Braking / Autobrake

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊◊◊	◊◊◊◊◊
Benefit Currently Documented	♦♦	♦♦♦

What is the technology?

- This technology class may be identified by a range of alternate names. The term used in this document is Forward Collision Mitigation (FCM), but other frequently used terms include collision imminent braking, autobrake, and autonomous braking.
- FCM systems detect the distances and closing speeds of objects in the path of the vehicle and automatically decelerate or stop the vehicle if the driver does not respond to the alarm provided by the system.
  - Crashes that are potentially preventable may still occur due to late braking and/or braking without sufficient force. Many drivers are not used to dealing with safety-critical braking situations and do not apply enough braking force to avoid a crash. FCM is designed to reduce the number and severity of these types of collisions.
- Implementations of this class of technology may include Forward Collision Warning (FCW) and Brake Assist (BA) technology that pre-primes the brake system.
- Forward Collision Mitigation is a level 1 vehicle automation system (Function-Specific Automation) (NHTSA, 2013).

Crash Reduction/Prevention

- An Insurance Institute for Highway Safety (IIHS) study has estimated that FCW/FCM could prevent up to 1.2 million crashes in the United States each year, including 66,000 serious and moderate injury crashes and 879 fatal crashes (Jermakian, 2011).
  - In terms of events, this would translate into potentially preventing or mitigating approximately 20% of the total number of police-reported traffic crashes.
  - In terms of fatalities, this would represent a little over 2% of total deaths.
- An Australian report employing a crash reconstruction technique (Anderson et al. 2012) that considered 104 crashes involving rear-end and other FCM relevant scenarios and estimated a 20-40% reduction in fatal crashes and 30-50% of injury crashes if 100% penetration of the technology was assumed.
- In a mathematical simulation drawing on data from the National Automotive Sampling System Crashworthiness Data System (NASS CDS), Kusano and Gabler (2012) estimated that combined FCW and pre-crash brake assist technologies could have prevented 7.7% of the rear-end collisions modeled.
  - Extending this analysis to possible injury reduction, the combined FCM technologies were estimated to potentially prevent 50% of Abbreviated Injury Scale (AIS) injuries of category 2 or above.

- Another modeling approach combining data from NASS CDS and test track and simulation data (Van Auken, Zellner et al. 2011) and developing estimates for a next generation FCM system predicted that installation of the technology throughout the light-vehicle fleet might decrease crash events by 9.3% and fatalities by 3.7%.
    - Estimates for rear-end crashes were reduction of events by 28.1% and fatalities by 35.1%.
- A statistical modeling / simulation evaluation based on the German In-Depth Accident Study (GIDAS) database and supplemented by speed characterization and driver behavior data from NASS CDS and Volvo's crash database (Coelingh et al. 2007) estimated that, assuming ideal conditions such as100% penetration, dry road conditions, etc., a 50% reduction in rear-end crashes might result.
    - A subsequent study with the same lead author (Coelingh et al. 2010) considering additional combinations of technologies as part of the FCM system and somewhat different modeling and data reported an estimated reduction in fatalities for rear-end crashes of 30%.
    - Another study using the GIDAS database and estimates based on driver reactions to a Bosch system (Georgi et al. 2009) reported potential benefits of a 55% reduction in rear-end crashes for all drivers and up to a 72% reduction when considering an implementation with automated emergency braking for drivers who failed to respond to an emergent braking situation.
- In a simulator based study (Yasuda et al. 2011), in which vehicles were proceeding at a relative velocity of 20 km/h, rear-end crash reduction estimates of 48% were reported for FCW plus brake assist and an extremely high estimation of a 90% reduction in rear-end crashes under these conditions with a system that include FCW, brake assist, and automated emergency braking.
- Property damage liability claim rates are lower on average for vehicles equipped with forward collision mitigation (Eichelberger & McCartt, 2012; IIHS, 2012; Lund, 2013). Moreover, the models equipped with autonomous braking (i.e. Acura and Mercedes) are more effective than similar vehicles equipped only with forward collision warning.
    - An insurance claims based study based on comparable Volvo models with and without a FCM system (Isaksson-Hellman & Lindman, 2012) and reported a 23% reduction in rear-end crashes for the equipped vehicles.
- The Insurance Institute for Highway Safety (IIHS) conducted a series of five test runs at speeds of 12 and 25 mph on the track at the Vehicle Research Center (IIHS, 2013). In each test, an engineer drove the vehicle toward a stationary target designed to simulate the back of a car. Sensors in the test vehicle monitored its lane position, speed, time to collision, braking and other data.
    - The highest-scoring cars and SUVs have autobrake and substantially reduce speeds in both the 12 and 25 mph tests. Most of these systems prevent the 12 mph collision. However, not all the cars behave the same and this is why cars have been categorized by the IIHS as a three-tier rating system of superior, advanced

and basic to reflect that even a basic forward collision warning system can provide significant benefits.

Consumer Awareness & Trust

- In a recent survey (Robertson, Vanlaar, Marcoux, & McAteer, 2012), 2,506 Canadians were polled on major available safety technologies (832 over the phone and 1,674 online). The following results were for Forward Collision Warning (FCW) but may have some relevance for FCM:
    - The results showed that only 23.6% of the respondents were familiar with FCW (Female: 15.1%, Male: 32.6%).
    - 60.0% of drivers who were familiar with FCW said that FCW would be easy to use (Female: 54.1%, Male: 66.2%).
    - 46.5% of respondents considered FCW to be useful.
    - 66.3% of those surveyed mentioned that they would be willing to use FCW if it is already included in the car.
- A 2012 IIHS survey (Eichelberger & McCartt, 2012) of owners of Volvo vehicles with crash avoidance technologies including FCM (City Safety) found that, despite some annoyance: the majority of drivers left the systems turned on most of the time; felt the systems made them safer drivers; and would want them in their next vehicle.
- False braking events can adversely affect customer confidence and acceptance in FCM.
    - A false 0.6 g braking event is more likely to provoke a negative customer reaction compared to a simple alarm (loud beeping noise and flashing red warning lights).

Mobility Significance

- No substantive research was identified during the course of this review that explicitly considered the impact of FCW on mobility.
    - It might be hypothesized that safety technologies such as FCM that are intended to alert and, if necessary, intervene for drivers in potentially dangerous situations may increase the confidence of individuals who are otherwise concerned about their ability to continue to drive safely due to aging or other factors; however, this needs to be objectively evaluated.

Other Benefits

- None Identified

Technology Penetration

- FCM is primarily present in luxury vehicles today. However, as more vehicles begin to feature FCM as either optional or standard features, the price of the system is likely to decrease.

Frequency of Use

- No substantive data has been identified to date on the frequency with which drivers with cars equipped with FCM drive with or without the technology active.
- Most FCM systems are on by default, and require drivers to deactivate them if they do not want to use them.

Training and Education

- No substantive publicly available data or research was identified that examines the impact of training/education on the usage of Forward Collision Mitigation.

Behavior Adaptation

- In a field study (Sayer et al., 2011) evaluating the impact of an integrated crash warning system found that drivers were slightly more likely to maintain shorter headways; more time was spent at time headways of one second or less with the integrated system in the treatment condition (24%) than in the baseline condition (21%).
    - Some have suggested that drivers who put too much faith in these systems may be less observant or drive more aggressively; however, additional research is indicated to determine whether this may or may not be a substantive behavioral pattern and whether safety net safety benefits are negatively impacted as a result.

Auditory Demand

- Many FCM systems issue an auditory alarm. However, no substantive research specifically considering auditory demand associated with FCW use has been identified to date.

Visual Demand

- FCM systems may include a visual indicator and/or alarm. However, no substantive research specifically considering visual demand associated with FCW use has been identified to date.

Haptic Demand

- Several of field trials of FCW / FCM have used systems that include haptic stimuli; however, no substantive research specifically considering haptic demand associated with FCW use has been identified to date.

Cognitive Demand

- No substantive research has been identified to date that specifically has considered the cognitive demand associated with FCM systems.

Vehicle Type

- No relevant data on vehicle type has been identified in to date; however, this question has not been a significant focus of the literature review at this point.

Limitations / Failure Conditions

- While currently available test track data (IIHS, 2013) indicate that some FCM systems are likely to offer substantial safety benefits under certain conditions, drivers need to be aware that FCM technology will not prevent all forms of crashes and that they need to maintain an appropriate level of attention to the driving environment at all times.
- Weather and environmental conditions can influence the system. Camera-based systems are less effective at night than radar-based systems. Also, camera-based systems can be "blinded" by direct sun light (e.g., early sunrise and late sunset). Both radar and camera systems can be obscured by snow/ice build-up in front of the sensors.

Differences between Implementations

- A recent experiment conducted by the IIHS (IIHS, 2013)showed that manufacturers have implemented their FCM systems differently.
    - Some FCM systems can slow down or completely stop the car to avoid some front-to-rear crashes if the driver fails to brake or steer out of the way in response to a warning; others were much less effective under the conditions tested.
- Some systems, depending on the conditions, are also designed to detect parked vehicles, stationary vehicles, and other roadside objects such trees, guard rails, sign posts, etc.
- Some systems are designed to detect pedestrians and large animals in daylight conditions.

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Lane Departure Warning (LDW)

Initial Ratings	Overall	Scenario Specific
Potential Overall Benefit	◊◊◊	◊◊◊
Benefit Currently Documented	♦	♦

What Is the Technology?

- Lane Departure Warning (LDW) systems provide alerts whenever a driver appears to (i.e. a turn signal is not activated) drift too close to the edges of the lane or partially cross the lane marking (i.e. when a turn signal is not activated). They are primarily designed to reduce high speed accidents on highways and freeways. (Note: this review does not consider "lane keeping assist" / lane departure prevention technologies that adjust steering to actively assist in keeping the vehicle within lane boundaries.)
- LDW systems typically use visual, audible, and/or vibratory warnings.
- LDW only systems should be differentiated from lane keeping assistance systems that automatically adjust steering to keep the vehicle in the lane. Lane keeping assistance systems may provide a warning before engaging.
- LDW is a level 0 vehicle automation system (No-Automation)(NHTSA, 2013)

Crash Reduction/Prevention

- Crash records were extracted from the 2004-2008 files of the National Automotive Sampling System General Estimates System (NASS GES) and the Fatality Analysis Reporting System (FARS) (Jermakian, 2011). Crash descriptions were reviewed to determine whether the information or action provided by each technology potentially could have prevented or mitigated the crash. This technology potentially could prevent/mitigate up to 179,000 crashes per year (3% of all crashes), including 37,000 nonfatal serious and moderate injury crashes and 7,529 fatal crashes.
    - Based on the published 25–30% effectiveness estimates for rumble strips, a more realistic estimate of crashes that may be prevented by LDW systems would be 45,000–54,000 per year (Jermakian, 2011).
    - A statistical estimation study using crash data from the United Kingdom (Robinson et al, 2011) and estimates of technology effectiveness reported a benefit potential in the range of 7-29% for fatality reduction and 13-34% for serious injuries.
    - A study using crash data from the Australian state of New South Wales (Anderson et al. 2011) developed benefit estimates of fatal crash reductions in scenario specific conditions in the range of 11-13% and reductions of 1-9% for injuries.
- A field operational test conducted in 2004 and 2005 (Wilson, Stearns, Koopmann, & Yang, 2007) estimated that LDW systems could reduce road-departure crashes by

between 9,400 and 74,800 annually if all passenger vehicles were equipped with these systems and they worked as intended.

- During the field test, LDW systems were turned off 45% of the time because of weather and other factors. At that rate, the estimated reduction in crashes would drop to between 5,200 and 41,200.

- A project using statistical modeling and simulation of a Volvo pre-production LDW system (Gordon et al, 2010) produced an estimated benefit of a 47% reduction in lane-departure crashes, assuming ideal conditions.
  - A likely more realistic evaluation considering variable lane markings, non-ideal weather condtions, etc., produced an estimated target crash reduction of 33%. Taking further factors into consideration, a final estimated crash rate reduction was placed in the range of 13% to 31%.
- A simulation modeling study that drew on an analysis of a database of serious road-departure crashes (Kusano & Gabler, 2012) found a wide range of estimated benefit depending on when warnings were provided. Estimated crash reductions were 3-5% for warnings delivered at time of lane-crossing and 19-34% for warnings delivered one second prior.
  - Another modeling based simulation study (Tanaka et al. 2012), but based on Japanese crash data, also found potential benefit to be dependent upon the timing of warnings. In a model where the warning was delivered one second after a lane crossing resulted in an estimated 5% reduction in scenario specific crashes. Maximum benefit was seen in the modeling for warnings provided 1 second prior to a lane-crossing, which showed a 25% reduction.
- In a field study (Sayer et al., 2011), an integrated system (LDW plus curve-speed warning (CSW), lane-change/ merge (LCM), and FCW) had a statistically significant effect on the frequency of lane departures, decreasing the rate from 14.6 departures per 100 miles during baseline driving (two weeks without active LDW) to 7.6 departures per 100 miles during treatment (period in which the system was operational). (See also report by Nodine et al. (2011).)
  - Keeping in mind that the system included features beyond basic LCW, Nodine et al. (2011) estimated that the combined technologies had a target crash type reduction potential in the range of 6% - 29%.
- In contrast with estimates from FOT and simulation modeling studies, a recent analysis of insurance claim data (Lund, 2013) suggests that LDW alone (without active lane keeping assistance) may actually increase these types of crashes.
  - Only Volvo LDW systems were associated with decreases in claim frequency, and that is likely due to pairing of LDW with forward collision warning and forward collision mitigation technologies (autonomous braking systems).

Consumer Awareness & Trust

- In a recent survey conducted by the Traffic Injury Research Foundation (TIRF), 2,506 Canadians completed a poll on major available safety technologies (832 over the phone and 1,674 online) (Robertson, Vanlaar, Marcoux, & McAteer, 2012).
    - Most respondents were not familiar with LDW systems. Only 21.6% of respondents were aware of this system (15.9 for women, 28.3% for men).
    - Of those who were familiar with LDW, 47.9% agreed that the safety feature in new vehicles help protect drivers in the event of a collision. For those who were not familiar with LDW, 37.3% agreed. (These endorsements are somewhat concerning given that LDW alone is a warning system and should not logically provide any actual protection in a crash event except to the extent to which it might reduce the severity of a crash if an evasive maneuver undertaken in response to the warning reduced the severity of a crash event.)

Mobility Significance

- No substantive research has been identified to date that examined the mobility significance of lane departure warning systems.
    - It may be hypothesized that appropriate implementations of this technology might increase driver confidence and enhance comfort while driving for all drivers, including those with disabilities; however, this needs to objectively evaluated.

Other Benefits

- None Identified

Technology Penetration

- No substantive research has been identified to date examining the technology penetration of LDW systems.

