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AVSC Information Report for Adapting a Safety Management System (SMS) for Automated Driving System (ADS) SAE Level 4 and 5 Testing and Evaluation

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Rationale

Automated Driving Systems (ADS) present a new development opportunity for transportation and mobility. The potential benefits associated with these systems have brought people and resources from different backgrounds to support its ongoing development. Managing the operational safety risks during testing is an important aspect of SAE Level 4 and 5 ADS development, and therefore additional information on organizational safety management can help demonstrate the industry's commitment to managing these safety risks appropriately and engender public confidence during testing.

A Safety Management System (SMS) is one approach designed to support organizational safety in a systematic and integrated way. The intention of the SMS framework is to promote a safety culture, assess and manage safety risk, evaluate risk control strategy effectiveness, and support organizational safety policies and objectives. The automotive industry already manages the safety of testing and evaluation using a variety of different mechanisms that address the goals of an SMS framework. By referencing this information report, organizations can consider and apply additional safety management approaches to their ADS test operations.

Preface

The Automated Vehicle Safety Consortium™ (AVSC) is an industry program of SAE Industry Technologies Consortia® (SAE ITC) working to quickly publish best practices that will inform and lead to industry-wide standards advancing the safe deployment of automated driving systems (ADS). The members of this consortium have decades of accumulated experience focused on safe, reliable, and high-quality transportation. They are committed to applying those principles to SAE level 4 and level 5 automated vehicles so that communities, government entities, and the public can be confident that these vehicles will be deployed safely.

The Consortium recognizes that knowledge sharing plays a vital role in supporting continuous improvement for the ADS industry. In addition to publishing best practices, AVSC supports publishing information reports and other document types to create awareness amongst industry players of sound and effective approaches that may aid in engendering public confidence in the efficacy of ADS-DVs.

Comment and open discussion on the topics are welcome in appropriate industry forums. As discussion unfolds, AVSC documents may be revised as significant information and/or new approaches come to light that would increase public trust.

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Introduction

Maintaining safety during development of SAE Level 4 and 5 ADS includes the operational processes by which prototype ADS are tested. These processes include ADS test methods and locations, evaluating results, and iterative system updates. While the safe performance of the Dynamic Driving Task (DDT) during testing is important, the structure of these processes surrounding its testing and evaluation can play a role in the overall safety culture of the organization. Safe testing and evaluation operations allow the ADS organization to collect performance data to help contribute to assessing the safety performance of the ADS itself.

The purpose of this information report is to draw attention to the role of organizational safety when testing and evaluating SAE Level 4 and 5 ADS during development. One method of continuously improving organizational safety in this context is through the use of a Safety Management System (SMS), a framework which has helped other industries enhance safety for certain operations. Existing policies [1, 2, 3, 4, 5, 7, 8] were also considered and informed the development of this report. The SMS framework provides a useful structure to consider risk-based decision-making for the test and evaluation of ADS. The components of an SMS address how an ADS organization can manage the safety of test operations, including key responsibilities, processes, proactive risk assessment, and decision-making.

Industry participants may find this information report helpful to reference when assessing their organization's approach to safety management for ADS testing and evaluation programs. Similar to other frameworks, the goals of an SMS for ADS test and evaluation include the following:

- **Promotes continuous learning:** An organization can continuously seek and analyze safety information and take action to mitigate potential safety risks in the operation of its ADS testing program.
- **Ownership:** An organization can clarify authority, responsibility, and accountability for safety management within its organization for the purposes of its ADS testing operations.
- **Scalability:** An organization, regardless of size, can tailor systems, programs and resources to document and track potential safety hazards in its testing operations to resolution.
- **Transferability:** An organization can consider how changes within the organization may affect ADS testing operational safety.

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1. Scope

This Automated Vehicle Safety Consortium™ (AVSC) ***Information Report for Adapting a Safety Management System (SMS) for Automated Driving System (ADS) SAE Level 4 and 5 Testing and Evaluation*** **(AVSC000007202107)** shares information on a Safety Management System (SMS) framework considering ADS testing and evaluation operations. This report was developed to provide ADS organizations with information about the role of organizational safety, which may be considered in the ADS testing and evaluation process. The SMS framework represents a method used in other non-automotive industries (e.g., aviation [1, 6], rail [7], nuclear [8]) for the goal of enhancing safety performance of the organization's operational activities.

This information report does not consider ADS deployment or commercialization activities, nor does it consider the design and development of DDT performance. For assessing the safe performance of the ADS, industry members are encouraged to reference other AVSC publications such as *AVSC Best Practice for Metrics and Methods for Assessing Safety Performance of Automated Driving Systems (ADS)*. Further, AVSC encourages open industry dialog on all topics for future learning and safety enhancements.

2. References

2.1. Applicable Documents

The following publications were referenced during development of this document. Documents are cited, where appropriate.

2.1.1. SAE Publications

Unless otherwise indicated, the latest issue of SAE publications apply. Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AVSC00001201911	AVSC Best Practice for In-Vehicle Fallback Test Driver Selection, Training, and Oversight Procedures for Automated Vehicles Under Test
AVSC00006202103	AVSC Best Practice for Metrics and Methods for Assessing Safety Outcomes of Automated Driving Systems (ADS)
SAE J3016C_202007	Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems
SAE J3018B_201503	Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)

2.1.2. Other Documents

[1] Federal Aviation Administration, “Safety Management Systems,” [Online]. Available: https://www.faa.gov/about/initiatives/sms/. [Accessed 14 January 2021].

