

NSTSCE

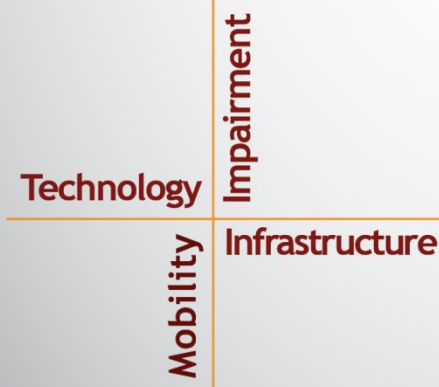
National Surface Transportation
Safety Center for Excellence

Vehicle Information Reporting Systems (VIRS)

Navigating a Roadmap of Options

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EXECUTIVE SUMMARY

In 1981, the Vehicle Identification Number (VIN) standard was first consolidated, as part of 49 C.F.R Part 565, into Federal Motor Vehicle Safety Standard No. 115. The 17-digit VIN structure used today was established as a result of a petition by the Motor Vehicle Manufacturers Association and Volkswagen. The purpose and scope of the standard is defined in section 565.10 as follows: “...a vehicle identification number (VIN) system and its installation [purpose is] to simplify vehicle identification information, retrieval, and to increase the accuracy and efficiency of vehicle recall campaigns.” The VIN standard currently tracks data elements such as manufacturing details, vehicle descriptors, vehicle security codes, and serial numbers. To date, the purpose of the VIN standard has not included the identification of safety features or vehicle equipment. In light of recent advancements in Automated Driving Systems (ADS) or Advanced Driving Assistance Systems (ADAS), this project seeks to explore how the VIN standard may expand its purpose to report the presence of this information.

The only existing Vehicle Information Reporting System (VIRS) today is the VIN, the purpose of which, as noted, does not include the reporting of safety features or equipment. Should the current VIN standard be expanded to include fields indicating the presence of ADS and ADAS, the efficacy and impact of these technologies on crash avoidance and crash mitigation safety may be more accurately determined. This also offers the opportunity to break down current obstacles to both researchers and stakeholders in accurately informing policymakers about the efficacy of real-world application of ADS and ADAS safety features.

Modifying the VIN to include information on ADS and ADAS technologies could shed valuable light on how to maximize these systems’ safety features as crash prevention strategies. In any case, research is needed to determine the best way of tracking these ADS- and ADAS-related technology features, either through the modification of the current VIN standard, or via an alternative VIRS.

The research team held a series of meetings to solicit stakeholder feedback on a number of VIRS alternatives and their associated considerations and challenges. The six alternatives (shown in Figure E1 below) involved (1 and 2) two methods of implementing a modified VIN, (3) barcodes, (4) optical chips, (5) event data recorders, and (6) a write-in option for a “participant-specified” VIRS alternative. Qualitative data of the feedback meetings was obtained from transcriptions and was further analyzed to identify preferences for VIRS alternative options. Quantitative data was obtained using a Likert-type survey adapted from the System Usability Scale (Sauro, 2011) which was administered to participants to determine a letter grade of potential usability for each VIRS alternative.

Unfortunately, due to time and budget constraints, no original equipment manufacturers (OEMs) participated in this project. Thus, this feasibility study may provide an incomplete view without the feedback of these entities. A Phase 2 of this project would be needed in order to capture the perspectives of OEMs and the results of should be interpreted as such—potentially biased to only the type of stakeholder groups that participated.



E1. Illustration. VIRS study concept.

LIST OF ABBREVIATIONS AND SYMBOLS

ADAS	advanced driver assistance system
ADS	automated driving system
AEB	automatic emergency braking
AIAM	Association of International Automobile Manufacturers
Alliance	Alliance of Automobile Manufacturers
CIB	crash imminent braking
DBS	dynamic braking support
DDT	dynamic driving task
DMV	Department of Motor Vehicles
EDR	event data recorder
FCW	forward collision warning
FMVSS	Federal Motor Vehicle Safety Standards
IIHS	Insurance Institute for Highway Safety
ISO	International Organization for Standardization
MMUCC	Model Minimum Uniform Crash Criteria
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of Proposed Rule Making
NSC	National Safety Council
PII	personally identifiable information
SME	subject matter expert
SUS	System Usability Scale
TMA	Truck Manufacturers Association
VIN	vehicle identification number
VIRS	vehicle information reporting system
VSC	vehicle stability control
USDOT	United States Department of Transportation
VTI	Virginia Tech Transportation Institute

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CHAPTER 1. INTRODUCTION

PROJECT OBJECTIVE, SCOPE, AND ASSUMPTIONS

Vehicles with advanced driver assistance systems (ADAS) and automated driving systems (ADS) may reduce crash frequency and severity, but this can be difficult to determine because current vehicle identification numbers (VINs) do not include fields indicating their presence. As a result, crash reporting statistics do not include this information, limiting the scope and accessibility of crash analyses. An opportunity exists to improve our understanding of ADAS and ADS safety by adding new VIN fields to include such information. The research team conducted this study to identify what information is needed to improve crash reporting to include ADS and ADAS features and how the process of changing VINs or using another vehicle information reporting system (VIRS) alternative might occur.

This project served primarily as a concept and feasibility exploration experiment. In soliciting stakeholder feedback on different VIRS, this project sought to answer the following research questions:

- How effective are ADS or ADAS at reducing the frequency and severity of automobile crashes?
- Should the presence of these systems be encoded into the current VIN structure to better understand safety impacts from crash reporting?
- Would another VIRS alternative better serve the purpose of reporting the presence of ADS and ADAS?

In answering these questions, the project made the following assumptions:

- Based on an analysis of published comments, reports, and responses to the last docket for VIN modification in 2008, stakeholders who use VINs are willing to discuss, and are potentially in favor of, modifications.
- ADS and ADAS features must have a standard of consistency in their definitions and technological capabilities before a VIRS could move from concept to development

As such, the project's scope was narrowed to focus only on ADAS- or ADS-related modifications to the VIN, as well as four other VIRS alternatives. While other occupant protection systems exist and could be potentially beneficial to include in a VIRS, this project chose to focus only on the broader categories of ADAS and ADS in this first step of concept exploration. These results could lead to further research focused on more specific features and systems and how they might be integrated into a VIRS. Furthermore, there is glaring inconsistency among manufacturers with regard to standard taxonomy for, and performance requirements of, ADAS features. As this project was a feasibility and concept exploration study, participants were asked to evaluate each of these VIRS alternatives given the hypothetical scenario that these inconsistencies had already been addressed. The issue of inconsistencies has been explored by organizations such as AAA and will be addressed in later sections. While establishing consistency is key to the development of any potential VIRS, it was considered as out of scope for this project in order to evaluate the feasibility of VIRS alternatives. The results of this research could potentially narrow the selection of VIRS alternatives to one to three options that could more appropriately address how to map ADAS or ADS features in a consistent way.

The research team is in agreement with the National Safety Council (NSC) that, "VIN databases provided by the automotive industry do not uniformly provide information about ADAS. The VIN databases also wouldn't give information about aftermarket additions or disablement of ADAS, nor would they shed light on driver interaction with ADAS before and during a crash." (2017). The research team recognizes that there is a risk in capturing the presence of ADAS and ADS information in a static manner within the VIN. This method may not be flexible and dynamic enough to capture future developments in technology, software updates that change technological capabilities, and aftermarket installations. As such, stakeholders were probed to consider these shortcomings, and were presented with VIRS alternatives that may better address this issue.

This project also narrowed the scope to looking at VIRS alternatives through the lens of meeting specific data elements, as explained further in later chapters, rather than mapping a detailed plan of how these features might be reported. Each VIRS alternative was presented in raw form to solicit creative brainstorming among stakeholders about what each might look like in implementation form. The comment by NSC above also sheds light on the need to understand not only when these technologies are present, but also to know when they are engaged or not engaged. This inspired the research team to expand VIRS alternatives to include Electronic Data Recorder (EDR) technology, which is more complex and all-encompassing. The introduction of this element allowed for stakeholder discussion about how important this second layer of crash reporting is to different industries, regardless of whether other VIRS considered could meet this data threshold.

VIRS alternatives of barcodes, optical chips, EDRs, and a “participant-specified” (i.e., free response option) were selected based on discussions with subject matter experts (SMEs), existing technology, and the ability of a particular VIRS to capture important data elements. While other VIRS options exist, this project focuses on the options listed for purposes of a concept exploration. It is assumed that any change to a VIRS to include the presence of ADS or ADAS features will result in some level of burden to OEMs. Unfortunately, direct feedback from OEM stakeholders was not obtained for this project due to time and budget constraints. Had a focus group been conducted, the data may have revealed different results.

BACKGROUND

According to the National Highway Traffic Safety Administration (NHTSA), in 2017, an estimated 6.45 million police-reported motor vehicle crashes occurred in the United States (2017). There is great potential for lowering this statistic through ADS or ADAS technology. In order to evaluate motor vehicle crash safety concerns, accident reporting is a key element in guiding policy makers toward investments and regulations, potentially through mandating certain ADS or ADAS equipment.

Determining the presence of ADS and ADAS safety features in accident crash reporting on public roadways is essential to determining the safety potential of these systems. Government agencies and stakeholders, such as the Insurance Institute for Highway Safety (IIHS), have acknowledged that ADAS features, such as forward collision warning, lane departure warning, blind spot assist, and adaptive headlights, could prevent or mitigate nearly one third of crashes—more than 1.8 million crashes a year (Anderson, 2014). As ADS and ADAS technology grows, a strong need is emerging for data to determine whether or not these features can prevent deaths and injuries as a result of motor vehicle crashes (NHTSA, 2017). A potential way to capture this information is by modifying the VIN to include these features, which, in turn, will allow for more accurate analyses of crash reporting statistics.

Rulemaking has historically used crash reporting statistics to inform the effectiveness of crash prevention or mitigation technologies using research studies that examine the data of pre-and-post introduction of vehicle safety technology. A valuable way in which this data is gathered often occurs with partnerships between OEMs and transportation safety research organizations. While this approach allows rulemaking to measure observed change, there are many external variables that may have a direct effect on the types of crashes reported. Research such as that conducted by the Pacific Institute for Research and Evaluation have provided important data in the introduction of these technologies. This study analyzed police-reported crashes between the years 1998 and 2002 to evaluate the real-world effectiveness of vehicle stability control (VSC) in six US states. They had a control group and test group of vehicles equipped with VSC as a standard feature to study impact types and crash involvement rates (Bahouth, 2005). While invaluable data, a drawback to this type of methodology is that not all contextual parameters can be equally compared. For example, variables such as changes in travel patterns or infrastructure may change over the course of several years. There may also be drawbacks to using insurance-collected data when it is difficult to identify whether the driver was the primary insured client or their family member. This data may also provide the plane of damage, but little detail surrounding the crash—information that may be pertinent to determining effectiveness of safety technologies. A further complexity is knowing the opposite of crash reporting, but rather,

how many crashes did this safety technology avoid? Without the presence of an EDR, and the necessary legal rights to access the data, much of this information is lost.

There have been some previous attempts to identify the presence of ADAS features on a vehicle through crash reporting statistics. For example, a study was conducted to identify all vehicles equipped with a given safety technology feature and then analyze crash reporting data only directly related to this pool of equipped vehicles. The Insurance Institute for Highway Safety (IIHS) published a study in 2010 that examined the potential of four different crash-avoidance, passenger-vehicle technologies: side view assist, forward collision warning/mitigation, lane departure warning/prevention, and adaptive headlights. The methodology to determine the effectiveness of these technologies relied on crash records extracted from the 2004–08 files of the National Automotive Sampling System General Estimates System (NASS GES) and the Fatality Analysis Reporting System (FARS). Contextual parameters of the crash such as time of day and road characteristics help to situate the data into real-world effectiveness (Jermakian, 2011).

While this allows for relevant information, there is a potential risk that the data is biased towards only audiences who purchased the add-on of this safety feature to their vehicle. One could argue that this may be a priority for groups of older ages rather than young purchasers. The implementation of a VIRS may eliminate some of this bias in identifying a broader range of make and model vehicles and improve the utility and accessibility of this type of data. So while the implementation of a VIRS through a VIN number may provide a more complete picture than previous studies, a VIRS alternative of an optical chip or barcode may appear to be a more feasible option in a world of fast-paced development in vehicle safety technology. A VIRS, when married to crash reporting data, may potentially allow for higher-level approximations and more accuracy in determining the real-world effectiveness of ADS or ADAS features.

Previous efforts conducted by NHTSA (49 C.F.R Part 565 Docket No. NHTSA–2007–27830) explored the feasibility of modifying the current VIN to ensure that there would be a sufficient number of unique manufacturer identifiers and alphanumeric codes for at least another 30 years. However, to date, there has been limited research completed to consider the best way of tracking the features associated with ADAS/ADS technologies using the VIN. While NHTSA has explored some of these opportunities for modification within the New Car Assessment Program (NCAP), like this research, the opinions and feedback from stakeholders are still in an exploratory state.

METHODOLOGY

This report will first define the existing VIN structure in its original purpose and scope, and then explore, with relevant stakeholders, the potential need to modify the VIN to include data on the presence of ADAS and ADS. In this project, stakeholders were defined and identified as any relevant party that may utilize, depend on, or otherwise be affected by the VIN in their work regarding transportation safety, risk assessment, or crash analysis and response. The types of stakeholders were divided into categories depending on their organization type.

- **Federal and state government:** any individuals involved in an agency that represented transportation safety at the governmental level, including departments of transportation.
- **Insurance organizations:** either those from an insurance company, or an affiliate of an insurance company conducting safety research.
- **Law enforcement:** police officers of any position from any jurisdiction (city, county, or state).
- **Safety advocacy group stakeholders:** organizations involved with transportation safety that lobby or conduct research within the field.
- **Technology developers and suppliers:** any companies involved in the development and supply of technology, supplies, or parts directly to OEM companies.

This report will present feedback from stakeholders on proposed approaches to determine the viability and efficacy of VIRS alternatives to report the presence of ADAS or ADS features. The

three-phased approach includes: 1) a literature review to identify VIN past needs and any modification process to determine a potentially viable future method for including ADS or ADAS features, 2) an establishment of the V-Model of Systems Engineering as the governing framework in which data elements were defined and quantitative measurement tools were selected, and 3) data collection using focus group and interview structures with stakeholders to determine interest level and what steps they would need to take to modify the VIN or implement a different VIRS alternative (Figure 1).

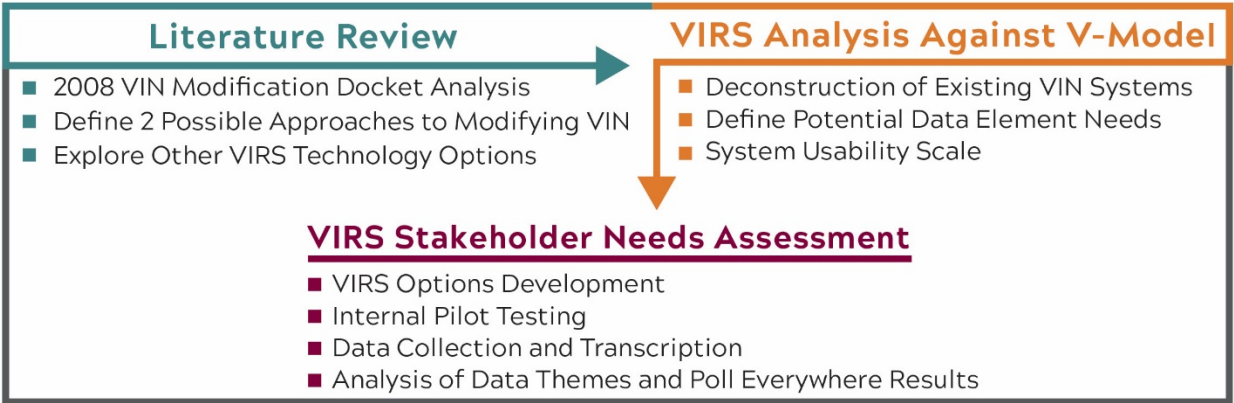


Figure 1. Flowchart. Mixed methods task outline.

Figure 2 displays the two objectives of this research for determining the best approach toward the inclusion of ADS/ADAS information as determined by stakeholder needs. This report summarizes the findings from regulatory analysis, technology exploration, and stakeholder feedback.

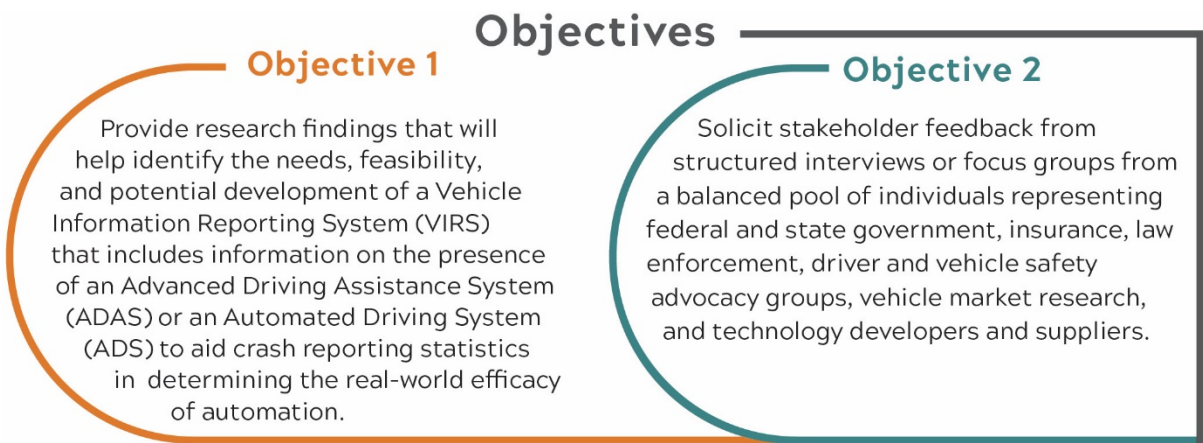


Figure 2. Illustration. Objectives of VIRS research.

DOCUMENT OVERVIEW

The steps taken to accomplish these objectives will be the focus of this document:

- Chapter 2 describes the findings from research associated with the preliminary project tasks, including the literature review, the 2008 VIN revision docket analysis, and current support for modification.
- Chapter 3 describes the research methods used in developing the stakeholder survey and both mixed-method analysis approaches, including the V-Model and System Usability Scale (SUS).
- Chapter 4 presents the main data collection approach and recruiting process for stakeholder groups.
- Chapter 5 details the findings from the VIRS stakeholder feedback groups and the SUS scores.
- Chapter 6 summarizes cross-cutting findings from the needs assessment and draws attention to potential opportunities for future VIRS development.

VIN HISTORY AND BACKGROUND

NHTSA created the VIN standard through the enactment of Federal Motor Vehicle Safety Standard (FMVSS) No. 115 in 1981 in an effort to increase public safety (Figure 3).



Figure 3. Timeline. Historical development of the VIN standard.

NHTSA defined the purpose and scope of creating a VIN standard as tri-fold, the first goal being “...to enhance the public safety by deterring vehicle theft based on the assumption that drivers of stolen vehicles are more likely to operate those vehicles unsafely and thus be involved in vehicle crashes.” Secondly, the VIN “...serves to increase the accuracy and efficiency of recall campaigns.” Finally, the “...VIN has also become a key identifier in data systems that track such things as compliance with federal importation regulations, vehicle registrations, insurance coverage, and motor vehicle crashes.” The creation of a systematic VIN system was originally in response to a petition in 1976 on behalf of the Motor Vehicle Manufacturers Association and Volkswagen of America, Inc. The final rule of the VIN system was then modified in 1996 to consolidate VIN requirements into 49 C.F.R Part 565, eliminating FMVSS No. 115. Under this system, SAE International issues and coordinates manufacturer identifiers which comply with International Standard 3780. Furthermore, The International Organization for Standardization (ISO) applied a standard for the World Manufacturer Identifier, which corresponds to all automotive builders in order to maintain consistency across international borders (ISO, 2009).

VIN codes are uniformly a 17-digit strew of alpha-numeric combinations, with the exception of the letters I, O, or Q, as these are easily confused with the numbers 1 and 0. As seen in the theoretical example of a light vehicle in Figure 4, each digit represents a key piece of information about a vehicle’s OEM, make, model, year, and features.

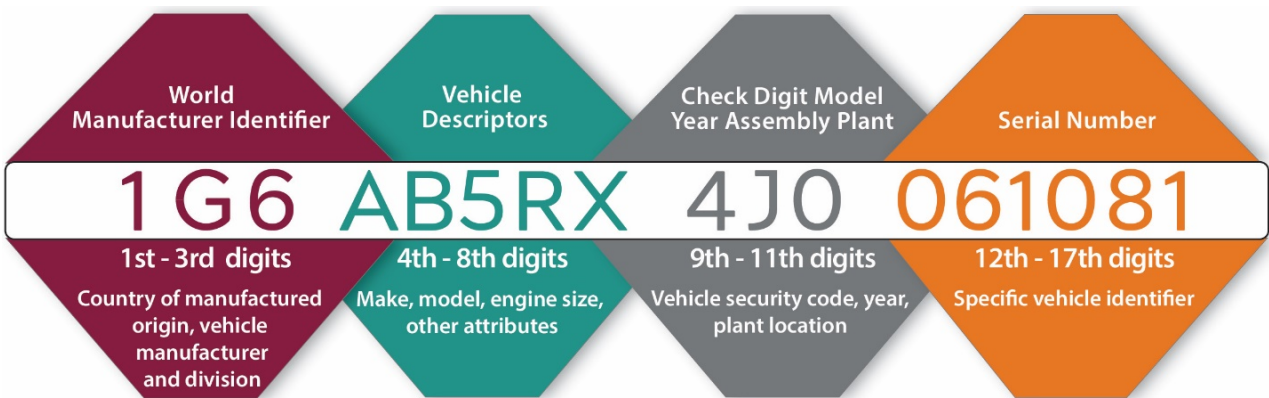


Figure 4. Illustration. Example VIN decoded.

Digits 1–3 uniquely identify the country of origin, the vehicle manufacturer, and the division in which it was produced. Digits 4–8 encode the build platforms, manufacturing options, engine sizes, restraint devices, and other OEM-specific attributes. Digit 9 is a check digit derived from a calculation inclusive of every alpha-numeric digit within the VIN. Digit 10 refers to the model year of the vehicle, with an encoding system based on decades, which will be reset with the 2020 model year. Digit 11 is the exact location of the plant the vehicle was built. Lastly, Digits 12–17 indicate a serial number from a model’s production line that includes specific features (49 C.F.R Part 565 Docket No. NHTSA–2008–0022). This research report discusses options for modifying the VIN. Potential options were presented to stakeholders as an open discussion around adding additional digit(s) or modifying VIN positions 4–8, or other preferred digit positions, to indicate the presence of ADAS or ADS features, as discussed in more detail in Chapter 3.

In 2008, when the last modification to the VIN standard occurred, NHTSA expanded the system in response to a petition by SAE International. Manufacturers were faced with the issue of repetition in VIN numbers and requested an expansion of character requirements. Thus, the VIN standard was modified to ensure the uninterrupted unequivocal identification of all vehicles for

at least 30 years from the date of manufacture to the date of vehicle destruction (NHTSA, 2008). The 10-year mark for this 30-year standard has now passed but with the development of automated technology, such as ADS and ADAS features, the VIN standard may need to be revisited sooner than the original 30-year projection.

