Industry Standards

1 Creation of the Report on Standardization for Vehicle Automated Driving Systems (RoVAS)

For a long time, automated driving has been regarded as the ultimate dream for vehicles. In accordance with increasing social need and technological advancements, a practical system for automatically controlling the acceleration, braking, and steering of a vehicle is within reach. Many application systems are being considered based on differences in the roles played by the automated driving system and the driver (in an automated driving system, since the system itself can also be said to be a "driver," the phrase "human driver" is used below to differentiate between the system and the person. However, the word "driver" is used in figures and tables for simplicity). The indices that express the degree to which the system automatically performs control in relation to the human driver are referred to as the "automation level." There are many different ideas about how best to define these automation levels and various countries and organization have submitted proposals, but the automation levels proposed by the SAE International of the U.S. (SAE) are currently regarded as the basis for discussions of this topic.

Table 1 shows the definitions of the different automation levels proposed by the SAE. The red line running through the middle of the table indicates the boundary between driving tasks mainly performed by a human driver and those that are mainly performed by a system. Table 2 shows a brief summary of each automation level from the standpoint of the human driver. There are also a variety of other elements, such as the place where the vehicle is being used (such as private roads, public roads, and parking lots), the vehicle speed range, and the purpose of the automation (safety, efficiency, convenience, or the like). Various different automated driving systems can exist depending on how these elements are combined. When an automated driving system is to be used by a wide variety of general users, it is extremely important to clearly define and standardize the role of the human driver and the functions of the vehicle so that the system can be used properly without confusion. Since there are also many different technologies that are related to automated driving systems, these are also likely to require the establishment of many new standards. The parties that will help to develop these standards will also be very diverse. Automated driving is quickly becoming the next big product category and international competition to develop these systems is already becoming quite intense. Japan has already recognized this as a strategic field and is aiming to shape international standards to the advantage of Japanese automakers in the competitive international vehicle market.

However, at the present time the standardization items for automated driving systems and the division of responsibilities to carry out this standardization are not clear. Consequently, ISO/TC 204/WG 14 is promoting the creation of the Report on Standardization for Vehicle Automated Driving Systems (RoVAS) to clarify the overall picture of the standards related to automated driving. Another purpose of this report is to help identify the items that the concerned parties working on this topic need to standardize, help the concerned parties obtain a common understanding of how best to proceed with standardization work, and enable the promotion of systematic standardization. This article will provide details about the current state of automated driving and its standardization, the state of the work being carried out in WG 14, and also provide a summary of the RoVAS report and its positioning.

2 State of Automated Driving and Standardization

2. 1. Current state of automated driving systems

Research and development into automated driving sys-

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Table 1 SAE definitions of automation levels

SAE level	SAE name	SAE definition (simplified expression)	Steering and acceleration/deceleration performed by	Monitoring of driving environment	Driving task backup	System capability (driving modes)
0	No Automation	Full-time performance by human driver of all aspects of driving	Human driver	Human driver	Human driver	None
1	Driver Assistance	Driving mode-specific performance by driving support system of either steering or acceleration/deceleration	System performing either task	Human driver	Human driver	Some driving modes
2	Partial Automation	Driving mode-specific performance by one or more driving support systems of both steering and acceleration/deceleration, with the human driver performing all remaining aspects of driving	System	Human driver	Human driver	Some driving modes
3	Conditional Automation	Driving mode-specific performance by an automated driving system of all aspects of driving, with the human driver responding appropriately to requests to intervene from the system	System	System	Human driver	Some driving modes
4	High Automation	Driving mode-specific performance by an automated driving system of all aspects of driving, even if the human driver cannot respond appropriately to requests to intervene	System	System	System	Some driving modes
5	Full Automation	Full-time performance by an automated driving system of all aspects of driving	System	System	System	All driving modes

Table 2 Automation level from the viewpoint of the driver

SAE level	Name	Controls performed by the system	Monitoring of driving environment by human driver	Backup by human driver required	Human driver position	Performance of other tasks
0	No Automation	None	Required	Human driver performs all driving tasks	Driver's seat	No
1	Driver Assistance	Automated control of either steering or acceleration/deceleration		Human driver performs all driving tasks (some automation)		
2	Partial Automation	Automated simultaneous control of both steering and acceleration/deceleration		Immediate response by human driver required		
3	Conditional Automation		Not required	Response by human driver required within a short time		Yes, but must reassume driving tasks within a short time
4	High Automation			Response by human driver required after vehicle stops	Inside vehicle	Yes
5	Full Automation			Not required	Does not have to be inside vehicle	

tems has been promoted and advanced for many years to help make significant improvements to social issues involving vehicles, such as traffic accidents and congestion, and to help realize convenient modes of transportation that people can use with peace of mind. Many different research institutions and automotive industry companies have carried out research showing the technical possibilities and effects of automated driving (1). Automated driving systems are already being utilized in special situations, such as on work vehicles that operate in locations that are difficult for people to enter and by automakers to run tests that would be difficult for a human driver to perform (2). Starting in the early 1980's, intelligent transport systems (ITS) were introduced that utilized information communications technologies. Automated driving technologies were also developed linking with cooperative ITS to connect vehicles and infrastructure.