[2] GlobalAutoRegs, “UN Regulation No. 157 Automated Lane-Keeping Systems (ALKS),” [Online]. Available: https://globalautoregs.com/rules/247-automated-lane-keeping-systems-alks. [Accessed 14 January 2021].

[3] State of California, “Title 13, Division 1, Chapter 1 Article 3.7 - Testing of Autonomous Vehicles,” [Online]. Available: https://www.dmv.ca.gov/portal/uploads/2020/06/Adopted-Regulatory-Text-2019-1.pdf. [Accessed 14 January 2021].

[4] ISO; International Organization for Standardization, “ISO 26262-1:2018(en),” Technical Committee ISO/TC 22, Road vehicles Subcommittee, SC 32, Electrical and electronic components and general system aspects, 2018.

[5] ISO; International Organization for Standardization, “ISO/PAS 21448: Road vehicles—Safety of the intended functionality,” ISO, 2019.

[6] Britton T., “History of Aviation and Four Pillars,” 10 February 2016. [Online]. Available: http://aviationsafetyblog.asms-pro.com/blog/history-aviation-sms-programs. [Accessed 14 January 2021].

[7] Office of the National Rail Safety Regulator, “Guideline Safety Management System,” Office of the National Rail Safety Regulator, Adelaide, 2019.

[8] International Nuclear Safety Advisory Group (INSAG), “Management of Operational Safety in Nuclear Power Plants (INSAG-13),” International Atomic Energy Agency, Vienna, 1999.

[9] Federal Aviation Administration, “Order 8040.4B: Safety Risk Management Policy,” 2 May 2017. [Online]. Available: https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8040.4B.pdf.

[10] National Academies of Sciences, “Safety Management Systems for Airports, Volume 2: Guidebook (2009),” The National Academies Press, Washington D.C., 2009.

[11] International Civil Aviation Organization, “Safety Management Manual,” ICAO Document 9859, Montreal, Quebec, Canada, 2009.

[12] Federal Aviation Administration, “Advisory Circular 120-92B: Safety Management Systems,” 8 January 2015. [Online]. Available: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-92B.pdf. [Accessed 21 May 2021].

[13] “ISO 45001:2018; Occupational health and safety management systems,” ISO, 2018.

[14] Federal Aviation Administration, “Part 139 Safety Management System Implementation Study,” November 2011. [Online]. Available: https://www.faa.gov/airports/airport_safety/safety_management_systems/external/pilot_studies/media/part139SMSImplementationStudyRoundtable.pdf.

[15] European Union Aviation Safety Agency, “Regulation (EU) No 376/2014 of the European Parliament and of the Council on the reporting, analysis and follow-up of occurrences in civil aviation, amending EU No 996/2010 and repealing Directive 2003/42/EC,” 3 April 2014. [Online]. Available: https://www.easa.europa.eu/document-library/regulations/regulation-eu-no-3762014. [Accessed 9 December 2020].

3. Definitions

These definitions are provided for reader convenience and are not intended to supplant or replace established legal or “terms of art” definitions.

3.1. Harm

Physical injury or damage to the health of persons [4].

3.2. Hazard

A system state or set of conditions that, perhaps together with a particular set of non-ideal environment conditions, have the potential to lead to a safety event. Potential source of harm (physical injury or health damage) caused by malfunctioning behavior of the item or process [4].

3.3. Incident

An occurrence that may have led to a safety event that affects or could affect the safety of operations [9].

NOTE: Often referred to colloquially as a close call or near miss.

3.4. Investigation

A process conducted for the purpose of loss prevention (e.g., loss of life, loss of property, etc.) which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations [10].

3.5. Risk

The combination of the probability of occurrence of harm and the potential severity of that harm [4].

3.6. Risk Control or Risk Mitigation

Anything that mitigates the safety risk of a hazard. Safety risk controls necessary to mitigate an unacceptable risk should be measurable and monitored for effectiveness [10].

3.7. Safety Culture

The way safety is perceived, valued, and prioritized in an organization. Enduring values, attitudes, motivations, and knowledge of an organization in which safety is prioritized over competing goals in decisions and behavior [4].

3.8. Worst Credible Condition

The most unfavorable conditions or combination of conditions that are reasonably expected to occur [10].

4. Introduction to the SMS Framework

An SMS is a framework that integrates safety principles, processes, and practices to enhance organizational decisions based on safety risk. The individual components of an SMS, when working in an integrated and synergistic fashion, are one way to enable an organization to identify, track and trace potential safety risks at a holistic level. This type of approach can help encourage better organizational safety when testing and evaluating SAE Level 4 and 5 ADS during development.