DEFINING ADS AND ADAS FEATURES

SAE International published its most recent Surface Vehicle Recommended Practice J3016, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, in June 2018. This document presents recommendations for appropriate terms and definitions related to automated driving system technologies (SAE J3016_201806, 2018). SAE's distinction between six total levels of automated driving, ranging from level 0 to level 5, was used as the framework for this project. Level 0 is defined as a system with no automation present; levels 1 and 2 include ADAS features; and at the other end of the spectrum, level 5 refers to a system that provides full automation and, similar to level 4, does not require a fallback-ready driver. In cases where a vehicle is unable to perform a dynamic driving task (DDT), level 4 and 5 vehicles will perform a DDT fallback in order to achieve a minimal risk condition. An ADS that performs these operations comprises the hardware and software that are collectively capable of performing the entire DDT on their own. The term ADS applies specifically to SAE levels 3, 4, and 5 (SAE International, 2018).

Considerations for stakeholders as they relate to ADS deployment have centered on thorough reporting of all ADS-related incidents for the purposes of accurate statistics and establishing liability. The Model Minimum Uniform Crash Criteria (MMUCC) was updated in August 2017 to include NHTSA guidance to law enforcement for SAE definitions and recording ADS data on crash reports. The crash report template provides new fields for law enforcement to specify the vehicle's ADS capabilities and the driving automation engaged at the time of the crash (NHTSA, 2017). However, it is important to note that the MMUCC provides only guidance, rather than a mandatory crash reporting standard for law enforcement. As such, it is currently unknown how many states have implemented this guidance, and it is difficult to determine how effective this new crash report template is in reporting the presence of ADAS/ADS.

In 2018, NHTSA reiterated best practices for legislatures and state highway officials regarding ADS. NHTSA proposes that states consider training public safety authorities in conjunction with ADS deployments to improve their knowledge and understanding of ADS-equipped vehicles and potential interactions. NHTSA also suggests that coordination among states would assist in expanding the knowledge and expectations for human driver behavior when interacting with an ADS-equipped vehicle (NHTSA, 2018). Additional information about each of these efforts is discussed in Chapter 2.

CHAPTER 2. DOCKET ANALYSIS OF 73 FR 23367 2008 TO INFORM POTENTIAL VIN STANDARD REVISION

Relevant stakeholders have shown preliminary support for modifying the VIN to include ADS and ADAS features. IIHS, NSC, and the Consumers Union have all offered comments regarding ADAS and ADS. Despite some divergence into the tangential issues discussed above, all agreed that changing the VIN would help stakeholders and rulemakers begin to more precisely measure these systems’ real-world safety and technology potential.

As noted earlier, previous NHTSA efforts (i.e., 49 C.F.R Part 565 Docket No. NHTSA–2007–27830) explored the feasibility of modifying the current VIN to ensure a sufficient number of unique manufacturer identifiers and alphanumeric codes for at least another 30 years. In order to evaluate the feasibility and methodology of modifying the VIN standard, it was instructive to analyze the standard’s original 2008 modification process and stakeholder feedback, during which NHTSA responded to a petition from SAE and modified the VIN to extend its life until the year 2038 (23 FR 23367, 2008). NHTSA made two major changes during this process: (1) the area where manufacturers report a vehicle’s make was moved from the first to the second section, and (2), the fourth, fifth, and sixth VIN positions could include both alphabetic and numeric characters, and alphabetic characters became allowable in position seven. These changes expanded the supply of manufacturer identifiers and VINs available for use, ensuring the VIN system’s viability for at least 30 years.

To make these changes, NHTSA engaged in a formal rulemaking process, issuing a notice of proposed rulemaking (NPRM) for public review and comment submission. The process culminated in a final rule being issued (72 FR 56027, 2007; 73 FR 23367, 2008). In total, there were 25 comments on the NPRM; a sampling of the commenters is included in Table 1.

Table 1. Sampling of 2008 docket commenters.

Sampling of 2008 Docket Commenters
Advocates for Highway Safety (Advocates)
Alliance of Automobile Manufacturers (Alliance)
Association of International Automobile Manufacturers (AIAM)
BMW of North America
Ford Motor Company
General Motors (GM)
Harley-Davidson Motor Company
National Association of Clean Air Agencies (NACAA)
National Insurance Crime Bureau (NICB)
New York State Department of Environmental Conservation (NYDEC)
New York State Department of Motor Vehicles (NYDMV)
Northeast States for Coordinated Air Use Management (NESCAUM)
Oregon Department of Environmental Quality (ODEQ)
Oregon Department of Motor Vehicles (ODMV)
Truck Manufacturers Association (TMA)
Washington State Department of Ecology (WDE)
Wisconsin Department of Transportation (WisDOT)

There were several consistencies found in the comments from the 72 FR 56027, 2007 NPRM that may serve as useful if the VIN were to be modified in the future for crash avoidance strategies through reporting the presence of ADS or ADAS features. These consistencies in comments are outlined in the following two sections.

MODIFYING VIN TO ENCODE ADDITIONAL INFORMATION

The Oregon Department of Environmental Quality, Oregon Department of Motor Vehicles (DMV), New York State Department of Environmental Conservation, the Washington State Department of Ecology, the National Association of Clean Air Agencies, Advocates for Highway Safety, and Northeast States for Coordinated Air Use Management all addressed modifying the VIN to include emission standards information in their docket comments on 72 FR 56027, 2007 NPRM. These organizations all supported either adding a digit or encoding additional information in digits 4–8 to capture whether or not a vehicle met federal emission

standards, California emission standards, or both. One change proposed by several of these entities suggested modifying the VIN to include engine type, which would provide information about potential emission levels in order to help support air quality and transportation modeling efforts.

NHTSA responded to these agencies' comments/requests as follows:

The agency is not adopting at this time amendments to address any of the recommendations for the VIN to include additional information elements, not because those recommendations lack merit, but instead because there is a pressing need for today's rule to be in place to assure the uninterrupted continuation of the VIN system. (49 C.F.R Part 565 Docket No. NHTSA–2007–27830, p. 18)

NHTSA's reply implies an urgency in 2008 to push forward a rule that would ensure the non-repeatability of VINs before model year 2010 vehicles were manufactured. Because the rule has passed and is set to endure for 30 years from the regulation date, this sense of urgency has dissipated. Recognizing the need to potentially modify VINs in the future and re-examine encoded information, NHTSA states in the final rule, 73 FR 23367, 2008, that the regulation:

... reflect[s] the fact that there has been little change over the decades in the information that must be conveyed by a VIN despite the development of new circumstances that may lend themselves to the inclusion of new or different information. As such, the agency plans to initiate a separate comprehensive review focused on the information requirements of the VIN system. This will address whether those requirements should be changed, and if so, how those changes should be made. (49 C.F.R Part 565 Docket No. NHTSA–2007–27830, p. 19)

No separate comprehensive review has been initiated since the 2008 Federal Regulation modifying VIN requirements. The emergence of ADAS and ADS technologies may be the "new circumstances that lend themselves to the inclusion of new or different information" that NHTSA refers to in the quote above. The recording of VINs in law enforcement crash reports serves a vital role in research for crash prevention strategies. Similar to the request to include emission standards in VINs, the inclusion of vehicle "families"—or, in the case of ADS/ADAS, vehicle "levels of automation"—could be of benefit. This could be accommodated by modifying VIN digits 4–8 or by adding an 18th digit. If an 18-digit VIN were to be developed, the process of rulemaking to effect that change would involve decisions to begin rulemaking based on congressional mandate, research showing a safety problem, experience indicating need for amendment, or a petition from the public. An NPRM would then be issued with an opportunity for stakeholders to comment, and revisions could be incorporated should NHTSA decide to proceed with a final rule.

MODIFYING EXISTING VIN STRUCTURE

In the 72 FR 56027, 2007 NPRM there was some opposition on behalf of the Alliance of Automobile Manufacturers (Alliance) and the Association of International Automobile Manufacturers (AIAM) on NHTSA's proposed change to require the encoding of passenger car restraint system information in VINs. Alliance stated this change would "...create an unnecessary and unjustified burden on manufacturers because each running change relating to a vehicle's restraint system could require a new VIN." AIAM reinforced this opposition of the change, stating that it could: "...require development of a complex coding scheme which may ultimately prove impractical due to the number of possible combinations of these elements" (49 C.F.R Part 565 Docket No. NHTSA–2007–27830, p. 19).

In light of the opposition in 2008 towards expanding information within VINs, some of the same pushback may be expected today if VIN modification were proposed, as this would require changes from a variety of industries. Information relevant to the VIN that is stored in the history databases of DMVs can vary from state to state. In addition to the VIN, stored data also includes accident-related information (salvage title, junk titles, damage disclosure information); flood damage; fire damage; police accident reports; odometer deficiencies; mileage listings; taxi, commercial and transportation network registration; government registration; stolen vehicle information; fleet information; recall information; sale information by auctioneer or dealer; and finally, emissions and safety inspection information. Any stakeholders for whom one or more of these aspects is relevant would be required to modify their internal systems. For example, one of

the largest software producers previously involved with VIN, R.L. Polk and Company (acquired by IHS Markit), is used by many state DMVs. Thus, these organizations may actively oppose VIN modifications, which would likely disrupt their operations.

Fortunately, based on NHTSA's previous response to opposition, the regulatory body may support proposals to change the VIN. NHTSA's 2007 response to Alliance and AIAM was as follows:

The agency does not agree with the Alliance and the AIAM that this change is overly burdensome.... This suggests to the agency that if a manufacturer knows well in advance of restraint system changes that will occur during a vehicle's production run, creating a VIN to account for those changes would be no more difficult than accounting for the different engines that can be installed in a particular vehicle model. (49 C.F.R Part 565 Docket No. NHTSA-2007-27830, p. 20)

NHTSA stated in a later section:

There may be some cost impacts in changing data systems to account for features of the VIN that are different than those of current VINs... However, NHTSA does not believe the costs will be significant... manufacturers will be able to adjust their systems as needed over time to be able to generate VIN characters under the expanded options for characters contained in the final rule. This ability to adapt slowly to the final rule will further ameliorate the cost impact of the final rule. (49 C.F.R Part 565 Docket No. NHTSA-2007-27830, p. 41)

General Motors addressed the 2007 NPRM by suggesting quick adoption of the final rule to integrate VIN changes to their internal computer database systems in a timely manner. If VINs are to be modified, the same urgency of the rulemaking process may be desired by other OEMs. This would be to allow adequate time to accommodate the change required from a variety of stakeholders' VIN databases that might be affected.

The Oregon DMV reinforced this need for urgency in their comment in response to 72 FR 56027, 2007 NPRM:

As long as our software vendor receives new VIN configuration information and has enough time to update/install the new software, DMV will not be impacted by this change. If the vendor cannot obtain and install the new software prior to implementation of this proposed change, our agency will be severely impacted. We would not be able to verify VIN information and vehicle data would need to be manually keyed into our computer system for over a million transactions annually. Changing VIN configurations to meet the demand for new VIN numbers appears to be a more attractive solution than lengthening the VIN to include additional characters. (pp. 1-2)

The Truck Manufacturers Association (TMA) stated the following in response to 72 FR 56027, 2007 NPRM:

Lastly, implementing this rule will likely require significant computer system reprogramming. For this reason, we encourage the agency to publish the Final Rule quickly in order to provide sufficient lead time to accomplish this work prior to the model year 2010 effective date. (p. 2)

Lastly, the National Insurance Crime Bureau reflected NHTSA's opinion in response to 72 FR 56027, 2007 NPRM:

As an active member of the Technical Committee, [the National Insurance Crime Bureau] supported these changes and the SAE Petition because its software can be modified, without undue burden or expense, to recognize and decode the proposed new structure. (p. 2)

As these concerns indicate, any VIN modification would likely require adequate notice and sufficient time for industries and organizations to retool and implement any changes into their business processes.

MODIFYING VINS TO ADD A DIGIT

In order to modify VINs to include ADS or ADAS features, the team identified two potential options. The first would be to use existing space but add more information. Manufacturers already have to include more information about vehicle characteristics than can be directly encoded in five digits, and currently use complex encoding encryption to accomplish this. This option could not be executed without amending federal regulations, as the information required in a VIN is prescribed by federal regulation Section 565.15 (b). For light passenger cars, the information required includes the vehicle's make, line, series, body type, engine type, and all restraint devices and their locations. Including more information may be technically possible without adding another digit, but this would require addition an attribute(s) in the federal code.

In the 72 FR 56027, 2007 NPRM there were some comments that addressed the potential of a second option: adding a digit to the VIN. To add a digit and change the vehicle descriptor section (second section) of the 73 FR 23367, 2008 regulation, § 565.13 b; 565.15 a, b, c, d, d3 would need to be revised. In addition, the following definitions in either 571.3, or locally in 565.12, would require revision: "Level of driving automation" and "Advanced driver assistance systems." This would be a more viable option today in a regulatory sense if VINs were to change to include ADS or ADAS features. On the other hand, it would create a much larger cost to all stakeholders involved. NHTSA addresses this directly:

The members of the committee representing operators of data systems that utilize the 17-character VIN system indicated that there would be some costs involved in making software and other modifications to data systems required by changes proposed in the petition, but that those costs would be extremely small compared to what would be required to deal with an expanded number of VIN characters. The petition noted that "any increase in the quantity of characters beyond the current seventeen would require massive software changes to all programs that use a motor vehicle VIN, and would affect not only automotive OEM's, but also state DMV's, local governments, insurance companies, law enforcement agencies, research companies, NHTSA's National Center for Statistics and Analysis, as well as others. (49 C.F.R Part 565 Docket No. NHTSA-2007-27830, p. 42)

Comments from stakeholders were requested on the proposed costs of adding a digit.

BMW showed the same hesitation towards the cost of adding an additional digit in response to 72 FR 56027, 2007 NPRM: "With regard to NHTSA's request for comments regarding implementation cost, we agree that the cost of implementing a character in position 7 would not be as great as increasing the quantity of characters to more than 17..." (p. 2).

In response to 72 FR 56027, 2007 NPRM, the TMA leaned more towards the 17-character VIN system as opposed to the expansion to 18 characters due to potential costs in response to 72 FR 56027, 2007 NPRM: "In particular, TMA supports preserving the 17-character VIN system. We believe that expanding the VIN to 18 or more characters would result in additional costs without appreciable benefit" (pp. 1-2).

The Wisconsin Department of Transportation was supportive of adding a digit to VINs in response to 72 FR 56027, 2007 NPRM, but for the purpose of encoding the maximum speed of a motorcycle or low-speed cycle. Their reasoning was that this is a more systematic use of title and registration for these types of vehicles both for use on highways, and in academic or safety studies for discrimination of vehicles based on speed. While they did not propose a direct method for encoding an extra digit, it is important to note that they supported the concept in the past and may be likely to support an additional digit in the future for new ADS or ADAS features.

OTHER SOURCES OF STAKEHOLDER SUPPORT FOR VIN REVISION

Insurance Institute for Highway Safety

IIHS showed support in their response to the request for comments on *Automated Driving Systems: A Vision for Safety* (Docket No. NHTSA-2017-0082). As full supporters of the deployment of automated technology, IIHS believes safety should take precedence in the future of transportation and technology, and expressed disappointment in the absence of a NHTSA research plan to evaluate "the real-world safety of automated driving systems...." They emphasize that there should be no delay in harnessing the potential of automated driving

technology to eliminate the 9 out of 10 crashes stemming from human error. Realizing this potential involves gathering data on how these automated systems operate in the real world, including analyzing crash reporting statistics. IIHS urges NHTSA to require the following information of companies involved in the use of ADS/ADAS:

1. A description of each automated driving system, its level of automation, and its operational design domain;
2. Information that identifies vehicles equipped with one or more automated driving systems; and
3. In the event of crashes, information describing the state (engaged or not) and performance (measures describing its motion and the motion of other involved vehicles) of an automated driving system equipped to a vehicle involved in a crash. (*Automated Driving Systems: A Vision for Safety* [Docket No. NHTSA-2017-0082 p. 1])

While the third suggestion is out of scope for this project, the use of EDRs to capture ADS performance in crashes could be useful in crash reporting statistics for determining the efficacy of these safety systems. With regard to VINs, IIHS supports the modification of VINs to be inclusive of automated technologies, stating the following:

Analyses comparing real-world crash experience with and without automated driving systems and different implementations of the technology are fundamental to understanding their effects on safety, and knowing the presence or absence of these systems at the VIN level is the cornerstone for carrying out these evaluations. (*Automated Driving Systems: A Vision for Safety* [Docket No. NHTSA-2017-0082 p. 3])

IIHS reflects on their study conducted with the Highway Loss Data Institute, which successfully evaluated the inclusion of driver assistance systems on police-reported crashes with VIN-level information about automated safety features. This was made possible by the willingness of manufacturers to disclose the VINs of vehicles whose design models included this equipment. As the first study to document the potential of automated technology through crash statistics, it was key in getting automakers to commit to including automatic emergency braking (AEB) as a standard feature by 2022. As exemplified by the effects of this study, crash statistics remain a key component in rulemakers' decisions to standardize certain automated features. With the absence of automated features in VINs for crash reporting statistics, their injury-preventing benefits may not be fully realized (IIHS, 2018).

National Safety Council

The NSC, in their position paper *Undercounted is Underinvested*, recognized the data vacuum regarding the potential protective effects of ADAS in crashes, emphasizing that, "Post-crash information sharing would yield valuable information for manufacturers and prevention professionals" (2017). In order to collect data about ADAS for crash-reporting statistic purposes, NSC mentions several methods. First, there is the option of providing new fields on crash reports for law-enforcement to indicate the appropriate SAE level of automation (i.e., 1–5). As there are currently no consumer production vehicles at levels 3–5, and there is inconsistency of optional automated features in levels 1–2, this method would provide limited information and, as NSC states, "may not provide knowledge useful for crash prevention" (2017). Alternatively, they mention data linking with VINs as a more efficient way to capture specific information about automated features in the early stages of technology development for ADS levels 1 and 2. They acknowledged the barriers with an ADS-only VIN indexed database, and the need for EDRs in crash reporting statistics, but at the preliminary level, linking data to VINs may prove to be a useful method. NSC includes the following in their list of recommendations to NHTSA:

As part of ADAS data collection, NHTSA should consider standardizing ADAS nomenclature and/or taxonomy. Require ADAS fields in VIN reports. Currently ADAS fields are not required to be provided by automakers to NHTSA for the VIN database. The VIN reporting requirement should be updated to include ADAS data fields. (2017, p. 5)

Consumers Union

The Consumers Union advocacy group, publisher of *Consumer Reports*, is a relevant stakeholder representing the interest of the general public in the market for new vehicles. They offered comments in response to the NCAP Docket No. NHTSA-2015-0119 supporting the modification of VINs for crash reporting statistics.

The general public consults *Consumer Reports* in regard to safety standards when determining whether or not to buy a car, and these safety ratings are based on crash statistics using VINs. The Consumers Union argues that this poses the risk of making safety ratings insignificant if they do not include the number of crashes potentially avoided (i.e., low crash rate) based on new automated features. The Consumers Union is supportive of the modification of VINs, as evidenced by the following comment:

With regard to NHTSA's proposal on the VIN (vehicle identification number) – in which it hopes to collaborate with the manufacturers to code specific crash avoidance technologies and combinations into the VIN, which would be associated to the make, model, trim, and model year levels – we would support this effort for two reasons. First, such an effort would eventually allow used car buyers, including buyers of the vehicles many years from now, to decipher which safety equipment is on the vehicle. Second, should insurers begin to provide premium adjustments for such technologies, as we imagine they would, they will need some way to identify which cars are equipped with which systems. A recoded VIN would benefit consumers in both of these respects. (2016, p. 5)

Furthermore, the Consumers Union remarked, as did IIHS (as quoted earlier in this report), that crash avoidance technologies such as the following should be included: "...forward collision warning (FCW), crash imminent braking (CIB), and dynamic brake support (DBS) in the crash avoidance rating, as the current research team suggests. CIB and DBS are commonly referenced in tandem as [AEB] technologies." (2016, p.5)

Alliance of Automobile Manufacturers

Alliance also provided an industry perspective in their response to NHTSA's request for comments on their 2015 proposal to rework the agency's New Car Assessment Program (Docket No. NHTSA-2015-0119). Alliance recognizes the need to periodically revisit NCAP to evaluate how the integration of new technology may require program modification. In their response, Alliance argues that while there should be a way of easily identifying crash avoidance technology on a vehicle, VIN modification is not the best approach due to concerns about privacy and practical implementation (Alliance, 2015).

Alliance notes that NHTSA is now trying to expand the purpose and scope of the VIN from a safety recall focus to a focus that includes improved data collection for NCAP crash avoidance ratings. The issue they raise is that NHTSA is unclear as to the purpose of certain elements they would like to encode within the VIN, specifically within digits 4–8. NHTSA has proposed the inclusion of entertainment systems and vehicle base price, which are irrelevant to crash avoidance technologies. This also has related consumer privacy issues, as these bits of feature information can be personalized and traceable should they be revealed (Alliance, 2015).

NHTSA also suggested the inclusion of currently mandated equipment, such as rear visibility cameras and electronic stability control, in the VIN, which is arguably redundant, as the equipment is already mandatory and should therefore be installed by default. Alliance cites some of the issues discussed in previous sections by commenters on the 2008 docket who wanted a variety of information to be encoded in the VIN. Alliance requested that the competing information be examined closely and the purpose and that the scope of the VIN be defined clearly so as to most efficiently use the limited space to report valuable information (Alliance, 2015).

Alliance also brought up the much discussed issue of inconsistency among manufacturers with regard to the technological capability and nomenclature of certain crash avoidance technologies, such as park assist (Alliance, 2015). While this is out of scope for this project, it is important to note that OEMs are also recognizing this issue and acknowledge that consistency is needed before this information could be incorporated into the VIN or any other VIRS.

A new VIN standard would also be unable to capture the flexibility in the development of crash avoidance technologies. Alliance notes that if these technologies receive an update or upgrade, it would occur after the VIN was generated, thus causing incorrect information and increased risk of production errors. If modification to VIN were to occur, the changes would need to be clear from the beginning to avoid an unfair cost and burden to manufacturers who might be required to constantly update information as crash avoidance technology evolves (Alliance, 2015).

CHAPTER 3. RESEARCH METHODS

The VIN standard is currently the only standing vehicle information reporting system that is consistently used across a variety of stakeholders. The research team began with this system as a starting point to explore how VIN modification may serve as a reporting system for information about the presence of ADAS/ADS. VIN modification had several potential drawbacks, including a lack of flexibility to encode future technologies and the potential level of burden that may fall on manufacturers and other stakeholders. In examining whether the modification to the VIN system was feasible, the research team chose to expand the scope in examining how other systems used in conjunction with, or separately from, VINs may better serve this purpose.