Frequency of Use

- As noted earlier, in a field test (Wilson, Stearns, Koopmann, & Yang, 2007) LDW systems were found to be turned off 45% of the time because of weather and other factors.
- Of Volvo and Infinity drivers who own vehicles equipped with LDW and consented to a telephone interview (Braitman, McCartt, Zuby, & Singer, 2010):
    - 69% reported using the system all of the time
    - 93% reported using their LDW systems at least occasionally
    - It should be kept in mind that the extent to which reported use and actual use correspond is unknown in such self-report data
- A subsequent interview study of Volvo owners (Eichelberger & McCartt, 2012) found a lower self-reported frequency of use, with 59% reporting that they used the system all of the time. Other findings included:

- One-quarter (25%) of owners of LDW systems mentioned that the warnings were annoying, and 9% said they were distracting. For all the other technologies considered in the interview (adaptive cruise control, distance alert, collision warning with full auto brake, and driver alert control), fewer than 5% mentioned that those technologies were annoying or distracting.
- Sixty-six percent (66%) of owners who were annoyed said they had turned off the system, compared with 19% of those who were not annoyed or did not know whether they were annoyed.

Training and Education

- No substantive research has been identified to date that examined the impact of training/education on the usage of LDW.

Behavior Adaptation

- During a field test (LeBlanc et al., 2006), drivers using LDW systems improved their lane-keeping behavior, traveling near or beyond the lane edge less frequently, and increased their use of turn signals.
- Self-report data on usage must be interpreted cautiously if observational data is not available for comparison purposes. See the survey data above under "Frequency of Use" as well as the following:
  - 67% of survey respondents said that LDW improved their general lane-keeping behavior, and 60% said they increased use of turn signals (Braitman et al., 2010).
  - IIHS conducted a survey of Volvo owners (Eichelberger & McCartt, 2012) who drove with LDW turned on. Fifty-five percent reported no change in their use of the turn signal when the system was turned on, and 44% of drivers said they used their turn signal more often with it. Sixty-one percent reported no change in how often they drifted from their lane, and 35% said they drifted from their lane less often.
- In a field study (Sayer et al., 2011) with an integrated system that included LDW, drivers were less likely to make unsignaled lane changes in the treatment condition than during baseline driving and had a lower number and reduced duration of lane excursions. See also report by Nodine et al. (2011).

Auditory Demand

- Owners who had heard a LDW auditory alert were surveyed (Eichelberger & McCartt, 2012). Among these drivers, 96% agreed that the warning sound was useful, 33% agreed it was annoying, 7% agreed it was too loud, and 1% agreed the sound was too quiet.

Visual Demand

- LDW systems usually do not use a visual warning, instead relying on auditory alarms and/or haptic (vibration feedback) in the steering wheel or seat. When visual alerts are involved, typical warnings may include a flashing symbol on the dashboard display or heads-up display

Haptic Demand

- Some LDW systems vibrate the steering wheel or the driver's seat (on the side corresponding to the lane departure.) to simulate a rumble strip-like sensation.

Cognitive Demand

- No substantive research has been identified that examined the cognitive demands of LDW systems.

Vehicle Type

- In some systems, LDW has two settings: a less sensitive setting that warns the driver when a tire crosses a lane marking, and a more sensitive setting that warns the driver before the tire crosses the lane marking. The less sensitive setting is the default setting.
- Some systems require lane markings on only one side of the vehicle, whereas other systems require lane markings on both sides (Eichelberger & McCartt, 2012).
- Some LDW systems incorporate road edge detection which attempts to identify unmarked transitions between the pavement and a soft shoulder.

Limitations/Failure Conditions

- In a field test of a prototype road departure warning system, the system was available 76% of the time on freeways compared with only 36% on non-freeways (Wilson et al., 2007).
- In a survey of Volvo owners, 77% reported that the LDW system had never failed to warn them when they believed they were at risk of drifting out of their lane. However, 17% reported that it had (Eichelberger & McCartt, 2012). That is, the system failed to warn them when it should have (a "false negative"). The most frequently reported situations in which this happened included missing or unclear lane markings (60%), inclement weather (17%), driving at slow speeds (7%), and driving in the dark (7%).
- An area which may be worthy of more research is the issue of driver annoyance with false alarms, which may be particularly an issue with LDW systems. See Tijerina et al. (2010) for a consideration of an adaptive LDW design which was intended to reduce frustration by reducing false alarms. The trade-off with such a system is that the number of times the system should warn the driver but fails to then increases.
- Lane marking quality and environmental conditions can affect LDW performance to the extent that they impact the system's ability to identify traffic lanes (see citation above).
    - Many systems rely upon having good, visible road markings and may not be able to detect an unmarked road edge.
    - Lane departure warning systems rely on the ability of the sensors to register lane markings, which may be problematic on roads that are not well marked or are covered with snow.

- Many current LDW systems have reduced lane detection rates in low light or inclement weather compared to normal light and weather conditions (Sayer et al., 2010).
- Sensors such as cameras may be influenced by environmental factors such as lighting or precipitation. Wilson et al. (2007) found that an LDW system was available 56% of the time during dry, daytime conditions, but only 4% of the time during wet, nighttime conditions.

- Many crash avoidance technologies rely on the driver to take action (IIHS, 2012). The effectiveness of these systems depends on whether drivers accept the technologies, understand the information from the system, and respond appropriately. This is especially true for warning systems, since a valid warning is useless if it is ignored. It is generally assumed that if drivers experience too many false alarms, they may find the systems to be annoying, overwhelming, or unhelpful and may disable them. Additionally, interpreting warnings from multiple systems may be confusing or even distracting for some drivers. Objective data on these assumptions is limited or lacking all together.

Differences between Implementations

- Different LDW systems may activate at different speeds (Eichelberger & McCartt, 2012), depending on the manufacturer (between 40 mph to 120 mph vs. over 70 km/h).
    - They may also de-activate at different speeds.
- Some LDW systems are combined with input from a Blind Spot Radar System to provide an imminent warning if there is a vehicle in the space you are approaching when executing a lane change.

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Appendix D – Educational Support Materials

The RFP that initiated this project did not specifically call for the development of educational support materials for the consumer on the selected technologies. The MIT AgeLab project leads elected to gather information and descriptions on each of the technologies that might prove useful to AAA-FTS and/or individual AAA clubs in developing such support material as desired at a future date. There is no presumption on our part that the representative content provided need be presented in the same format as currently used in the sheets.

The educational support material sheets include the following content sections:

- *What Is It?* – A short one to two paragraph description of what a technology is and the conditions under which it might be relevant. This is intended as a very brief, high level orientation to the technology.

The sections listed below represent a next level down description and elaboration of information on the technology, but again presented at a consumer oriented level.

- *Why Would I Use This Technology?* – This section generally expands somewhat on what the technology is, why it is relevant, and sometimes includes additional information on how and/or why it works.
- *What Do Drivers Think?* – This section generally highlights information on consumer satisfaction with the technology.
- *How Well Does It Work?* – This section addresses objective data on the expected potential and/or observed safety benefits of the technology. It is based on selected data drawn from the *Crash Reduction/Prevention* section of the technology review sheet.
- *Who Benefits Most?* – This section highlights relevant information on the type of drivers, driving conditions, or type of vehicles that may benefit the most from availability of this technology.
- *In What Situations Doesn't It Work*? - Similar to the *Limitations / Failure Conditions* section of the technology review sheet, but presented at a consumer level.
- *Mobility Significance* – Similar to the *Mobility Significance* section of the technology review sheet, but presented at a consumer level.
- *Not All Systems Are Alike* – Similar to the *Differences between Implementations* section of the technology review sheet, but presented at a consumer level.
- *Different Names, Same Idea* – A listing of alternate names that different manufacturers may use to describe their implementation(s) of a particular type of safety technology.

As noted in the main body of the report, these supplemental educational support material sheets are seen as starting points that would benefit from additional review and refinement to ensure fully accurate translation of technical details into consumer oriented language. Citations from which most statements are made are provided in the "Technology Review Sheets" provided in Appendix C and reference to them will likely be useful in reviewing. This material is presented here to support idea generation and to serve as a reference base in the further development of consumer oriented educational support materials.

Electronic Stability Control (ESC)

What Is It?

Electronic Stability Control systems help you maintain or regain control of your vehicle in difficult driving situations, such as during unexpected turns or while negotiating icy roads. These systems work by automatically applying the brakes, reducing the engine power, and/or adjusting the vehicle's tire suspension to prevent "loss of control" events. "Loss of control" accidents are extremely common, accounting for up to 40% of fatal car crashes. Studies have shown that Electronic Stability Control systems are highly effective in helping a driver maintain control of the vehicle, and substantially reduce the risks associated with loss of control, preventing many accidents.

Electronic Stability Control continuously monitors tire movement and steering wheel activity to sense a loss of traction or slippage. In such situations, Electronic Stability Control systems can reduce engine power, apply brakes independently to each wheel, and correct tire suspension much faster than the driver could. These systems are particularly helpful in managing unexpected events, or driving on wet or icy roadways. They are also especially helpful to drivers of large vehicles, such as SUVs.

<u>Just the Facts</u>

Why Would I Use This Technology?

Loss of control crashes, in which the driver cannot adequately control his/her vehicle, are extremely common, accounting for up to 40% of fatal accidents annually. ESC systems detect situations where the vehicle may not be responding to the driver's control, and automatically adjust the brake, throttle and tire suspension to compensate. The primary benefit of this technology is that it **increases the driver's ability to control the vehicle and substantially reduces accident risk.**

What Do Drivers Think?

About 50% of consumers do not know about ESC or whether it is implemented in their vehicle. Those who are familiar with ESC generally have a high opinion of it. In a survey of ESC aware drivers, 89% said that they felt the technology made them safer.

How Well Does It Work?

ESC systems are highly effective, and could help prevent up to 800,000 single-vehicle crashes per year (48%). Fatal crashes could be reduced 40-56%. An experiment that simulated common loss of control situations found that accidents were greatly reduced in the ESC-enabled situations.

Who Benefits Most?

ESC systems are highly beneficial overall, especially for drivers who own larger vehicles such as SUVs. In addition, drivers who commonly find themselves on icy or wet roadways would also derive the most benefit from these systems.

In What Situations Doesn't It Work?

ESC systems are designed to detect situations in which the driver may be under- or over-steering (as in a sharp, sudden turn), or in cases where the driver is not adequately controlling the vehicle (as on icy roads). The system would not affect cases such as unintentionally drifting out of the lane. It does not have much effect on rear-end collisions. Anecdotal reports by some drivers suggests that they may drive more aggressively under some conditions due to their confidence in the system's ability to recover control, which may lower the overall gain that might be obtained otherwise.

Mobility Significance

ESC systems increase driving comfort in adverse driving conditions, reducing driver stress.

Not All Systems Are Alike

ESC is designed to be kept on at all times. Some versions have an "off switch" that can be used in situations where ESC might control the vehicle too often (as when stuck in snow or mud). The type of switch and how long it stays off will vary between car manufacturers.

Different Names, Same Idea

Electronic Stability Control systems can be found under a number of different names, including:

- Vehicle Stability Assist
- Vehicle Dynamic Control
- Electronic Stability Program
- Dynamic Stability Control
- StabiliTrak
- AdvanceTrac

Adaptive (Automatic) Cruise Control (ACC)

What Is It?

Adaptive (Automatic) Cruise Control senses where the forward vehicle is relative to your own vehicle, and slows down and speeds up your vehicle to maintain a consistent headway time. Unlike traditional cruise control, which can only be set to a single speed, Adaptive (Automatic) Cruise Control can adapt when other vehicles change their speed. Adaptive (Automatic) Cruise Control may help prevent around 13,000 crashes per year.

Adaptive (Automatic) Cruise Control is most beneficial to drivers who often drive on highways. It may also improve the driver's ability to navigate traffic and improve fuel economy. It is important to keep in mind that these systems are designed to respond to other moving vehicles, and do not detect objects that are very small or stationary. Camera-based systems can be affected by the time of day and weather conditions, whereas radar-based systems can be obstructed by ice or snow.

Just the Facts

Why Would I Use This Technology?

Adaptive (Automatic) Cruise Control adjusts the vehicle's speed in response to other vehicles' changes in speed. The primary benefit of this technology is that it **helps the driver manage his speed and maintain a safe headway time to other cars.**

What Do Drivers Think?

Drivers who already own an ACC system have a very high opinion of it, with 76-93% of survey respondents reporting that they would buy the system again. Nearly half of respondents said that the system helps relieve stress. About a third of respondents said that the system made them a safer driver.

How Well Does It Work?

ACC systems may help prevent 13,000 crashes per year. Surveys suggest (see above) that most drivers are very satisfied with these systems.

Who Benefits Most?

ACC is primarily available in luxury and higher-end vehicles, though this is expected to change in the coming years. Drivers who often drive on highways would derive the most benefit from this technology.

In What Situations Doesn't It Work?

ACC systems are not designed to respond to stationary or particularly small objects. Surveys have shown that relatively few drivers are aware of these types of limitations, and may overestimate the system's protective benefit. Some drivers also have difficulty telling when ACC is active, as opposed to standard cruise control.

Mobility Significance

Although ACC's mobility benefits are relatively minor, the system would help smooth a driver's control of the vehicle, and allow him/her to focus on other aspects of driving.

Not All Systems Are Alike

ACC can be found under several configurations based on the time between the vehicle.

Different Names, Same Idea

Adaptive (Automatic) Cruise Control can be found under a number of different names, including:

- Autonomous cruise control
- Intelligent cruise control

Adaptive Headlights

What Is It?

Adaptive headlights adjust their direction and intensity in response to the driver's steering to provide additional light on curves, turns, hills, or to highlight potential hazards. Poor visibility is a common cause of crashes, and this technology may help prevent up to 142,000 crashes per year (about 90% of all crashes caused by visibility problems).

Adaptive headlights are most effective on moderate to high-speed roads in dark conditions, particularly when going around curves. Adaptive headlights also may be beneficial to persons other than the driver. They point more toward the road, reducing glare for other drivers, and may increase the visibility of pedestrians.

<u>Just the Facts</u>

Why Would I Use This Technology?

Adaptive headlights adjust their direction and intensity to provide additional illumination on curves, turns, and hills and to highlight potential hazards. The primary benefit of this technology is that it **increases the visible range of the forward roadway, particularly when navigating curves and turns.**

What Do Drivers Think?

Studies show that few drivers are aware of adaptive headlamp technology (31%), among those who are, 60% agree that it is a beneficial safety feature.

How Well Does It Work?

The Insurance Institute for Highway Safety estimates that adaptive headlights are potentially relevant to 90% of crashes that occur on curves at night; however, the extent to which having adaptive headlights translates into actual crash reductions is still being actively studied. It has been found that vehicles equipped with adaptive headlights are involved in fewer crashes with other vehicles than vehicles that are not.

Who Benefits Most?

Adaptive headlights would be most beneficial to drivers who often drive at night. Since the technology is passive (automatic), it will be of some use to almost all drivers.

In What Situations Doesn't It Work?

Though these systems can improve visibility, they do not warn the driver about potential obstacles. The lights do not make it safer to speed. This is especially important to keep in mind, as about a quarter of drivers who use adaptive headlights have reported that they are willing to drive faster with this technology turned on.