SMS is typically comprised of four main components (Figure 1):

1. **Safety Policy and Objectives (SPO):** Establish or enhance safety practices with a clear safety policy, safety roles and responsibilities, and organizational safety objectives.
2. **Safety Risk Management (SRM):** Proactively manage risk using safety risk assessments.
3. **Safety Assurance (SA):** Monitor, analyze, and measure overall safety performance, including effectiveness of its safety risk controls, safety management, and associated processes.
4. **Safety Promotion (SP):** Regularly conduct activities that inform, educate, and heighten the safety awareness of employees.

An SMS establishes an overarching management of risk across disparate departments by incorporating safety risk management and safety hazard resolution into an organizational safety framework. The SMS framework has been used by other industries [1, 7, 8] as well as emerging uses by certain ADS developers, to encourage better organizational safety practices to help evaluate and control safety risks; monitor and analyze the success of safety initiatives and risk mitigations; and increase awareness to promote continuous improvement in safety.

FIGURE 1 SMS components.

5. SMS Components

5.1. Safety Policy and Objectives (SPO)

The SPO component defines the management of safety across the organization and sets structure of safety accountability, authority, safety performance indicators (SPIs), organization resource planning, and the emphasis on "just culture"[1] within the organization. The SPO in an SMS functions to establish a clear safety policy, safety roles and responsibilities, and organizational safety objectives, and is typically comprised of four elements:

1. Safety Policy (5.1.1)
2. Safety Organization (5.1.2)
3. Safety Roles and Responsibilities (5.1.3)
4. Safety Objectives (5.1.4)

5.1.1. Safety Policy

In an SMS, the Safety Policy provides guidance to employees and can serve as the catalyst to acceptance and participation by employees in the SMS and its processes. It functions to represent the organization's commitment to safety, its commitment to implementing the SMS, and a visible endorsement from senior leadership of the operational safety objectives for the organization. Companies with an SMS may have different ways to communicate the safety intent and would tailor it for their organizations.

An organization developing a Safety Policy would consider:

- Capturing the concept that all humans make errors, and human errors should be expected;
- Expressing organization's commitment to encourage and empower employees to report operational safety concerns without fear of repercussions;

[1] "Just culture" means a culture in which front-line operators or other persons are not punished for actions, omissions, or decisions that are commensurate with their experience and training, but in which gross negligence, willful violations, and destructive acts are not tolerated. "Just culture" is an essential element of a broader "safety culture," which forms the basis of a robust safety management system [15].

- Expressing management's commitment to acknowledge and investigate a potential safety concern;
- Defining a mechanism to regularly and accurately report safety concerns, including provisions for employees to submit feedback on the process (e.g., Safety Reporting System as described in 5.1.1.1).

A Safety Policy in an SMS would reflect the beliefs and values of the organization and its leaders regardless of succession or transition, including the importance of continuous improvement.

5.1.1.1. Safety Reporting System In an SMS, a Safety Reporting System is used to bring safety hazards to the attention of organizational leadership, thus supporting the Safety Policy. Reporting forms or channels are made easily available and not cumbersome to use. Such a system also would have policies on:

- The purpose and goals of the reporting system;
- The safety reporting process for the organization;
- The rights, privileges, protections, obligations, and confidential treatment of those doing both the reporting and those reviewing the reports without fear of reprisal.

The purpose of a clearly written Safety Reporting Policy in an SMS is to help encourage the proper disclosure, reporting, and accountability of safety concerns.

5.1.2. Safety Organization

In an SMS, a Safety Organization refers to the reporting and communication structure within a company responsible for overseeing the implementation and operation of the SMS. The design of a safety organization is unique to the size and needs of the organization.

An effective design of the Safety Organization in an SMS generally depends on the organizational management style and culture of the organization but potentially includes:

- Empowerment of employees to communicate safety concerns to management or appropriate safety personnel;
- Formation of a committee (i.e., Safety Review Board (SRB) [11] or Safety Committee) to actively monitor the effectiveness of SMS implementation, issue resolution, and safety performance against the organization's safety policy and objectives;
- Procedural controls designed to protect against a conflict of interest with test operations, which is transparent, auditable, and available for review by SRB;
- Organizational responsibilities documented, auditable, and available for review by SRB;
- Leadership and maintenance of the SMS, which has a direct and significant impact on daily execution.

5.1.3. Safety Roles, Responsibility, and Accountability/Authority

In an SMS, there are several high-level principles that are normally considered when assigning safety roles in an organizational structure. These may include:

- Decision makers have direct and unbiased links to those who can provide safety information.
- Safety considerations influence decision making, which means that decision makers have access to necessary safety information at the time safety-related decisions need to be made.
- Multiple layers of management support SMS by being involved in investigations, and safety risk assessments, as appropriate.
- Relevant managers, supervisors, and employees at all levels outside of the safety organization are knowledgeable about their role to support the functions of the SMS.
- Anyone in an organization feels empowered to raise safety concerns and take the appropriate actions to promote safety.

Each organization setting up an SMS would determine the specific roles that best align in their organizational structure. An SMS would cover the responsibilities that are shown in Table 1. Depending on the organization, these responsibilities may be named and distributed differently than how they are listed, and Table 1 shows examples of some roles which can be referenced in other global standards [11, 12].

TABLE 1 Example Roles and Responsibilities.