THEORETICAL FRAMEWORK

Adaptation of V-Model of Systems Engineering

The V-Model of Systems Engineering (Figure 5) is used as a trusted model by the United States Department of Transportation (USDOT) for transportation professionals in developing new products. USDOT defines the model as follows:

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. (2007, p. 5)

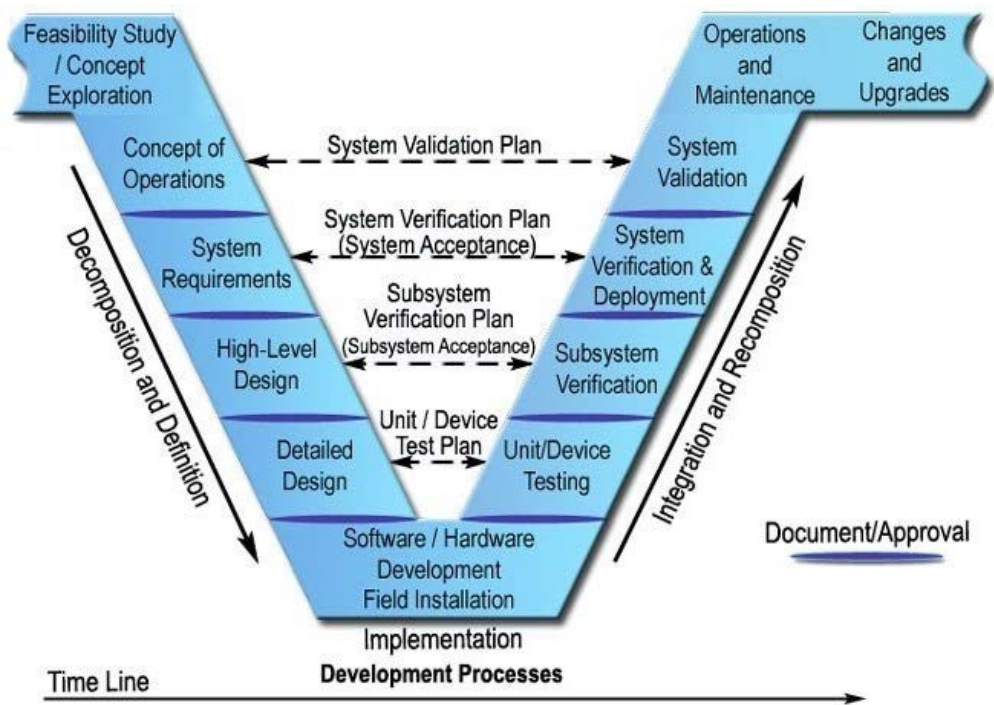


Figure 5. Illustration. V-Model version of systems engineering.

The starting point for this project began at the top of the V with Feasibility Study/Concept Exploration. While this project did not follow the complete lifecycle process, it adapted some key elements in developing a potential new VIRS system. The concepts in the arrow on the left-hand side, Decomposition and Definition, were used in the feasibility study by breaking down the challenges and considerations of the current VIN system. Decomposition of a system into smaller subsystems allows for manageable hardware and software components.

Traceability is a powerful concept that ensures that the system implemented at the end of the project is directly connected with the user needs identified at the beginning. In deconstructing which needs a VIRS meets or does not meet, and by defining those needs clearly to stakeholders, this project sought to identify the next steps towards development of a VIRS that includes the presence of ADAS/ADS technology that keeps users—stakeholders in this case—at the forefront.

The first step in the Decomposition and Definition process is defining evaluation criteria, or defining the problem. The research team defined the problem as follows: ADSs and ADAS features are not systematically identified on production passenger vehicles. Without such

identification, it is not possible to determine how effective ADAS and ADS are at reducing the frequency and severity of crashes. A further issue is that not all ADAS safety features are created equal among manufacturers. Each has different technological capabilities and different nomenclatures, as discussed further in research conducted by the AAA Foundation in the Internal Interviews section.

The second step is defining the constraints of the system. Based on the problem definition, how can constraints, such as costs, etc., that may limit acceptable alternatives be determined? Cost and flexibility were identified as the largest constraints in modifying the VIN standard or developing a new VIRS. Flexibility is essential as the development of ADAS/ADS continue to evolve; thus, it was determined that the system needed to be adaptable enough to allow either the addition of new technologies or the removal of out-of-date items. Further, costs should not outweigh benefits for either vehicle manufacturers or consumers. Neither should costs be overly disruptive to the vehicle manufacturing process.

Definitions of Data Elements

Defining constraints for this project became equivalent with defining necessary data elements. It became evident over the course of the project that not every VIRS system could meet all the data element requirements, and that some VIRS alternatives met certain elements better than others. For example, modifying the VIN standard may appear to have a low level of burden, but the VIN may not be flexible enough for future technology in rulemaking processes. Data elements were primarily identified and defined during SME discussions, as will be discussed further in the Internal Interviews section. See Figure 6 for each data element definition.

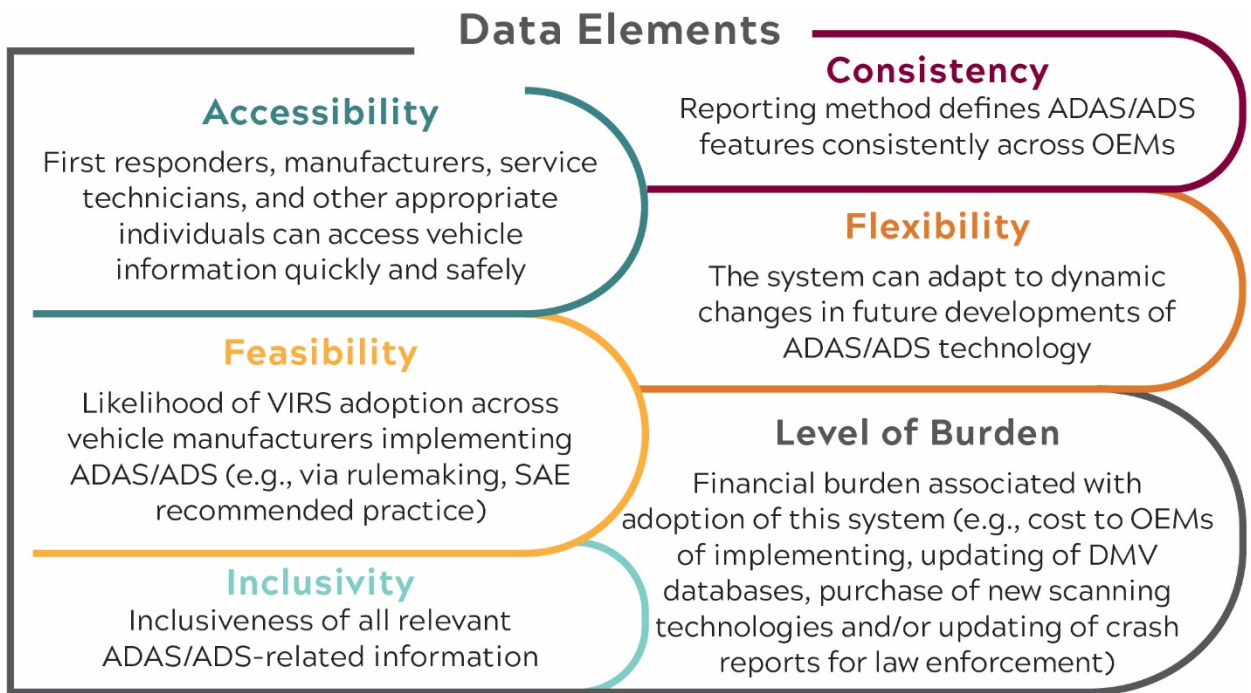


Figure 6. Illustration. Data element definitions.

System Usability Scale

The third step in the V-Model System exploration is defining how success will be measured. As this project took place primarily in the feasibility/concept exploration stage, the strongest measure of potential success was the “potential” usability of the system. The theoretical framework used for this project was the SUS (Sauro, 2011).

The SUS is a questionnaire widely used across multiple disciplines as a method of measuring the perception of usability. It was first developed in 1986 by John Brooke and has since been cited in over 600 research publications. The questionnaire is known for its brevity and reliability as well its ability to communicate information to a variety of audiences with an easy to understand scale range of 0–100. The system is intended to provide a measure of the user’s subjective view of the usability of a system using a Likert-type scale survey and 10 questions. Figure 7 shows the standard version used.

The System Usability Scale Standard Version	Strongly				
	Disagree		Agree		
	1	2	3	4	5
1. I think that I would like to use this system frequently.	0	0	0	0	0
2. I found the system unnecessarily complex.	0	0	0	0	0
3. I thought the system was easy to use.	0	0	0	0	0
4. I think that I would need the support of a technical person to be able to use this system.	0	0	0	0	0
5. I found the various functions in this system were well integrated.	0	0	0	0	0
6. I thought there was too much inconsistency in this system.	0	0	0	0	0
7. I would imagine that most people would learn to use this system very quickly.	0	0	0	0	0
8. I found the system very awkward to use.	0	0	0	0	0
9. I felt very confident using the system.	0	0	0	0	0
10. I needed to learn a lot of things before I could get going with this system.	0	0	0	0	0

Figure 7. Screen capture. Standard version of the SUS.

The 10 questions used in the SUS can be adapted for any technology. For the VIRS project, modifications were made to both the wording and the number of questions. Modifications to wording are permissible if they generally follow the progression of alternating between positively and negatively worded statements. This is to ensure that respondents are reading questions carefully, taking their time, and minimizing extreme responses or acquiescence bias (Sauro, 2011). When data analysis is performed, the 1–5 rating scale must be reversed for negatively phrased questions. For example, question one would use the scale shown in Figure 7 with the number (1) representing Strongly Disagree and the number (5) representing Strongly Agree. Question 2 would use the opposite scale with the number one (1) representing Strongly Agree and the number (5) representing Strongly Disagree.

Changes to grammar or tense are not shown to affect responses. If needed, negatively worded items can be rephrased positively as long as there is a balance of alternating positive/negative in all questions (this was not necessary for this project). Synonyms can be used to replace certain adjectives to make them more appropriate; for example, “cumbersome” is often replaced with the word “awkward” (Sauro, 2011).

Figure 8 shows the adaptation used for the current project. The first question replaced “frequency” with “benefit,” as frequency of VIRS use, versus the data itself, would vary from industry to industry. For example, law enforcement may record an 18-digit VIN frequently due to the nature of their crash reporting procedures, but the insurance industry may only use the ADAS information from that VIN once for their research. Question 2 remained the same, as it was straightforward. Question three was modified from “easy to use” to “easily accessible by first responders,” since the use of any VIRS would begin at the step of crash reporting by law enforcement. Furthermore, this was a feasibility study and thus no VIRS alternative was fully developed for a participant to use and it would have been therefore impossible to adequately analyze the system as “easy to use.” Question four attempted to generalize the wording from a “technical person” to a more general “technical support or research for training.” This is because a singular technical instructor may not be applicable to all stakeholder types in learning how to use a new VIRS alternative. Questions five and six were made more project specific by plugging in the specific functions of “ADAS/ADS features.” All participants were informed that question five and six operated on the assumption that ADAS/ADS features had been theoretically standardized for the purpose of this study. Thus, “tracking” or “integrating” features did not refer to the ability for standardization, which was out of scope. Rather, these looked at the reporting *capability* of the VIRS alternative to report such information, if theoretically standardized.

Question seven was adapted to be more general to all industries. Question eight replaced “awkward” with “cumbersome” as it seemed more relevant to the operation of an actual VIRS system. Question nine, similar to question seven, changed the wording from “people” to “industries” to be more relevant to this project. The tenth standard question, “I needed to learn a lot of things before I could get going with this system” was removed entirely. It was considered out of scope for this project because it was focused on actual usability, whereas this project was focused on “potential” usability. There was no actual product to test nor was there a great deal that could be learned that was directly related to a VIRS without the specification of a design, software package, or hardware platform. With this exception, the focus of the usability scale was maintained closely. Each usability measure is bolded in Figure 8 below.

may have rushed through the survey without answering thoughtfully. This situation would be indicated by an agreement or disagreement of high 4s or 5s on the Likert-type scale.

There were times when missing values occurred due to a participants' withdrawal of an answer, or failure of the polling software. This project also used a poll of 9 questions instead of the standard 10, as one question did not fit the project's purpose. As Sauro instructs, reliable SUS scales with only 1–2 missing values can still be calculated by changing the multiplier from 2.5 to 2.778, and changing the 0–40 range to 0–36 with one missing value.

The SUS is not intended to be diagnostic. Thus, the research team chose to use the combined method of discussion questions and the scale to include more descriptive information as to why participants thought a VIRS may or may not have strong potential usability. Each question was displayed to the focus group with live results using a Poll Everywhere Software plug-in within PowerPoint. When there were areas of opposing views or results that may have appeared abnormal based on the preceding discussion, participants were probed to comment further. Comments were recorded and analyzed qualitatively to provide descriptive interpretations to the poll results.

SUBJECT MATTER EXPERT INTERVIEW METHODOLOGY DEVELOPMENT

Internal Interviews

SME interviews were first conducted internally to determine the accuracy of information and feasibility of a VIRS alternative study. All SMEs were Virginia Tech Transportation Institute (VTTI) employees with significant experience in vehicle safety, including ADAS and ADS features. Prior to joining VTTI, SME 1 worked at a major U.S. OEM for 20 years. While there, SME 1 held a variety of positions centered on vehicle safety, including the Automotive Safety Office's Advance Rulemaking and Strategy department. In this role, SME 1 worked with government agencies and other safety organizations to help enhance motor vehicle safety in a number of areas, including crashworthiness, cyber security, and ADS.

SME 1 expressed concern over the burden to manufacturers of implementing updates to the systems and processes already in-place. This SME also expressed concerns that the data may not provide details on potential feature release changes, which may impact the understanding of real-world system performance and how that performance might benefit the consumer, safety research, and insurance rate determinations. Further, the use of SAE level of automation as an identifier was discouraged as there are too many variables in technological capabilities.

SME 2 has 20 years of experience in ADAS. Similar to SME 1, SME 2 discouraged the use of SAE levels of automation, as they are high-level definitions and would lead to significant variance in interpretation of where specific implementations fall. SME 2 advised that any VIRS should be granular enough to characterize technological capabilities that evolve from year to year. SME 2 suggested coding fundamental components of automation, such as duration of hands-off wheel and lateral and longitudinal support. This led to the suggestion of using an EDR as a VIRS alternative because it could potentially record some of this information. SME 2 also confirmed the problematic issue of different manufacturer sensor suites and technological capabilities.

SME 3 has over 19 years of experience in transportation safety, including emerging technologies such as ADAS and ADS. Echoing the other two SMEs, SME 3 stated that SAE levels and ADAS technology are difficult to capture, as the technology is quickly evolving. SME 3 suggested defining a minimum performance standard level or code for each capability. SME 3 also drew attention to how it might be possible to differentiate between active and passive safety in a reporting system and eventually map that to crash type.

All SME comments were incorporated into the development of the focus group structure, the VIRS alternatives, and data element definitions.

Scope of Focus Group Related to ADS and ADAS Feature Consistency

Based on the preliminary docket and literature review as well as the SME interviews, it became apparent that a significant challenge in the development of any VIRS alternative lies in the inconsistency among rulemaking, manufacturers, and stakeholders in defining a clear standard

taxonomy and performance requirements for ADAS/ADS technology. For example, AAA details the inconsistencies found among stakeholders as outlined in the bullets below and as shown in Figure 10 (AAA, 2019):

- OEMs have mainly coined the variety of terms for marketing purposes, but they are not the only entities who are inconsistent in terminology.
- NHTSA has used at least three different technology names, including Automatic Emergency Braking (AEB), Dynamic Brake System (DBS), and Crash Imminent Braking (CIB) to describe automatic emergency braking.
- SAE has used multiple unique names, such as collision imminent braking and forward collision mitigation systems, to describe automatic emergency braking.

ADAS Feature	Unique Names
Adaptive Cruise Control	20
Lane Keeping Assistance	19
Blind Spot Warning	19
Rear Cross Traffic Assistance	14
Automatic High Beams	18
Semi-Automated Parking Assist	12

Figure 10. Screen capture. ADAS nomenclature inconsistencies (AAA, 2019, p. 14).

To further complicate this issue, as seen in Figure 11, even OEM ADAS suite packages could have a different number of features included. As with the introduction of any new technology to the market, there is a certain level of competition among businesses to create something that is unique to them. OEMs thus compete to develop their own safety suites and unique features of safety technologies for market penetration and affordability to the consumer. As technology develops further, and certain businesses rise toward market domination, consistent nomenclature may appear as a result. Prior any industry convergence, the inconsistencies that exist make it difficult to propose a clear development strategy of a VIRS to capture this varying and complex information.

Brand	ADAS Suite Name	# of features inc.
Acura	AcuraWatch	8
Ford	Safe and Smart Package	7
Honda	HondaSensing	4
Lexus	Lexus Safety System+	5
Mazda	i-ACTIVESENSE	6
Mercedes-Benz	Intelligent Drive	7
Nissan	Intelligent Safety Shield	8
Tesla	Enhanced Autopilot	4
Toyota	Safety Sense	7

Figure 11. Screen capture. Suite feature inconsistencies (AAA, 2019, p. 15).

Research groups, such as the Consumer Reports Advocacy Group, Thatcham UK Research Solutions, Mobileye Software, and Denso Worldwide are currently working on potential methods of standardization that may serve useful for the incorporation of a future VIRS alternative. For example, the Consumer Reports Advocacy Group has created its own ADAS Nomenclature Working Group. The core goal of their initiative is two-fold:

1. That each ADAS technology gets a single name.
2. That the names are chosen to maximize consumers’ intuitive understanding of the purpose, capabilities, and limitations of the technologies (Friedman, Fisher, & Wallace, 2018).

Thatcham UK Research Solutions is defining features into two greater categories—Assisted vs. Automated—as defined below (Stewart, 2018):

- *An Automated Vehicle* is a vehicle capable of operating in clearly defined automated mode(s) which can safely drive the vehicle in specified design domains without the need to be controlled or monitored by an individual.
- *An Assisted Driving Vehicle* provides drivers with continuous driving assistance for sustained periods of time in specified design domains. The driver is required to remain engaged with the driving task and driver monitoring systems will be in place to ensure this happens. (p. 8, 10)

British research center Thatcham Research is also exploring the definition of ADAS features by their environment, infrastructure, and road condition (e.g., speed, intersection, controlled vs. uncontrolled [parking lot is controlled]). In addition, Thatcham is investigating means by which to judge automakers on the clarity of their system names for the general public. Those using “pilot,” which implies control, will get a lower grade, while those with “assist” will likely get a higher grade (Stewart, 2018).

Mobileye Software appears to have an interesting categorization approach that parallels internal SME interview feedback. On their website, they categorize ADAS features in terms of three pillars of technological capability: [Sensing, Mapping, and Driving Policy](#). Similarly, Denso Worldwide groups ADAS features into the following functionality areas: [Sensing, Prediction, Interactivity, Connectivity, and Protection/Cybersecurity](#). This approach mirrors some of the suggestions in the stakeholder feedback interviews, where it was suggested that in the “next steps” discussion phase, ADAS features be categorized broadly by functionality or technological capability, as explained further in Chapter 5.

Over the course of this project, a new consortium of four organizations (AAA, Consumer Reports, J.D. Power, and the NSC) came together to work on a standardized approach toward advanced driver assistance technology naming conventions. They divide these technologies into five categories by type:

1. Driving Control Assistance
2. Collision Warnings
3. Collision Intervention
4. Parking Assistance
5. Other Driver Assistance Systems

With variance across OEMs, the research team could not determine a viable way of standardizing this information within the scope, budget, and timeline of this project. Research conducted by other organizations will be an essential piece of any future VIRS development.

As this was an exploratory project only, this issue was incorporated as a discussion point and a reminder of scope at the beginning of each focus group (Groups Come Together on Safety Tech Naming, 2019). Each participant was informed that while including ADS/ADAS information in a reporting system is of utmost importance in moving forward, this project would examine *only* the potential usability of such a reporting system. This project focused on the process of flow of data between stakeholders and the most ideal reporting system for that information. Thus, each group was asked to table the issue of consistency across organization and assume a hypothetical scenario in which consistency was established. Given that scenario, they were asked how they would then rate the potential usability of the system. While participants obliged with the premise in this exercise, it is important to note that, unsurprisingly, all stakeholders unanimously reiterated the importance of establishing consistency as a next step before developing a VIRS.

Pilot Testing

Pilot testing consisted of three focus groups across internal VTTI departments. Participants were a mix of experts in transportation policy, recruitment, and automated technology development. The use of pilot interviews allowed the research team to obtain feedback from SMEs on the types of questions and materials used in the interviews and on the completeness and accuracy of information conveyed. The feedback provided during the pilot testing period was incorporated into the methods for the main data collection and analysis. For example, scripts were adjusted to provide more clarity and SUS questions were modified for more appropriate wording.

FOCUS GROUP METHODOLOGICAL APPROACH

In determining the best way of developing a stakeholder needs assessment, a mixed-methods approach of both quantitative and qualitative research methods was considered. Quantitative research through the SUS survey questions was determined as beneficial to this research, as it would produce a conclusive, consistent, and reliable set of results on the various VIRS options. However, without descriptive data behind the SUS scores, the team might have missed important points or a logical flow of thoughts. By using both of these methods, researchers were able to more completely understand the flows of information between industries. Further, researchers were able to gain insight into opportunities associated with the development of potential VIRS alternatives.

When interpreting the results of this effort to obtain stakeholder feedback, it is important to recognize the open-ended nature of these questions. Some participants chose to focus on aspects of a VIRS in relation to their industry and their industry only. Others included speculation as to the effect on other industries based on their past interactions; i.e., a state agency with law enforcement officials. The counts of the qualitative effort reflect the number of responses or agreement within one particular focus group. Some participants also expressed the same idea in response to multiple questions or oscillated between the options in a comparative analysis. Efforts were made to steer participants back on track to the VIRS alternative at hand and to encourage them to speak primarily on the nature of their particular industry.

FOCUS GROUP STRUCTURE

Prior to their scheduled focus group time or interview, each participant was provided with a copy of the technology definitions and adapted SUS questions, as well as the Poll Everywhere application guidelines to review prior to participating in the focus group or logging into a guided interview.

Welcoming Activities

Via participation in focus groups with their colleagues and peers, this qualitative method provided a space for honest feedback and, potentially, the development of new ideas to be arrived at collectively. For this effort, it was important that participants perceived the focus groups and interviews as being a safe and nonjudgmental space. After informed consents were verbally acknowledged, participants agreed to abide by the following group rules to ensure an open and comfortable flow of information:

- Listen to each other
- Everyone participate fully
- No side conversations
- Recognize that it's okay to disagree with others and don't criticize others
- You have the right to not comment or refuse to answer a question at any time

Opening Survey and Activities

After the Informed Consent, ground rules, and general introductions, the focus group participants' first task was to access the Poll Everywhere site for their first poll question, as shown in Figure 12.

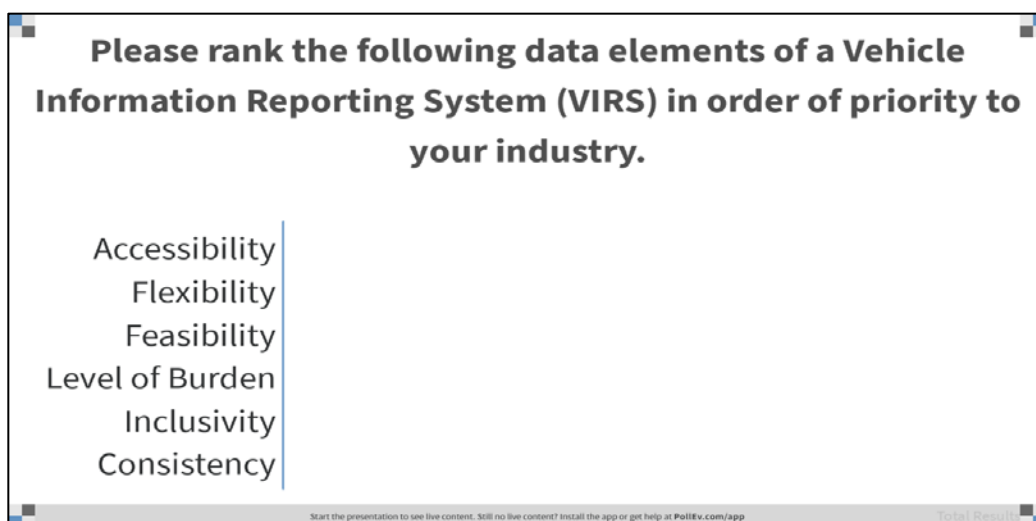


Figure 12. Screen capture. First Poll Everywhere survey – ranking data elements.