Mobility Significance

Adaptive headlights enhance the driver's field of view in dark or other poor visibility conditions. They extend the hours during which a person can comfortably drive.

Not All Systems Are Alike

Future adaptive headlamp systems may adjust the beam pattern to prevent glare for the oncoming motorist, thereby allowing your vehicle to operate in high beam mode more frequently. Federal requirements (FMVSS) do not presently permit such systems.

Different Names, Same Idea

Adaptive headlights can be found under a number of different names, including:

- Advanced Forward Lighting System
- Adaptive Headlamp

Additional terms that might be used to identify this technology include "cornering headlights", "steerable headlights", etc.

Back-Up Cameras

What Is It?

Back-Up Cameras allow the driver to view the area behind the rear bumper and see small objects that may be obstructed by the vehicle's blind spots, or may not ordinarily be visible at all. Backover crashes account for a small number of overall crashes, but these events are much more likely to involve small children, and have a high likelihood of fatality. It is estimated that back-up cameras could reduce this type of accident by as much as 46%.

Back-up cameras would likely be useful to suburban or passengers van drivers who often back out of a driveway, or urban drivers who frequently parallel park. They would be especially useful to older drivers, who often lack the flexibility necessary to turn and thoroughly check the blind spot.

There are several different versions of back-up camera systems. Some systems simply provide a view from the back of the vehicle, while others pair this view with a sensor that warns (audible alarm) if an object is detected too close to the back of the vehicle. Other systems will even apply the brakes automatically to prevent a potential collision.

<u>Just the Facts</u>

Why Would I Use This Technology?

Backover accidents account for a fairly small percentage of total accidents, but they are more likely to lead to severe injury or death. They provide an easily accessible view of the back of the vehicle, and may warn the driver if a potential crash/collision is detected. The primary benefit of this technology is that it makes it **much easier to monitor a difficult to see area around the vehicle and take corrective action as a result.**

What Do Drivers Think?

Opinion on back-up cameras is very positive, with 80% of surveyed drivers agreeing that the technology improves their safety. 96% of respondents found the technology easy to use. Older drivers were more likely than younger drivers to be interested in the system. However, many drivers (67% in one survey) believe that the system will be active regardless of the speed traveled, when in fact it will not.

How Well Does It Work?

Backup cameras reduce the likelihood of a backover accident by at least 46%. It is difficult to say whether this extends to differences in insurance claims, as the likelihood of a backover crash is small to begin with.

Who Benefits Most?

Back-up cameras are currently installed in about 25% of all vehicles, and would likely be useful to suburban drivers who often back out of a driveway, or urban drivers who frequently parallel park. They would be especially useful to older drivers, who often lack the flexibility necessary to turn and thoroughly check the blind spot.

In What Situations Doesn't It Work?

Many back-up camera systems will turn off if the vehicle is traveling faster than a certain speed (6 MPH in many implementations). Drivers should remember to continue to check their rearview mirrors, as some drivers, may become overly reliant on the camera.

Mobility Significance

Back-Up Cameras increase the driver's field of view, and may be especially useful to older drivers who have trouble stretching to check the blind spot.

Not All Systems Are Alike

Back-Up Cameras can be found under several different configurations. Image quality will vary between different implementations and conditions. Some cameras overlay guidelines onto the video. Others are connected to a sensor that will warn the driver if a rear obstacle is getting too close, and some may even automatically slow down the vehicle.

Different Names, Same Idea

Back-Up Cameras can be found under a number of different names, including:

- Rear-View Camera

Forward Collision Warning (FCW)

What Is It?

Forward Collision Warning systems alert you when your vehicle is about to collide with another vehicle some distance ahead of yours. This is a very common type of collision that results in about 1.4 million crashes per year, or about a quarter of all collisions. Research has shown that Forward Collision Warning systems can substantially reduce the risk and severity of a crash.

Forward Collision Warning systems may be most helpful in alerting the driver to dangerous situations, helping him or her to respond more quickly as the need arises. The type of warning that the systems use will vary between vehicles; some use a flashing light, while others use an alarm sound or vibration.

Forward Collision Warning systems should not be confused with Forward Collision Mitigation systems. Warning systems simply warn the driver when a collision is likely, but do not automatically apply the brakes. It is also important to keep in mind that different vehicles have the ability to detect different kinds of crashes. Some vehicles will only sound the alarm if it is about to collide with another moving vehicle, for example.

Just the Facts

Why Would I Use This Technology?

Forward collision crashes, in which the front of a vehicle collides with another vehicle on the road, are very common, accounting for up to a quarter of all crashes. FCW systems detect when the vehicle may be about to collide with another object, and alert the driver to encourage corrective action. The primary benefit of this technology is that it **alerts drivers to dangerous situations and allows the driver to take action quickly.**

What Do Drivers Think?

A recent survey showed that only about 24% of respondents were aware of FCW technology. Of those, 60% said the technology was easy to use, and 47% considered it to be useful. A study that asked about drivers' satisfaction with FCW found that drivers were moderately satisfied with it.

How Well Does It Work?

Studies of real cars have shown that FCW systems can reduce rear-end collisions by about 10%. Insurance studies have also shown that owners of cars equipped with FCW have lower claim rates than owners who do not have FCW.

Who Benefits Most?

FCW is most commonly available on luxury and higher-end vehicles, but that is expected to change in the next few years. Since all drivers need some help monitoring their surroundings, all types of drivers are expected to benefit equally.

In What Situations Doesn't It Work?

FCW systems can be camera-based or radar-based. Camera systems can be obstructed by build-ups of ice or snow, are less accurate at night, and can sometimes be "blinded" by sunrise and sunset. Radar-based systems are less susceptible to the time of day, but can be affected by snow and ice.

Mobility Significance

FCW would be beneficial for inattentive drivers, allowing them to react more quickly to dangerous situations they might have missed.

Not All Systems Are Alike

FCW systems may be camera-based or radar-based, and have different weaknesses as a result (see "In What Situations Doesn't It Work?"). Some systems use a flashing light to indicate a possible crash, while others play an alarming sound. Most importantly, some systems only detect possible collisions with moving vehicles, whereas others work with both moving and stationary vehicles. Some FCW systems can also "prepare" the brake to make braking more effective.

Different Names, Same Idea

Forward Collision Warning can be found under a number of different names, including:

- Crash Imminent Warning
- Pre-crash Warning

Forward Collision Mitigation (FCM) / Braking

What Is It?

Forward Collision Mitigation systems detect how far and fast the vehicle in front of your may be moving, and automatically apply the brakes if the driver does not responds himself. Many drivers fail to notice when they are entering into a potential crash situation. Even when they do notice, many will fail to apply the brakes quickly enough. Forward Collision Mitigation systems work to reduce the chance of crashes, and reduce the severity of collisions when they occur. It is estimated that these systems could prevent up to 1.2 million crashes per year.

Forward Collision Mitigation systems would be most useful for inattentive drivers who have trouble monitoring their surroundings at all times. It would also be especially helpful to drivers who have trouble reacting quickly to unexpected events, such as older drivers or those with disabilities.

Forward Collision Mitigation should not be confused with Forward Collision Warning. A Mitigation system will both warn the driver and slow the vehicle, whereas a Warning system will only warn the driver. Additionally, some systems will only detect other moving vehicles or vehicles traveling at a minimum speed, while others will detect both moving and stationary vehicles.

<u>Just the Facts</u>

Why Would I Use This Technology?

Forward collision crashes, in which the front of a vehicle collides with another vehicle on the road, are very common, accounting for up to a quarter of all crashes. FCM systems detect when the vehicle may be about to collide with another object, and automatically slow the vehicle. The primary benefit of this technology is that it **alerts drivers to dangerous situations and takes pre-emptive action to avoid a crash**.

What Do Drivers Think?

A recent survey showed that only about 24% of respondents were aware of FCM technology. Of those, 60% said the technology was easy to use, and 47% considered it to be useful. A study that asked about drivers' satisfaction with FCM found that drivers were moderately satisfied with it. Drivers who experienced a "false braking event", in which the system detects a crash that isn't happening and stops the vehicle, tend to have a lower opinion of these systems.

How Well Does It Work?

The Insurance Institute for Highway Safety estimates that these systems could reduce crashes by up to 20%, preventing 66,000 serious crashes and 879 fatal crashes per year.

Who Benefits Most?

FCM systems would be most useful for inattentive drivers who have trouble monitoring their surroundings at all times. It would also be especially helpful to drivers who have trouble reacting quickly to unexpected events, such as older drivers or those with disabilities.

In What Situations Doesn't It Work?

Camera-based FCM systems are less effective than radar-based systems, as these do not work as well at night and can be "blinded" by sunrise and sunset. It is also important for the driver to remain vigilant, and not become too reliant on the system for warnings and help.

Mobility Significance

FCM would be beneficial for inattentive drivers, allowing them to react more quickly to dangerous situations they might have missed. It would be especially helpful for drivers who react more slowly to their surroundings, whether due to age or disability.

Not All Systems Are Alike

FCM systems may be camera-based or radar-based, and have different weaknesses as a result (see "In What Situations Doesn't It Work?"). In addition, not all systems are capable of detecting stationary vehicles, or slowing the vehicle at the same rate.

Different Names, Same Idea

Forward Collision Mitigation can be found under a number of different names, including:

- Crash Imminent Brake (CIB)
- Autonomous Emergency Braking (AEB)
- Emergency Brake Assist (EBA)
- Predictive Brake Assist (PBA)
- Pre-crash warning and braking systems (PCWBS)

Lane Departure Warning (LDW)

What Is It?

Lane Departure Warning systems alert you whenever you unintentionally drift too close to the edges of the lane. Approximately 1.6 million lane departure accidents occur each year, accounting for more than a quarter of all vehicle accidents. Lane Departure Warning has been shown to be effective in improving a driver's ability to control the vehicle, and research suggests that these systems could substantially reduce the risk of accident.

Lane Departure Warning is particularly helpful for drivers who do a lot of driving on highways and rural roadways. It is less helpful for city drivers. The warning type varies between car manufacturers; some use an alarm sound, while others cause the driver's steering wheel or seat to vibrate, creating a feeling like driving over a rumble strip.

Lane Departure Warning systems should not be confused with Lane Departure Prevention systems (sometimes referred to as lane keeping assistance). Warning systems provide a warning, but leave any corrective actions up to you. Prevention systems gently steer the car to automatically re-center you in the lane.

Just the Facts

Why Would I Use This Technology?

Lane departure accidents are one of the most common accident types, accounting for 1.6 million road accidents per year. Studies have estimated that Lane Departure Warning (LDW) systems could prevent up to 179,000 accidents per year, including 7,500 fatal crashes. The primary benefit of this technology is that it **reduces accidents**.

What Do Drivers Think?

Studies that gave drivers a LDW system to try found that 85% of drivers reported liking the system and found it to be useful. 93% used the system at least sometimes, 77% felt it increased their safety, and 80% would buy the system again; 67% of drivers felt that LDW made them safer drivers.

How Well Does It Work?

LDW systems have been shown to improve lane-keeping by up to 34%, and in one study cut unintentional lane crossing in half. Drivers who used LDW systems also became more likely to use their turn signals, especially if they drove often on highways. Some in the driving safety research community have questioned the extent to which many regular drivers actually leave LDW systems active, and thus are able to benefit from the warnings. A need for additional naturalistic observation of how drivers interact with such systems and specific implementations of warning systems has been suggested.

Who Benefits Most?

LDW systems are most useful to drivers who often drive on highways and rural roadways. Some research suggests that the systems may provide greater benefit to younger drivers.

In What Situations Doesn't It Work?

LDW systems work by "looking" at the road's lane markings. These systems are less accurate on roads where lane markings are in poor condition, or in cases where bad weather obscures the markings. They are also somewhat less accurate at night or other low-light situations. These systems are better suited to highway driving, and will be less useful in cities.

Mobility Significance

LDW systems may increase driver confidence, and also help drivers realize when they may not be paying sufficient attention to the roadway.

Not All Systems Are Alike

Some manufacturers put the LDW system on by default, while others leave it off by default. Remember, you won't benefit from the system if it's not turned on, so check your car's manual to be sure you how the LDW system is activated and are aware of any conditions that will impact its function. Some LDW systems use an alarm sound, while others make the steering wheel or seat vibrate, similar to the feeling of a rumble strip.

Different Names, Same Idea

Lane Departure Warning systems can be found under a number of different names. As noted earlier, lane departure warning systems are conceptually different from lane keeping assistance systems that actively intervene in vehicle steering to aid in keeping your vehicle within lane boundaries. The latter technologies are often identified by terms such as "lane keeping assistance" and "lane keeping support".

Appendix E: Initial Conceptualization of Possible Rating Factors Shared with Experts for Discussion and Comment

As part of the initial task set for the project, we attempted to develop an exhaustive list of potential factors that might impact the overall effectiveness / safety benefit of a given technology. The resulting conceptualization and factor listing was then shared and discussed with a number of identified experts across academic, governmental, and industry settings. The material in the next section represents a version of the document that was used as part of these discussions. (It evolved and was updated during the course of the sequential discussion with the various experts.)

In developing the listing of potential factors, our intention was to start with a list of all the variables that one would ideally like to consider in assessing a technology and then move to evaluate what factors were practical to consider based on available sources of objective data. It was assumed that a significant reduction in the number and form of factors that could realistically be used in developing an objectively based rating system would occur. The eventual reduction and simplification of the primary rating methodology can be observed in the Technology Review sheets included in this report and the method of rating the broad safety impact of a technology eventually proposed in this report. This earlier material is reproduced here as it does still have some conceptual relevance to the assessment of driver vehicle interfaces (DVIs) and driver involved safety systems at different levels of assessment.

Conceptualization of a Technology Safety Benefit Rating System

(Based on November 15, 2012 version with minor additions.)

Conceptual contributors to an in-vehicle technology (IVT) rating system – The following conceptual grouping has been developed as a starting point for our consideration of factors that may contribute to the overall benefits or costs of a particular in-vehicle technology. Potential factors are broken out in more detail starting in the next section.