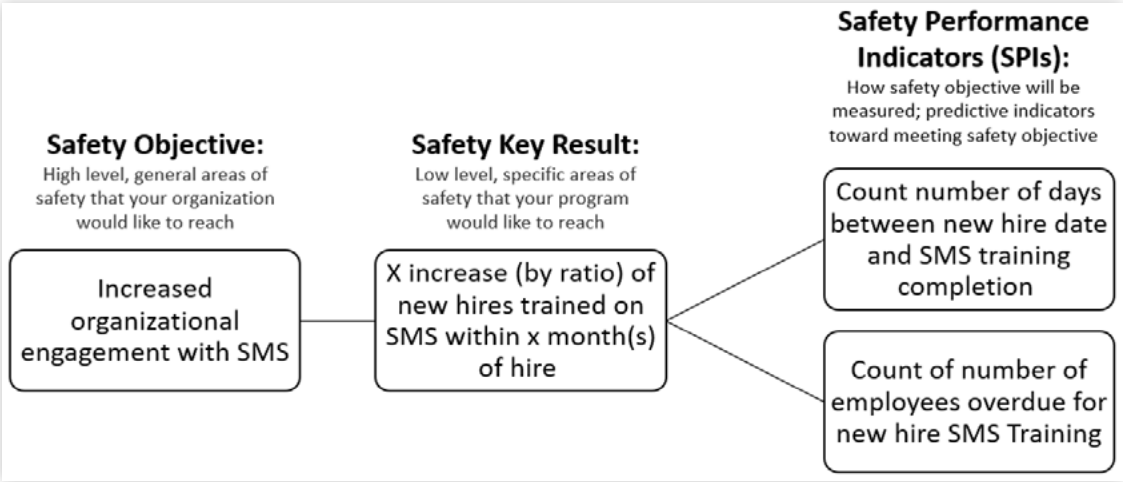
Key Responsibilities	Example Role
Individual who is responsible for the safety performance of the organization's testing and evaluation operations. This role may be assigned to a person with authority over multiple cross-functional departments.	Accountable Executive (AE)
Individual(s) responsible for the safety performance of a department or group of departments and determines the cross-functional nature of safety hazards.	Safety Manager(s)
Individual(s) or small group with delegated authority which collect and support analysis, investigations, safety risk assessments, and/or provide programmatic support of the organization's safety objectives.	Process Owner(s)

5.1.4. Safety Objectives

In an SMS, Safety Objectives are established in response to the overall safety goals of the organization. This can help the organization measure its safety performance. Each objective in an SMS has a set of key results and safety performance indicators (SPIs) to measure the progress and effectiveness towards meeting the objective. Figure 2 shows an example of how safety objectives can align with key results and SPIs.

In an SMS, results would be reviewed periodically to consider their relevance to achieving the safety objectives. Safety objectives may be revised to further continuous improvement. If safety objectives cannot be reached, they should be re-evaluated. Executive leadership may use safety objectives to monitor the performance of the SMS, while managers and process owners would use them to regularly review organizational safety performance.

FIGURE 2 Examples of the Relationship between Safety Objectives, Key Results, and SPIs.



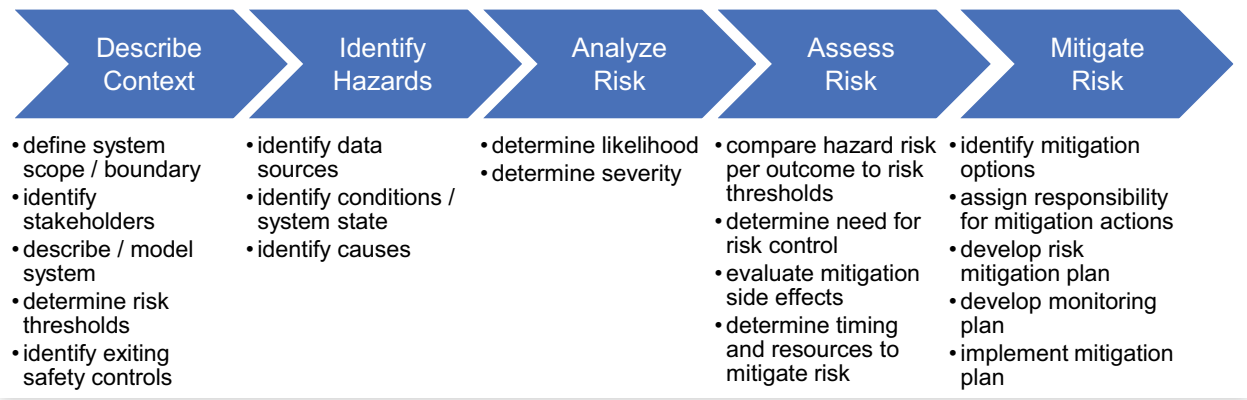
5.2. Safety Risk Management (SRM)

In an SMS, the Safety Risk Management component is intended to proactively identify and analyze safety risks. The output of SRM would contribute to organizational decisions based on safety risk assessment. The SRM is meant to be flexible to changes in organization, operations, or other safety hazards.

5.2.1. The SRM Process

The five-step SRM process shown in Figure 3, based on the aviation model [9], is one method for risk-based decision making and safety hazard resolution for an organization in an SMS. The steps shown in Figure 3 are an example of a systematic approach which guides decision makers toward actionable plans to reduce safety risk associated with testing and operations. The objective of risk management in an SMS is to identify and mitigate risk as appropriate.