Research and development aimed at the practical application of these technologies has been actively pursued since the beginning of the 21st century. In recent years basic automated driving system technologies, especially environmental recognition and control technologies, have advanced considerably and practical systems continue to be realized. Various driving support systems, such as

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parking assist steering, lane keeping, and vehicle speed and distance controls that use radar or image processing technologies, have already been launched on the market. These systems can perform lateral direction control, such as controlling the steering and the difference in left and right wheel rotation, and longitudinal direction control, such as controlling the throttle and brakes, independently of each other. Automated driving systems that combine both of these types of controls can automatically control the travel of the vehicle, and these systems are continuing to be realized. Automakers have already announced plans to introduce these systems to the market in the near future. The IT, defense, and electric vehicle industries, among others, are now pursuing development to achieve advanced automated driving systems. A more detailed summary of the history and technical content of automated driving systems can be found in the book Automated Driving: Systems and Technologies (3).

2. 2. Automated driving standardization and related trends

Various different organizations in many countries and regions have begun activities to standardize automated driving systems. Studies into how best to update and maintain the related regulations and standards have also begun.

2. 2. 1. Trends in the U.S.

Activities to standardize automated driving systems, and to update and maintain the related regulations and standards are progressing in the U.S. The National Highway Traffic Safety Administration (NHTSA) has created definitions for automation levels and drawn up guidelines for testing automated driving systems. The SAE has also created definitions for automation levels and other relevant terms. Guidelines for carrying out testing of autonomous vehicles on public roads in a safe manner were also standardized. The state of California is determining its own rules and regulations for performing automated driving tests on its public roads and preparing for when the general public will begin using vehicles with automated driving systems.

2. 2. 2. Current situation in Europe

Various organizations and countries in Europe are now examining the definitions for automation levels and other related items. The SMART64 project and the German Federal Highway Research Institute (BASt) have both developed definitions for automation levels. Various other projects, such as AdaptiVe, iMobility, and VRA, have also been examining issues related to the eventual realization of automated driving, as well as standardization and the legal system. In the UK the law was amended to allow for completely autonomous vehicle testing with no human driver to be carried out on public roads.

2. 2. 3. Current situation in Asia

In Japan, automated driving system projects are being carried out under the auspices of the Strategic Innovation Promotion Program (SIP) and the issues surrounding automated driving are being examined by the Japan Automobile Manufacturers Association (JAMA). Other work is being done to examine how best to incorporate international standards. In South Korea, the Korea Automotive Technology Institute (KATECH) is also examining issues related to automated driving systems.

Issues surrounding the realization of automated driving systems are being actively investigated and examined in many different countries and regions around the world and there are growing demands for standardization. However, this work has not progressed much farther than the examination of specific issues, such as definitions for automation levels. Unfortunately, the overall picture of international standards for automated driving has yet to be clarified.

3 Current State of ISO/TC204/WG14 ActivitiesI

3. 1. Scope of WG 14

The English name for WG 14 is Vehicle/Roadway Warning and Control Systems. The scope of the standardization activities being carried out by WG 14 can be summarized as follows: to standardize driving support systems, whether partially or fully automated, by using information from the driving environment to monitor the state of the human driver, to provide warnings about hazardous situations, and to provide advice on corrective driving actions, for the purpose of preventing accidents, improving efficiency, improving convenience, reducing the driving load, and improving the safety and security of driving. Figure 1 shows the scope of WG 14.

3. 2. Standardization work of WG14

The following is a list of the standardization items that WG 14 has been working on with a specific focus on the safety systems of the vehicle (4). (The items marked with an asterisk are currently under discussion).