- **Estimates of the significance of the safety area** - consideration of variables such as number of crashes, injuries, and fatalities that might be reduced through the use of technology. Measures might be drawn from statistical databases such as FARS and published statistical modeling research and other estimation methods. Identification and development of methodology for converting such information from this and other categories into meaningful ratings will be a key focus of the early portion of the project. While a full review of factors is necessary, elements of published crash reports such as location, e.g. intersection, highway, parking lots, rural road, etc., as well as types of collisions, e.g. lane departures, forward collision etc., and vehicle occupant information will need to be considered in weighting the benefits of a given technology.
- **Potential efficacy of the technology** – to what extent the technology might be expected to impact the identified area of safety concern. This domain focuses on how the technology can be expected to perform / benefit the drivers across all ages under ideal conditions. Potential benefits need to be weighed against a matrix variables in the categories below. Efficacy ratings also need to take into account the amount of learning required to derive maximum benefit. Some technologies do not require any driver involvement to provide benefit. Others require some understanding and experience with the technology. Thus ratings providing an estimate of benefits at both the novice and experienced user levels are likely to be a useful addition.
- **Potential drawbacks or limitations of the technology, including basic usability** – depending on how the evaluation matrix is eventually organized, this aspect is likely to involve the most sub-evaluations. Limitations of technologies include:
    - conditions under which the technology will not operate, performance may degrade, or actual failure may occur (dirt on camera lenses, weather, speed, tolerance boundaries);
    - extent to which the technology adds to the overall demand on the older driver (cognitive, visual, manipulative, auditory and haptic / tactile domain demands);
    - potential distraction that may under certain conditions introduce safety risks;
    - extent to which trust in the technology is required to derive benefit;
    - ease of learning how to effectively utilize the technology – which may involve the intuitiveness of the mental model, frequency of confusion experienced by drivers, effort or time (number of interactions) required to become proficient;
- **Potential connectivity and modularity of the technology** – although not a major consideration in the near-term, this factor will become increasingly important over the

next few years. Consumers increasingly expect to be able to control their mobile devices from their steering wheels, or conversely, to augment the vehicle with data from the mobile device (turn-by-turn navigation, for instance). Just as we ask to what extent an in-vehicle technology can integrate with external devices, we might also ask to what extent the technology can be separated from the vehicle. Is the technology available only as part of a high-end luxury package, or are there options that make the technology that make the technology more affordable and/or accessible to the average consumer. These factors may be thought of as "vehicle adjacent" contributors.

Potential Rating Factors

The following is a working initial list of rating factors that are potentially relevant to assessing the safety benefits or costs associated with in-vehicle technologies. This listing is in the process of being expanded and "detailed out". The current conceptual grouping below is seen as a starting point and may well change based on further thought and input from collaborators. Our intent is to develop this into an exhaustive list of theoretically relevant rating factors.

- **Safety Significance**
    - **Crash Reduction** (crashes / injury / fatality mitigation)
    - **Risk Reduction** (potential increased situational awareness benefits, i.e. back-up cameras, blind spot identification, lane departure, various warning systems)
- **Potential Efficacy**
    - **Ease of Learning** – This refers to the extent to which one has to learn how to use a system to benefit from the technology - which may involve the intuitiveness of the mental model, frequency of confusion experienced by drivers, effort or time (number of interactions) required to become proficient. Efficacy may vary to the extent to which a driver is a novice or experienced user of a system.
- **Drawbacks or Limitations**
    - **Limiting Conditions**
        - **Technical Limitations** – This refers to conditions under which the technology will not operate, performance may degrade, or actual failure may occur – i.e. weather, speed, and tolerance boundaries.
        - **Behavioral Adaptation** - This refers to unintended behaviors that can arise from repeated use of a new in-vehicle technology (IVT). For instance, studies on seatbelt use in the mid-90s showed that belted drivers drove at higher speed and gave themselves less headway between the forward vehicle. Similarly, younger drivers with access to rear-view cameras are much less likely to physically turn to look out of the rear-view window.

- **Added Demand**
  - **Cognitive Demand (Workload)**
  - **Visual Demand** - This refers to the amount of time that a driver must spend looking at an IVT in order to use it. The more time spent looking at something other than the road, the riskier a technology becomes. A number of experimental standards have been proposed for measuring visual demand.
  - **Manipulative (Motor) & Tactile Demand** - This refers to the complexity of physically manipulating the controls of an IVT. Technologies with simpler manipulative demands are less likely to distract the driver, whereas those that are more complicated or provide ambiguous tactile feedback are likely to be less safe and convenient to use. For example, a manual gearshift is simple to use, but using a stereo with dozens of smaller buttons presents much greater manipulative demand.
  - **Auditory Demand**
- **Distraction** – This refers to potential distraction that may arise from a technology that may under certain conditions introduce safety risks (some conceptual overlap with added demand – but not the same construct)
- **Trust** – This refers to the extent to which trust is required to derive benefit.
- **Ease of Learning** – *(This section is also listed under the primary heading, "Potential Efficacy"; there is a conceptual overlap here.)* This refers to the extent to which one has to learn how to use a system to benefit from the technology - which may involve the intuitiveness of the mental model, frequency of confusion experienced by drivers, effort or time (number of interactions) required to become proficient. Efficacy may vary to the extent to which a driver is a novice or experienced user of a system.

- **<u>Other categories for integration or breakout</u>**
  - **Frequency of Use** – This refers to the extent to which a system may have benefit if engaged, but data indicates a significant number of cases where drivers do not engage the technology for various reasons (not aware of how to engage, have actively disengaged, etc.) and thus tend not to derive benefit.
  - **Impact on Stress** - This can be conceptualized as a fairly direct measure of the driver's physiological comfort level, and can be measured by various physiological measures such as skin conductance and heart rate readings. (Self-report ratings are also relevant here but may or may not be seen as having as much objective validity – an open point for consideration.)
  - **Consumer Awareness, Use, and Satisfaction**
- **External Safety** - This refers to an in-vehicle technology's impact on the safety of persons or items outside the vehicle, such as pedestrians and intersections. Collision

detection systems that automatically slow the car have been shown to reduce the severity of pedestrian injuries in these types of crashes.

- **Comfort** – This refers to technologies largely identified as being outside of the primary safety domain but that may, nonetheless, provide some indirect safety benefits.
- **Convenience -** This refers to technologies largely identified as being outside of the primary safety domain but that may, nonetheless, provide some indirect safety benefits.

Detail on a Partial Listing of Rating Factors

From the list of potential rating factors, we intend to identify which factors are the most appropriate and feasible to consider in the near-term for a first generation rating system. One key criterion for identifying initially relevant factors is the availability of data to support the development of objective rating criteria. The following subsections cover a number (but not all) of the factor areas from the current list.

Crash Reduction

Data Sources

- Fatality Analysis Reporting System (FARS, NHTSA)
- Highway Loss Data Institute (HLDI, IIHS)
- National Automotive Sampling System (NASS, NHTSA)
- National Motor Vehicle Crash Causation Survey (NMVCSS, NHTSA)
- General Estimates System (GES, NHTSA)
- Consumer Reports safety data

Research Examples

- Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, *38*(2), 215–224. doi:10.1016/j.aap.2005.07.004
- Adell, E., Várhelyi, A., & Fontana, M. (2011). The effects of a driver assistance system for safe speed and safe distance–A real-life field study. *Transportation Research Part C: Emerging Technologies*, *19*(1), 145–155. doi:10.1016/j.trc.2010.04.006
- Cummings, P., & Grossman, D. C. (2007). Antilock brakes and the risk of driver injury in a crash: A case–control study. *Accident Analysis & Prevention*, *39*(5), 995–1000. doi:10.1016/j.aap.2007.01.005
- Curry, A.E., Hafetz, J., Kallan, M.J., Winston, F.K., Durbin, D.R. (2010). Prevalence of teen driver errors leading to serious motor vehicle crashes. *Accident Analysis & Prevention, 43(4),* 1285-1290. DOI:10.1016/j.aap.2010.10.019.

- Farmer, C. M. (2001). New evidence concerning fatal crashes of passenger vehicles before and after adding antilock braking systems. *Accident Analysis & Prevention*, 33(3), 361-369.
- Georai, A., Zimmermann, M., Lich, T., Blank, L., Kickler, N., & Marchthaler, R. (2009). New approach of accident benefit analysis for rear end collision avoidance and mitigation systems. *ENHANCED SAFETY OF VEHICLES.[vp]. 15-18 Jun.*
- Kusano, K. D., & Gabler, H. C. (2010). Potential Occupant Injury Reduction in Pre-Crash System Equipped Vehicles in the Striking Vehicle of Rear-end Crashes. *Annals of Advances in Automotive Medicine/Annual Scientific Conference*, *54*, 203.
- Page, Y., Foret-Bruno, J. Y., & Cuny, S. (2005). Are expected and observed effectiveness of emergency brake assist in preventing road injury accidents consistent. *Paper No 05*.
- Page, Y., Hermitte, T., & Cuny, S. (2011). How Safe is Vehicle Safety? The Contribution of Vehicle Technologies to the Reduction in Road Casualties in France from 2000 to 2010. *Annals of Advances in Automotive Medicine/Annual Scientific Conference*, *55*, 101.
- Suzuki, K., & Yamada, K. (2010). Method for Evaluating Effectiveness of Information Presentation in Terms of Collision Avoidance. *International Journal of Intelligent Transportation Systems Research*, *9*(1), 37–46. doi:10.1007/s13177-010-0023-8

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

Ease of Learning

Data Sources: again, difficult to quantify in a global sense. Data from Consumer Reports and JD Power, which assess convenience and ease of use, might make an acceptable proxy.

Research Examples

- Comte, S. L. (2000). New systems: new behaviour? *Transportation Research Part F: Traffic Psychology and Behaviour*, *3*(2), 95–111. doi:10.1016/S1369-8478(00)00019-X
- Llaneras, R. E. (2007). Safety Related Misconceptions and Self-Reported Behavioral Adaptations Associated With Advanced In-Vehicle Systems: Lessons Learned From Early Technology Adopters. *PROCEEDINGS of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*.
- Warner, H. W., & Åberg, L. (2008). The long-term effects of an ISA speed-warning device on drivers' speeding behaviour. *Transportation Research Part F: Traffic Psychology, 11(2),* 96-107.

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: ?

Cognitive Demand (Workload)

Data Sources: comparing workload effects using something like the n-back or clock visualization tasks might prove useful.

Research Examples:

- Brookhuis, K. A., van Driel, C. J. G., Hof, T., van Arem, B., & Hoedemaeker, M. (2009). Driving with a Congestion Assistant; mental workload and acceptance. *Applied Ergonomics*, *40*(6), 1019–1025. doi:10.1016/j.apergo.2008.06.010
- Davidse, R. J., Hagenzieker, M. P., van Wolffelaar, P. C., & Brouwer, W. H. (2009). Effects of In-Car Support on Mental Workload and Driving Performance of Older Drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *51*(4), 463–476. doi:10.1177/0018720809344977
- Ghazizadeh, M., & Boyle, L. N. (2010). Influence of Driver Distractions on the Likelihood of Rear-End, Angular, and Single-Vehicle Crashes in Missouri. *Transportation Research Record: Journal of the Transportation Research Board*, *2138*(-1), 1–5. doi:10.3141/2138-01
- Mehler, B., Reimer, B., Coughlin, J. F., & Dusek, J. A. (2010). Impact of Incremental Increases in Cognitive Workload on Physiological Arousal and Performance in Young Adult Drivers. *Transportation Research Record: Journal of the Transportation Research Board*, *2138*(-1), 6–12. doi:10.3141/2138-02
- Merat, N., & Jamson, A. H. (2008). The Effect of Stimulus Modality on Signal Detection: Implications for Assessing the Safety of In-Vehicle Technology. *Human Factors*, *50*(1), 145–158. doi:10.1518/001872008X250656
- Palinko, O., Kun, A. L., Shyrokov, A., & Heeman, P. (2010). Estimating cognitive load using remote eye tracking in a driving simulator. In *Proceedings of the 2010 Symposium on Eye-Tracking Research & Applications* (pp. 141-144). ACM.

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

Visual Demand

Data Sources: ISO recommends a "visual occlusion" method to gauge the amount of pure visual demand imposed by an IVT. Eye tracking and manual coding of visual glance behavior has also been used extensively.

Research Examples

- Birrell, S. A., & Young, M. S. (2011). The impact of smart driving aids on driving performance and driver distraction. *Transportation Research Part F: Psychology and Behaviour*, *14*(6), 484–493. doi:10.1016/j.trf.2011.08.004
- Devonshire, J. M. (2012). Effects of Automotive Interior Lighting on Driver Vision. doi:10.1582/LEUKOS.2012.09.01.001

- Engström, J., Åberg, N., Johansson, E., & Hammarbäck, J. (2005). Comparison between visual and tactile signal detection tasks applied to the safety assessment of in-vehicle information systems. In *Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design* (pp. 232-239).
- Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). *The Impact of Driver Inattention On Near-Crash/Crash Risk* (No. DOT HS 810 594) (pp. 1–224).
- Neale, V. L., Dingus, T. A., Klauer, S. G., Sodweeks, J., & Goodman, M. (2005). An Overview of the 100-Car Naturalistic Study and Findings. *National Highway Traffic Safety Administration, Paper*, (05-0400).
- Pettitt, M. A. (2008). Visual demand evaluation methods for in-vehicle interfaces. (Doctoral dissertation, University of Nottingham).
- Stevens, A., Burnett, G., & Horberry, T. (2010). A reference level for assessing the acceptable visual demand of in-vehicle information systems. *Behaviour & Information Technology*, *29*(5), 527–540. doi:10.1080/01449291003624212
- Yee, S., Nguyen, L., Green, P., Oberholtzer, J., & Miller, B. (2007). Visual, auditory, cognitive, and psychomotor demands of real in-vehicle tasks. UMTRI Technical Report (UMTRI-2006-20).

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

Manipulative (Motor) & Tactile Demand

Data Sources: ?

Research Examples

- Engström, J., Åberg, N., Johansson, E., & Hammarbäck, J. (2005). Comparison between visual and tactile signal detection tasks applied to the safety assessment of in-vehicle information systems. In *Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design* (pp. 232-239).
- Just, M. A., Carpenter, P. A., Keller, T. A., Emery, L., Zajac, H., & Thulborn, K. R. (2001). Interdependence of nonoverlapping cortical systems in dual cognitive tasks. *NeuroImage*, *14*(2), 417–426. doi:10.1006/nimg.2001.0826
- Merat, N., & Jamson, A. H. (2008). The Effect of Stimulus Modality on Signal Detection: Implications for Assessing the Safety of In-Vehicle Technology. *Human Factors*, *50*(1), 145–158. doi:10.1518/001872008X250656
- Yee, S., Nguyen, L., Green, P., Oberholtzer, J., & Miller, B. (2007). Visual, auditory, cognitive, and psychomotor demands of real in-vehicle tasks. UMTRI Technical Report (UMTRI-2006-20).

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: ?

Auditory Demand

Data Sources: no standardized data source.

Research Examples

- Kun, A., Paek, T., & Medenica, Z. (2007). The effect of speech interface accuracy on driving performance. *In INTERSPEECH (pp. 1326-1329).*
- Kun, A. L., Shyrokov, A., & Heeman, P. A. (2010). Spoken tasks for human-human experiments: towards in-car speech user interfaces for multi-threaded dialogue, In *Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 57-63). ACM.
- Merat, N., & Jamson, A. H. (2008). The Effect of Stimulus Modality on Signal Detection: Implications for Assessing the Safety of In-Vehicle Technology. *Human Factors*, *50*(1), 145–158. doi:10.1518/001872008X250656
- Shyrokov, A. (2006). Setting-up experiments to test a multithreaded speech user interface. (Vol. 54). Technical report ECE.
- Yee, S., Nguyen, L., Green, P., Oberholtzer, J., & Miller, B. (2007). Visual, auditory, cognitive, and psychomotor demands of real in-vehicle tasks. UMTRI Technical Report (UMTRI-2006-20).