FIGURE 3 Example Safety Risk Management System Process Steps.



An SRM component of an SMS uses a process (such as the one in Figure 3) to identify testing hazards in a proactive manner. Significant parts of the process include analyzing and assessing risks associated with identified potential hazards and creating appropriate risk mitigation strategies or risk controls to minimize or eliminate the impact of an undesired outcome.

The likelihood and severity of risks are determined by the organization would be based upon both available organizational and industry data, and in consideration with the worst credible condition. When assessing risk, controls for risk mitigation would be analyzed and assessed to help ensure no new hazards are introduced. Once the risk has been assessed and a mitigation plan is created, clear assignment of responsibility and a plan for monitoring the effectiveness of that mitigation leads to the Safety Assurance (SA) component of an SMS as described in 5.3.

5.2.2. Safety Risk Assessment

A Safety Risk Assessment (SRA) in an SMS is a process which may include a panel of stakeholders or peers to convene and evaluate the safety risks associated with a single safety concern or potential hazard, following the SRM process (example in Figure 3). The SRA can be informal or formal, depending on the risk level. For example, in some cases, the SRA is lengthy and highly formalized where there are multiple hazards with higher impact. In other cases, the SRA may be less lengthy and more informal. The objective of any type of SRA is to help ensure that the assessed safety risk is brought to the proper owner within the SMS organization for decisions on safety risk acceptance, mitigation, or rejection. Rejection, in this sense, usually refers to grounding operations, or rejecting the initiative. For example, when assessing the risk for changing the ADS-Operated Vehicle On-Road Testing Protocols, as described in *AVSC Best Practice for In-Vehicle Fallback Test Driver Selection, Training, and Oversight Procedures for Automated Vehicles Under Test*, not adopting the change would be a rejection of the risk. The SRM process typically results in mitigating actions to maintain an acceptable level of safety for that activity. Risk controls that are put into practice also are be monitored to determine their effectiveness.

The output of the SRA in an SMS is dynamic in nature, documenting the overall view of the testing organization's hazards and risks. This may include a running list of hazards, the mitigation actions, and implementation of safety controls.

There are several potential triggers for conducting an SRA in an SMS. These triggers are documented and included in SRA training. Some examples of these triggers include:

- System change (technological or process);
- Process change (alterations to test plans);
- Technology change (introduction of new software or hardware);
- Environment changes (testing or operations in a new city, route or other location);
- Incidents or safety events (such as those identified through field monitoring); and
- Significant trend in safety performance.

5.3. Safety Assurance (SA)

The SA component of SMS encompasses the processes which monitor the performance and effectiveness of safety risk controls.

In the context of an SMS, SA is how the organization monitors, analyzes, and measures the effectiveness of organizational safety performance, including effectiveness of its safety risk controls, SMS, and associated processes. SA objectives are:

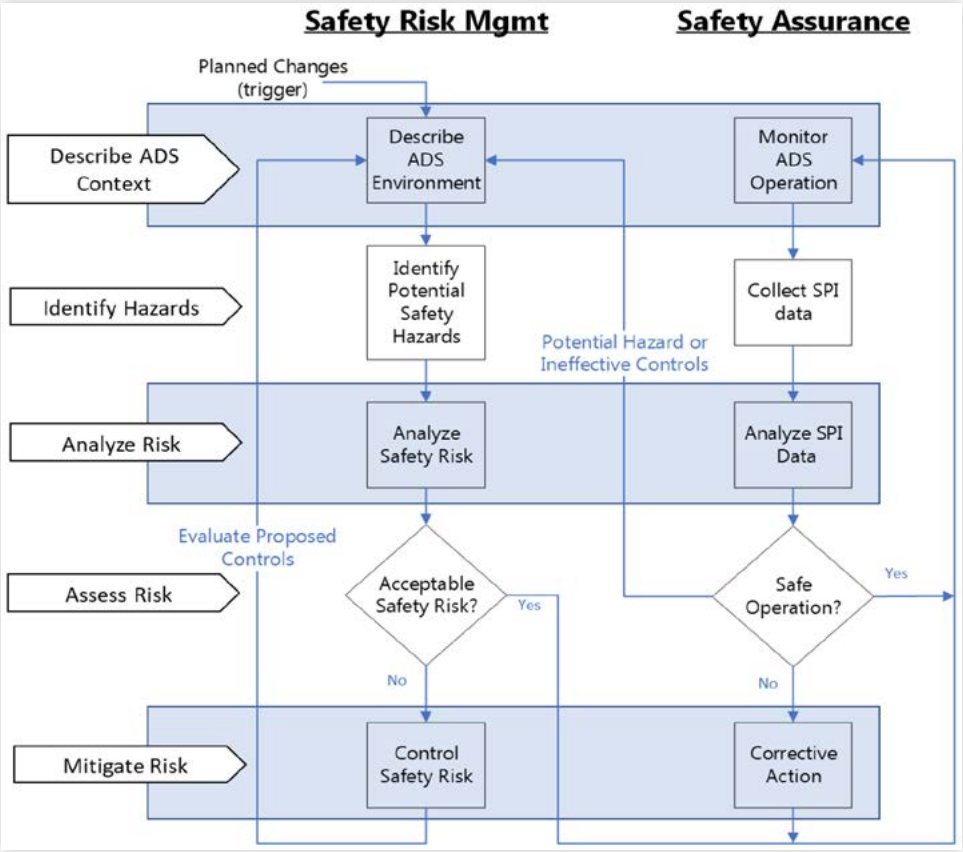
- Monitor safety data via several sources inside and outside the SMS component;
- Monitor select safety risk controls identified within the SRM component; and
- Provide safety data and analysis to decision makers to support continuous safety improvement.