After displaying the live results, participants were prompted to discuss the logic behind their ranking decisions so as to better understand how their answers applied to their industry specifically.

Presentation of the Six VIRS Alternatives

Each of the six alternatives, as identified within internal SME discussions, was then introduced in terms of a technology briefing and evaluation. It is important to note that each alternative was presented in a sort of “raw” form, in which design and location were not specified for purposes of soliciting potential creative ideas. Participants were simply presented an explanation of how the technology worked, and the discussion questions elicited further comments. A snapshot of the discussion questions, the presentation of which was identical for all six alternatives, is shown in Figure 13.

Each VIRS alternative was presented in a manner that allowed stakeholders to determine what each system brought to the table, and participants were given the opportunity to combine the best of all systems into one system ideal for their industry. Applying this to other technologies, such as barcodes, optical chips, and EDRs, formed a baseline of analysis. None of these systems were found to be ideal in the research team’s initial performance of the literature review. While some systems met some data elements, others were found to have met it better, etc. The feasibility study was then conducted to determine which data elements were the most preferred consistently across all stakeholder groups in a manner that could provide the foundation of a new VIRS concept. The purpose of talking through these options within focus groups allowed each stakeholder to gauge reactions of how one VIRS may better meet certain data elements, and the expression of loss or frustration if a VIRS were to lose a certain data element that another VIRS had. Presenting these VIRS options in order of most static to most dynamic guided stakeholders’ thought process with regard to how different VIRS could meet different data element requirements.

Discussion questions (as sampled below in Figure 13) were the means by which stakeholder needs were discovered, and encouraged dialogue regarding potential designs.

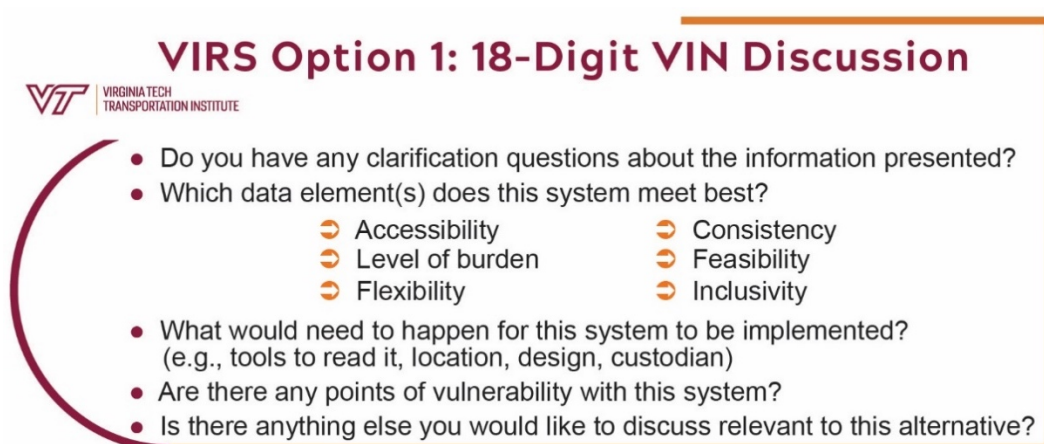


Figure 13. Screen capture. Sample slide of discussion questions for each VIRS alternative.

At the end of the group discussion, a SUS survey was administered for each VIRS alternative. Participants were permitted to make comments before or after submitting their survey results and were permitted to change their answers after further reflection or accidental submission of an incorrect selection. They were made aware when the final results were to be recorded before moving on to the next question.

18-Digit VIN and Modified VIN

The history of the VIN and its last revision process in 2008 were first discussed to provide consistent background information. The various purposes of the VIN digits were explained to participants using the graphic in Figure 4, which divides each section into colored diamonds.

VIN Option 1 was the 18-digit VIN. The methodology of modification discussed was either tacking a digit onto the end or placing an extra digit somewhere within the existing VIN standard.

Modified VINs were the second option and were described as the encoding of additional information somewhere within the VIN. The research team noted that, from initial literature review findings, the prime candidate location may potentially be digits 4–8. For this exercise, however, participants were asked to consider all digit locations and were encouraged to suggest new digit modification locations.

Barcodes

Barcodes were presented as a distinct and separate VIN alternative. These would be distinct from the barcode already attached to VIN in the windshield plate location of most vehicles. Barcodes were presented in their three existing forms: traditional rectangular barcode, QR code, and bulls-eye barcode. These three forms maximized the design possibilities while maintaining the same reading tool (laser device). Figure 14 shows a traditional barcode and a bulls-eye barcode in the form that is typically used today in the retail or healthcare industry.

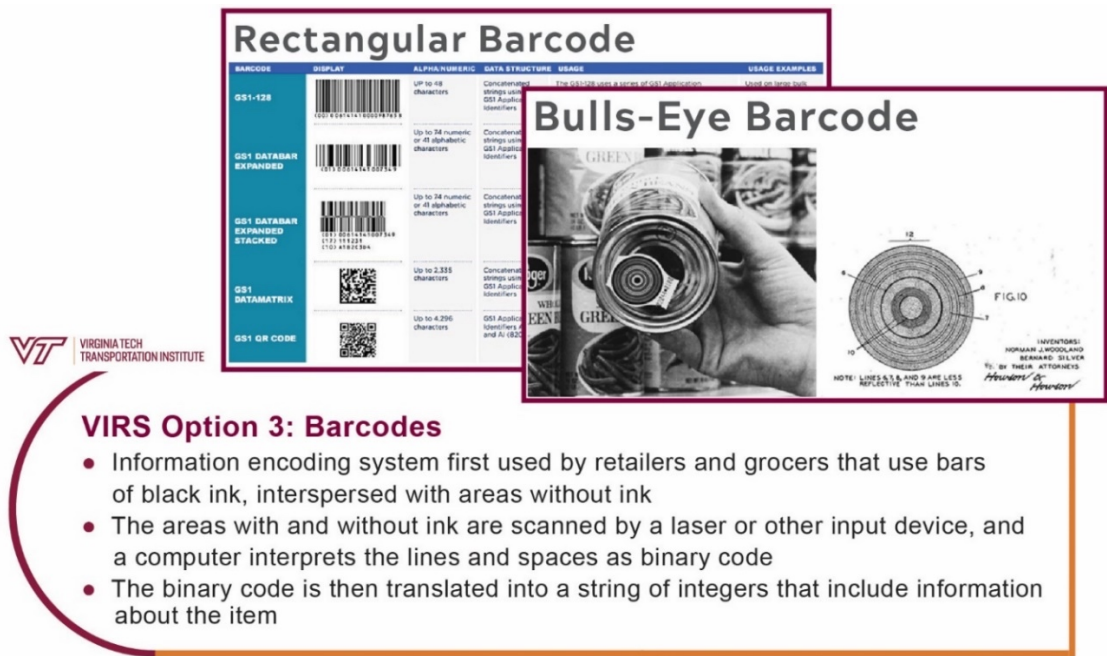


Figure 14. Screen capture. Barcode information slides presented to participants.

The bulls-eye barcode was a reversion to the very first barcodes ever produced in 1974 by Norman J. Woodland and Bernard Silver. This barcode uses dots and dashes from Morse Code to form the concentric circles. It was discontinued from the grocery and retail industry due to issues of condensation on products that would bleed the circles into one another, making the barcode impossible to read (Weightman, 2015). This type of barcode was included as an option because of its uniqueness as a quick visual indicator. It sparked conversation around condensation issues in barcode designs, and how that might relate to the interior or exterior location of the barcode. The presentation of the barcode as a VIRS alternative specified the following flow of information: it would be physically located on the vehicle and could be scanned and linked back to a database as a means of accessing information about the presence of an ADAS/ADS. The location on the vehicle was not specified, nor was the custodian of this database, so as not to bias participants in expressing the most ideal location and custodian for their industry.

Optical Chips

Optical chips are described in Figure 15 below. In terms of how these might work as a VIRS alternative, participants were given only the following constraints: chips would be designed to be accessed remotely/wirelessly if in proximity of the vehicle, but could also be physically extracted for external data reading via computer. If a crash or emergency situation does not allow for a vehicle to turn on or be back-powered, the physical extraction method would be necessary. Participants were also shown an embedded 1-minute clip of an optical chip general overview video on [YouTube](#).

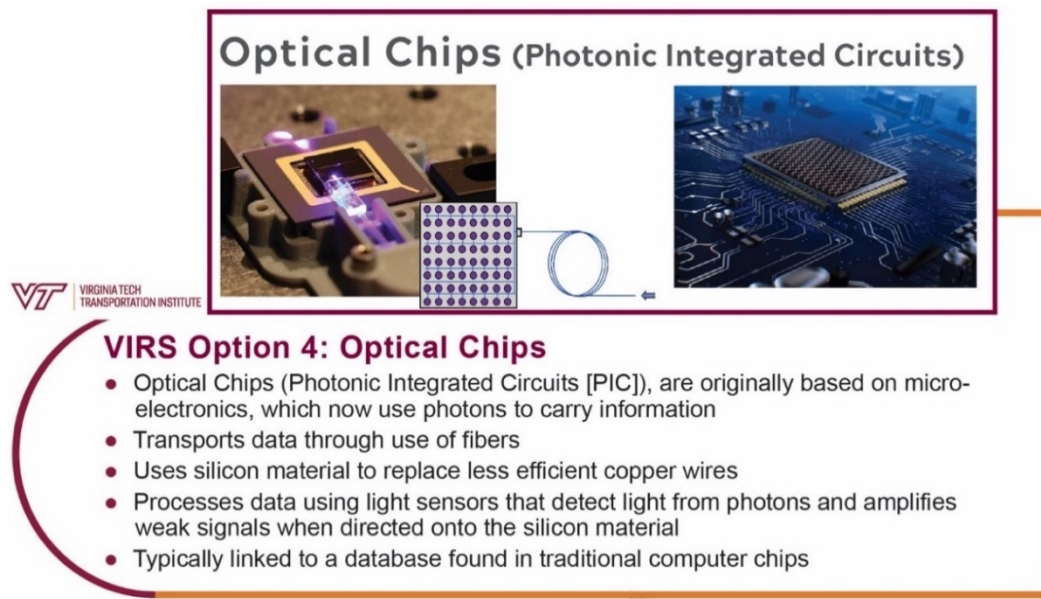


Figure 15. Screen capture. Optical chips information slides presented to participants.

EDRs

EDRs were presented in their currently existing form, as shown in Figure 16. 49 C.F.R Part 563 describes recording requirements and data elements for “if installed” EDRs. How EDR information can be obtained and the details of what data elements are recorded were not discussed with participants. As with other technologies, this information was presented in a raw form, in terms only of technological capabilities, with the goal of provoking creative feedback from stakeholders. Some stakeholders who were already familiar with the use of EDRs brought up the difficulty of accessing the EDR information due to federal regulation requirements. While these issues were noted, participants were steered back to the subject of how they would like to see EDRs operate in terms of a VIRS, and what the ideal flow of information for the future would be, regardless of current regulations.

Participants were informed that this option may appear very different from other VIRS options. Instead of directly reporting the presence or absence of an ADAS/ADS, EDRs convey this information almost by proxy. As a system that actively records data factors related to crash avoidance or mitigation, the EDR is capable of reporting whether an ADAS feature, or the ADS, was engaged prior to a crash event. An EDR would not report the engagement of a feature that a vehicle did not have, obviously; thus, reporting on a given feature would indicate the presence of that feature and the associated system. However, a challenge identified within the literature review—and one that was often discussed among participants—is that the EDR would not report all features. Rather, it would only report those that were engaged, and would only record a few minutes at a time. More discussion concerning this can be found in the section on EDRs.

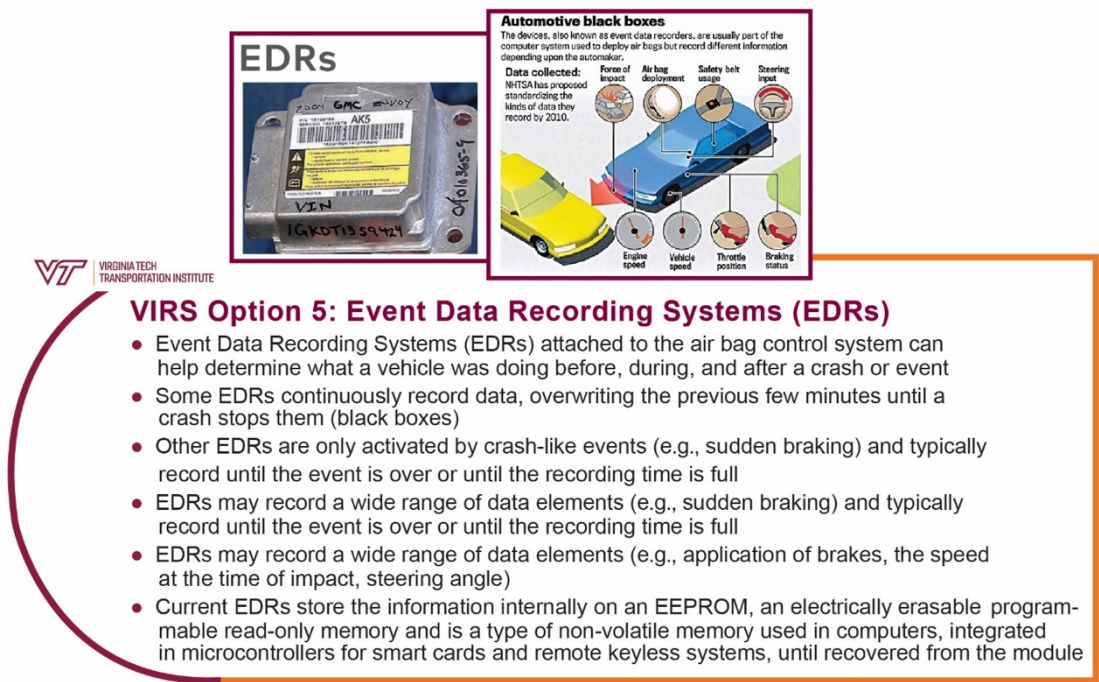


Figure 16. Screen capture. EDR information slides presented to participants.

Participant-specified Option

The participant-specified option was an opportunity for participants to express any new ideas from previous knowledge or from a technology that emerged during the focus group discussion. This could also be an opportunity for combining several of the VIRS alternatives presented. Each group was given the opportunity to either agree on an option to evaluate as a group, or to evaluate several options separately. Extra polls were added to the PowerPoint to address the latter situation, though it did not occur.

The discussion question slide for the participant-specified option is shown in Figure 17.

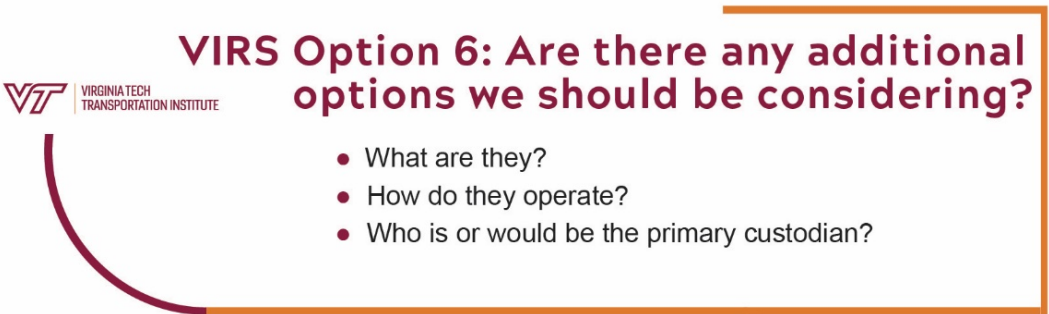


Figure 17. Screen capture. Participant-specified option slide.

Closing Survey and Activities

Participants finished the VIRS alternative assessment with a closing survey in which they ranked each VIRS in order of preference and, when prompted, explained the reasoning behind their selections (Figure 18). Closing questions (Figure 19) were then asked to explore how this study might be improved with other questions or metrics and to talk about future next steps.

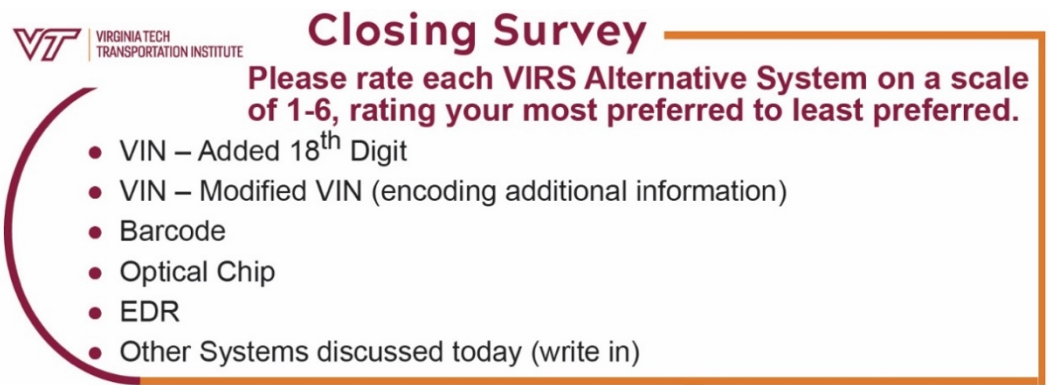


Figure 18. Screen capture. Closing survey slide.

Closing Questions

- Are there other discussion questions or metrics we could use to evaluate these systems?
- What are the potential next steps?
- Is there anything else you would like to discuss relevant to this?

Figure 19. Screen capture. Closing questions slide.

CHAPTER 4. STAKEHOLDER NEEDS ASSESSMENT DATA ANALYSIS

Qualitative data analysis methodology was adapted from a framework methodology—Marshall and Rossman’s (1999) four-step process and Ritchie, Spencer, and O’Conner (2003). The use of this methodology provided the research team with a framework that followed a logical and thorough process for organizing the data. In the first step, qualitative data was recorded via Zoom Video Communications web conferencing software. Data was then transcribed from the recorded audio into a legible document, with all personally identifiable information (PII) removed. From the transcripts, the data was categorized into themes and subthemes, charted, and calculated in a manner that was transparent and traceable.

MAIN DATA COLLECTION AND ANALYSIS

Focus groups were chosen as part of the data collection research methods due to their inclusive nature, allowing for the participation of multiple stakeholders at a time. Oftentimes, new ideas will arise in a setting that allows for the natural flow of discussion and breakdown of logical flow of thought. Focus groups were geared toward the inclusion of higher-level personnel within a stakeholder category. It was believed that higher-level personnel may have more insight into the process of information extraction and use of VIRS based on their positions and previous experience. This resulted in two focus groups, and these ultimately became interviews when individuals within the group had to drop out at the last minute due to job responsibilities. The only difference in the methodology was that interviewees answered each question on their own as opposed to answering alongside one or more (up to four) other participants.

As noted previously, focus groups and interviews were conducted online via Zoom. Only the audio function of this software was used. The video capabilities of screenshare were used only to present the project PowerPoint; no video recordings of participants or facilitators were made. Audio was recorded using the Zoom software and a backup handheld digital recorder. Participants were only recorded after declaring their verbal consent to the Informed Consent document for participation (see [Appendix A](#)). The Zoom Software was free for all participants to download on their computers, tablets, or mobile devices. Each participant was informed beforehand about how to install, initiate, and navigate the software.

RECRUITING PROCESS, CHALLENGES, AND BARRIERS

Potential participants were identified based on their current knowledge of and/or involvement with the current VIN system, crash reporting and analysis, and/or ADAS/ADS technologies, and government agencies. Fields of expertise included law enforcement, insurance, driver and vehicle safety advocacy, and technology development and supply. Individuals with these backgrounds were targeted as they have the most experience in this area and are most likely to be impacted by changes to the existing VIN system. Organizations from which these individuals were recruited were prioritized based on their ongoing interest in and involvement with VTTI’s current and past projects.

Participants were recruited using telephone and email scripts (see [Appendix A](#)), all of which were approved by Virginia Tech’s Institutional Review Board. Aside from working in one of the desired areas, the primary criterion for focus group participant eligibility was whether they had access to a computer. There were no age, experience, or gender restrictions for participation. Participants could be excluded if a particular stakeholder type were already filled, though the situation did not arise. Once a participant was screened for eligibility using the appropriate screening form, they were sent a confirmation email with several attached documents, including an Informed Consent Form, a list of discussion reference guide questions to prime them for discussion, instructions for connecting via Zoom, and the date and time of their confirmed appointment ([Appendix A](#)).

Response times for agreeing to participate varied depending on the leadership structure of departments. Across all stakeholder types, participants often required approval or needed to consult with superiors or their legal department before agreeing to participate. Consequently, there was a large scheduling delay within the study timeframe and a loss of participants. The explanation of the discussion topics in the recruiting script was intentionally vague to protect the proprietary nature of the study. As a result, some organizations declined participation out of fear of confidentiality and how their opinions might reflect on their organization. The recruitment team addressed this by emphasizing the stakeholder feedback nature of the discussion and the

various transportation-related safety developments involved. Recruiting efforts were halted entirely in some instances when there were legal concerns about opinions disclosed on behalf of a company, or the federal government in particular. The research team attempted to overcome these concerns by emphasizing that this study was sponsored by the National Surface Transportation Safety Center for Excellence consortium for the purposes of research, and participant identity would be protected according to Institutional Review Board protocols.

The focus groups and interviews were divided by stakeholder type, and attempts were made to balance two representatives from each of the six stakeholder categories: federal government, state government, law enforcement, insurance, safety advocacy, and technology developers and suppliers. Each focus group was permitted to have up to six individuals per meeting; these could come from any of the six stakeholder types, with a maximum number of six groups for the entire study. Due to project time and budget constraints, OEMs were unable to participate. However, direct OEM suppliers (i.e., tier 1 suppliers) of technology and parts were included to try capture some of the industry perspective, although suppliers likely have different views than the OEMs themselves. As the burden to OEMs would likely be the highest if a new VIRS alternative were to be implemented, it is important to note how the data analysis results may have changed had this group been included. The OEM technology and suppliers group was then changed to technology developers and suppliers to reflect the lack of OEM representation in this group.

FOCUS GROUP PARTICIPANT SUMMARY

The research team conducted a total of 10 focus groups and 2 individual interviews of higher-level personnel (Table 3). Due to time constraints and scheduling coordination, the largest focus group comprised four individuals. The broadest range of stakeholders available within the time constraints were scheduled. A focus group of two individuals was considered complete and a meeting time was then scheduled. Further, due to the unpredictable nature of these individuals’ schedules, it was not possible to fill every focus group, resulting in two individual interviews. When other colleagues were unable to join the Zoom session within a 10-minute time window of their scheduled focus group, the team opted to interview participants one-on-one as opposed to rescheduling. This helped to avert the potential of losing participants who would be unavailable or unwilling to reschedule. The biggest difference in the methodology was that interviewees answered each question on their own as opposed to answering alongside one to five other participants.

Table 3. Focus group/interview participation summary.