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

Behavior Adaptation

Data Sources: behavior adaptation is not represented in large databases. However, defining some standard metrics by which to measure behavior adaptation across multiple technologies (reaction time, vehicle telemetry changes, etc.) might make a promising side project.

Research Examples

- Adell, E., Várhelyi, A., & Fontana, M. (2011). The effects of a driver assistance system for safe speed and safe distance–A real-life field study. *Transportation Research Part C: Emerging Technologies*, *19*(1), 145–155. doi:10.1016/j.trc.2010.04.006
- Breyer, F., Blaschke, C., Farber, B., Freyer, J., & Limbacher, R. (2010). Negative Behavioral Adaptation to Lane-Keeping Assistance Systems. *IEEE Intelligent Transportation Systems Magazine*, *2*(2), 21–32. doi:10.1109/MITS.2010.938533
- Kiefer, R. J., & Hankey, J. M. (2008). Lane change behavior with a side blind zone alert system. *Accident Analysis & Prevention*, *40*(2), 683–690. doi:10.1016/j.aap.2007.09.018

- Llaneras, R. E. (2007). Safety Related Misconceptions and Self-Reported Behavioral Adaptations Associated With Advanced In-Vehicle Systems: Lessons Learned From Early Technology Adopters. *PROCEEDINGS of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*.
- Rudin-Brown, C. M. (2010). "Intelligent" in-vehicle intelligent transport systems: limiting behavioural adaptation through adaptive design. *IET Intelligent Transport Systems*, *4*(4), 252. doi:10.1049/iet-its.2009.0151
- Warner, H. W., & Åberg, L. (2008). The long-term effects of an ISA speed-warning device on drivers' speeding behaviour. *Transportation Research Part F: Traffic Psychology, 11(2),* 96-107.

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

External Safety

Data Sources

- Databases that specifically denote pedestrian vs. vehicle collisions.
- Databases that provide estimates of total damages (IIHS, HLDI, etc)

Research Examples

- Devonshire, J. M. (2012). Effects of Automotive Interior Lighting on Driver Vision. doi:10.1582/LEUKOS.2012.09.01.001
- Farah, H., Koutsopoulos, H. N., Saifuzzaman, M., Kölbl, R., Fuchs, S., & Bankosegger, D. (2012). Evaluation of the effect of cooperative infrastructure-to-vehicle systems on driver behavior. *Transportation Research Part C: Emerging Technologies*, *21*(1), 42–56. doi:10.1016/j.trc.2011.08.006
- Helmer, T., Scullion, P., Samaha, R. R., Ebner, A., & Kates, R. (2011). Predicting the Injury Severity of Pedestrians in Frontal Vehicle Crashes based on Empirical, In-depth Accident Data. *International Journal of Intelligent Transportation Systems Research*, *9*(3), 139–151. doi:10.1007/s13177-011-0036-y
- Oh, C., Kang, Y. S., & Youn, Y. (2009). Evaluation of a brake assistance system (BAS) using an injury severity prediction model for pedestrians. *International Journal of Automotive Technology*, *10*(5), 577–582. doi:10.1007/s12239−009−0067−4

Experimentally Derivable in Near-Term: Yes

Expert Opinion Available: Yes

Stress

Data Sources: Stress can be quantified directly as changes in heart rate or galvanic skin response. Stress can also be conceived of as a byproduct or covariate of the various demand factors outlined above.

Research Examples

- AgeLab citations
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008a). *Use of Advanced In-Vehicle Technology By Young and Older Early Adopters: Survey Results on Headlamp Systems*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008b). *Use of Advanced In-Vehicle Technology by Young and Older Early Adopters. Survey Results on Navigation Systems*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008c). *Use of Advanced In-Vehicle Technology by Younger and Older Early Adopters. Selected Results From Five Technology Surveys*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., Osberg, J. S., & Tefft, B. C. (2007). *Use of Advanced In-Vehicle Technology By Young and Older Early Adopters: Results on Sensor-Based Backing Systems and Rear-View Video Cameras*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., Osberg, J. S., & Tefft, B. C. (2008d). *Use of Advanced In-Vehicle Technology By Young and Older Early Adopters: Survey Results on Adaptive Cruise Control Systems* (pp. 1–110). National Highway Transportation Safety Administration.

Experimentally Derivable in Near-Term: Yes (readily)

Expert Opinion Available: Yes

Consumer Awareness, Use, and Satisfaction

Data Sources:

- Consumer Reports
- JD Power (specifically the Automotive Performance, Execution, and Layout subscale)

Research Examples:

- Böhm, M., Fuchs, S., Pfliegl, R., & Kölbl, R. (2010). Driver Behavior and User Acceptance of Cooperative Systems Based on Infrastructure-to-Vehicle Communication. *Transportation Research Record: Journal of the Transportation Research Board*, *2129*(-1), 136–144. doi:10.3141/2129-16

- Brookhuis, K. A., van Driel, C. J. G., Hof, T., van Arem, B., & Hoedemaeker, M. (2009). Driving with a Congestion Assistant; mental workload and acceptance. *Applied Ergonomics*, *40*(6), 1019–1025. doi:10.1016/j.apergo.2008.06.010
- Farah, H., Koutsopoulos, H. N., Saifuzzaman, M., Kölbl, R., Fuchs, S., & Bankosegger, D. (2012). Evaluation of the effect of cooperative infrastructure-to-vehicle systems on driver behavior. *Transportation Research Part C: Emerging Technologies*, *21*(1), 42–56. doi:10.1016/j.trc.2011.08.006
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008a). *Use of Advanced In-Vehicle Technology By Young and Older Early Adopters: Survey Results on Headlamp Systems*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008b). *Use of Advanced In-Vehicle Technology by Young and Older Early Adopters. Survey Results on Navigation Systems*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., & Osberg, J. S. (2008c). *Use of Advanced In-Vehicle Technology by Younger and Older Early Adopters. Selected Results From Five Technology Surveys*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., Osberg, J. S., & Tefft, B. C. (2007). *Use of Advanced In-Vehicle Technology By Young and Older Early Adopters: Results on Sensor-Based Backing Systems and Rear-View Video Cameras*. National Highway Transportation Safety Administration.
- Jenness, J. W., Lerner, N. D., Mazor, S. D., Osberg, J. S., & Tefft, B. C. (2008d). *Use of Advanced In-Vehicle Technology By Young and Older Early AdoptersSurvey Results on Adaptive Cruise Control Systems* (pp. 1–110). National Highway Transportation Safety Administration.
- Jiménez, F., Liang, Y., & Aparicio, F. (2012). Adapting ISA system warnings to enhance user acceptance. *Accident Analysis & Prevention*, *48*, 37–48. doi:10.1016/j.aap.2010.05.017
- Joshi, S., Bellet, T., Bodard, V., & Amditis, A. (2009). Perceptions of Risk and Control: Understanding Acceptance of Advanced Driver Assistance Systems. *Human-Computer Interaction–INTERACT 2009*, 524–527.
- Van Der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C: Emerging Technologies, 5(1),* 1-10.
- Warner, H. W., Özkan, T., & Lajunen, T. (2010). Drivers' propensity to have different types of intelligent speed adaptation installed in their cars. *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(3), 206–214. doi:10.1016/j.trf.2010.04.005

Experimentally Derivable in Near-Term: Yes (surveys)

Expert Opinion Available: Yes

Comfort

Data Sources: Consumer Reports and JD Power will likely have survey subscales available that address user comfort factors.

Research Examples

- Caberletti, L., Elfmann, K., Kummel, M., & Schierz, C. (2010). Influence of ambient lighting in a vehicle interior on the driver's perceptions. *Lighting Research and Technology*, *42*(3), 297–311. doi:10.1177/1477153510370554
- Coughlin, J. F., Reimer, B., & Mehler, B. (2011). Monitoring, managing, and motivating driver safety and well-being. *Pervasive Computing, IEEE*, *10*(3), 14–21. doi:10.1109/MPRV.2011.54
- Devonshire, J. M. (2012). Effects of Automotive Interior Lighting on Driver Vision. doi:10.1582/LEUKOS.2012.09.01.001
- Kyung, G., & Nussbaum, M. A. (2008). Driver sitting comfort and discomfort (part II): Relationships with and prediction from interface pressure. *International Journal of Industrial Ergonomics 38(5),* 526-538.

Experimentally Derivable in Near-Term: Yes (surveys)

Expert Opinion Available: Yes

Appendix F: Initial Consultations with Selected Industry Experts & Observers

Early in the conceptual development of the rating scale (November 2012), we solicited input on a number of formative questions from a number of safety experts, academics, and industry professionals. They were provided with a copy of the conceptualization of a rating factor list (See previous Appendix) and encouraged to offer their thoughts on the strengths and weaknesses of different methodologies for developing a rating scale from their unique perspectives. Input was initially obtained through conference calls with members of the project staff that typically ranged between one and two hours each. Many of the conversations provided valuable insights on the project that helped shape and focus our thinking going forward. Summaries of key content from these conversations (in the form of a follow-up memo to the person interviewed) were drafted and sent to each participant for review and comment. The memos were edited based on feedback from the participants. A report on the first 8 interviews and resulting refinements in our listing of potential factors to consider in technology ratings (*Conceptualization of a Technology Safety Benefit Ratings System: Initial Conversations with Select Experts*) was sent to AAA-FTS on December 2. This document was updated on December 14th. As noted below, three of the experts provided feedback on an anonymous basis as they spoke as individuals as opposed to formally representing their respective organizations.

Listing of Experts

Tom Baloga was the Vice President of engineering for BMW North America at the time of our call; he retired shortly thereafter. His main interests include intelligent in-vehicle systems, vehicle safety, and connected vehicle systems.

Azim Eskandarian is a Professor of Engineering and Applied Science at George Washington University, as well as the director of the Center for Intelligent Systems Research and the SEAS Transportation Safety and Security Program. His research focuses on intelligent in-vehicle systems, driver assistance, and collision avoidance technologies.

James Jenness is a Senior Research Scientist at Westat Inc., and has contributed to a large number of automotive safety projects. His work includes a NHTSA sponsored, extensive survey-based study of in-vehicle technology adoption by older drivers.

Neil Lerner is the Manager of Human Factors projects at Westat, Inc., and has done substantial work examining the effects of distraction on driving behavior, as well as drivers' perceptions of emerging in-vehicle technologies. He has collaborated with James Jenness on a number of projects.

Dan McGehee is an Adjunct Professor of Mechanical and Industrial Engineering at the University of Iowa Public Policy Center, as well as the director of the University's Human Factors and Vehicle Safety Research Program. His primary interests are in driver performance and behavior, interface design, and technology testing

Michael Perel is the former chief of the Human Factors/Engineering Integration Division at NHTSA (now retired).

Anonymous Number One has worked in the automotive industry for three decades, and currently oversees safety research for a consortium of automobile companies.

Anonymous Number Two is a research scientist with over thirty years of experience in both the automotive industry and academia, whose work on driver attention and behavior has helped set guidelines in the United States.

Anonymous Number Three is a senior engineer at a major automotive company whose work focuses on vehicle safety technologies. As part of his role, he is involved with international efforts in system testing and often acts as a liaison to regularity and other non-governmental traffic safety institutions.

Introduction Provided to Industry Experts

After an initial phone conversation with project lead Bryan Reimer, the following written introduction was provided to our initial select group of experts to provide a context for an extended conference call.

Developing a Consumer-Oriented Rating System for In-Vehicle Technologies

We have been tasked by the AAA Foundation for Traffic Safety with identifying and developing objective measures that can be used to construct a consumer-oriented rating system for in-vehicle technologies (IVTs). The resulting rating system should allow consumers to compare and contrast the effectiveness and efficacy of a wide range of IVTs in a manner that assists them in making informed purchasing decisions. In essence, if you have $2000 to spend, what are the most effective technologies for you to allocate these limited resources? It is our belief that effectively communicated information can educate consumers on the relative benefits of various IVTs and ensure that, where data exists, they are aware of safety advantages systems offer.

Rating the benefits or usefulness of a technology as much as possible on an objective basis presents a number of conceptual and methodological challenges, and we believe that the success of this undertaking will be greatly influenced by the breadth of perspective and depth of experience that can be taken into consideration in various ways in its development. Consequently, we have included as a fundamental component of this project, reaching out to a select group of knowledgeable individuals early in the process for input and comment.

As a starting point, we have chosen to conceptualize both IVTs and their underlying rating factors into the domains of safety, comfort, and convenience. Although we are primarily concerned with the safety impact of IVTs at the present time, comfort and convenience factors will also be considered insofar as they have the potential to improve the driving experience, reduce stress and demand on the driver, and thus ultimately influence roadway safety. This taxonomy is also forward-looking, and will potentially allow an expanded focus on rating more comfort- or convenience-oriented features, such as navigation and entertainment systems, in the future.

There are a number of ways to conceptualize safety and thus there are a broad range of factors that are potentially relevant to assessing the safety benefits or costs associated with IVTs. A core factor might be an estimation of the number of crashes / injuries / fatalities reduced based on the use of a given technology. Other factors that may exert both positive and negative influences include the usability of a system, learnability, understandability of when and how to engage or depend upon a system, behavioral adaptation to a technology, cognitive workload, distraction, tolerance to environmental conditions, etc. From a strategic standpoint, we believe that it makes sense to begin with as comprehensive a list of theoretically relevant factors as possible. While academic in nature, we believe the development of a comprehensive list will provide a more transparent basis on which to justify the selection of actual rating components (i.e. explicit reasons can be provided as to why various factors were or were not included). From that list, we intend to identify which factors are the most appropriate and feasible to consider in the near-term for a first generation rating system. One key criterion for identifying initially relevant factors is the availability of data to support the development of objective rating criteria. Therefore, we are also seeking input on data sources or bodies of existing research from government institutions, research institutes, or industry-affiliated organizations that may be particularly useful in assessing various IVTs on key factors. It is important to note that we also aim to highlight key factors that may be essential additions to a refined second generation system but for which data is not currently available; this process may aid in highlighting areas where future research activity would be valuable.

In brief then, we are reaching out to key experts: a) for input on additions to the initial broad factor list, b) for perspectives on the reduction of the theoretical list to key factors that are most promising for initial utilization in an objectively oriented assessment systems, c) suggestions regarding useful data sources, and d) thoughts on what one might see as major issues in the development of such a rating system. As one such expert, we are reaching out to you in specific to see to what extent you might have an interest in contributing to the further development of this project. Or, alternatively, we would very much appreciate it if you have any thoughts regarding someone you believe that we should consider contacting about this undertaking. Our intent with this brief introduction is really to provide just enough background on the project to hopefully lead to a follow-up conversation or other communication.