Examples of organizational SA practices in an SMS could include safety self-inspections, safety audits, safety reports, and the investigations performed following safety events and incidents. Integrating existing practices with the SMS components can help enable SMS implementation, when a method is identified to bridge these processes together. For example, when a safety hazard is identified, it would be helpful to have a method to escalate to the appropriate committee as defined in the safety organization (5.1.2).

SA processes could provide direct information about the performance of safety systems, which may include in-vehicle fallback test drivers (IFTD), test processes, or the organization overall.

The SA component typically does not include a specific order of steps as with the SRM component. For illustrative purposes, Figure 4 shows an example relationship between SRM and SA as adapted from the Federal Aviation Administration (FAA) Safety Risk Policy [9]. In that structure the two processes are integrated, and potential new hazards identified by SA are be fed back, analyzed, and assessed using SRM.

FIGURE 4 Relationship between SRM and SA adapted from FAA [9] for illustrative purposes.



5.3.1. Safety Performance Measurement

In an SMS, safety performance measurement is a means to assess the safety performance of the organization and the effectiveness of safety risk controls.

Organizations with an SMS use Safety Performance Indicators (SPIs) to measure operational safety performance and track changes. SPIs are intended to be traceable to the safety objectives established by the Safety Policy and Objectives (5.1). This could enable the organization to communicate safety performance and gauge progress toward the achievement of safety objectives.

Safety performance indicators used in an SMS are assessed and prioritized. SPIs that involve monitoring safety events such as crashes or traffic violations are typically more reactive. SPIs also are developed and used to proactively identify potential testing safety hazards beforehand.

This data is reviewed on a periodic basis and evaluated for applicability and effectiveness in an SMS. Organizations with an SMS generally establish a level at which a trend, audit or investigation would trigger an SRA. Some examples of SPIs for operational safety performance include:

- Safety hazard resolution metrics;
- Repeat safety hazards;
- Safety training completion statistics;
- Safety promotional event attendance;
- Repeat external or internal audit findings;
- Proactive versus reactive safety risk assessments.

5.3.2. Safety Performance Monitoring

Monitoring the safety performance helps the organization to gauge the progress and impact of safety risk controls developed and implemented in the SRM process (e.g., using appropriate metrics, select inspections, and safety audits either by internal personnel or outside organizations). Such monitoring helps to examine how well the organization is adhering to their internal policies.

For example, trend analyses could be performed to determine the frequency of indicators over specific periods of time. This could provide information on the positive and negative trends in safety performance and potentially identify areas in need of additional action and improvement. Because SPIs vary in relationship to safety performance, discretion is used to determine when monitoring results should be investigated further.

5.3.3. Safety Investigations

In an SMS, the SA component also includes investigations to determine the causes and implications of undesired outcomes. Safety investigations are launched as appropriate in order to analyze the safety implications of the organization's safety performance related to an identified concern or hazard. Regardless of the trigger, the information captured during a safety investigation can be helpful to identify gaps in safety processes and would allow for continuous improvement of the SMS.

5.3.4. SMS Evaluation

Continuous improvement is a core concept of an SMS. To help organizations with an SMS focus management efforts in the right direction, SA incorporates tools to measure improvement over time. One of the tools is the SMS self-assessment or evaluation [10].

Organizations with an SMS sometimes perform an evaluation of their SMS on a periodic basis. The goal of an SMS evaluation is to review the processes and resources to identify areas where improvements could be made. For example, evaluations could include reviewing and evaluating the actions taken to understand whether they are producing the desired effects. An example of an SMS evaluation model is included in Appendix A.

5.4. Safety Promotion (SP)

The Safety Promotion (SP) component of SMS includes activities that inform, educate, and heighten the safety awareness of employees. Already established communications resources, processes, and branding can be leveraged to help cultivate a more positive safety culture when an organization is setting up an SMS. Typically, there are three elements of SP:

- Training;
- Communication;
- Record keeping.

These combined elements help encourage employees to actively participate in the SMS. They provide a means to communicate the importance of safety information throughout the organization and a venue where records and lessons learned are shared and archived.

The commitment of senior leadership generally contributes to the success of SP [11, 13]. Active participation of senior leadership in SP would show visible and continuing support of SMS and could help employees to understand the priority of safety within everyday testing activities. The importance of the SMS is generally specified in the Safety Policy Statement (5.1.1) and magnified by active participation and oversight of SP activities.