Focus Group	Stakeholder Type	Number of Participants
1	Insurance	1
2	State Government	4
3	Law Enforcement	2
4	Insurance	2
5	State Government	3
6	Law Enforcement	2
7	Safety Advocacy	1
8	Technology Developers and Suppliers	2
9	Safety Advocacy	2
10	Federal Government	2
11	Technology Developers and Suppliers	3
12	Safety Advocacy	2

Table 3 shows the stakeholder type and number of participants within each focus group. The largest focus group was a group of four state government individuals. Due to the recruiting challenges outlined above, not all of these stakeholder groups were equally balanced. An extra safety advocacy group was substituted in place of the federal government group. As noted, the OEMs’ opinions of vehicles were not represented in this research. While technology developers and OEM suppliers were included, their opinions are not representative of a vehicle manufacturer’s opinion. It is important to note the absence of this stakeholder group’s opinion when interpreting the findings ([Chapter 5](#)).

DATA ORGANIZATION

After the focus group process was complete, researchers reviewed and became familiar with the data transcribed using the auto-transcribe feature in Zoom Cloud Recordings. This included cleaning the data of any PII and any minor editing necessary for spelling or incorrect transcription in preparing the data for analysis and consistency across transcripts.

GENERATION OF THEMES AND SUBTHEMES

The research team then further reviewed the transcripts to become familiar with key themes and subthemes. The team traced each theme and subtheme closely to the key focus group questions and follow-on question areas. The high-level themes for the opening activity consisted of the following data elements with the corresponding letter code; i.e., (a) = accessibility theme.

Accessibility (A)	Flexibility (F)	Feasibility (E)	Level of Burden (B)	Inclusivity (I)	Consistency (C)
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The high-level themes identified for all six VIRS alternatives are provided below.

Challenges (C)	System Needs (N)	Data Element (E)	Steps to Implementation (design, custodian, location, tools to read it) (S)	Points of Vulnerability (V)
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The high-level themes for the closing activity (below) had an extra layer involved that identified the related VIRS alternative option to the comment.

Future Next Steps (F)	Other Metrics (M)	Preference Reasoning (P)	Related Option (O)	18-Digit VIN (O)	Modified VIN (O)	Barcode (O)	Optical Chip (O)	EDR (O)	Participant Specified (O)
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Subthemes were then arranged in a logical order and color-coded within individual spreadsheets with their corresponding variable in parentheses.

4.5 DATA CODING

Responses were coded by theme and subtheme and grouped according to emerging patterns or categories (Figure 20 and Figure 21). They were tallied by number of separate participant mentions. The indexed comments were arranged into scenario-specific Microsoft Excel® workbooks, and individual spreadsheets (or thematic charts). These spreadsheets/thematic charts were then further sorted by subtheme (i.e., question or follow-up question) and secondary subthemes. Once sorted, the secondary subthemes and categorical responses were tallied and are reported in the subsequent chapters using descriptive statistics.

Stakeholder Type	Discussion Excerpts	Challenges (C)	System Needs (N)	Steps to Implementation Design, custodian, location, tools to read it (S)	Points of Vulnerability (V)	Total New Findings	Single digit not enough for information (C)	Not flexible enough for future technologies (C)
State Government	P1: Feasibility? I mean something was done before I imagined systems would...when you get into level of burden would be just the systems that feasibility is very straightforward. So probably feasibility...accessibility as well. I mean, it's a very straightforward accessible concept, you can go and see your VIN. So, arguably, the public could go and type it in and be like, hey, what does this mean, which would be useful for used cars, etc. But, yeah, my biggest concern would just be that the VIN stays with the vehicle for all time and OEM can update their car every other Tuesday. That's going to be a problem.		1	2		3		
State Government	P1: Speaking from law enforcement in the crash report all of our law enforcement use one crash report. We do collect VIN. It is free form. So they are not limited to 17-digits today. So it would just for us, really to be mainly a training effort across the state to make sure that they understand the importance of getting that data correctly entered into the system.			1		1		

Figure 20. Screenshot. Sample of binning column organization.

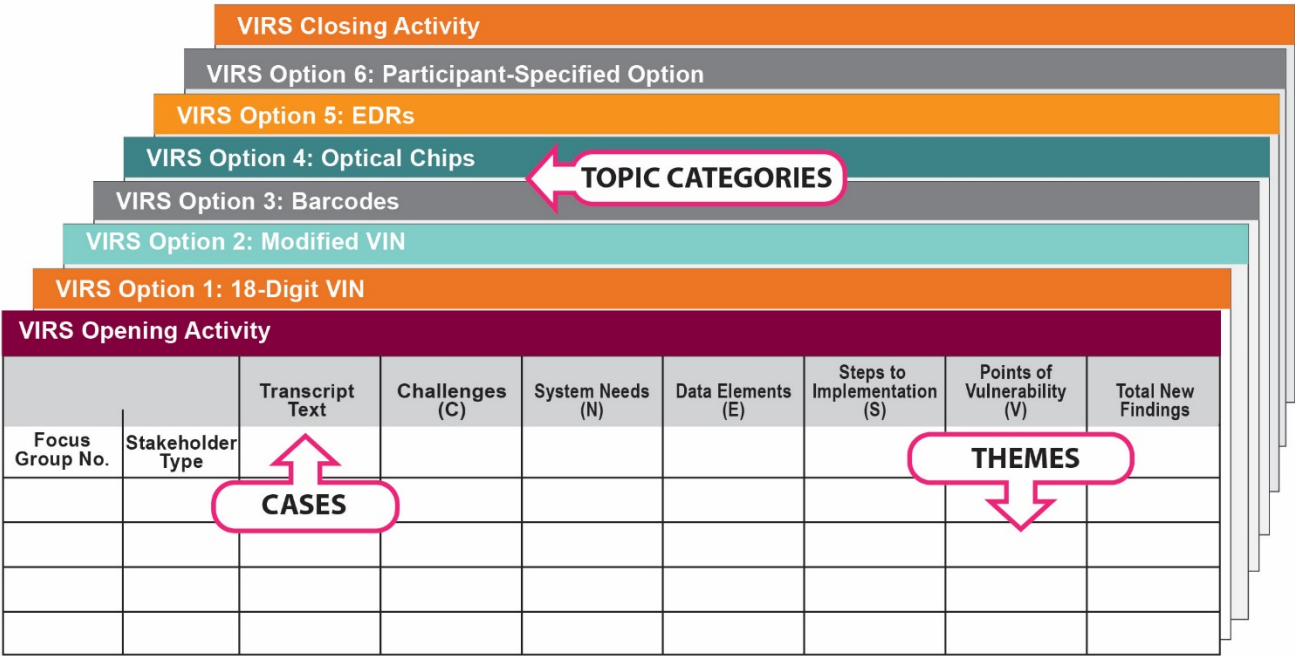


Figure 21. Illustration. Data analysis process (adapted from: Ritchie, Spencer, & O’Conner, 2003).

CHAPTER 5. INTERPRETATION OF FINDINGS INTO MEANINGFUL RESULTS

The team considered the findings from the thematic analysis with the SUS results to better understand the information provided. VIRS-related questions informed the stakeholder needs assessment discussion presented in this chapter and the following discussion summarizes the findings from the focus group and one-on-one interview analysis. First, a summary of the focus group and one-on-one interview participants is presented. Next, findings for each operational scenario will be reviewed with quotes to support statements and theories. Note that any word placed in all capital letters within a quote box is the substitution of a noun for PII. For example, a law enforcement officer may talk about their specific city. In this case the name of the specific city would be substituted with “LOCATION.”

The following sections provide an overview of the identified themes, needs, challenges, and steps to implementation associated with each VIRS evaluation activity. The responses detail how various stakeholders felt a VIRS may or may not best meet the need for a reporting system that is inclusive of an ADAS’s/ADS’s presence on a vehicle. Explanatory reasoning behind each of these selections can be found in their respective sections. The questions posed to participants are detailed in the Focus Group Structure section. Follow-up questions were administered as needed to gain clarity and insight into why a participant may have chosen their answer or how they might react differently if a different design or flow of information were in place.

If a comment about another VIRS alternative was made outside of the discussion for that specific alternative, the comment was placed into the other category, instead of the category under discussion. For example, while talking about EDRs, a participant may have reflected back about how a barcode met a data element better. In this case, their transcribed comment was captured within the barcode category, not the EDR category, unless it drew a distinct comparison or mention of EDR. Occasionally, a participant would respond with a rhetorical question such as “How would we account for software updates to an ADS level?” In this example, the response would be coded as “Needs to include software updates.”

Note: participant excerpts have been lightly edited for clarity and readability.

Table 4. VIRS alternative SUS score results.

VIRS Alternative	Overall Average SUS Score
18-Digit VIN	49.44454167
Optical Chips	49.27091667
EDRs	46.20354167
Modified VIN	44.37083333
Participant-Specified	42.98955
Barcodes	41.41920833

The closing activity indicated the following preference of VIRS alternatives in this order:

1. Participant-specified
2. 18-digit VIN
3. Modified VIN
4. Barcodes
5. EDRs
6. Optical chips

While the ranking results appeared to contradict the SUS score results above in Table 4, this difference can be attributed to the fact that the preference score rankings and the SUS score rankings were measuring two different variables: preference vs. real-world usability. Preferential ratings, alongside the transcription excerpts in each VIRS alternative’s respective section below, revealed the reasoning behind participants’ selections. While many participants preferred the idea of a certain VIRS conceptually or aesthetically, they were uncertain about its usability either due to lack of experience or knowledge with the VIRS, or had concern about other industries, such as OEMs and law enforcement. [Chapter 6](#) will provide a more detailed summary of crosscutting themes and conclusions.

The following acronym key in Figure 22 should be used to analyze the tables for the following VIRS alternative sections.

Technology Developers and Suppliers Key for Stakeholder Types	
FG	Federal Government
SG	State Government
TDS	Technology Developers and Suppliers
IN	Insurance
LE	Law Enforcement
SA	Safety Advocacy

Figure 22. Screen capture. Subthemes acronym key.

OPENING ACTIVITY

Overall, the poll results from the opening activity revealed that the data element of *consistency* was a priority across all stakeholder groups. As this information transcends a variety of industries, it was evident to stakeholders that a consistent, trans-disciplinary system must be in place. *Accessibility* was the second most preferred data element, and *feasibility* was the third. As most organizations confirmed that the flow of information begins with law enforcement recording VIRS information on crash reporting forms, accessibility for these individuals, in particular, was highly regarded.

Table 5. Top opening activity subthemes.

Opening Activity	Total	FG	SG	TDS	IN	LE	SA
Unusable if Information not Consistent (C)	13	1	4	3	2	0	3
Information/Training Needed to Access (A)	6	0	0	1	0	2	3
Important for Industry Research/Data (A)	5	0	0	2	1	0	2

The top three subthemes by stakeholder type are shown above in Table 5. A more detailed list of the top themes for this section can be found in [Appendix B](#).

The participant excerpts below capture some of the reasoning behind these selections.

Honestly, if it's not consistent, I don't know how we in our industry could use it for any type of intelligence data-gathering.

– Insurance

For vehicle services, the consistency in data for title and registration is very important. You know, and just little anomalies created a lot of headache when it comes to title and registrations, so . . . consistent data is key.

– State Government

The accessibility is about what is the purpose of these . . . and that it's not for research, per se, in my mind. It's for allowing first responders access to relevant information. So accessibility is critical right now. As you all know, there is no standard. There's no ability for anybody to take much of the encoded data from the systems in any shape, form or manner and that's got to change.

– Safety Advocacy

PARTICIPANT-SPECIFIED OPTION

The participant-specified option VIRS alternative was rated as the most preferred among all participant focus groups. However, the participant-specified option is only representative of the fact that it was a participant’s “idealistic” system, as it varied from group to group. More details below explain how qualities among all of these different group options can provide insight into

stakeholder needs and potential combinations. The top subthemes for the participant-specified VIRS option are shown in Table 6. Focus group 5 (state government) and focus group 7 (safety advocacy) chose not to analyze an additional participant-specified option. Thus, the data in Table 6 is only representative of 10 of the 12 groups that chose to participate.

Table 6. Top participant-specified option subthemes.

Participant-Specified	Total	FG	SG	TDS	IN	LE	SA
Urgency for VIRS technology now (C)	8	0	8	0	0	0	0
Simple VIRS for reporting combined with complex VIRS for technology capability (N)	7	1	0	3	0	2	1
VIRS is a good supplement with other VIRS (S)	5	2	0	0	1	1	1
Current regulation hinders easy access to VIRS (C)	4	0	0	3	0	0	1
VIRS that links back to a live-updated database (N)	4	0	0	1	2	0	1
Easily accessible (E)	4	2	0	0	1	1	1
Strong visual indicator (S)	4	0	1	0	0	2	1
Concerns with privacy (V)	4	0	0	2	0	1	1

Many participants expressed the urgency for a VIRS today, and thus were supportive of options that were already in place/already exist or that could be easily implemented.

I'm going with the EDR and the barcode. The EDR I'm going with because it's something that we use. We already have . . . experts out in the field that know how to use that and you get into your barcode, but you still have to look at . . . how do you get it, how do you pay for it, what all can you do, what's the ease of doing it, how much trainings involved with it. There's just unfortunately a lot of different questions, which I'm sure from the different industries that you've talked to, have probably come up with.

– Law Enforcement

The excerpt above correlates closely with the second top subtheme in that it emphasizes maximizing reporting information through the combination of a simple VIRS with a more complex one. Others suggested the combination as supplemental information, as illustrated by the several participant comment excerpts below.

I think you have to . . . 1) find the easiest accessibility and then 2) [combine] the technology piece, so that being either the EDR or the chip, whichever one is going to be the best. So to me, you kind of have almost, it's almost like saying, old school and new school is now being combined. I need the old school because I need it easy. And you're training someone down to the dumbest or lowest level. Which is, I can read a code and I can see that letter or number and I can say okay this is automated to your higher end or your technology piece. Which is going to be your chips or your EDR . So I think you got to have the combination of those two pieces.

– Law Enforcement

Personally, if we're talking about the option of the EDR in conjunction with VIN within an additional 18th digit, I think these are really complementary improvements that could each move forward independently of one another. I think encoding the automation status in the EDR in my opinion should have been done yesterday. There's no reason that needs to wait while we explore how to encode other information in a modified VIN as well.

– Safety Advocacy

I guess I would amend my comment to say the additional digits in the VIN and the EDR. The VIN would indicate what equipment is actually on that vehicle, but the EDR adds the other layer of what actually activated with a crash, potentially, so those two things in combination are the things that my industry looks at the most.

–Technology Developers and Suppliers

Others were highly supportive of a strong visual indicator as another subtheme. A state government participant commented on this directly:

I sort of liked the idea of the VIN with the code because the code gives you that ability to update, but the VIN is a visual. I mean, if you knew it was the fourth digit, you could visually check that pretty fast. Does this vehicle have the potential for level 5 or not. I mean . . . there's something visually about that VIN number that you could get some information pretty quickly.

– State Government

Other subthemes were raised regarding accessibility, linkage to a database, concerns with privacy, and regulation hindering access. These echoed many of the concerns in previous comments and were unique to each group’s combination. Unique combinations of new VIRS alternatives are discussed further in [Chapter 6](#).

18-DIGIT VIN

An 18-Digit VIN was the second most preferred out of the six VIRS alternatives among all participant focus groups. The top 10 subthemes are summarized in Table 7. A more detailed breakdown of stakeholder feedback subthemes for the 18-digit VIN questions can be found in [Appendix B: Stakeholder Feedback Data of VIRS Options](#).

Table 7. Top 18-digit VIRS subthemes.

18-Digit VIN	Total	FG	SG	TDS	IN	LE	SA
Single digit not enough for information (C)	21	1	1	3	7	3	6
Level of burden high (E)	18	0	7	0	5	5	1
Modifications to government agency databases (S)	13	0	2	0	0	9	2
Need consistent or standardized ADAS/ADS information (S)	13	1	0	5	3	2	2
Aftermarket installs should be captured (N)	10	3	1	0	2	0	4
Needs more information than just ADAS/ADS (N)	10	2	0	0	1	0	7
Appears feasible (E)	10	0	1	2	3	1	3
Level of burden low (E)	9	0	0	3	4	1	1
Easily accessible (E)	9	0	1	1	1	4	2
Modification to crash reporting forms (S)	8	0	0	1	0	6	1

The greatest advantage to this technology is its familiarity of structure (most feasible, somewhat low level of burden) and strong visual indicator (for law enforcement). The greatest concern of this technology is dynamic flexibility for future technology. Many participants posed the question: Is one digit enough? Some were more comfortable with the potential for a 19-digit VIN. Others ended up on the other end of the spectrum, expressing concern that the more digits are allowed for expansion, the more convoluted the data becomes. Some went so far as to say that if one additional digit is allowed, then the amount of numbers within a VIN will never stop expanding.

Again, the thing I struggled with the most in this whole conversation is a combination of options in one vehicle and how one digit can actually decode that.

– State Government

Okay, I guess I was wondering if an 18th digit is enough. Just one digit, even if it is alphanumeric to cover all the complexities that could be anticipated with ADAS and ADS technology.

– Federal Government

The data shows some conflicting opinions around whether the burden of modifying the VIN would be high or low. The risk of continual expansion of the VIN number resulted in concerns around a higher level of renewed burden to any stakeholder requiring modification of their database systems, tools, or hardware. Alternatively, others argued it would be a lower level of burden than starting with a completely new VIRS alternative altogether. This opinion regarding

level of burden may also vary by industry, as law enforcement deals with data differently than an insurance or safety advocacy group. Following is a sampling of excerpts that speak to this variety of opinions.

...And I think you would probably see that throughout the United States that 17 digits has been standard for so long that . . . paperwork and computer systems are based primarily on that just because it hasn't changed for so long . . . that would be the biggest hurdle for the states to overcome....

– Law Enforcement

.... I was going say it would be in a form that those individuals would be used to working with. An understanding. So it wouldn't be a new system for them to learn.

– Safety Advocacy

At the field level it wouldn't be a problem for us to collect any information because it's a matter of the officer working the crash and adding an extra number to his report or whatever. The problem is going to come in when you start getting into the computer system, you know, the trench system. Seventeen characters and then any other systems that we have to go through for DMV, we are running into the problem that the other [participant] just spoke about. But field level wouldn't be that much of a problem, collecting that extra information and then knowing that is the automated vehicle system.

– Law Enforcement

Throughout other VIRS alternatives and in the closing comments, participants revisited a primary strength of the 18-Digit VIN system—it is an easy visual indicator.

Yeah, I mean, if it was just to let me know, and I'm just throwing this out, if it was the letter A, at the very end for automated. I mean, that would be very simple for someone to be able to look at and be able to know that this thing had an automated driving feature to it that we need to consider now for our investigation.

– Law Enforcement

Because it is a familiar system [as] you noted prior to all this, with regards to local law enforcement, saying, "Oh, well, we'd be able to immediately tell the difference between a 17 digit number and 18 digit number," that I think has a pretty powerful stance with regards to being recognizable and not needing a lot of explanation.

– Safety Advocacy

Aftermarket installations and optional technologies were a large concern with the static structure of a VIN number, but the inclusion of this type of information was paramount across all six alternatives. No suggestions were made as to how this information might be included. However, it was recognized as a need, as multiple participants expressed the problem of the reporting and presence of ADAS/ADS technology not following the lifecycle of the vehicle through several owners. As ADAS/ADS updates become more software-based, participants within safety advocacy believe this to be an escalating issue, as illustrated by the excerpts below.

...this might be wrong but it's my understanding, that all OEM vehicle makes and models, leave the factory with all the hardware and software needed for their, quote unquote autopilot system installed on the vehicle. The technology is either activated or not activated at the point of sale depending whether the purchaser chooses to be for it or not. And going forward as a lot of these systems will likely be more software-based where all the vehicles have the requisite hardware, that is likely to become a bigger issue. So personally, I have some doubt that fiddling with the VIN will be able to help us with [the] elephant in the room, so to speak.

– Safety Advocacy

The parts that it doesn't get to would be any aftermarket installs. So if someone did a forward collision [system] after-market, we won't see that... and so that's a gap. And it's hard to modify, it's impossible to modify a VIN after the fact, so even if you required after-market installers to somehow codify that, you're not going to see that with the VIN.

– Insurance

MODIFIED VIN

Modified VIN was the third most preferred VIRS alternative among all participant focus groups. The top subthemes for modified VIN are shown in Table 8.

Table 8. Top modified VIN VIRS subthemes.

Modified VIN	Total	FG	SG	TDS	IN	LE	SA
Trouble differentiating old VIN from new VIN (C)	10	1	0	3	0	0	6
Not flexible enough for future technologies (C)	10	5	2	3	0	0	0
Training needed to use (S)	10	0	0	2	0	4	4
Strong visual indicator (S)	9	0	0	7	0	2	0
Level of burden low (E)	8	0	2	3	1	1	1
Inflexible/flawed data storage systems (C)	7	2	0	4	0	1	0
Level of burden high (E)	7	1	2	1	0	2	1
Aftermarket installs should be captured (N)	6	2	0	4	0	0	0
Unable to speculate (C)	6	0	1	4	0	0	1
Not easily accessible by first responders (E)	6	0	0	4	0	1	1
Prefers modification to be 4th-8th digits (S)	6	0	2	0	1	3	0

The primary concern for this VIRS, particularly for the safety advocacy stakeholder group, was the ability to distinguish between an old VIN standard and a new VIN standard when information is recoded. This correlated closely with the theme “training needed to use,” as a new VIN decoding scheme would have to be issued to avoid the other concern of “inflexible/flawed data storage systems.” Furthermore, the recoding of information may have to occur multiple times in the future to accommodate future technologies, which stakeholders felt was not ideal or feasible in terms of the rulemaking process.

Others disagreed with the above concerns and were in favor of the modified VIN over the development of a whole new system. The desire for a familiar, existing system was valued for posing a low level of burden to stakeholders. One participant had previous experience with the change process of the VIN standard shifting from 13 digits to 17 digits. While this participant did not recall the exact repercussions of this change, they expressed that it had been done before and thus appeared feasible.

A participant from law enforcement stated that those who have been in the field long enough know the VIN structure well—to the point that they can quickly predict some initial vehicle information from the VIN. This participant brought up the point that if the existing VIN structure were to be modified, they would be able to quickly identify visually if a position had changed (e.g., if VIN position X was changed from numeric characters only to alphabetic characters). Others felt the VIN system could get muddled with old meanings and new meanings and could result in increased inaccuracy across a variety of stakeholders. There were questions surrounding how a stakeholder would know whether the VIN was the old-style versus the new style that reports the presence of ADAS/ADS.

Stakeholders were probed to discuss whether or not they thought the modification could occur within the 4th-8th digits, or if there was a better location within the VIN for encoding information about ADAS/ADS. Among those who agreed, the 4th-8th digits were viewed as the prime area because these are the digits concerned with vehicle descriptors and attributes. An OEM supplier participant also suggested the plant location digit may be a good location to modify due to its minimal usage today.

A more detailed breakdown of stakeholder feedback subthemes for the Modified VIN questions is in [Appendix B: Stakeholder Feedback Data of VIRS Options](#).

BARCODES

The barcode VIRS alternative was the fourth most preferred VIRS alternative among all participant focus groups. The top subthemes for the barcode VIRS are shown in Table 9.

Table 9. Top barcode VIRS subthemes.