- ACC: Adaptive Cruise Control
- FVCWS: Forward Vehicle Collision Warning Sys-

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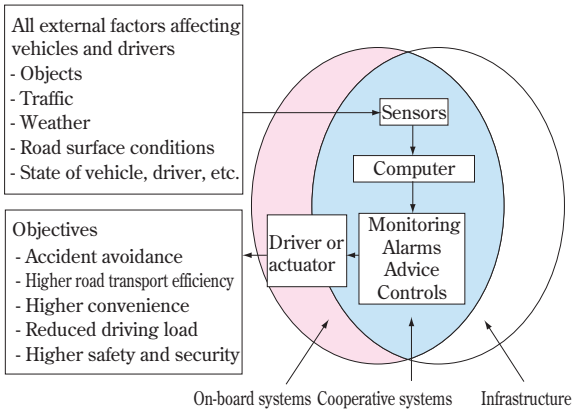

Fig. 1 Scope of WG 14

tems

- MALSO: Maneuvering Aid for Low Speed Operation
- LDWS: Lane Departure Warning Systems
- LCDAS: Lane Change Decision Aid Systems
- LSF: Low Speed Following Systems
- FSRA: Full Speed Range Adaptive Cruise Control
- ERBA: Extended Range Backing Aid Systems
- LKAS: Lane Keeping Assist Systems

* FVCMS: Forward Vehicle Collision Mitigation Systems

* PAS: Parking Assist Systems

* PCMS: Pedestrian Collision Mitigation Systems

* RBDPS: Road Boundary Departure Prevention Systems

In recent years, the standardization of cooperative vehicle-to-infrastructure and vehicle-to-vehicle systems has also been promoted.

- TIWS: Traffic Impediment Warning Systems
- CIWS: Cooperative Intersection Warning Systems

* CSWS: Curve Speed Warning Systems

* HNS: Hazard Notification Systems

* CACC: Cooperative Adaptive Cruise Control

* RoVAS: Report on Standardization for Vehicle Automated Driving Systems

* CFVBWS: Cooperative Forward Vehicle Braking Warning Systems

4 Summary of RoVAS Report

Section 2 of this article described that progress is being made toward the practical utilization of automated driving systems, but that the overall picture of standardization is not yet clear. Therefore, a Technical Report (TR) was created to help clarify the issues surrounding the standardization of automated driving.

4. 1. Purposes and aims of RoVAS

The purposes and aims of the TR are as follows.

(1) A large variety of different automated driving systems are being considered and the items that need to be standardized are also very diverse. The overall picture needs to be systemically clarified. Strategic and systematic initiatives must be promoted so that the standards that will be implemented in the future can be determined and finalized as quickly as possible.

(2) Japan should take a leading role in identifying and documenting the standardization items and then create a foundation to lead efforts to create international standards for automated driving technologies in the future. Japan should indicate that it is already examining the standardization proposals when presented by other countries and organizations, and place itself in a position to take charge of standardization or in an indispensable consultation role for standardization work.

To achieve these objectives, it was important to eliminate omissions and ensure that the opinions of Japanese officials were reflected. Discussions and consultations were held with all of the concerned parties and organizations in advance and a proposal that reflected all of those opinions was created.

4. 2. Content of RoVAS report

The full English title of the RoVAS report is: Report on Standardization for Vehicle Automated Driving Systems (RoVAS) – Beyond Driver Assistance Systems –.

The final portion of the title refers to the will to move on to the next step from the driving support systems that have been developed up until now.

4.2.1. Composition of report

- Introduction and scope: necessity of creating the TR and the scope of the examination
- Standardization item candidates: identification and systemization of standardization candidates
- Approach for proceeding with standardization: proposals of concerned organizations and priority items

Originally, information about the current state of automated driving and the state of the examinations into standardization was included, but it was decided to show this as reference information at the end of the report instead.

4. 2. 2. Standardization item candidates

The standardization items were identified and selected

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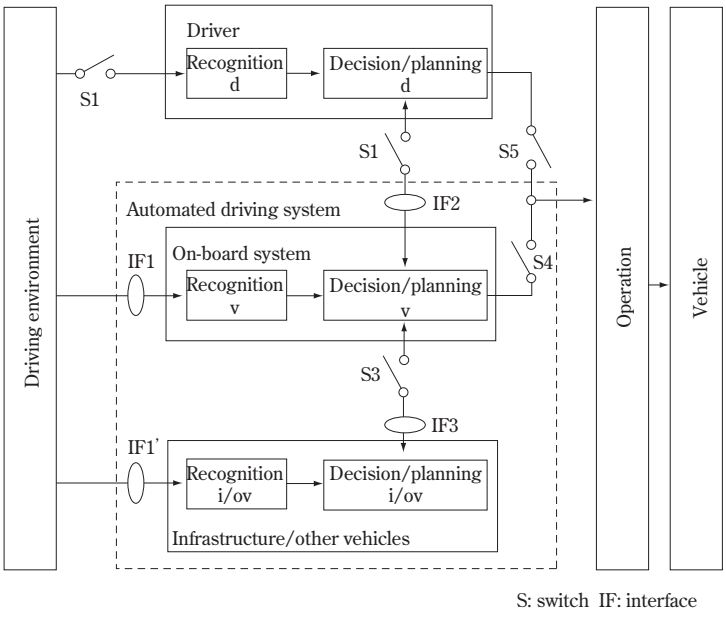