5.4.1. Training and Education

In an SMS, training and education is integrated at appropriate levels of the organization and content is reviewed on a periodic basis. Each member of the staff is provided with the appropriate level of training to support performing their duties in an effective and safe manner. SMS education helps address the following concepts:

- Why SMS is important to the organization?
- What SMS is designed to do for the organization?
- How are safety priorities and decisions made in the organization?
- What roles and responsibilities does each staff member play as part of an SMS?
- What are the existing safety policies and procedures?
- How should potential safety hazards and risks be reported?

In an SMS, not all members of an organization require the same level of training on SMS concepts and processes. SMS training is based on the skills and competencies needed by individual positions within the organization. In general, everyone has a basic understanding of SMS, while others could need more detailed knowledge regarding certain aspects of SMS, e.g., SRM, SRA, or risk monitoring. For example, front-line employees in an SMS may need to only have a high-level knowledge of SMS principles, but require a more intimate knowledge of what a hazard is, how to identify such safety hazards, and how and where to report the hazard. Teaching general strategies rather than specific actions can help employees develop the knowledge base and competencies to support the SMS.

5.4.2. Safety Communication

Safety communication helps to promote active engagement in the SMS and the development of a positive safety culture. Effective communication in an SMS builds awareness for employees, provide insight on safety perspective from senior leadership, and promote the sharing of safety information across organizational divisions. Examples of effective SMS safety communications sometimes includes sharing the organizational safety policy, the importance of reporting safety hazards, publishing relevant safety metrics, etc.

A safety communication strategy in an SMS balances familiar promotion methods with the knowledge and expectations of employees, to build and shape the types of communication based on the needs of the organization. In general, these communications are consistent with existing communications processes, tone, branding, and outreach channels within individual companies.

5.4.3. Safety Record Keeping

The function of keeping records of safety-related activities falls under the Safety Promotion component of an SMS. Organizations with an SMS typically maintain the following records per their established retention policies:

- Safety training; e.g., individual and SMS-specific training;
- Safety audits, inspections, and hazard reports;
- Safety compliance deficiencies and corrections; and
- Safety data and trend analysis results.

6. SMS Implementation

In this report, considerations for implementation of an SMS for ADS-DV testing and evaluation operations are taken from the airline industry and based upon the lessons learned by airlines and airports who participated in FAA sponsored SMS pilot studies. The primary sources for the information are the FAA Advisory Circular 120-92B: *Safety Management Systems for Aviation Service Providers* and the Transportation Research Board's Airport Cooperative Research Program (ACRP) Report 1: *Safety Management Systems for Airports, Volume 2: Guidebook*.

Note that the operation of aircraft is significantly different from the operation of automobiles, in the sense that operating an automobile involves many more vehicles used in varied and uncontrolled circumstances and, in the case of public roads, typically by non-professional operators.

6.1. Mapping the Organization

If an SMS is to be implemented, the first step is to start with mapping and analysis of the ADS organization. For example, the process may consider organizational structure, operational environment, and specific functions of testing and evaluation groups [12], and how these line up with the SMS framework. In this step, an analysis would, and identify any gaps which may exist, identify responsible and accountable personnel.

6.2. Mapping Existing Processes to SMS Components

The next step is to consider mapping existing safety processes as a basis for SMS implementation. The analysis identifies the processes already existing in the organization, compare with the components and elements of the SMS model, and identify opportunities for safety improvements [10, pp. 40-41].

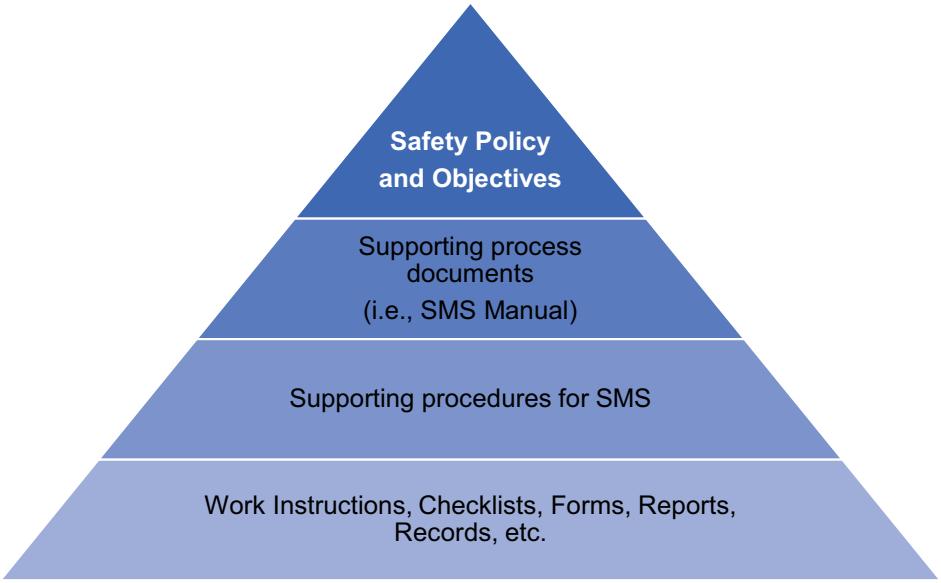
The analysis sometimes includes both a document review and interactions with staff. The document review would focus on items such as existing operations, organizational safety-related documents, and current procedures [14]. As the SMS is developed, the investigation process could be examined, refined, and adapted for use within the SA component (5.3).