Barcodes	Total	FG	SG	TDS	IN	LE	SA
Needs to be connected to VIN somehow (N)	12	2	2	1	2	0	5
Flexible (E)	9	1	1	0	2	3	2
Use smart phone as tool to read it (S)	8	1	2	2	0	2	1
Tools expensive/not available (S)	8	0	0	1	1	1	5
VIRS that links back to a live-updated database (N)	7	2	2	0	0	0	3
Aftermarket installs should be captured (N)	7	1	1	3	1	0	0
Jurisdictional budgets restrict issuing tools to officers (C)	6	0	0	0	0	3	3
Inflexible/flawed data storage systems (C)	6	1	0	4	0	0	1
Multiple locations of barcode similar to VIN (N)	6	1	0	3	0	2	0
VIRS ability to update frequently (N)	6	2	2	0	0	0	2
Easily accessible (E)	6	2	1	2	0	0	1

The most common response in regard to how a barcode could be designed was its need to relate to the VIN. While participants were told that this barcode would be separate from the one currently located on many of the VIN plates, they still expressed the need for connection for the most holistic view of data. This could potentially take the form of just modifying what the current barcode connects to and forming a barcode-linked VIRS system that would report the presence of ADAS/ADS.

The greatest advantage expressed by focus groups was the barcode’s ability to encode the most information in an external database, as seen by the flexible theme in Table 9. Stakeholders preferred the flexibility of a database that could evolve and change with developing ADAS/ADS technologies. Furthermore, participants from federal and state governments and safety advocacy expressed the need for live updates—meaning there would need to be an active custodian of this database. Two participants from safety advocacy and state government suggested that state departments of transportations would be the best custodian for this live-updated database. Similar comments suggested tying the VIN data to the database used by DMVs for vehicle registration. Others within the technology developers and suppliers industry suggested that OEMs may be the best custodians in regard to ADAS, as manufacturer software updates may occur, and information would be updated more quickly than if the OEM had to report the changes to a state entity (though states defer to the FMVSS for the certification of vehicles and their components). Without a consistent custodian to perform the live updates, participants expressed concern that the data would be invalid, hence the “inflexible/flawed data storage systems” theme.

The following summarizes this idea for many of the responses.

... I would add one thing to NAME's point. I think barcodes can hold a tremendous amount of information...especially [depending] on the type you use. Which is fantastic. The downside in that same timeframe that I ran into is that people realize it can hold a whole lot of information, so the standard changes so much more quickly. If you limit what can actually be captured or recorded there, those little technology leaps tend to happen less frequently and only when they're absolutely necessary.

–Technology Developers and Suppliers

Honestly, I think it gives you maximum flexibility. I think it also attacks aftermarket [issues] because a new barcode can be generated for any additional add-ons. So, I think there's some value there....

– Insurance

Federal government stakeholders, technology developers and supplier companies, and law enforcement spoke on concerns surrounding design, location, and crash survivability. If a barcode were to be in the same location as the tire pressure label, and the door jamb was crushed within a crash, law enforcement may not be able to scan the barcode. Several stakeholders suggested the repeatability of a barcode in multiple locations on the vehicle, just as the VIN is stamped in multiple locations on a vehicle, to mitigate this potential vulnerability.

The greatest concern regarding this technology was having the appropriate tools to read it. Participants within insurance, safety advocacy, and technology developers and suppliers were most supportive of this VIRS because of its easy access. Most mobile devices today are equipped with barcode scanners, and thus a new tool may not need to be issued. However, both law enforcement stakeholder groups confirmed that a mobile device was not an ideal tool for two reasons. The first is that the use of a personal device in a crash reporting situation would put an officer in a position of having their personal device confiscated as evidence. A method to avoid this would be to use a jurisdictionally issued smartphone device. However, this limits accessibility of tools, as many jurisdictional budgets do not include smartphone issuances to their officers.

Following is a participant excerpt that illustrates the above concerns.

So I think that would be the easier way to go, to create an app, download it to your phone, just like any other police app, and utilize [it] as a tool in the toolbox versus actually giving [police] a handheld device that was scanned because, one, you don't have to [worry about] break[ing it], who to return it to, so on and so forth. And the cell phones are already in the hands of these officers. Now I don't know about local jurisdictions though, [phone] insurance, officers, and counties. When you run into that problem of them having smartphones for every officer.

– Law Enforcement

EDRs

EDRs were rated as the fifth most preferred VIRS alternative among all participant focus groups. The top subthemes for the EDR VIRS are shown in Table 10.

Table 10. Top EDR VIRS subthemes.

EDRs	Total	FG	SG	TDS	IN	LE	SA
Good for post-crash analysis not crash response (C)	15	1	6	3	1	1	3
Not easily accessible by first responders (E)	15	2	1	2	1	5	4
Needs more information than just ADAS/ADS (N)	14	4	1	1	5	1	2
EDR is a good supplement with other VIRS (S)	11	1	0	3	0	3	4
Current regulation hinders easy access to EDRs (C)	9	0	0	1	3	3	2
Need to know if human or ADS driving (N)	7	3	0	1	2	1	0
How many crashes it avoided (not just crashes that occurred) (N)	7	3	0	1	3	0	0
Tools expensive/not available (S)	7	1	0	1	1	2	2
Training needed to use (S)	7	1	0	2	0	3	1
Appears feasible (E)	5	1	0	0	1	2	1
Level of burden high (E)	5	0	1	2	0	2	0
Location/design relates to crash survivability (S)	5	1	0	0	1	3	0
Rulemaking needed/involved (S)	5	1	0	3	0	0	1
OEMs as custodian (S)	5	2	0	2	0	1	0

While many stakeholders from different backgrounds were familiar with EDRs and the legal process and restrictions to accessing them, they had trouble envisioning how the flow of information may occur. In the federal regulations, NHTSA considers the owner of the vehicle to be the owner of the data within an EDR. Thus, in order to download information from an EDR, NHTSA must request permission, or data access can be mandated through court order subpoenas, or state laws governing crash investigations (Event Data Recorders, 49 C.F.R. § 563). The process today involves accessing the EDR physically through the console, which several

stakeholders recognized would make it difficult for law enforcement to quickly report the presence of an ADAS/ADS. This complex process is why many stakeholders saw the EDR as providing good information for crash reconstruction or safety research but noted there was a need for something more simple and easily retrievable, such as a VIN or barcode. Hence the top five subthemes.

I personally think it would be a great data collection point for the system itself but knowing how cumbersome it is to access EDRs, and depending on where they are, because again, each make and manufacturer is different. The locations are just all over the passenger compartment. How accessible is it going to be for me to get to the EDR to get to that data? So if it was standalone data in the EDR, it's no different than what I'm going through now. So . . . I like it for the collection point but it's got to have a joint system with it somewhere else so that is more easily accessible to know whether it was automated or not.

– Law Enforcement

So this would, in my opinion, give us a superior level of detail on the much smaller subset of crashes in which first responders or others obtain the data from the vehicle's EDR. In a routine crash investigation that does not happen for obvious reasons. So, I mean, big picture. I think this probably would result in getting no more information than we get presently from the 17-digit VIN from about 95% of the vehicles involved in crashes or thereabouts. But with the benefit being that we get vastly superior information for a small subset of the vehicles that are involved in the most serious crashes. Which, incidentally, are the crashes we care the most about and need to learn the most about. So I mean it's not a straightforward trade-off. It has cons that are big, but it also has pros that are also big.

– Safety Advocacy

A participant from the insurance industry had concerns around the complexity of EDRs as a VIRS alternative:

My observations on this front are that, I agree that if we're to assess these technologies we . . . need to know which vehicles are fitted with these systems. Actually, it's three things we need to know: which vehicles are fitted with what technologies, we need to know when these technologies are active, and then we need to know much more about the crashes that occur. But I think an initiative such as this should focus on accomplishing one of those things. If we were to attempt to take on all of those things, the likelihood of success probably diminishes.

– Insurance

An EDR would only report the engagement of a feature that a vehicle actually had, and thus it would report the presence of an ADAS/ADS feature. However, a challenge that was identified within the literature review, and that was often discussed among participants, is that an EDR would not report all features if it only reports those that were engaged, and those that were engaged at the time of a crash. Not knowing whether or not these features were engaged could be valuable missing data. Insurance stakeholders brought up the interesting point that while EDRs provide valuable information within a crash window, they would fail to record how many crashes the ADAS/ADS feature helped to avoid. This information is equally as important in capturing the safety efficacy of these technologies, and thus an ideal VIRS alternative would include this type of information.

I guess the EDR, seems like it would be very focused on crash investigations and not necessarily focused on non-crash events. So ideally, these ADAS and advanced driving systems would prevent crashes. So if you only get information about when a system is equipped or active when it crashes it seems like you might be missing a bunch of times where it was equipped, inactive, and avoided a crash. I guess you know there's ways to artistically to look at that, you see that maybe a car is no longer represented in a certain type of crash. But if it's going back to NAME's earlier comment, if it's optional equipment and for all those ones that aren't involved in crashes, you don't know whether it was truly equipped or active, it may be hard to...I like the idea of knowing when it's active.

– Federal Government

I certainly see other people needing it, it's almost unrelated to crash data. As an insurer, I would love to extract to find out how much...how many...close events the technology helped avoid. I don't want to trigger just for an event, I'd like to know how many times this system came into effect, and there was no event.

– Insurance

It seems like this has a very similar downfall to the chip option, which is that these are meant to be triggered solely for crash, which means that all of the data and planning purposes aren't accessible unless you crash and it's successfully removed and then recorded. And that seems to not be sufficient to what my industry needs out of a system that's recording, or trying to track, ADS and ADAS uses.

– State Government

The insight that law enforcement provided into the process of extracting data from EDRs confirmed the research team's initial findings that a court subpoena or state law would be needed to access the information and that EDRs are often difficult to get to depending on the crash situation. A law enforcement officer's ability to back-power a vehicle or get to the vehicle's EDR is of high concern, as shown in the excerpts below.

Those EDR boxes are in the . . . worst places of the vehicle because if you've got to get the module itself and you're not able to go through the DLC [data link connector], which is just basically plugged into the dash, hook a computer up and do it that way, that's the ideal way. Most of the time when we have a vehicle it's going to be smashed to pieces and we're not going to be able to access it that way. So that means you have to go through the car to get the module itself. Sometimes you have to call the fire department out. Sometimes call the tow driver service out. You have to cut out metal, cut down the plastic... I did two or three within the last two weeks and one took me two and a half hours to get to, because the vehicle was smashed up so bad and the fire department has so much trouble using even their equipment to cut through metal to get to it. And then once we get to it, how badly is it crumpled up? Even though the module itself will be there . . .there may be metal or stuff that's bent around it. And then you have to try to work your way around that and get it all. Once you get that module out, then you can hook it up and do everything to it. So the accessibility sometimes can be very time consuming. . . . [I]n some cases, you [are] not able to get the logistics that you need . . . to get into the vehicle to get the information. So, the search warrant might be easy, but actually getting your hands on [the EDR] may be the hard part.

– Law Enforcement

Or [it might be] just really, really time-consuming to get down to that module. You know, you have a vehicle and you're able to still have power to it and [responders] didn't cut the wires [so] you can go out to the scene and through the course of your investigation plug into the DLC and use your user equipment to get that. Now . . . [let's say] my crash team has one EDR That EDR equipment is based out of LOCATION. So if I have a crash in LOCATION, I'm not going to have that EDR readily available to me that night. So that means that vehicle's going to have to be towed to a tow yard and then once it leaves the scene we go into search and seizure. So we got to get deeper permission from the elder [officer in command] or get a search warrant, or go back to that jurisdiction where it was towed to conduct that search warrant. So you run into a lot of other problems, not just the module, but a lot of outside things, just trying to get . . . that information.

– Law Enforcement

New information from a law enforcement stakeholder revealed that accessing the EDR requires a manufacturer-specific cable, which may vary by year and model, and may not be available within that jurisdiction. One jurisdiction often must borrow a proprietary cable from another jurisdiction, causing a greater delay in extracting the necessary information.

And then one other thing I'm going to touch on, you have the OEM system, the OEM system makes up 65 percent of the vehicles, I'm just estimating here. And then you have the OEM system, which is a whole different setup, and then you have the OEM system which are different kits. So—by different manufacturers. OEM has their own kit. You need to have those kits, but then you also need to have the cables for those kits. So, you may have cables that you bought for 2007 to 2017

then you got buy kits for 2018 OEMs. Do you have those cables? Is your organization getting the money to buy those cables and to keep you updated for the technology? There's just a lot of things you're going to run into with EDRs.

– Law Enforcement

Technology developers and suppliers brought up a unique speculation around privacy concerns in using EDRs as a VIRS alternative. As explained above, the owner of the data is considered the owner of the vehicle. This stakeholder concern is illustrated by the following:

I mean clearly having the data afterwards will probably help you....would be very useful for crash reconstruction and so forth. But then...once again...who owns that data, and who has access to the data after the crash? If I'm in a crash and it shows that I'm at fault, is it my data? Or will the insurance company use that data against me? So I guess it kind of... thinking about it more kind of comes back to that privacy concern that some people may have [about], you know, Big Brother's watching me, what I'm doing, and once again, it's kind of a balance there between privacy and, you know, if it's being useful data to progress research. But if it's misused, what're the implications of that?

– Technology Developers and Suppliers

In general, participants valued the information that the EDR could provide, but preferred a more dynamic VIRS alternative in terms of recorded information, one that was easier to access, and that connected to something more simplified for crash reporting in the immediate situation. EDRs combined with a simplified option, such as a VIN or a barcode, was a common suggestion in the participant-specified option.

OPTICAL CHIPS

Optical chips were the least preferred VIRS alternative among all participant focus groups. The top subthemes for the optical chip VIRS are shown in Table 11.

Table 11. Top optical chip VIRS subthemes.

Optical Chips	Total	FG	SG	TDS	IN	LE	SA
Unable to speculate (C)	11	1	2	2	1	4	1
Strong inclusivity (E)	11	1	2	2	1	2	3
Data extraction protocols needed (N)	10	0	0	5	2	2	1
Not easily accessible by first responders (E)	10	1	3	0	2	2	2
Location/design relates to crash survivability (S)	9	2	1	1	1	3	1
Can extract data wirelessly if in proximity of vehicle (S)	8	1	3	2	1	0	1
Flexible (E)	7	0	1	0	3	1	2
Not a priority for first responders (S)	7	1	4	0	1	1	0
Do not support this VIRS for industry (S)	7	0	1	0	0	0	6
OEMs as custodian (S)	7	1	2	0	2	0	2
Concerns with privacy (V)	7	0	0	4	1	1	1
Information could be hacked by criminals (V)	7	0	0	3	1	2	1
Tools expensive/not available (S)	6	0	3	1	0	1	1

Most of the responses indicated that it was difficult to speculate on the technology itself and how the flow of information would work. Many stakeholders found optical chips to be a new technology concept. Their limited exposure to this technology meant that they were unable to speak to their use with much detail, which explains why the top subtheme in the table above is “unable to speculate.”

Um, I don't know, I've never encountered this technology before, or at least not that I'm aware of. Maybe I use it every day. But I didn't know I did. I guess my maybe my lack of understanding is limiting my ability to form an opinion.

– Technology Developers and Suppliers

Many noted, however, that an optical chip has a high capacity for information storage and thus could be inclusive and flexible enough in the near future for new ADAS/ADS technology developments. Others suggested that this information could be kept in an OEM database accessible to those extracting the chip, which would account for any software updates or changes to features. A few excerpts to illustrate these three subthemes are shown below:

Yeah, it seems, with regards to like inclusivity, kind of rises to the top, just from the ability of how much data it can capture based on the vehicle. Obviously maybe too like flexibility, like if it needs to be updated or there's additional information that could come from the OEM if it is something kind of like OnStar where you could access it in real time. That flexibility of being able to have kind of multiple options for reading it might also [be a reason to] keep it.

– Safety Advocacy

But again, I think on like what would need to happen for them to be implemented those same issues that the barcode brought up. Kind of with who would be reading it and how would they read it and probably the training that would have to go along with knowing what additional features and information this could provide in addition to VIN would need to take place. And there would need to be consistency across the board for it to be effective.

– Safety Advocacy

I mean you have a lot of flexibility to encode a lot of information into any kind of computer chip so it can hold a wealth of information. It could hold things like dates of install, it could probably be dynamically modified within the vehicle to say whether something is being used and when, so these chips can hold a lot of information.

– Insurance

...So you can get into a technology like this, you know, is that a by specific thing for each manufacturer. And you talking about financial cost, of course could be pretty great, or a lot of agencies could not afford to do that.

– Law Enforcement

If this was designed in such a way that it was connected to the system and would know when you had some sort of additional coding into it, and you know, I guess, it seems like there's probably a lot of work to be able to define that, but if you did have some sort of a software update that gave you enhanced capabilities. If it was somehow tied into the system, then there could be an advantage to have more flexibility in changing vehicle capabilities over time.

– Federal Government

As explained in [Chapter 3](#), optical chips were presented as being accessible in two ways. The primary access method would be for law enforcement to extract information remotely/wirelessly if in close proximity to the vehicle. The second access method serves as a back-up strategy, wherein an optical chip could be physically extracted then inserted into a computer to access the data. If the crash or emergency situation does not allow for a vehicle to turn on, or to be back-powered, physical extraction would be necessary. Participants were very concerned about the feasibility and amount of effort required for the physical access method, which may be required frequently depending on the nature and severity of the crash. The quotes below express participants’ opinions regarding physical extraction of the chip.

Yeah, that defeats all usability for the ORGANIZATION. The planning data we need for that, that would decrease dramatically...if we have to remove the chip then [we have to hope] that you're not in a bad enough crash that you can't get to said chip.

– State Government

So standardization of this type of technology from my point of view would be crucial. Talking about the different ways we might get information currently off a passenger vehicle or a commercial motor vehicle. One, the equipment to do that is incredibly expensive. Two, it requires power to the vehicle. Three, as you mentioned, that something that might be able to be extracted physically much like

an airbag module or an [engine control module]. Those create unique difficulties. One, the positioning of it, two you have to have the tools and equipment to be able to get to it and remove it. And then three, you have evidence and custody and storage issues. So, I mean, I really like this idea, but equating it to things I'm familiar with now, where we try to get that information, it's desperately hard to keep up with the ways to get at that information roadside.

– Technology Developers and Suppliers

The quotes above help explain the next three top subthemes: data extraction protocols needed, lack of accessibility by first responders, and location/design related to crash survivability. Several participants agreed that trying to physically extract an optical chip in difficult weather conditions may not be a priority for first responders. Additionally, there is a risk of the chip being dropped, lost, or damaged, which would result in total loss of information. Another concern pertains to the wireless tools required to access the chip, which brings up the same concerns as barcodes in terms of requiring use of a cell phone or expensive wireless device, which might not be possible for all jurisdictions due to budget constraints.

And I'm just wondering, would this be something that would require somebody with a little more technical expertise, if you will, to be able to safely remove for the purpose of downloading if you were unable, because you just never know what you're going to get out of a crash? How much trauma, if you will, the vehicle is going to actually suffer.

– Law Enforcement

I guess we've had good luck with systems that are equipped with EDRs in the sense that they're kind of central to the vehicle. But there have been circumstances where there's been significant heat damage. And in aviation, we see a lot of problems where, you know, the forces are much higher. And sometimes the temperature can be higher for a longer period, especially if they're crashing in remote locations where there isn't emergency response there quickly. So I don't know how much of a problem that would be, but there are times where we have crash damage to commercial vehicles and can't extract data because of fire or because of the crash forces. So survivability may be a component, survivability may be a factor.

– Federal Government

Furthermore, if an optical chip has the ability to be physically extracted, and there is no rulemaking in place restricting access, bad actors may be able to extract chip information easily. A participant from the technology developers and suppliers stakeholder group also expressed concern about cyber-attack vulnerabilities due to the optical chip’s ability to wirelessly transmit data.

...I think there's points of vulnerability. I think any computer chip can be theoretically subject to some sort of cyber-attack.

– Insurance

How do you manage the accessibility and level of burden of making sure that only the right people can get to it. For sure, like the VIN code in the windscreen anyone can go up and read but here like you could... imagine if someone's able to hack this they can just drive around and collect information about all cars in the streets.

– Technology Developers and Suppliers

In summary, the optical chip’s greatest strength as a VIRS alternative was its inclusivity and ability to encode a lot of information. The greatest challenges were concerns among various stakeholders about the chip’s accessibility for extraction and what rulemaking, tools, and restrictions would need to be in place to ensure its security and survivability.

CLOSING ACTIVITY

Many of the subthemes that emerged within the closing activity were crosscutting for all stakeholders. The top subthemes for all stakeholders are shown in Table 12.

Table 12. Top closing activity subthemes.

	Closing Activity	Total	FG	SG	TDS	IN	LE	SA
123	More development of VIRS needed (M)	8	2	3	0	1	0	2
124	OEM stakeholder feedback necessary as first step (F)	6	1	2	0	0	3	0
125	Too much training/research/money (P)	6	0	3	0	0	1	2
126	Consistency of ADAS/ADS before VIRS can be developed (F)	5	0	3	1	0	1	0
127	Inconsistency between OEMs in technology functionality (P)	5	0	0	1	0	2	2
128	Rulemaking needed to establish (F)	4	0	2	0	0	2	0
129	Exists today so low level of burden (P)	4	0	2	0	1	0	1

As the project was a feasibility study/concept exploration according to the V-Model, it was understandable that participants wanted to see the VIRS alternative in action as a testable concept, as indicated by the top subtheme. More development of VIRS was expressed as a need both in detailing how these VIRS alternatives would report ADAS/ADS features, and also in modifying existing VIRS, such as VIN and EDRs, to better accommodate the type of information stakeholders want to be able to extract. Many expressed the need for feedback from OEMs before they would feel comfortable fully analyzing a VIRS, as a large portion of the burden would likely fall on their shoulders. This project may have revealed more information regarding the feasibility of VIRS alternatives had it allowed for more time and interaction with manufacturer stakeholders.

With any new system come concerns about implementation. Participants in state government, technology developers and suppliers, law enforcement, and safety advocacy all had concerns about the training, cost/benefit, and research needed for their industry to implement a VIRS. Thus, the most preferred VIRS were often those already in existence, so as to minimize the level of burden for industries. Before even considering implementation, many participants were adamant about the establishment of consistent approach (e.g., industry standard, rulemaking) for defining the ADAS and ADS features’ performance across vehicle makes and models.

Other Discussion Questions or Metrics

Participants were asked if there were any other aspects of their operations associated with the scenarios that the researchers should be aware of or that should have been discussed. Figure 23 displays the most common expressions of additional metrics and questions by stakeholder groups overall.

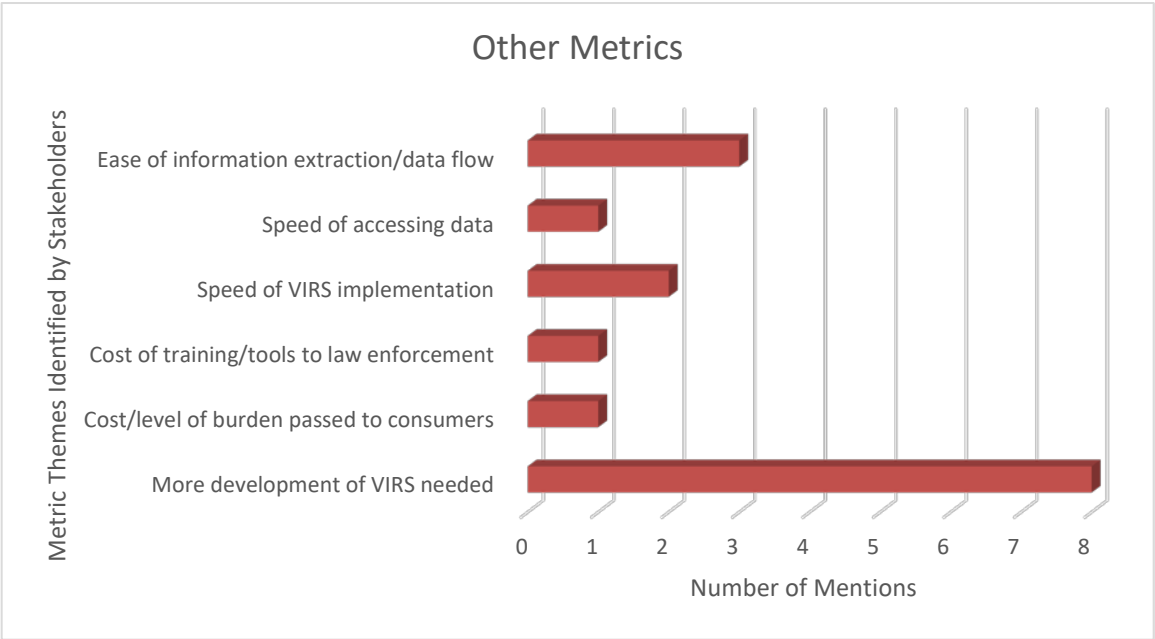


Figure 23. Chart. Additional metrics suggested by focus groups.