Fig. 2 Notional functional architecture of automated driving

in accordance with the following three principles, since it was necessary to clarify the overall picture, as mentioned previously.

(1) Select the items systematically from a wide range of options while using a notional architecture that shows the whole picture of automated driving as reference.

(2) Select a wide range of possible items regardless of which organization will be in charge of the standardization. The division of responsibilities for the standardization will be considered separately.

(3) Set aside the decision about when the standardization will occur for a separate discussion. Select a wide range of items that are thought to have possibilities in the future.

The notional functional architecture shown in Fig. 2 was hypothesized to help identify and select the items for standardization.

The roles played by the human driver and the system differ depending on the automation level, so a clear division of these roles was selected as a target for standardization. The conditions and methods to be used to transition the state of the vehicle from system control to human driver control when it becomes difficult for automated driving to continue were also selected as critical standardization items.

The physical architecture of the system was also examined. Items, such as the interfaces between individual elements of the physical architecture (for example, sensors), were assumed to be standardization items. However, the physical architecture and division of function responsibilities will differ depending on the mounting positions of the individual systems, so the standards for items such as the specifications of individual elements (even those that fall within the scope of international standards) were not addressed in this TR.

Some standardization items for automated driving systems must be considered even though these are not derived from the functions and physical architecture. For example, the standardization of items such as the definitions of terms and automation levels, safety, reliability, security, system records (drive recorder), privacy, testing methods, driver's licenses, vehicle certification, and the requirements for identifying automated driving vehicles can all be considered. These items were selected from examples of standardization studies being carried out in various countries and regions as general common items and other items. These items were also selected by listening to the opinions of experts in the relevant fields. Table 3 shows a list of the standardization items that were selected as candidates.

5 Progress of RoVAS and Future Initiatives

5. 1. Progress

In May 2014, a WG 14 international conference was

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Table 3 List of standardization item candidates

Major classification	Minor classification	Items with the possibility to be standardized
General common items	Definitions of terms	Definitions of terms
	Automation levels	Definitions of the different automation levels
	Reference architecture	Notional reference architecture
Basic functional requirements	Requirements the system must satisfy at each automation level	Awareness of driving environment (identifying location, static and dynamic states of driving environment, such as maps and traffic information)
		Sensing range and targets
		Control performance (responsiveness, range of control)
		Awareness of whether or not the applicable conditions are being satisfied
	Requirements the human driver must satisfy at each automation level	Necessity to monitor system operations
		Necessity of driver to re-assume responsibility for driving tasks (necessity of driver to be in a position to immediately re-assume responsibility for driving tasks, whether or not it is permissible to perform tasks other than driving, such as reading, necessity of being present in the driver's seat)
	Requirements that concern the transition of functions between the driver and the system at each automation level	Content that the system must transmit/communicate
		Requirements for the handover/transition time
		Interactions with the driver (hand over control after driver gives consent, response when there is no answer from driver)
		HMI
	Requirements for the transitions between different automation levels of the system	Content that the system must transmit/communicate
		Requirements for the handover/transition time
		Interactions with the driver
		HMI
	Requirements for each automation level if a system malfunction occurs	Requirements for the system operations at each automation level, such as processing principles, if a system malfunction occurs
		HMI
	Communication requirements for cooperative systems	The way that information is handled when the position of the preceding vehicle (inter-vehicle distance and direction) detected by on-board sensors and the position of the preceding vehicle according to vehicle-to-vehicle communication is different
	Requirements for information from external sources in a cooperative system	Content of information provided by infrastructure and other vehicles
		Accuracy
		How current is the information
		Resolution
Other	Reliability requirements	Fault tolerance
		Fail-safe functions
		Fool proofing
	Security requirements	Data security
		Cyber-security requirements
		Requirements so that sensors cannot be caused to malfunction
	Requirements for system operation records	Event data recorder
		Privacy
	Testing requirements	Function tests (test scenarios, etc.)
		Safety & reliability tests (test scenarios, test conditions, use cases for tests)
		Test methods (theoretical checks, emulation, actual on-board tests, test conditions that combine these, etc.)
	Requirements of the standards for certification	Certification items
		System diagnostics
		Application to use the automated driving system
	Interfaces with other vehicles and pedestrians	Display of the fact that the vehicle is currently under automated driving control
		Display of the fact that the vehicle is currently driving in a platoon
		Interface that replaces eye contact between pedestrians and the driver