6.3. Develop SMS Documentation

After existing organization and processes are mapped to the SMS framework, the next step, if an SMS is being implemented, is to consolidate, develop, and create the documentation that guides the implementation and function of the SMS for the ADS organization. SMS documentation ideally aligns with existing company process templates and methods to ease SMS integration. Organizations often use naming conventions which align best with their existing company lexicon. Some general examples of SMS documentation are shown in Figure 5.

An SMS Manual or plan (or similar guidance document) is used to describe the four key elements of an SMS [12] as well as the supporting policies and procedures that are in place. SMS documentation also references relevant regulatory documents (if applicable) and explain how the SMS contributes to compliance of applicable regulations.

FIGURE 5 Levels of SMS Documentation [10].



Source: National Academies of Sciences, Engineering, and Medicine. 2009. *Safety Management Systems for Airports, Volume 2: Guidebook*. https://doi.org/10.17226/14316. Adapted and reproduced with permission from the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.

6.4. Implementation Plan

In implementing an SMS, the next step is to form an implementation plan. The content and format of the implementation plan depends upon the approach used by each organization. The plan generally includes a timeline and assignment of key responsibilities for personnel involved in the implementation process (5.1.3). Additionally, communicating the implementation plan throughout the organization can be an early example of Safety Promotion.

Making the implementation plan visible and valuable to a wide variety of the work force is a strategy used to help the success and acceptance for the SMS.

7. Summary

This information report describes one organizational approach—Safety Management System (SMS)—that is used for operations in other industries and could be considered by ADS organizations in the context of increasing organizational safety performance when administering testing and evaluation of ADS-DVs.

8. About Automated Vehicle Safety Consortium™

The objective of the Automated Vehicle Safety Consortium™ is to provide a safety framework around which automated vehicle technology can responsibly evolve in advance of the broad use of commercialized vehicles. The consortium will leverage the expertise of its current and future members and engage government and industry groups to establish safety principles and best practices. These technology-neutral principles are key considerations for deploying SAE level 4 and level 5 automated vehicles on public roads.

AVSC Vision:

Public acceptance of SAE level 4 and level 5 automated driving systems as a safe and beneficial component of transportation through industry consensus.

AVSC Mission:

The mission of the Automated Vehicle Safety Consortium™ (AVSC) is to quickly establish safety principles, common terminology, and best safety practices, leading to standards to engender public confidence in the safe operation of SAE level 4 and level 5 light-duty passenger and cargo on-road vehicles ahead of their widespread deployment.

The AVSC will:

- Develop and prioritize a roadmap of pre-competitive topics;
- Establish working groups to address each of the topics;
- Engage the expertise of external stakeholders;
- Share output/information with the global community;
- Initially focus on fleet service applications.

9. Contact Information

To learn more about the Automated Vehicle Safety Consortium™, please visit https://avsc.sae-itc.org.

Contact: AVSCinfo@sae-itc.org.

10. Acknowledgements

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11. Abbreviations

ACRP - Airport Cooperative Research Program
ADS - Automated Driving System
ADS-DV - Automated Driving System-Dedicated Vehicles
AE - Accountable Executive
ALKS - Automated Lane-Keeping Systems
AVSC - Automated Vehicle Safety Consortium™
DDT - Dynamic Driving Task
FAA - Federal Aviation Administration
FMEA - Failure Modes and Effects Analysis
IFTD - In-Vehicle Fallback Test Driver
ICAO - International Civil Aviation Organization
SA - Safety Assurance
SAE ITC - SAE Industry Technologies Consortia®
SMS - Safety Management System
SP - Safety Promotion
SPI - Safety Performance Indicators
SPO - Safety Policy and Objectives
SRA - Safety Risk Assessment
SRB - Safety Review Board
SRM - Safety Risk Management

Appendix A: SMS Evaluation Model Example

An SMS evaluation examines and evaluates the SMS elements and how they function within each component. The SMS evaluation looks at the in-place SMS elements to help evaluate how effectively they are functioning through rating their performance. As appropriate, sometimes the evaluation looks only at individual elements of the SMS or even individual units within the organization to check how well they are performing their SMS roles and tasks [11].

Table A.1 shows an example SMS evaluation scoring table for the Safety Policy and Objectives component. The assessment tables are designed to organize and consolidate the information and observations collected during an SMS assessment.

TABLE A.1 SMS Evaluation Scoring Table (Example).

SMS Components and Elements	Sub-Element Score	Element Score	Component Score
1. Safety Policy and Objectives			
• Management commitment			
▪ Published safety policy statement			
▪ Acknowledgement by employees			
• Safety accountabilities of managers			
• Safety personnel			
• SMS implementation and management			
• Documentation			
▪ Legal and other requirements			
▪ SMS documentation			
▪ Records management			
▪ Coordination of emergency response plan			

The sub-elements and rating system are developed by the safety manager and approved by the accountable executive, based on the specific requirements of the organization using an SMS. Expectations for each item are documented and understood by the evaluation team in advance of the evaluation.