In due course we aim to make all aspects of this project public, informing industry and other key stake holders of our intent and seeking their input where appropriate. However, it is our intent to flesh out the model more fully with a limited set of individuals prior to moving in this direction. Given that we are contacting a limited number of individuals on a selective basis at this time, we would appreciate it if you would be willing to keep the substance of this communication relatively confidential for the time being. We are happy to acknowledge you as a direct contributor or as an anonymous source. We appreciate your time and consideration.

Appendix G: Information Requests and Interaction with Industry

The project was initially introduced to automotive industry through a briefing to The Alliance of Automobile Manufacturers Safety Policy Committee on January 17, 2013 and Global Automakers Safety Committee on February 1, 2013. Materials from these briefings appear below. At the conclusion of the meetings we asked companies to supply a key contact, help in selecting technologies for rating, and relevant data to support the objective rating of technologies. Through contacts provide by attendees of these briefings as well as other industrial contacts, we assembled a list of contacts in the following vehicle manufactures: BMW, Daimler, Ford, General Motors, Honda, Jaguar Land Rover, Mitsubishi, Nissan, Subaru, Toyota, Volkswagen, and Volvo. Follow on discussions with contacts were held on March 5th 2013 and April 9th 2013 (see materials below). A request for information on technologies selected for rating was issued in early May. An introductory email and detailed questionnaire (long form) was then sent to the key contacts at all of the vehicle manufactures trying to gather detailed information to support the objective rating of technologies. At the request of several manufactures, we created a shorter questionnaire (short form) (see materials below). In addition to efforts focused on gathering data from vehicle manufacturers, we reached out contacts at Tier 1 suppliers including: Bosch, Continental, Delphi, Denso, Johnson Controls, Takata, Valeo, and Visteon, with request for information on the technologies.

We received considerable information on different technologies from a number of vehicle manufacturers and suppliers. Many of the contacts provided marketing information on various systems and a select number of contacts provided more specific technical detail. Numerous one-on-one conversations were held with manufacturers and suppliers to draw further insight on the availability of data suitable for the objective rating of technologies.

Finally, on December 18th 2013, a briefing on the developed system was provided to solicit any final comments from industry supporters.

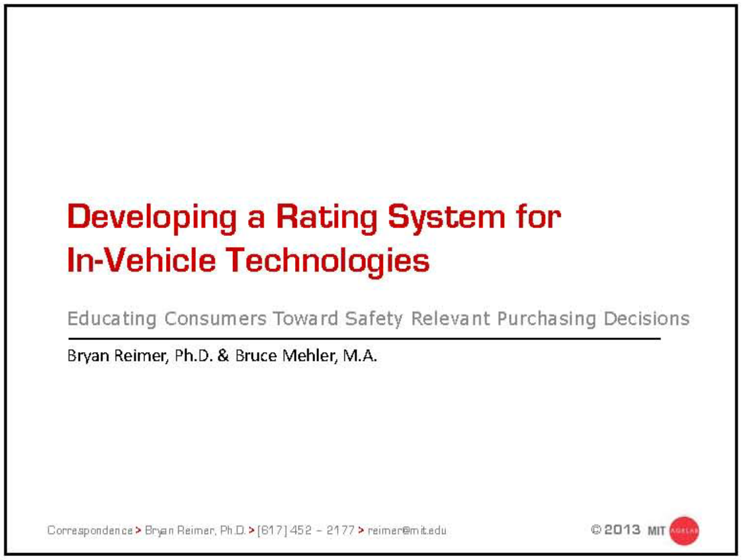
Formal information requests to industry included the materials listed below.

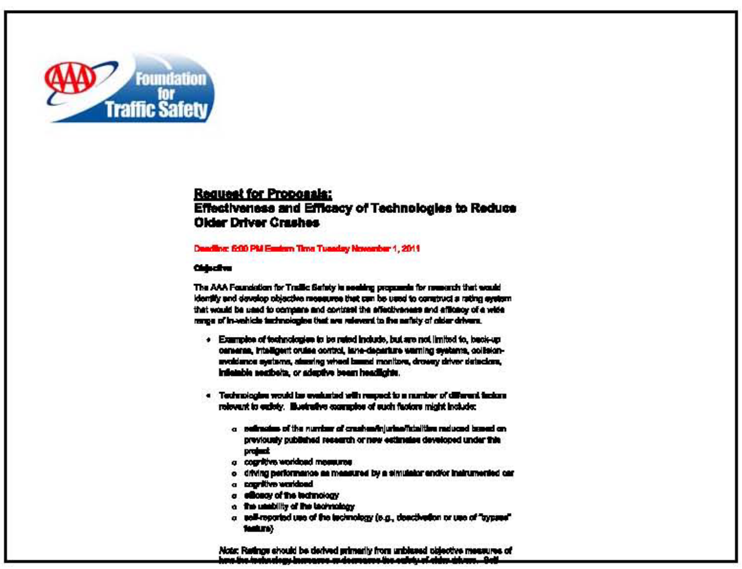
- PowerPoint slides that were used during our initial briefing of industry at the offices of the Alliance of Automotive Manufacturers and the Association of Global Automakers in Washington D.C.
- A supplemental document was provided to individuals who attended the aforementioned briefing to provide additional background on the project that attendees could share with colleagues to identify an appropriate representative or representatives who might serve as formal contacts for further interaction.
- Invitation to participate in industry discussion on rating project that took place on March 5th, 2013 – sent to contacts developed out of presentations before the Alliance of Automotive Manufacturers and the Association of Global Automakers as well as other contacts.
- Invitation to participate in follow-up industry discussion and presentation of concept materials that took place on April 9th, 2013.
- Cover letter / e-mail introduction to information request packet.

- A two page project introduction document "Project Synopsis". (Not included here.)
- A technology prioritization list soliciting input from industry on technologies they felt were most import to include in the rating project.
- A long form for providing detailed information. Individual forms were provided for each of the technologies selected for inclusion in the phase I evaluations along with a blank form that could be completed for any technology that industry representatives felt we should seriously consider including in the first round ratings.
- A "short" version of the form was subsequently developed to encourage sources that had limited time / resources available to contribute to the project.
- Also provided were early draft versions of the materials being developed for electronic stability control to provide additional context for the type of information we were attempting to develop on the other technologies. (Not included here.)

Briefing Slides

The following slides were used during our initial briefing of industry at the offices of the Alliance of Automotive Manufacturers and the Association of Global Automakers.





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MIT AgeLab

Human Behavior Across the Lifespan

Our lab, located within the Engineering Systems Division at MIT, focuses on multi-disciplinary approaches to understanding and optimizing systems with a specific emphasis on studying issues across the life-span. This work falls into a number of domains:

- Human Factors
- Cognitive Engineering
- Neuroergonomics
- Psychology
- Psychophysiology
- Social Science
- Computer Science
- Ergonomics
- Computer Human Interface Design
- Augmented Cognition

MIT ESD

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MIT AgeLab

Human Behavior Across the Lifespan

We have extensive history working with the automotive industry, engaging with:

- Audi
- BMW
- Chrysler
- Daimler
- Delphi
- Denso
- Fiat
- Ford
- General Motors
- Honda
- Hyundai
- Nissan
- Peugeot
- Takata
- Toyota
- Volkswagen
- Volvo
- ...and others

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

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Vehicle Ratings

- Vehicle Crashworthiness
  - NHTSA
  - IIHS
- Overall Vehicle Experience/Satisfaction
  - Consumer Reports
  - Edmunds
  - Kelley Blue Book

These organizations rate the vehicle **holistically**, but do not rate individual technologies.

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Emerging Technologies

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

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3

Obstacles to Purchase & Adoption

1. Consumers have a **poor understanding** of how new in-vehicle technologies work, and what benefits they may have. (Llaneras 2007)

2. Experienced drivers may be **less inclined** to try unfamiliar technologies or to be receptive to their potential benefits. (Jenness et al. 2008, AAA Foundation for Traffic Safety et al. 2008)

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Obstacles to Purchase & Adoption

3. Automobile sales **dropped 41%** during the Great Recession, and are only now approaching pre-Recession levels. (Alliance Sales Data 2012)

4. Consumers have more options than ever, but a much smaller amount of money with which to pursue them.

5. Consumers want to know which in-vehicle technologies make the most sense to invest in given their individual **driving needs and limited resources**.

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Our Task

The AAA Foundation for Traffic Safety tasked us with creating a **data-driven rating system** for new in-vehicle technologies, analogous to NCAP crashworthiness, but extended to scalar ratings of individual technologies.

This system has the potential to educate and guide consumers towards more confident and strategic **purchasing decisions** that will enhance automotive safety.

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Trusted Information Sources

Objective Research

Smart, Safe Consumer Advocate

54 Million Members

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Conceptual Vision

We view the system's rating factors as falling into **three broad areas**.

The initial selection of technologies to be rated are oriented toward safety, but later versions could encompass other in-vehicle technologies.

Correspondance > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Current Progress

Consulted a diverse set of experts during the identification of factors for the rating scale:

- Engineering/Human Factors specialists
  (industry)
- Safety specialists
  (government, foundations, industry & academia)
- Behavior/Cognition specialists
  (industry & academia)
- Public policy & marketing experts
  (industry, foundations & academia)

Correspondance > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Current Progress

Rating Factors

- Safety Significance
  - Crash Reduction
  - Risk Reduction
- Potential Efficacy
  - Ease of Learning
- Drawbacks & Limitations
  - Technical Limitations
  - Behavioral Adaptation
- Added Demand
  - Cognitive Workload
  - Visual Demand
  - Auditory Demand
  - Tactile Demand
- Distraction
- Stress
- Consumer Factors
  - Trust
  - Awareness
  - Frequency of Use
  - Satisfaction

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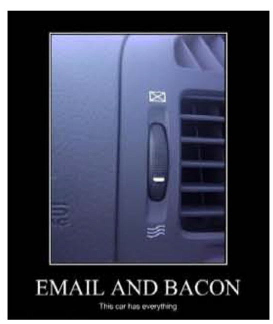
Current Progress

Technologies of Interest

- Electronic Stability Control?
- Lane Departure Warning?
- Lane Keeping Assist?
- Adaptive Cruise Control?
- Forward Collision Mitigation?
- Forward Collision Warning?
- Blind Spot Detection?
- Back-Up Cameras?



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Timeline

- Next six months
  - Identify sources of existing data to complete evaluations of candidate technologies, in collaboration with expert panel.
- End of 2013
  - A rating system with ratings completed for five example technologies due to AAAFTS
- Start of 2014
  - AAAFTS / AAA has the option of publicizing the scale
- Beyond
  - Refinement of rating system through increased emphasis on empirical data

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Going Forward

What Are We Looking For?

Support from your organization in the development and refinement of the rating system, specifically:

- A **contact** in your organization to facilitate communication and collaboration.
- Thoughts on **technologies** that you feel are important to include.
- Relevant **data** to support objectivity of the ratings.

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Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

We Need Data

- This rating system is to be data-driven. Therefore, we see value in considering:
  - Internal **studies** on in-vehicle technologies
  - **Specification** documents for technologies
  - Relevant **research** on:
    - The driver-vehicle relationship
    - How the technology operates, and in what conditions
    - Crash reduction potential
- **Shared data can be kept de-identified and confidential, if desired.**

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Help Us Help You!

We view automotive technology companies as **key collaborators and contributors** to this project.

The more input that industry has on this rating system, the more **informative** it will be.

Ultimately, the rating system is a tool for **promoting technologies and educating consumers** that will enhance safety and confer maximal benefit to industry, government, and automotive safety.

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Summary

- We are developing a rating system for new in-vehicle technologies.
- In the near-term (2013), we will base ratings on currently available empirical data and the aggregate opinions of an expert panel.
- In the long-term, the goal is to base the ratings primarily on empirically-derived data.
- The overall focus is on helping consumers make informed purchasing decisions.

Correspondence > Bryan Reimer, Ph.D. > (617) 452 – 2177 > reimer@mit.edu

Our Task

Our ultimate goal is to produce a succinct rating system for new in-vehicle technologies that can be presented to consumers in a compact, understandable, and actionable manner.

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Presentation Supplement

Presentation Supplement 2013-3

Developing a Rating System for In-Vehicle Technologies

Bryan Reimer, Bruce Mehler,
Jonathan Dobres, & Joseph Coughlin

January 17, 2013

AgeLab: More than Just Age

The Massachusetts Institute of Technology AgeLab examines issues pertaining to system optimization and human behavior *across the lifespan*. Our work encompasses a range of domains including human factors, ergonomics, computer science, social science, cognitive engineering, and human-computer interface design.

Over the last several years, we have engaged with a large number of automotive manufacturers and suppliers to investigate behaviors, cognition, and physiological responses of drivers as they are interact with a variety of technologies, interfaces, and operating conditions. Laboratory research has included developing new methodologies for assessing driver distraction associated with visual-manipulative and cognitive demands, devising strategies for optimizing the driver-vehicle interface, and measuring the stress/workload of drivers' engagement with Advanced Driver Assistance Systems (ADAs).

Emerging In–Vehicle Technologies

In the last fifteen years, a large variety of new comfort, convenience and safety technologies have been introduced into the motor vehicle. However, publically available data is limited on the extent to which there are barriers to the effective use of these technologies. If aspects of a technology's design are hindering or preventing its adoption or use, its potential safety benefits are negated.

While consumer-focused resources that rate or assess the whole vehicle have existed for decades (crashworthiness tests, Consumer Reports, Edmunds, etc.), there is no comparable resource that rates these new in-vehicle technologies themselves. While newer programs like NCAP take note of the presence of a technology, they do not rate that technology *per se*.

Consumers often lack a strong understanding of the benefits of emerging in-vehicle technologies (Llaneras 2007). Combined with a change in attitude brought on by the financial constraints of the Great Recession, many consumers want to know which in-vehicle technologies make the most sense to invest in given their individual driving needs and limited resources. Moreover, as US demographics begin to shift older, it will be increasingly important to understand how this population segment understands and uses (or do does not use) new technologies (Coughlin & Reimer 2006).

Our Task

The AAA Foundation for Traffic Safety (AAA-FTS) tasked us with creating a data-driven rating system for new in-vehicle technologies. Conceptually similar in some respects to NCAP, this system has the potential to educate and guide consumers towards more confident and strategic purchasing decisions that will ultimately enhance automotive safety.

We conceive the rating system as one in which rating factors are classified into the broad areas of safety, comfort, and convenience. In the near-term we will emphasize the safety area, but this overlapping model gives us the flexibility to assess any in-vehicle technology.

In consultation with a variety of experts from government institutes, academia, and industry, we have developed a matrix of possible rating factors (e.g., accident reduction potential, ease of learning, cognitive workload, trust, etc.).

Going Forward

Over the next six months, we will assemble an expert panel to construct an initial set of ratings for a handful of in-vehicle technologies. A draft of the rating system is due to AAA-FTS by the end of 2013, at which time they will have the option of publicizing the results and developed methodologies. Our (MIT and AAA-FTS) intent is to then further refine the system through an increased emphasis on empirical data.