held in Oslo, Norway to discuss the RoVAS TR. At this conference, Japan proposed the creation of a TR that concerns the standardization of advanced driver support systems that are expected to be put into practical use in the near future. After this, additional discussions were held in Japan and it was decided that the content of this TR should more widely cover all aspects of automated driving in general. In October 2014, a WG 14 international conference was held in Vancouver and a draft of the RoVAS TR was presented. WG 14 then presented the

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standardization items that should be examined in the future based on the content of the draft TR to the TC 204 workshop on automated driving that was also being held in Vancouver. The TC 204 plenary session in Vancouver resolved to hold a vote on the Draft Technical Report (DTR) of RoVAS as soon as possible. However, because the report had not yet been examined very thoroughly within WG 14, time was first spent on further studies and improvements. In April 2015, at the WG 14 international conference in Hangzhou, China it was finally decided to hold the DTR vote. Some minor corrections and modifications were necessary at the WG 14 conference in Hangzhou, but it was decided to hold the DTR vote after these are completed.

5. 2. Future initiatives

It is likely that RoVAS will be established as a TR of the ISO in the near future. The following are some ideas about how this TR can be utilized.

5. 2. 1. Utilization of the overall picture of RoVAS

A wide range of different items and issues can be covered by utilizing both a top-down approach based on the architecture via a policy of clarifying the overall picture and also a bottom-up approach that draws on the knowledge of many different concerned parties and organizations, as well as other concerned activities and investigations. This may not be perfect, but it should cover the whole range of topics currently considered to be within the field of automated driving. Many different individual parties and organizations will be thinking about the overall picture when working to promote the standardization of automated driving. The RoVAS report should be useful to these parties and organizations in considerations and decision making of items that should be covered, items that need to be addressed right away, and areas where the special features of automated driving can be exercised fully. The field of automated driving is one that will continue to grow in importance and should attract more attention and effort. The top-down promotion of a systematic approach to determining the next focus of automated driving standardization is critical for both Japan and its automotive industry so that it can assume an advantageous position over its international competition. It is sincerely hoped that the RoVAS report will be a helpful contribution toward this goal. This policy has been taken up by officials from the Ministry of Economy, Trade and Industry (METI) as a good example of how to promote international standardization strategies (5).

5. 2. 2. International leadership

The field of automated driving is critical for the automotive industry in the near future. Many different countries, regions, industries, and standardization organizations will be actively tackling the issue of standardization of automated driving. It is necessary for Japan to exercise strong leadership and advance the international standardization of automated driving in an advantageous manner. It is thought that the presentation of the overall picture of standardization and the identification of the areas that should be addressed next in the RoVAS TR clearly demonstrated Japan's strong presence in this field and its motivation to tackle these issues. Consequently, this should help move the discussions and standardization work in the right direction. It will be necessary for Japan to continue to exercise strong leadership on the standardization of critical items. For example, it is thought that items such as the basic concepts underlying the division of responsibilities when both a human driver and automated driving system are participating in driving tasks, and the basic methods for transferring control between the human driver and the system will be extremely important. Japan should take the lead in advancing the standardization of these items.

Various automakers have announced the launch of automated driving systems on the market in the near future (6)-(8). At the TC 204 automated driving workshop in Hangzhou, China in April 2015, WG 14 indicated that the following four systems are expected to be put into practical use in the very near future, making standardization an urgent necessity. These four automated driving systems are automated parking, automated following of the vehicle in front during congestion, automated driving on highways, and automated lane changing. Among these four systems, it was decided to start on standardization for automated parking. It was agreed that Japan would work on the standardization of automated parking in cases where a human driver is inside the vehicle and Germany would work on the standardization of automated parking in cases where the human driver is watching from outside the vehicle. Competition over who writes the standards for automated driving systems has already begun in earnest.

The RoVAS TR will provide knowledge about the standardization of automated driving not just to parties in Japan, but also to other countries, regions, and related organizations. Japan may have taken the lead at the

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starting point, but the main battles will begin now. Since international standards are an important way to gain an advantage in the business world and also in technology and product development, Japan needs to quickly and strategically promote the standardization of automated driving.

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