The most commonly stated metric was the desire to see VIRS alternatives developed further. Participants across stakeholder types agreed that if optical chips or EDRs were to serve as a viable VIRS alternative, there would need to be more technological development. EDR concerns included the device’s limited availability and data carrying capacity. While the design of an EDR is sufficient for today’s purposes, expanding its purpose to be used as a VIRS may require

modifications to increase its information carrying capacity and accessibility. The concept of an optical chip in a vehicle would likely require further research to be developed. Analyzing these comments could potentially form a new metric of “technological advancement ability.”

The second most common suggested metric was “ease of information extraction/data flow.” All stakeholder groups at some point expressed concern regarding law enforcement’s ability to get to the information. This confirmed the research team’s initial findings that the flow of data has a starting point at the crash scene, where law enforcement officials record information about the vehicle.

Potential Future Next Steps

When asked about potential future next steps that should be considered, all groups recognized gathering OEM stakeholder feedback as a necessary first step, along with consistency among OEMs in defining and aligning ADS and ADAS features’ performance measures (Figure 24).

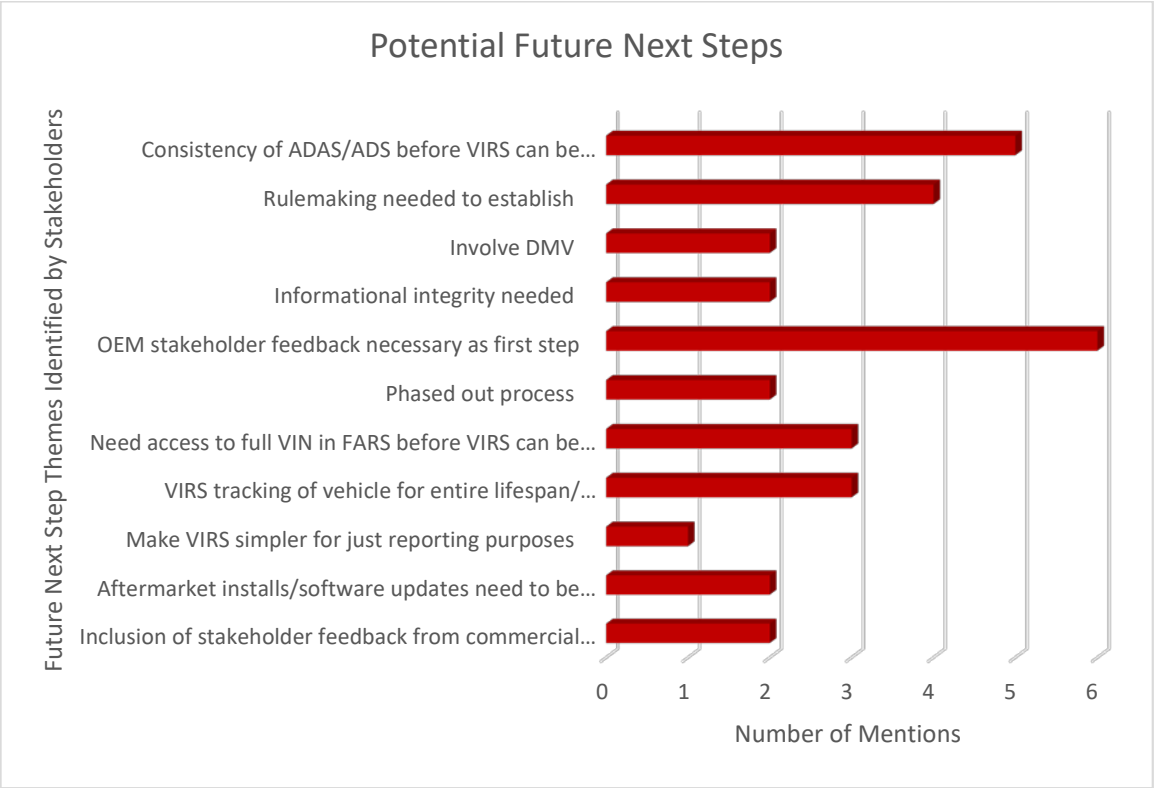


Figure 24. Chart. Potential future next steps themes across all focus groups.

A participant from the insurance stakeholder group suggested a follow-up project idea of mapping various ADAS technologies to the alternatives to show how each might work in action, as stated below.

I think it would've been helpful to have a markup of all of the various ADAS options today and how they could potentially map into each of your options? I don't know if that's been done already... but that would've been a great example of "ok—here are all the options we know of today, here's how they would've been standardized, and here's how they would map into this option.

– Insurance

As representative of most stakeholder participants, state government stakeholders expressed some iteration of the following concern about the need to standardize ADS and ADAS nomenclature and definitions before any VIRS alternative development would be feasible.

I know we went on the assumption that this would be solved, but the assumption that ADS and ADAS will be defined in a manner that could actually be consistently reported would be...number one. Because until that assumption is true or close to being true, I just don't see anyone putting the money into... at least I don't see state governments having the funding or the federal government to have the funding to make the technological changes necessary for any of this to work until that assumption is true.

–State Government

Another participant, quoted below, emphasized the need to include OEMs in any discussions, as many of the options would affect them directly.

Well, I mean, it's far reaching as far as when you when you talk about doing something with the barcode on the VIN obviously. It's a discussion with manufacturers. I guess it really kind of starts there and then is going to kind of trickle down. Because then you're talking about, you know, having to having to get people up to speed...that have to deal with this on a regular basis...as to what's coming.

– Law Enforcement

Further Comments

The final question of whether there were any other further comments simply echoed what was repeated before. Participants often summarized their opinions for all of the VIRS alternatives, which did not reveal any new findings.

SUMMARY AND SUS SCORES OF STAKEHOLDER FEEDBACK

The poll scores for each participant within the 12 focus groups were recorded and then later converted into SUS scores, as shown in Table 13.

Table 13. VIRS alternatives’ average SUS score across all focus groups.

VIRS Alternative	Overall Average SUS Score
18-Digit VIN	49.44454167
Optical Chips	49.27091667
EDRs	46.20354167
Modified VIN	44.37083333
Participant-Specified	42.98955
Barcodes	41.41920833

As outlined in [Chapter 3](#), the adapted version of the SUS questions required a conversion metric to use 9 questions instead of 10. The sum was taken for each option’s nine raw poll data scores that fit on the Likert-type 1–5 scale of Strongly Agree to Strongly Disagree for negatively worded questions. For positively worded questions, the scale was reversed from 5–1 with 5 being Strongly Agree and 1 being Strongly Disagree. The sums of these scores were then multiplied by a factor of 2.778. This yielded the results in Table 14.

Table 14. Average SUS score calculations of each focus group.

18-Digit VIN SUS Score		Barcodes SUS Score		EDRs SUS Score	
Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score
FG1	55.56	FG1	72.228	FG1	25.002
FG2	45.1425	FG2	31.2525	FG2	67.3665
FG3	55.56	FG3	41.67	FG3	38.892
FG4	47.226	FG4	29.169	FG4	48.615
FG5	50.93	FG5	37.966	FG5	53.708
FG6	36.114	FG6	40.281	FG6	36.114
FG7	38.892	FG7	41.67	FG7	50.004
FG8	75.006	FG8	40.281	FG8	45.837
FG9	52.782	FG9	50.004	FG9	55.56
FG10	37.503	FG10	34.725	FG10	50.004
FG11	37.503	FG11	34.725	FG11	50.004

18-Digit VIN SUS Score		Barcodes SUS Score		EDRs SUS Score	
Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score
FG12	61.116	FG12	43.059	FG12	33.336
Average Score	49.44454167	Average Score	41.41920833	Average Score	46.20354167

Modified VIN SUS Score		Optical Chips SUS Score		Participant-Specified Option SUS Score	
Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score	Focus Group Number	Average Converted SUS Score
FG1	63.894	FG1	58.338	FG1	75.006
FG2	44.448	FG2	52.782	FG2	29.8635
FG3	54.171	FG3	48.615	FG3	26.391
FG4	36.114	FG4	47.226	FG4	62.505
FG5	40.744	FG5	48.152	FG5	N/A
FG6	40.281	FG6	44.448	FG6	41.67
FG7	41.67	FG7	58.338	FG7	N/A
FG8	55.56	FG8	52.782	FG8	30.558
FG9	41.67	FG9	44.448	FG9	37.503
FG10	38.892	FG10	48.615	FG10	45.837
FG11	38.892	FG11	48.615	FG11	44.448
FG12	36.114	FG12	38.892	FG12	36.114
Average Score	44.37083333	Average Score	49.27091667	Average Score	42.98955

Each focus group’s corresponding stakeholder type is shown above in Table 14. The average converted SUS score of each participant within a focus group was taken, and was then averaged out, as shown in Table 15. Note that Focus Group 5 (State Government) and Focus Group 7 (Safety Advocacy) opted out of the Participant-specified Option survey, as they did not have any additional VIRS alternative suggestions to measure on the SUS. In this case, the scores were left blank so as not to skew the average.

The data revealed that of this sample size of 12 focus groups, the 18-digit VIN was seen as the most potentially usable VIRS alternative regardless of stakeholder type. Optical chips were rated as second highest on the SUS, with EDRs at third. Modified VIN, the various participant-specified options, and barcodes were rated as the least potentially usable on the SUS, and received F letter grades. Each VIRS alternative’s position on the letter grade scale is shown below in Figure 25. Note that in this figure scores were rounded to the nearest third decimal point.

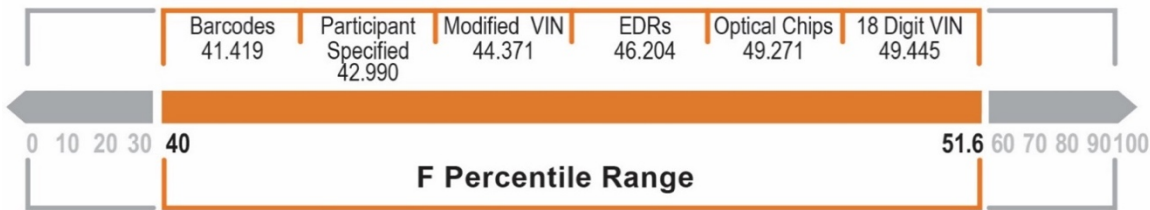


Figure 25. Graph. SUS scale letter grade for VIRS alternatives across all focus groups.

Sauro remarks in *The System Usability Scale* that most technologies, regardless of industry, rarely score above a C+ on the scale (2011). This is due to the fact that the SUS scores on a scale of 1–100 are not percentages but should be considered as a percentile ranking. An SUS score above 68 would therefore be considered above average and anything less than a 68 would be below average. The likely theory as to why these VIRS alternatives all scored below average is due to the vague nature of descriptive assessment instead of hands-on application. The VIRS alternatives in this project were performed at the feasibility and concept exploration stage of the V-Model, and thus were not fully developed for testing. Therefore, the ranking of these VIRS

alternatives should be looked at contextually within the percentile range of their fellow alternatives. It is from this data, combined with comments from the qualitative data, that both stakeholder needs and *potential* feasibility of these VIRS alternatives can be determined.

SUS Question Variance for Each VIRS Alternative

In examining the quantitative data, the research team found that there were some variances within stakeholder groups regarding their assessment of the VIRS alternatives’ usability. Interestingly, these variances and the competing poll data within each group were consistent across most stakeholder groups. It is possible to conclude from this that the questions were difficult to address in the context of a high-level concept exploration. It would be helpful to see if this would still be the case once these VIRS alternatives were manifested into a testable design. On the other hand, this data also reveals highly common considerations and challenges surrounding each of the alternatives that caused disagreement among participants. The following sections address these discrepancies and use qualitative data as a supplemental analysis to determine the reasoning behind these competing SUS poll selections. The table of questions has been reproduced here in Figure 26 for reference.

Figure 26. Screen capture. SUS scale adapted version for VIRS 5.10 quantitative data analysis.

Statistical Package for the Social Sciences Software was used to complete the quantitative data analysis. The dataset used contained the recorded poll results from the Poll Everywhere software that included both the raw Likert-type scale results as well as the converted SUS score results. As the software limited the use of numbers as a variable name, the 18-Digit VIN was coded as “DigitVIN.” Another anomaly was the stakeholder type Technology Developers and Suppliers; this was renamed as “Transportation” to shorten and limit the acronyms used in variable names.

The first analysis run on the poll dataset was Cronbach’s Alpha to determine the internal validity of the data, which is defined as reliable if the score is above .7. This dataset yielded a Cronbach’s alpha score of .73. While established as reliable, this is still fairly low. Sauro theorizes that for some SUS data, a lower alpha score can reveal participants’ struggle in answering questions (2011). For this project, this is likely due to the fact that there was no physical technology developed that could be tested. All of the responses to the questions were theoretical or hypothetical (i.e., if the technology were to exist). The point in administering this survey recognizes the abstract nature of presenting technology in an undeveloped form, which is why this project’s scope centers on the needs assessment qualitative data that emerged from the poll results.

A descriptive variable analysis was then performed in order to determine the mean scores and standard deviations of each variable’s SUS scores, as shown in Table 15. The stakeholder group number was recoded so that focus groups of the same stakeholder type were grouped together.

Table 15. Descriptive variable analysis of VIRS alternatives.

A one-way analysis of variance was then conducted to determine if there was a significant difference between stakeholder groups on SUS scores for each VIRS alternative option. Significance level for this assessment was defined as $\alpha = .05$. As shown below in Table 16, the only significant difference between the options occurred within the EDR VIRS alternative option, which has an SUS score (as bolded below) of $\alpha = .014$.

Table 16. One-way variance analysis.

VIRS Option		Sum of Squares	df	Mean Square	F	Sig
Barcode SUS	Between Groups	113.08	5	22.616	.569	.723
	Within Groups	755.58	19	39.767		
	Total	868.66	24			
18-Digit VIN SUS	Between Groups	160.41	5	32.083	.368	.864
	Within Groups	1655.93	19	87.154		
	Total	1816.34	24			
Modified VIN SUS	Between Groups	879.61	5	175.922	1.715	.180
	Within Groups	1949.24	19	102.592		
	Total	2828.85	24			
Optical Chip SUS	Between Groups	206.97	5	41.394	.801	.562
	Within Groups	981.49	19	51.657		
	Total	1188.46	24			
EDR SUS	Between Groups	1043.32	5	208.664	3.868	.014
	Within Groups	1024.91	19	53.943		
	Total	2068.23	24			

A Tukey Honest Significant Difference (HSD) analysis was then run to identify which stakeholder group type means were significantly different. The focus group numbers were again recoded to ensure stakeholder groups of the same type were grouped together. The analysis revealed that the significant difference for the EDR VIRS alternative occurred between the state government and law enforcement groups. There was a 24-point difference between the means of these two stakeholder groups, as shown in bold font in Table 17. The previously discussed qualitative data describing stakeholders’ personal experiences may explain this difference. Both law enforcement groups had experience accessing EDRs and were generally unsupportive of this option due to the lack of ease in EDR accessibility, the variety of tools required to read the data, and the time it takes to access this information. On the other hand, state governments were on the approving end of these requests, and therefore saw EDR access in terms of something they often have to approve and therefore these devices might need to be easily accessible to law enforcement. A larger sample size may be needed in order to determine alternate theories for this significant difference in means.

Table 17. Tukey HSD analysis by stakeholder group for EDR VIRS alternative.

	95% Confidence Interval for Mean						
	Mean	Standard Deviation	Standard Error	Lower Bound	Upper Bound	Minimum	Maximum
Insurance	40.74	13.70	7.91	6.70	74.79	25.00	50.00
State Government	61.51	7.93	3.00	54.18	68.84	50.00	69.45
Law Enforcement	37.50	13.70	6.85	15.70	59.31	22.22	55.56
Safety Advocacy	45.56	11.55	5.17	31.21	59.91	30.56	55.56
Technology Developers and Suppliers	47.92	8.60	4.30	34.24	61.60	36.11	55.56
Federal Government	50.00	3.93	2.78	14.72	85.30	47.23	52.78
Total	48.89	12.88	2.58	43.58	54.21	22.22	69.45

CHAPTER 6. CROSSCUTTING THEMES, UNIQUE CONCLUSIONS, AND POTENTIAL FOR FUTURE VIRS DEVELOPMENT

DEFINE CONSISTENCY OF ADAS/ADS

Across all stakeholder groups, many participants struggled with how to answer questions concerning the capability of VIRS to report the presence of ADS or ADAS features. The opening slides addressed the “elephant in the room” regarding the inconsistency of these features. While many participants were able to table this issue and talk theoretically around the potential of a VIRS, toward the end they echoed their concern about making such a broad assumption. At some point during the process, all stakeholder groups emphasized the need to establish some consistency. Some advocated for NHTSA to implement rulemaking for OEMs, while others advocated for OEMs to come to agreement among themselves. Regardless of which industry they thought should bear the burden, the fact remained that a reporting system would only be as good as the information it is reporting. If that information is inconsistent, the foundation of the VIRS could be catastrophic. In the future development of a VIRS, it would be relevant to explore the different possibilities of strategizing ADS or ADAS features in a way that would allow them to be consistently reported, regardless of manufacturer variances. Feedback from OEMs as to how this might be accomplished would be essential to the success of future VIRS development.

SHIFT ADAS/ADS REPORTING FROM TECHNOLOGY TO FUNCTIONALITY

A few stakeholders had suggestions (provided in the excerpts below) that echoed what the research team found in internal interviews. Suggestions from two SMEs to examine ADAS technology by functionality rather than technology name may be useful. For example, it may make more sense to look at torque or steering inputs than the ADAS term “lane-keeping assist.” Another interesting concept was grouping ADAS features into greater categorical themes. One participant likened ADAS feature groups as similar to groupings used to identify types of drugs, such as stimulants, depressants, etc. ADAS features could be grouped into potential larger groupings, such as steering-based or braking-based. This approach may serve as useful in examining how to map a consistent system of ADAS features to a potential alternative VIRS.

... I think it's kind of difficult because even if you label things all the same, they're really not all the same, because everybody does the system functions differently. It would have to be like ESC where the product is standardized to be, in my opinion, to be really clear to researchers, like we have online. Even to be able to see the technology differences between systems.

–Technology Developers and Suppliers

...I think the ESC example is a good one because there the functionality's validated, you know, as a part of the FMVSS test, or compliance that you have to show with the vehicle that has that [functionality]. You could imagine that you have some sort of a [performance]... rather than getting into exactly which technology is being used to have the ADS or ADAS functionality.... You know, like this vehicle with this system can pass this specific test. That means that it has functionality that meets this. And then that's what you would base the VIN digit on as opposed to, you know, I'm using a radar-based system or I'm using a camera-based system that, like you can kind of more look at the functionality from the driver's perspective as opposed to how the vehicle actually accomplishes that functionality. So you kind of abstract away from that, so I mean that's, a thought of how you can remove the inconsistency and you focus on functionality, rather than technology.

–Technology Developers and Suppliers

UNIQUE PARTICIPANT-SPECIFIED OPTIONS FOR POTENTIAL VIRS DEVELOPMENT

Participants often suggested new options for potential VIRS development. These frequently came out as speculations in the closing activity (after the participant-specified option poll/discussion) or throughout discussions, but stakeholders chose not to evaluate them during their “participant-specified option” opportunity. Those fond of the optical chips suggested a similar RFID technology where information could be extracted wirelessly. Another suggestion linked back to a collaborative database in which OEMs provide the information, but NHTSA or state DMVs would be the designated custodians of this information.

An additional option is the concept of having a VIN with both a shorthand and longhand information reporting system. For example, one participant likened the VIN to the zip code extension where you have the general city location, but a longer 4-digit extension that would tell you more precise information. A 4-digit extension may be useful as a potential VIRS, as it could be easily identified and reported by law enforcement but could contain more information for further post-crash analysis by insurance and safety advocacy groups.

Lastly, there was a suggestion for an ELD similar to what is used in the heavy vehicle industry. More information is provided in the excerpt below as to what this might look like for a VIRS alternative.

... ELDs, the electronic logging devices for drivers' hours of service that have to be connected to the company's database to be able to communicate, basically communicate to an officer, at roadside, all the drivers' documentation and their hours, their record of duty. And that communication model could be used in a similar way to get vehicle information. So, in a sense, we have the ELD, the electronic logging device. We could have that for the driver information. We could have a vehicle logging device for the vehicle information and I kind of think that that would suit many of the desires of the solution offered in your options.... The challenge is connecting the vehicle, you know, the VIN number to that system, to that logging device. So as far as who is the custodian of the data, I mean these are all third-party providers of a device. The information off the vehicle could be...communicated to the company that owns the vehicle and that could be then provided to those who need to use it like law enforcement or researchers or others. I don't have all of the solution, but I have an idea at least in concept in some potential sort of avenues of making it happen.

–Technology Developers and Suppliers

CONCLUSION

In conclusion, this project successfully met its goals in determining the feasibility and concept exploration of different VIRS alternatives according to relevant stakeholders. Missing from the study data was essential feedback from OEMs. A follow-up study to include this missing stakeholder group would be necessary before the development of any future VIRS could occur. Using the V-Model to deconstruct and decompose the various data elements that might make up the ideal VIRS across all industries led to a few values that were unanimously identified by stakeholders. The information that a VIRS would report needs to be easily accessible to all parties, from law enforcement who access it immediately at the crash reporting stage, to safety advocacy researchers who may want to access it years down the road. A VIRS for all stakeholders must have the ability to adapt and change with the times in a way that is flexible and dynamic. Every VIRS alternative had its drawbacks, and it was clear that there was not one single existing technology presented that could meet the ideal purpose. A usable solution will require a combination of a simple VIRS that provides both a high-level “quick grab” of information through a strong visual representation with a VIRS that has the ability to provide more detailed, complex information upon further examination to stakeholders who may need it. Further research will be needed to determine the development of such a VIRS that incorporates ADAS/ADS information in a consistent way across all stakeholder groups.

APPENDIX A. RECRUITMENT MATERIALS

FOCUS GROUP RECRUITMENT E-MAIL

Dear [NAME]:

Hello! I am contacting you today to provide information on the activities associated with a project that looks to potentially enhance the current VIN Standard. We have been examining the feasibility and interest of several alternatives as a future way of reporting the presence of Automated Driving Systems (ADSs) and Advanced Driving Assistance Systems (ADAS) in crash reporting statistics.