We believe that successful development of this rating system will be of great benefit to the industry, as it is will encourage consumers to consider purchasing technologies that are strategically useful for them. We are seeking support from your organization in the development and refinement of this rating system. In specific, we are looking for a contact in your organization to facilitate communication, thoughts on important technologies to include, and relevant data to support the objectivity of the ratings. Data might include internal studies, specification documents, and other relevant research on an in-vehicle technology that contributes to an objective evaluation of the nature of the benefit and effectiveness. Any data contributed to this project can be kept confidential at the request of the contributor.

We view automotive technology companies as key collaborators and contributors to this project. The more input that industry provides in the development on this rating system, the more informative it will be. Ultimately, we see the rating system as a tool for promoting useful technologies and educating consumers that will enhance safety and confer maximal benefit to industry, government, and automotive safety.

References

Coughlin, J., & Reimer, B. (2006). New Demands from an Older Population: An Integrated Approach to Defining the Future of Older Driver Safety (pp. 1–8). Presented at SAE International.

Llaneras, R. E. (2007). Safety Related Misconceptions and Self-Reported Behavioral Adaptations Associated With Advanced In-Vehicle Systems: Lessons Learned From Early Technology Adopters. *PROCEEDINGS of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.*

About the Researchers

Bryan Reimer, Ph.D.

Bryan Reimer is a Research Engineer in the Massachusetts Institute of Technology AgeLab and the Associate Director of the New England University Transportation Center. His research seeks to develop new models and methodologies to measure and understand human behavior in dynamic environments utilizing physiological signals, visual behavior monitoring, and overall performance measures. Dr. Reimer leads a multidisciplinary team of researchers and students focused on understanding how drivers respond to the increasing complexity of the operating environment and on finding solutions to the next generation of human factors challenges associated with distracted driving, automation and other in-vehicle technologies. He directs work focused on how drivers across the lifespan are affected by in-vehicle interfaces, safety systems, portable technologies, different types and levels of cognitive load. Dr. Reimer is an author on over 70 peer reviewed journal and conference papers. Dr. Reimer is a graduate of the University of Rhode Island with a Ph.D. in Industrial and Manufacturing Engineering.

reimer@mit.edu
(617) 452-2177
http://web.mit.edu/reimer/www/

Bruce Mehler, M.A.

Bruce Mehler is a Research Scientist in the Massachusetts Institute of Technology AgeLab and the New England University Transportation Center, and is the former Director of Applications & Development at NeuroDyne Medical Corporation. He has an extensive background in the development and application of non-invasive physiological monitoring technologies and research interests in workload assessment, individual differences in response to cognitive demand and stress, and in how individuals adapt to new technologies. Mr. Mehler is an author on numerous peer reviewed journal and conference papers. He received an MA in Psychology from Boston University and a BS degree from the University of Washington.

bmehler@mit.edu
(617) 253-3534
http://agelab.mit.edu/bruce-mehler

Jonathan Dobres, Ph.D.

Jonathan Dobres is a postdoctoral research associate in the Massachusetts Institute of Technology AgeLab. Dr. Dobres's research interests are varied and include human-computer interaction, user experience design, visual attention, and visual learning. He received a BA, MA, and PhD in Psychology (Brain, Behavior, and Cognition) from Boston University. His research concerned the effects of feedback, or knowledge of results, on how people learn visual tasks, as well as computational approaches to visualizing changes in human perception. He has also worked for the Traumatic Brain Injury Model System at Spaulding Rehabilitation Hospital, part of a long-term national study on the effects of traumatic brain injuries. His current research focuses on driver behavior, and how interacting with in-vehicle technologies impacts driver behavior, cognition, and physiology.

jdobres@mit.edu
(617) 253 - 7728

Joseph F. Coughlin, Ph.D.

Joseph F. Coughlin is founder and Director of the Massachusetts Institute of Technology AgeLab and Director of the US Department of Transportation's Region I New England University Transportation Center. He served as the Chair of the Organization for Economic Cooperation & Developments 21-nation Task Force on Technology and Transportation for Older Persons, is a member of the National Research Council's Transportation Research Board Advisory Committee on the Safe Mobility of Older Persons. He served as a Presidential appointee to the White House Conference on Aging and has consulted or served on technology and design boards for BMW, Daimler, Nissan, and Toyota. Prior to joining MIT, Dr. Coughlin led the transportation technical services consulting practice for EG&G, a global Fortune 1000 science and technology firm.

coughlin@mit.edu
(617) 253-4978
http://www.josephcoughlin.com/

About the AgeLab

The AgeLab is a multi-disciplinary research center dedicated to improving quality of life for older adults and those who care about them. Based within the Engineering Systems Division at Massachusetts Institute of Technology, the AgeLab is uniquely suited to translate cutting edge scientific and technological breakthroughs into innovative solutions that help address challenges posed by the world's aging population.

The AgeLab views longevity as an opportunity to innovate – to invent a new definition of quality living throughout the lifespan. AgeLab activities set agendas of government and business, serve as a catalyst for change, and act as platforms to create new ways to remain engaged, connected, independent, and healthy.

Funded by businesses around the world, AgeLab research focuses on transportation, health & wellness, caregiving, longevity planning, shopping, lifelong engagement, and even play. AgeLab research informs the design of new technologies, aids in government policy decisions in the United States and abroad, and educates older adults and their families on important consumer issues.

Contact Information

Agelab
Massachusetts Institute of Technology
77 Massachusetts Avenue
Room E40-291
Cambridge, MA 02139-4307
Phone: (617) 253-0753
Fax: (617) 258-7570
Email: agelab@mit.edu
Website: http://agelab.mit.edu

Invitation to Participate in Industry Discussion on Rating Project

Invitation / Agenda for March 5th Industry Discussion and Presentation Material

Dear [ ],

Thank you for helping to coordinate [COMPANY]'s collaboration with the MIT AgeLab on the AAA-FTS sponsored project to create a rating system for in-vehicle technologies. Our next step in this process will be to arrange a conference call among the industry representatives who have so far committed their company's support to the project. This call will be centered on discussing:

A proposed set of factors being considered for developing the underlying basis of the rating system. Factors currently being considered include the technology's accident reduction/prevention potential, frequency of use, visual, auditory and/or tactile demands, ease of learning, consumer trust and awareness, potential drawbacks and failure conditions, etc. The factors' relevance to the rating system and availability of related data should be taken into consideration. Input on additions / exclusions will be actively taken under advisement as will thoughts on concepts for translating the factors into system ratings.

Technologies for initial consideration in the rating system. Our mandate is to include a minimum of 5 technologies in the initial rating. Again, the availability of data for rating a given technology should be kept in mind when discussing this point. A general discussion of what data is (and is not) available for vehicle technologies and/or rating factors is intended. However, more specific discussions will be held privately with each manufacturer.

The level of depth the rating system should go into on a specific technology, i.e.. does FCW based upon a radar or vision system need to be discussed separately? What are manufacturers' thoughts on including with the ratings a listing of vehicle models that are available with the selected technologies?

What operating conditions (urban, highway) or user types (older drivers) should be considered for categorical grouping in the rating system? Our current view is that various technologies will show differential advantages depending on various user characteristics.

In the near-term, we plan to reduce the available data to a set of more digestible statistics, and then provide this information to a panel of experts, who will provide feedback that will ultimately inform the first version of the rating system. The panel will include leading figures from industry, academia, and government institutions. We are also seeking your input on potential additional panel members.

Other suggestions, concerns and thoughts from an industry perspective.

Next steps following the call - individual conversations with OEMs on specific technologies, follow-up with selected suppliers, and others.

We would like to schedule the teleconference within the next few weeks, ideally for March 5th, 5th, or 12th (9am – 5pm EST). Please let us know if you would be available for a call (approximately 2 hours long) on these dates.

Given the difficulty involved with scheduling this call across multiple parties, we would greatly appreciate a response on preferable data's and times as quickly as possible.

Bryan Reimer, Jonathan Dobres, and Bruce Mehler

MIT AgeLab

Invitation to Participate in Follow-Up Industry Discussion

Invitation / Agenda for April 9th Industry Discussion and Presentation Material

Everyone,

Attached you'll find a set of documents we'll be discussing during tomorrow's conference call. These documents incorporate feedback from our previous teleconference, as well as feedback from AAA-FTS and further elaboration on our part. Attached:

1. Rating Documentation: Explains the models and rationale that underlie the four broad rating categories that we envision presenting to consumers.

2. Consumer Technology Explanation: This documentation is intended to help you collaborate with us. It provides written explanations of what we see as useful in constructing public-facing descriptions of various in-vehicle technologies.

3. Electronic Stability Control: Example consumer-facing document. (This example is for illustrative purposes and is not intended to represent a fully developed presentation.)

4. Technologies: A listing of in-vehicle technologies that were discussed at the last conference call, with those that are currently prioritized for the first phase of the rating system highlighted.

As we emphasize in the documents themselves, while we consider the concepts as presented to be fairly well developed, we are open to input regarding additions, refinements, modifications, etc. that might improve the proposed approach. We are sharing these working documents with you specifically for the purpose of gathering input and your assistance in improving upon them. Over the course of tomorrows call our agenda is as follows:

1. Discussion of the proposed approach for calculating technology rating
2. Discussion of the proposed consumer focused technology explanation
3. Review of the ESC illustration
4. A discussion of what type of factors should be added to describing the theoretical limits of system
5. A discussion of what type of factors should be added to describing the human factors limitations involved with a system
6. A review of the in-vehicle technologies that are being considered for inclusion in the first phase of this project
7. Requests for information and supporting materials that may be useful in rating and explaining selected technologies

8. A survey of what theoretical and human factors elements are most crucial for describing each technology (identification of research gaps)

9. Supplier contacts that can help with #7 and #8

10. Next steps

We are looking forward to the conversation tomorrow.

Best wishes.

Bryan, Bruce and Jon

Cover Letter

Industry Input to the MIT AgeLab AAA-FTS In-Vehicle Technology Rating Project

May 3, 2013

Dear Colleague:

Attached with the e-mail you will find the following:

- **Technology Information Forms** – A form for each of seven technologies. The cover page explains the overall purpose of the form. They are being provided in Word and Google Doc formats so that input can be typed directly into a document. Alternatively, a link is provided below for an on-line version. While sending material back to us in document format has some advantages at our end, the on-line version is also being offered since it provides a totally anonymous method of providing input since an e-mail connection is not involved.

  https://docs.google.com/forms/d/1Uqq9fpQ1fiC4_GWtMMtTmzfvQK0i2al9a-0taaWq2mg/viewform?sid=7f733369c89be39&token=jafPaz4BAAA.lWHXDm1-r0D0CH7cxn9GkQ.ZHkDTNa9RIw1KDQRVrR5SQ

  You are equally welcome to submit one form per technology or to distribute multiple copies to various members of your organization to fill-in selected portions or to obtain a broader perspective from within the organization.

- **Technology Prioritization List** – Please use this form to give us feedback on technologies that you feel should be included in this consumer education project and the relative priority with which they should be considered.

- **Technology Information Form (blank)** – If you feel strongly that there are additional technologies that should be included in the first round of the evaluation project, you are welcome to use the blank form to write-in the technology name, fill-in information on the technology, and submit.

- **Electronic Stability Control** (Illustrative Example) – ESC is being included as a reference technology for which there is a relatively extensive body of objective information and research available. This brief document is an early "work in progress" example that is intended to give an idea of the kind of information we are seeking. This is meant to stimulate thought and should not in any way constrain the kinds of information that you feel may be useful to contribute to inform the public and the evaluation process.

We realize that a great deal of effort could be invested in exhaustively completing these forms, but also believe that this project provides you, as representatives of the automotive industry, with an opportunity to contribute to educating the public about the potential value of investing in various safety technologies. Your experience, insight, and any data sources that you can identify that contribute to the development of a better understanding of safety benefits of these technologies is greatly appreciated. Please don't hesitate to contact us with any questions.

Bryan Reimer, Bruce Mehler, & Jonathan Dobres

Technology Prioritization Rating Form

Technologies

For the first round of technology ratings, we are currently considering the technologies listed immediately below. (Note: *Electronic Stability Control* is being included specifically as a reference technology for which there is a relatively extensive body of objective information and research available.)

- Lane Departure Warning
- Back-up Cameras
- Forward Collision Warning
- Forward Collision Mitigation
- Adaptive / Smart Cruise Control (headway management)
- Adaptive Headlamps
- Electronic Stability Control

Other Technologies under Consideration:

Active input is being sought from industry and other sources to prioritize other technologies to be included in the assessment process. Please help us in this process by adding additional technologies to this list that you feel should be considered. Then please rank the list in terms what you see as their order of importance. If you feel a technology should not be included, mark with an "x" or cross out.

__ Active rollover protection

__ Automated/Assisted Parking

__ Anti-lock Braking Systems

__ Blind Spot Detection

__ Driver Monitoring Systems

__ Emergency Brake Assist

__ Lane keeping aids

__ Night Vision/Low-light Systems

__ Three-point seatbelts for all positions

__ Active seat belts

__ Seat belt reminders

__ Active head restraints

__ Rear crash warning systems

__ Crash preparation systems

__ Navigation systems

__ Pedestrian detection

__ Phone tethering

__ Automatic brake drying

__ ______________________________

__ ______________________________

__ ______________________________

__ ______________________________

__ ______________________________

__ ______________________________

Long Form

Industry Input to the MIT AgeLab AAA-FTS Technology Rating Project – Technology Specific Information

Introduction to This Form - The Massachusetts Institute of Technology AgeLab has been tasked by the AAA Foundation for Traffic Safety to develop a comprehensive rating system for new in-vehicle technologies. AAA-FTS initiated this undertaking after observing that many consumers have a poor understanding of how new in-vehicle technologies work, and what benefits they may offer. The present focus of the system is on safety relevant technologies. A primary goal of this project is educational, to guide consumers towards more confident and strategic purchasing decisions that will enhance automotive safety by better educating them about new in-vehicle technologies that are most relevant and beneficial to their individual driving needs.

This form is intended to gather input from the automotive industry and traffic safety community that can be used to better develop these educational materials and to contribute to the identification of data and data sources that may be useful in the objective assessment of current safety technologies. **The information gathered through these forms will be combined with input from other industry sources to inform the overall project. Information and perspectives provided here will not be publically attributed to a specific manufacturer or source. Thus, while we view these forms as providing well-informed input from industry experts, they are not viewed as necessarily representing formal policy statements by a given manufacturer, industry representative, or other organization. These forms deliberately do not have a formal space for identification of the person or persons completing the form and responses can be treated entirely as confidential.** While the ability to follow-up with questions should they arise would be useful, identifying information to allow follow-up may be supplied at your own discretion. In addition, we anticipate that various stakeholders within an organization may have different perspectives. Where possible, submission of forms from multiple stakeholders within an organization is encouraged.

While this form may appear somewhat long at first, we recognize that many of the sections will not apply to all technologies and can simply be rated as "N/A". Similarly, if copies of these forms are provided to more than one individual or group within an organization, there may be a number of sections for which you have no background or specific expertise to comment upon. Please feel free to leave such sections blank.

If you cite technical reports, publications, or other supporting material that is technically public but may be hard to locate, please include them as attachments. If there are confidential reports you would like to supply, please reach out to us so that appropriate safeguards can be put in place before providing us with access to the material.

Finally, due to the aggressive schedule for this project, we would appreciate it if you can return individual forms as they are completed rather than waiting until all technologies have been reviewed or all stakeholders have responded. **Returning Forms** – Please return by e-mail to Dr. Bryan Reimer at: reimer@mit.edu

We would be glad to arrange a phone conversation to answer any questions or to discuss any topic areas in more detail. We can be contacted as below:

Bryan Reimer 617-452-2177 reimer@mit.edu
Bruce Mehler 617-253-3534 bmehler@mit.edu

For the Consumer

This section is intended to collect a consumer oriented, moderately detailed, mid-level overview of the technology. The subsection headings should be used as a guide for information we wish to communicate to the consumer. However, we are very open to considering any information or perspective that the industry feels would be useful in educating the public. You are encouraged to add proposed sections or material as you see fit. Be as brief or as expansive as you wish. Where possible, please reference (by number, name, or other indicator) empirical research or other objective data source for all assertions and add the source to the Reference List at the end of this document.

Note: This form is being supplied as a Word document so you can type information directly into the document.

Why Would I Use This Technology?

What is the purpose and major benefits of the technology? When asserting a benefit, please reference an empirical research source and include in the Reference List.

Insert here…

What Do Drivers Think?

Consumer survey and opinion data about the public's perception and use of the technology. As above, please cite sources.

How Well Does It Work?

Please summarize salient points about the efficacy of the technology, and go into a little more detail than the first subsection about relevant research. May include more detailed estimates of safety impact. Always cite sources.

Who Benefits Most?

Please highlight any driver demographics (families with small children, teens, older drivers) or situations (urban, rural, highway, night driving, icy environments, etc.) for which the technology is particularly beneficial.

In What Situations Doesn't It Work?

Drivers sometimes assume that a technology will provide protection in situations where it is not designed to function. Use this subsection to help educate the public about misunderstandings about a technology including technical limitations, conditions where it is not active, etc.

Mobility Significance

Does the technology have particular benefits for older drivers or persons with limited mobility?

Not All Systems Are Alike

If there are relevant differences between different implementations of the general technology type that impact what conditions they work under, relative effectiveness, etc., they should be highlighted here. (Technical or research data should be cited where possible to increase likelihood of inclusion.)

Different Names, Same Idea

Is the general technology known under a variety of industry names? If so, what are some of the common ones? (You are welcome to include brand specific names.)

Other

Please elaborate on any broad topic areas that are not addressed by the headings above. Feel free to add any additional information that you feel should be included to help educate the public about this technology.

The Underlying Knowledge Base

The section is intended to identify the underlying knowledge base and research that can be used to evaluate the actual safety benefit of a given technology. The information and data sources identified here will be combined with material gathered from other sources. As part of the educational component of the project, we anticipate also using this input in the development of technology review summaries that will be made available to industry, researchers, consumer advocates, etc. Draft versions of these summaries will be made available to contributors for review and comment before formal release. As noted earlier, material will compiled and individual comments and observations will not be attributed to specific contributors.

The intent here is to identify findings and data sources that can contribute to an objective evaluation of the function and effectiveness of a technology. Where empirical research or other objective data exists that is relevant to a category, please insert a brief summary statement highlighting the major finding , reference the source (by number, name, or other indicator), and then add the source to the Reference List at the end of this document.

If you are aware of research in a given category, but feel that the findings and/or conclusions are questionable or incorrect for some reason, please note this. Identifying questionable or poor research can be as important as identifying good work.

If there are no data sources that can be cited for a given category, please indicate if this is because no research appears to have been done (No Research) or if the category is not applicable / relevant to this technology (N/A). We are fully aware that for many of the technologies this may be the case and understand that there may be little or no details entered for a number of sections.

In summary:

- Entries can be as brief or as extensive as desired.
- Key statistics or findings should be supported by a citation / source that you add to the Reference List.
- If a factor area listed is not applicable to the technology, please explain why.
- Please feel free to comment on research reports or data sets that you believe misrepresent a technology (either underrating or overrating).

I. Scenario Significance

What issue, problem or risk is this technology attempting to address, and what statistics are available to quantify the significance of the problem? Are there relevant data from NHTSA or other sources that can be cited on number of crashes, injuries, fatalities, property damage associated with the issue the technology is intended to mitigate or eliminate?

Insert here…

II. Benefits & Theoretical Efficacy

Under What Conditions Is It Intended to Work? How Successful Is It?

What conditions is this technology designed to work under and what data is available indicating how successful it is at providing a benefit under these conditions? Be sure to enumerate specific safety benefits *and supporting data. (If there are different versions of the technology that have different effectiveness characteristics, specify as needed.)*

Other Benefits

If there are non-safety related benefits associated with the technology, they can be detailed as well. These might be convenience or comforted related, or might offer other benefits such as improvements in fuel economy.

Technical Limitations

Are there any conditions under which the technology will not operate, performance may degrade, or actual failure may occur (i.e. weather, speed, tolerance boundaries, etc.)?

Limitation Mitigation

For any of the limitations mentioned above, have any solutions been developed to offset, reduce, or remove these limitations?

Implementation Differences

Are there major differences between implementations of this general class of "technology" that need to be considered in evaluating its effectiveness, understanding or using the technology?

III. Human Interaction with the Technology

We recognize that there may be limited information available on how drivers interact with a particular safety technology and how this may influence its effectiveness. Please circle one of the summary ratings after each topic heading to indicate the extent to which you feel this aspect of human interaction with the technology is important. We understand that there may be little or no detailed information available to fill-in a number of the subsections.

Summary Importance Ratings: After each subheading, there are the headings:

- N/A not applicable to this technology
- NI not important
- MI moderately important
- VI very important

User Involvement (Please circle one: N/A, NI, MI, VI)

Does a driver need to know any anything about the technology to benefit from it or does it work largely or fully automatically?

Activation State and Use (Please circle one: N/A, NI, MI, VI)

As implemented in your vehicles, does the technology default on or does the user have to engage it? Does it default to a last used mode on start-up? If the user has to turn the technology on (or has the ability to turn it off), is there any data on the percentage of drivers who actively use the technology?

Incorrect Assumptions by Users (Please circle one: N/A, NI, MI, VI)

Are there misassumptions that drivers sometimes make about the technology? Assumptions that it will do certain things it is not designed to do? (These are important to identify from an educational perspective – if drivers make uninformed assumptions about what a technology should do that are outside of its design specification, a fundamentally good technology may get an undeserved poor reputation.) Both industry experience and identified research citations are appreciated here.

Consumer Awareness & Trust (Please circle one: N/A, NI, MI, VI)

What data is available on consumers' awareness of the technology, how it works, when they should and should not depend on it? Are there any data on consumers' level of satisfaction and trust in the technology? Survey data is acceptable here if citations to the data sources can be provided.

Behavioral Adaptation (Please circle one: N/A, NI, MI, VI)

This refers to behavior changes resulting from the use of the technology that may impact its net safety gain. Is there any suggestion of, or data on, behavioral adaption occurring or not occurring with this technology?

Demand Associated with the Technology

A technology may offer potential benefits while also placing certain demands on the driver before they can derive that benefit. Engaging a system may involve a degree of mental, visual, manipulative, or auditory workload. Attending to a warning may similarly require some amount of attention and resource allocation. What data are available on the extent to which the technology places some level of demand on the driver in each of the following domains? If a domain is not relevant to the implementation of this technology, please explain why.

Visual (Please circle one: N/A, NI, MI, VI) -

Auditory (Please circle one: N/A, NI, MI, VI) **-**

Manipulative (motor) (Please circle one: N/A, NI, MI, VI) **-**

Tactile (vibratory sensation) (Please circle one: N/A, NI, MI, VI) **-**

Cognitive (mental workload) (Please circle one: N/A, NI, MI, VI) -

Other -

Distraction or Confusion (Please circle one: N/A, NI, MI, VI)

Providing drivers with increased information in the form of added displays, warnings, automated corrections, etc. offer potential benefits but may also introduce some degree of distraction or confusion. What data are available on the extent to which this technology does or does not result in a degree of distraction or confusion in some drivers? What data are available on the extent to which a net positive benefit results from the technology?

Ease of Learning (Please circle one: N/A, NI, MI, VI)

Some systems require little or no familiarity with the technology to derive benefit from them. Others have a steep learning curve for a user to become comfortable with them, but may become second nature once the user has developed a good mental model of how they work. To what extent does the user need to learn how to use the system to derive benefit? Is there any data on how long most users take to become comfortable with the technology? Is there any data on the percentage of users who actively use the technology?

Stress (Please circle one: N/A, NI, MI, VI)

If a technology makes a driver more comfortable / less stressed driving under certain conditions, this may support an indirect safety benefit by increasing the driver's spare capacity to attend to the primary driving task. Is there any evidence that the technology increases or decreases driver stress in any way?

Other / Broad Comments on the Driver's Relationship to the Technology

Please use this space to share any additional information on how drivers appear to interact with the technology or to make any general comments on this topic area.

IV. Who Benefits Most? (Expanded)

This section can be used to expand upon the "Who Benefits Most?" segment of the consumer information form. Please highlight any driver demographics (families with small children, teens, older drivers) or situations (urban, rural, highway, night driving, icy environments, etc.) for which the technology is particularly beneficial. What data is available to support these views?

V. Mobility Significance (Expanded)

This section can be used to expand upon the "Mobility Significance" segment of the consumer information form. Does the technology have particular benefits for older drivers or persons with limited mobility? What data is available to support these views?

VI. External Safety

This refers to a technology's impact on the safety of persons or property outside of the immediate driver's vehicle, such as pedestrians and other vehicles. For example, a low-speed collision detection system that automatically slows the vehicle may reduce the severity of pedestrian injuries, conferring a benefit outside of the immediate vehicle. Data on both positive and negative external safety considerations should be noted here.

VII. Other Considerations

Please use this area to comment on any other factors that you feel should be taken into account in evaluating the safety benefits of this technology? What data is available to evaluate this technology on any such factors?

Research Needs

In addition to the educational objectives of this project, another goal is to identify areas where additional research is needed in the assessment and optimization of current and emerging safety technologies. Work in these areas is carried out individually and jointly by partnerships involving industry, academia, foundations, and government. If you feel that there are research needs specific to this technology, or that apply more generally to a safety related issue, that would be useful to promote as a research agenda, please comment below.

References

Please list here all empirical research or other objective data sources that are used to back-up statements made about a technology. Technical specification documents and industry reports, if they can be made available for review, can be cited for this purpose. If you cite technical reports, publications, or other supporting material that is technically public but may be hard to locate, please consider including them as attachments.

Please feel free to cite sources in any format that is convenient, from web links to formal academic citations.

Short Form

Industry Input to the MIT AgeLab AAA-FTS Technology Rating Project: Technology Specific Information

This form is a short version of the full *Technology Information Form* that was developed to allow the industry to provide detailed input to the MIT AgeLab AAA-FTS Technology Rating Project. The primary intent of this information support request is to ensure that the industry has an ample opportunity to:

1. help identify information that can be drawn upon to establish the extent to which various new and emerging technologies provide a safety benefit to the consumer, and
2. contribute to the framing of educational materials that can help better inform the public about why they might wish to consider purchasing vehicles with various technologies given their particular needs and individual driving considerations.

While a number of industry sources have commented positively on the comprehensive nature of the full form, some have indicated that they would like to contribute but may not have the ability at this time to make full use of the complete form. We want to make it clear that contributing selective input to this process is more meaningful than not contributing at all. As noted in the information supplied with the full form, respondents should feel free to fill-in or skip sections based on availability of expertise, time, etc. Similarly, while commenting on all the technologies being included in the first round review provides a given contributor the widest opportunity to have their perspective represented, selecting to comment on a targeted subset of technologies of greatest interest to your group or company is certainly a reasonable option.

To encourage the widest possible input to this project, we are providing this short version of the information input form as an optional method of contributing. Please consider using this short form for commenting on technologies that you are not able to review in detail using the full form, or as an alternate approach overall to sharing what you consider to be important information or descriptive material.

We would be glad to arrange a phone conversation to answer any questions or to discuss any topic areas in more detail. We can be contacted as below and forms can be returned to Dr. Bryan Reimer at reimer@mit.edu.

Bryan Reimer	617-452-2177	reimer@mit.edu
Bruce Mehler	617-253-3534	bmehler@mit.edu

Technology

Please indicate below what technology you are commenting on in this form.

__ Lane Departure Warning

__ Back-up Cameras

__ Forward Collision Warning

__ Forward Collision Mitigation

__ Adaptive / Smart Cruise Control (headway management)

__ Adaptive Headlamps

__ Electronic Stability Control

__ Other: ___________________________

Responses can be as brief or as extensive as you would like to contribute to this project. A partially completed form has more impact than no response.

Please provide a short description that highlights for the consumer what this technology is intended to do and why they would benefit from having and using the technology. *(What would you like to say to the consumer about this technology through the educational medium of this project?)*

Who is likely to benefit the most from this technology? *(Are there any driver demographics (families with small children, teens, older drivers) or situations (urban, rural, highway, night driving, icy environments, etc.) for which the technology is particularly beneficial?)*

Is there anything the consumer should understand about how this technology works and what it does and does not do? (*Drivers sometimes assume that a technology will provide protection in situations where it is not designed to function. Use this section to help educate the public about misunderstandings about a technology including technical limitations, conditions where it is not active, etc.)*

What objective data is available to support the position that this technology provides an actual safety benefit? *(We are looking for input on both what is available in the public domain that can be reviewed as well internal data that might be shared for purposes of this project. What convinced you / your company that this technology was worth investing in? What has been learned over time that makes the case for a safety benefit?)*

Are there features of particular implementations of this class of technology that the public should be made aware? *(While this project is currently oriented toward educating the public about a technology as a class as opposed to rating individual implementations, there may be features you feel should be part of the discourse. If there are relevant differences between various implementations of the general technology type that impact what conditions they work under, relative effectiveness, etc., they should be highlighted here. Any mitigation solutions developed to deal with potential limitations can be highlighted. Technical or research data should be cited where possible to increase likelihood of inclusion.)*

Research Needs – Are there any gaps in our current understanding of these technologies where additional research would be useful? *(In addition to the educational objectives of this project, another goal is to identify areas where additional research is needed in the assessment and optimization of current and emerging safety technologies. Work in these areas is carried out individually and jointly through partnerships involving industry, academia, foundations, and government. If you feel that there are research needs specific to this technology, or that apply more generally to a safety related issue, that would be useful to promote as a research agenda, please comment below. For example, are there enhancements in sensor technology that are needed? Are there human factors considerations related to how drivers perceive and interact with this technology that would be useful to understand more fully?)*

End of Document.