We will be soliciting feedback through a series of meetings with various stakeholders from OEMs, rulemaking, insurance and many others. I would like to invite you and others within your organization to participate in one of our discussions. During these discussions, we will be soliciting feedback on the considerations and challenges of enhancing the VIN standard and using evaluation metrics to determine stakeholder interest. Individuals must have access to an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities in order to participate in the Poll Everywhere survey. Meetings will last up to 2 hours and will be held through Zoom teleconferencing. Additionally, individuals must have access to an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities in order to participate in the Poll Everywhere survey.

If your organization has a member that you would like to recommend for our discussion groups, please let me know by **[DATE]**. Please feel free to share this request with any colleagues who may be interested in participating. If you have questions, I will be available by telephone to discuss.

Best regards,

[RESEARCHER]

NAME | TITLE

Virginia Tech Transportation Institute | 3500 Transportation Research Plaza (0536), Blacksburg, VA 24061

Telephone: xxx-xxx-xxxx | name@vtti.vt.edu

FOCUS GROUP CONFIRMATION E-MAIL

Note: *This email to be sent to those individuals completing the online recruitment survey and who will be scheduled to participate*

Dear [NAME]:

Thank you for agreeing to participate in one of the Virginia Tech Transportation Institute's VIRS Alternatives Stakeholder Feedback Meetings. During the meeting we will be asking you for your feedback on the considerations and challenges of various VIRS options and using evaluation metrics to determine stakeholder interest.

Your meeting is scheduled for [Date, Time] and will be held [Zoom Teleconferencing Link].

Please log into the interview using the following information [Include Zoom Information Here]. Additional [Zoom] information is included below for your reference.

The meeting may last up to two hours. During the course of the meeting you will:

- Be asked to log into the online interview session and connect to the audio portion of the interview via the Zoom hosting site's voice over internet protocol (VOIP) or a telephone. Individuals must have access to an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities in order to participate in the Poll Everywhere surveys.
- Be reminded of the information included within the attached Informed Consent Form. Please review this information prior to our session. You will be provided an opportunity to discuss any questions or concerns you have with a researcher.
- Provide verbal consent to participate in the study and to be audio recorded.
- Listen to a brief description of the research study after which you will be asked to provide your opinions and feedback on a number of alternatives for enhancing the VIN standard.
- Be asked to fill out a survey of evaluation metrics in order to determine stakeholder interest.

In order to facilitate the free flow of conversation, prior to beginning our discussion, we will ask for your permission to audio record our conversation. The audio recordings will be used to supplement our handwritten notes. Should you decline to grant your permission to be recorded, we will ask you to log off of the call. All personally identifying information will remain secure and confidential. So that you can fully participate, please remember to use an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities.

To further facilitate the discussion, we have attached a list of questions that will be guiding our discussion. We encourage you to use this list to take notes during our discussion.

Confidentiality

- Individual responses will be aggregated for reporting purposes, and general information (e.g., industry, insurance etc.), not individuals, will be referenced in the research reports. Should you agree to have our discussion recorded, your name will not be associated with your transcript.
- The audio recordings will be deleted upon completion of the transcription process; however, the researchers and the study sponsors will retain copies of the de-identified transcripts. Again, all personally identifying information will be redacted from the transcripts.

If you have questions, I will be available by telephone to discuss.

We appreciate your willingness to share your experience with us and look forward to talking with you further about this exciting research study.

Best regards,

[RESEARCHER]

NAME | TITLE

Virginia Tech Transportation Institute | 3500 Transportation Research Plaza (0536), Blacksburg, VA 24061

Telephone: xxx-xxx-xxxx | name@vtti.vt.edu

Attachments: Informed Consent Form

Zoom User Information

- View a short video explaining how to join a Zoom meeting: [Attend a meeting](#)
 - **Note:** We will not be using the video option available through Zoom. You **do not need** a web camera to participate. If you have a web camera, please do NOT use it.
 - **Note:** If you cannot download or run the application, you will be provided an option to join from your browser.
- Make sure your computer or tablet has the minimum system requirements: [Join a test meeting](#)

If you have any questions about join a Zoom meeting, please contact, <researcher name> at <XXX-XXX-XXXX>.

FOCUS GROUP RECRUITMENT CALL SCRIPT

Note: Initial contact between participants and researchers may take place over the phone or via email. If taking place via phone, read the following Introductory Statement. If interested, follow-up with the recruitment email.

Hello. This is _____ with the Virginia Tech Transportation Institute. I am contacting you today to provide information on the activities associated with a research project that looks to potentially enhance the current VIN Standard through a Vehicle Information Reporting System (VIRS). We are seeking feedback from stakeholders to examine the feasibility and interest of several VIRS alternatives as a future way of reporting the presence of Automated Driving Systems (ADSs) and Advanced Driving Assistance Systems (ADAS) in crash reporting statistics.

I would like to invite you and/or one of your colleagues to participate in one of our discussions. During these discussions, we will be soliciting feedback on the considerations and challenges of various VIRS options and using evaluation metrics through a survey to determine stakeholder interest. All personally identifying information will remain secure and confidential. Additionally, individuals must have access to an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities in order to participate in the Poll Everywhere survey.

Can I share additional information about these discussions with you?

[If interested]. Great! Would you like to schedule your meeting at this time? [If not already known, verify email address for confirmation email of scheduled time agreed upon].

[If not available to schedule at this time] I'll forward you an email that contains additional details in terms of scheduling options and participation. [If not already known, verify email address]. Once you've had a chance to review, please feel free to contact me with any questions.

[If not interested] Thank them and move on.

I have one last question to ask before we end the call. Are you aware of any colleagues who may also be interested in participating in this review?

[If yes] Great! You can forward them my contact information or if you feel comfortable providing me their contact information, that works too. [confirm preference] Thank you for your time! [end call]

[If no] Thank them for their time. [end call]

FOCUS GROUP DISCUSSION REFERENCE GUIDE

Helpful Acronyms

VIRS- Vehicle Information Reporting System

ADS- Automated Driving System

ADAS- Advanced Driver Assistance System

VIN- Vehicle Identification Number

EDR- Event Data Recorder

Definitions

Vehicle Information Reporting System (VIRS)- A system that has the ability to encode and report specific information unique to a vehicle.

Automated Driving System (ADS)- The hardware and software that are collectively capable of performing the entire Dynamic Driving Task (DDT) on a sustained basis, regardless of whether it is limited to a specific Operational Design Domain (ODD); this term is used specifically to describe a level 3, 4, or 5 driving automation system.

Advanced Driver Assistance System (ADAS)-An active system within a vehicle comprised of applications that aid the driver in crash avoidance situations (e.g., adaptive cruise control, emergency braking).

Data Elements of VIRS

Accessibility- First responders, manufacturers, service technicians, and other appropriate individuals can access vehicle information quickly and safely

Flexibility- The system can adapt to dynamic changes in future developments of ADAS/ADS technology

Feasibility- Likelihood of VIRS adoption across vehicle manufacturers implementing ADAS/ADS (e.g., via rulemaking, SAE recommended practice)

Level of Burden- Financial burden associated with adoption of this system (e.g., cost to OEMs of implementing, updating of DMV databases, purchase of new scanning technologies and/or updating of crash reports for law enforcement)

Inclusivity- Inclusiveness of all relevant ADAS/ADS-related information

Consistency- Reporting method defines ADAS/ADS features consistently across OEMs

Poll Everywhere Application Instructions

In order to begin, please to navigate to the Poll Everywhere site using the link provided below on your device equipped with internet capabilities: www.PollEv.com/kaitlynfitzg128

The website will inform you to use either the website or download the app depending on your preference. The next screen will prompt you to register. Please choose the option of using anonymous credentials so as not to bias opinions during the live results reveal. When you submit your answers to the poll, there will be no confirmation screen, but the results have been

received. You may resubmit your answers for as long as the poll is open and up until the researcher moves on to the next question at which point the ability to respond to that question will not be available.

FOCUS GROUP INFORMED CONSENT FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY Consent to Take Part in a Research Study

Title of research study: Vehicle Information and Reporting Systems (VIRS) Stakeholder Feedback Meetings

Principal Investigator: Michelle Chaka (mchaka@vtti.vt.edu; 734-678-7474)

Other study contact(s): Tammy Trimble (ttrimble@vtti.vt.edu; 540-231-1036); Kaitlyn Fitzgerald (kfitzgerald@vtti.vt.edu; 540-231-1535)

Key Information: The following is a short summary of this study to help you decide whether or not to be a part of this study. More detailed information is listed later on this form. We invite you to take part in this research study because you have knowledge of the topic we are studying.

What should I know about being in a research study?

- Someone will explain this research study to you
- Whether or not you take part is up to you
- You can choose not to take part
- You can agree to take part and later change your mind
- Your decision will not be held against you
- You can ask all the questions you want before you decide

What should I know about being in this research study?

This study will solicit stakeholder feedback on a number of vehicle information reporting system alternatives and associated considerations that may be used to identify system needs in reporting the presence of Automated Driving Systems (ADS) or Advanced Driving Assistance Systems (ADAS) in crash reporting statistics. Participants in this study will participate in a 2-hour focus group (more detailed information can be found under “What happens if I say yes, I want to be in this research?”). There is minimal risk involved with participating in this study. More detailed information about the risks can be found below under “Is there any way being in this study could be bad for me?”. There are no benefits to you from your taking part in this research. However, possible benefits to others include the industry gaining a better understanding of the needs, feasibility, and potential development of a Vehicle Information Reporting System (VIRS) that reports information on the presence of ADAS/ADS technologies to aid in the collection and analysis of crash reporting statistics which is needed to determine the real world-efficacy of vehicle automation.

Detailed Information: The following is more detailed information about this study in addition to the information listed above.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at Kaitlyn Fitzgerald (kfitzgerald@vtti.vt.edu; 540-231-1535); Tammy Trimble (ttrimble@vtti.vt.edu; 540-231-1036); or Michelle Chaka (mchaka@vtti.vt.edu; 734-678-7474)

This research has been reviewed and approved by the Virginia Tech Institutional Review Board (IRB). You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your rights as a research subject
- Your questions, concerns, or complaints are not being answered by the research team
- You cannot reach the research team
- You want to talk to someone besides the research team to provide feedback about this research

How many people will be studied?

We plan to include about 70 people in this research study through Zoom Teleconferencing or at a location of the participant's choosing in Washington D.C.

What happens if I say yes, I want to be in this research?

- The meeting will serve as an informal discussion group where you will be invited to share your thoughts and opinions on some VIRS options and evaluation metrics through a survey of the feasibility of these systems. In order to facilitate the free flow of conversation, prior to beginning our discussion, we will ask for your permission to audio record our conversation. The audio recordings will be used to supplement our handwritten notes. No personally identifying information (i.e., your name) will be transcribed. We will take steps to protect your privacy and keep confidential your personally identifying information. Please be aware that because this is a group discussion, others in the group may share what they hear in the group setting.

The meeting may last up to 2 hours. During the course of the meeting you will:

- Be reminded of the information included within the attached Informed Consent Form. Please review this information prior to our session. You will be provided an opportunity to discuss any questions or concerns that you have with a researcher.
- Provide written consent to participate in the study and to be audio recorded.
- Listen to a brief description of the research study after which you will be asked to provide your opinions and feedback on a number of VIRS alternatives,
- Asked to fill out a survey using Poll Everywhere of evaluation metrics in order to determine stakeholder interest. Individuals must have access to an electronic device (e.g., smartphone, tablet, laptop) with a data plan and/or wireless capabilities in order to fully participate.

What happens if I say yes, but I change my mind later?

You can leave the research at any time, for any reason, and it will not be held against you.

If you wish to leave the study early, please tell us right away. We will not use any data collected from you in our analysis if you wish to end your participation and withdraw your data.

Is there any way being in this study could be bad for me?

There is minimal risk involved in this study. The minimal risks include possible minor discomfort from expressing your opinions in front of others in a group setting.

What happens to the information collected for the research?

We will make every effort to limit the use and disclosure of your personal information, including research study and medical records, only to people who have a need to review this information. We cannot promise complete confidentiality. Organizations that may inspect and copy your information include the IRB, Human Research Protection Program, and other authorized representatives of Virginia Tech.

If identifiers are removed from your private information or samples that are collected during this research, that information or those samples could be used for future research studies or distributed to another investigator for future research studies without your additional informed consent.

The results of this research study may be presented in summary form at conferences, in presentations, reports to the sponsor, academic papers, and as part of a thesis/dissertation.

Can I be removed from the research without my OK?

The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include inappropriate behavior or if suspect of under the influence or causing a disturbance to the group.

What else do I need to know?

This research is being funded by the National Surface Transportation Safety Center for Excellence (NSTSCE) for the Virginia Tech Transportation Institute.

No monetary compensation will be provided. No guarantee of benefits is made to encourage you to participate. Your opinions and perceptions will contribute to the general body of knowledge associated with VIRS alternatives to inform various stakeholders.

PARTICIPANT'S PERMISSION – VERBAL CONSENT

By providing verbal consent at the beginning of the focus group, you will be indicating that:

- ☐ You have read and understand the requirements, procedures, and conditions of this study.
- ☐ You have had all of your questions about the nature of the study answered.
- ☐ You are voluntarily agreeing to have your voice recorded during the focus group.
- ☐ You understand that you may withdraw from this study at any time without penalty.

APPENDIX B. STAKEHOLDER FEEDBACK DATA OF VIRS OPTIONS

Key	
FG	Federal Government
SG	State Government
TDS	Technology Developers and Suppliers
IN	Insurance
LE	Law Enforcement
SA	Safety Advocacy

Item No.	Opening Activity	Total	FG	SG	TDS	IN	LE	SA
1	Unusable if Information not Consistent (C)	13	1	4	3	2	0	3
2	Information/Training Needed to Access (A)	6	0	0	1	0	2	3
3	Important for Industry Research/Data (A)	5	0	0	2	1	0	2
4	Public Education and Outreach (C)	5	0	1	0	3	0	1
5	Ability to Adapt to New Technology (F)	4	0	1	0	0	0	4
Item No.	18-Digit VIN	Total	FG	SG	TDS	IN	LE	SA
6	Single digit not enough for information (C)	21	1	1	3	7	3	6
7	Level of burden high (E)	18	0	7	0	5	5	1
8	Modifications to government agency databases (S)	13	0	2	0	0	9	2
9	Need consistent or standardized ADAS/ADS information (S)	13	1	0	5	3	2	2
10	Aftermarket installs should be captured (N)	10	3	1	0	2	0	4
11	Needs more information than just ADAS/ADS (N)	10	2	0	0	1	0	7
12	Appears feasible (E)	10	0	1	2	3	1	3
13	Level of burden low (E)	9	0	0	3	4	1	1
14	Easily accessible (E)	9	0	1	1	1	4	2
15	Modification to crash reporting forms (S)	8	0	0	1	0	6	1
16	Capture "if equipped" with optional features/suites (N)	7	1	0	1	2	0	3
17	Not flexible enough for future technologies (C)	6	1	0	0	1	0	4
18	Over the air updates to vehicle should be captured (N)	6	0	2	0	0	0	4
19	Strong Visual Indicator (S)	6	0	0	1	0	1	4
20	OEMs as custodian (S)	6	1	0	0	1	2	2
21	Operational directions needed for first responders (N)	5	0	0	0	0	2	3
22	Additional digit allows for flexibility (E)	5	0	0	1	4	0	0
23	Support this VIRS (S)	5	1	0	1	0	2	1
24	Needs custodian who will define/be consistent (S)	5	2	0	1	1	1	0
25	Training needed to use (S)	5	0	1	0	0	4	0
26	Effects titling and registration (C)	4	0	2	0	0	0	2
27	Benefit of Information outweighs the negative (C)	4	0	1	1	2	0	0
28	Unable to Speculate (C)	4	0	0	1	0	2	1
29	Prefers 19 digit VIN over 18 digit VIN (N)	4	1	0	1	0	0	2
30	Information accessible to criminals (V)	4	0	0	0	0	4	0
Item No.	Modified VIN	Total	FG	SG	TDS	IN	LE	SA
31	Trouble differentiating old VIN from new VIN (C)	10	1	0	3	0	0	6
32	Not flexible enough for future technologies (C)	10	5	2	3	0	0	0
33	Training needed to use (S)	10	0	0	2	0	4	4
34	Strong Visual Indicator (S)	9	0	0	7	0	2	0
35	Level of burden low (E)	8	0	2	3	1	1	1
36	Inflexible/flawed data storage systems (C)	7	2	0	4	0	1	0
37	Level of burden high (E)	7	1	2	1	0	2	1
38	Aftermarket installs should be captured (N)	6	2	0	4	0	0	0
39	Unable to Speculate (C)	6	0	1	4	0	0	1
40	Not easily accessible by first responders (E)	6	0	0	4	0	1	1
41	Prefers Modification to be 4th-8th digits (S)	6	0	2	0	1	3	0
42	Easily accessible (E)	5	0	0	0	2	1	2
43	OEMs as custodian (S)	5	2	0	1	2	0	0
44	Takes time to learn (C)	4	0	0	1	0	3	0
45	Prefers Modification to the 11th digit (S)	4	0	2	0	2	0	0
Item No.	Barcodes	Total	FG	SG	TDS	IN	LE	SA
46	Needs to be connected to VIN somehow (N)	12	2	2	1	2	0	5
47	Flexible (E)	9	1	1	0	2	3	2
48	Use smart phone as tool to read it (S)	8	1	2	2	0	2	1
49	Tools expensive/not available (S)	8	0	0	1	1	1	5
50	VIRS that links back to a live-updated database (N)	7	2	2	0	0	0	3
51	Aftermarket installs should be captured (N)	7	1	1	3	1	0	0

52	Jurisdictional budgets restrict issuing tools to officers (C)	6	0	0	0	0	3	3
53	Inflexible/flawed data storage systems (C)	6	1	0	4	0	0	1
54	Multiple locations of barcode like VIN (N)	6	1	0	3	0	2	0
55	VIRS ability to update frequently (N)	6	2	2	0	0	0	2
56	Easily accessible (E)	6	2	1	2	0	0	1
57	Location/design relates to crash survivability (S)	6	2	0	1	0	1	1
58	OEMs as custodian (S)	6	2	2	0	0	0	2
59	Over the air updates to vehicle should be captured (N)	5	1	2	0	0	0	2
60	Training needed to use (S)	5	0	0	1	0	1	3
61	Rulemaking needed/involved (S)	5	0	0	0	0	0	5
62	Personal phone bad tool-surrendered as evidence (C)	4	0	0	2	0	2	0
63	Takes time to learn (C)	4	0	2	2	0	0	0
64	Allows for consistency (E)	4	0	1	0	1	0	2
65	Strong inclusivity (E)	4	0	0	1	1	0	2
66	Strong visual Indicator (S)	4	2	0	0	0	1	1
67	Counterfeited Barcodes (V)	4	0	0	0	2	2	0
68	Barcodes become unstuck (V)	4	0	3	0	0	0	1
	Optical Chips	Total	FG	SG	TDS	IN	LE	SA
69	Unable to Speculate (C)	11	1	2	2	1	4	1
70	Strong inclusivity (E)	11	1	2	2	1	2	3
71	Data extraction protocols needed (N)	10	0	0	5	2	2	1
72	Not easily accessible by first responders (E)	10	1	3	0	2	2	2
73	Location/design relates to crash survivability (S)	9	2	1	1	1	3	1
74	Can extract data wirelessly if in proximity of vehicle (S)	8	1	3	2	1	0	1
75	Flexible (E)	7	0	1	0	3	1	2
76	Not a priority for first responders (S)	7	1	4	0	1	1	0
77	Do not support this VIRS for industry (S)	7	0	1	0	0	0	6
78	OEMs as custodian (S)	7	1	2	0	2	0	2
79	Concerns with privacy (V)	7	0	0	4	1	1	1
80	Information could be hacked by criminals (V)	7	0	0	3	1	2	1
81	Tools expensive/not available (S)	6	0	3	1	0	1	1
82	OEMs inconsistent in production (C)	5	0	3	0	0	2	0
83	Takes time to learn (C)	5	0	1	1	1	2	0
84	Allows for consistency (E)	5	0	0	0	4	1	0
85	Level of burden high (E)	5	0	2	2	1	0	0
86	Training needed to use (S)	5	0	0	0	1	2	2
87	Requires power or back power (C)	4	0	0	2	0	0	2
88	Not different than other options (C)	4	0	0	0	2	1	1
89	Effects titling and registration (C)	4	0	4	0	0	0	0
90	Needs to be connected to VIN somehow (N)	4	1	0	0	2	1	0
91	First responders need to know if equipped before scene arrival (N)	4	1	0	0	0	0	3
92	VIRS ability to update frequently (N)	4	2	0	1	1	0	0
93	Operational directions needed for first responders (N)	4	0	0	0	2	2	0
94	Support this VIRS (S)	4	0	2	0	0	2	0
	EDRs	Total	FG	SG	TDS	IN	LE	SA
95	Good for post-crash analysis not crash response (C)	15	1	6	3	1	1	3
96	Not easily accessible by first responders (E)	15	2	1	2	1	5	4
97	Needs more information than just ADAS/ADS (N)	14	4	1	1	5	1	2
98	VIRS is a good supplement with other VIRS (S)	11	1	0	3	0	3	4
99	Current regulation hinders easy access to VIRS (C)	9	0	0	1	3	3	2
100	Need to know if human or ADS driving (N)	7	3	0	1	2	1	0
101	How many crashes it avoided (not just crashes it was in) (N)	7	3	0	1	3	0	0
102	Tools expensive/not available (S)	7	1	0	1	1	2	2
103	Training needed to use (S)	7	1	0	2	0	3	1
104	Appears feasible (E)	5	1	0	0	1	2	1
105	Level of burden high (E)	5	0	1	2	0	2	0
106	Location/design relates to crash survivability (S)	5	1	0	0	1	3	0
107	Rulemaking needed/involved (S)	5	1	0	3	0	0	1
108	OEMs as custodian (S)	5	2	0	2	0	1	0
109	Too much time needed to extract information (C)	4	0	3	0	0	1	0
110	Too different from other options (C)	4	0	3	0	0	0	1
111	Capture "if equipped" with optional features/suites (N)	4	4	0	0	0	0	0
112	Support this VIRS (S)	4	1	0	0	1	2	0
113	High risk of data misinterpretation (V)	4	0	1	2	0	1	0

114	Concerns with privacy (V)	4	0	2	1	0	1	0
	Participant-Specified	Total	FG	SG	TDS	IN	LE	SA
115	Urgency for VIRS technology now (C)	8	0	8	0	0	0	0
116	Simple VIRS for reporting combined with complex VIRS for technology capability (N)	7	1	0	3	0	2	1
117	VIRS is a good supplement with other VIRS (S)	5	2	0	0	1	1	1
118	Current regulation hinders easy access to VIRS (C)	4	0	0	3	0	0	1
119	VIRS that links back to a live-updated database (N)	4	0	0	1	2	0	1
120	Easily accessible (E)	4	2	0	0	1	1	1
121	Strong Visual Indicator (S)	4	0	1	0	0	2	1
122	Concerns with privacy (V)	4	0	0	2	0	1	1
	Closing Activity	Total	FG	SG	TDS	IN	LE	SA
123	More development of VIRS needed (M)	8	2	3	0	1	0	2
124	OEM stakeholder feedback necessary as first step (F)	6	1	2	0	0	3	0
125	Too much training/research/money (P)	6	0	3	0	0	1	2
126	Consistency of ADAS/ADS before VIRS can be developed (F)	5	0	3	1	0	1	0
127	Inconsistency between OEMS in technology functionality (P)	5	0	0	1	0	2	2
128	Rulemaking needed to establish (F)	4	0	2	0	0	2	0
129	Exists today so low level of burden (P)	4	0	2	0	1	0	1

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