A National Project in Japan: Innovation of Automated Driving for Universal Services

Hajime Amano and Takahiko Uchimura

Abstract In 2014, the Japanese government initiated a research and development project on automated driving systems. Background, scope, focuses and expected outcome of the project are described in this paper. Deployment of the Intelligent Transport Systems has been actively promoted by the Japanese government in the past 20 years. Technological and operational platforms essential for automated driving systems were formulated as a result of collaboration among public agencies, industries and academia. Application of automated driving technologies is expected to contribute to overcome societal challenges, such as aging society, in addition to road traffic safety, efficiency and enhanced mobility.

Keywords Automated driving · Dynamic map · Cooperative system · GNSS · Human factors · Active aging

1 Outline of the Project

The Japanese government has set out strategies to revitalize Japanese economy and science, technology and innovation. These are closely linked to each other. Under those strategies, a new R&D program was created named Cross-Ministerial Innovation Promotion Program (SIP). Ten projects started in 2014 under SIP. One of them is a project on automated driving systems lead by Dr. Hiroyuki Watanabe as the Program Director [1].

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1.1 Objectives

The objective of the research and development program named SIP was to revitalize Japanese economy and put the country back on the track of sustainable growth by gaining competitive advantages in science and technology. The objective specific to the automated driving project is to provide road traffic safety, environmental sustainability and universal transportation services with special attention to one of the most serious challenges for Japanese society, aging and declining population.

We named the automated driving project as SIP-adus, which stands for innovation of Automated Driving for Universal Services. Inclusive society, where diverse people in diverse communities actively participate in generating values, will enhance both wellness of individuals and economic development. Automated driving technologies integrated with social innovations should provide everyone with mobility to fully exercise his or her capacity, enabling sustainable development of the society [2].

1.2 Scope

We are looking at the evolution of vehicles in the following way. Built-in features of driving assistance are already in the market and getting popular. Cooperative systems have been in nation-wide operation for some years in Japan. Those are integrated into highly automated systems and moving forward to fully automated driving.

Piecewise implementation of technologies, infrastructure and organizational structure will lead us to feasible and sustainable automated driving systems (see Fig. 1).

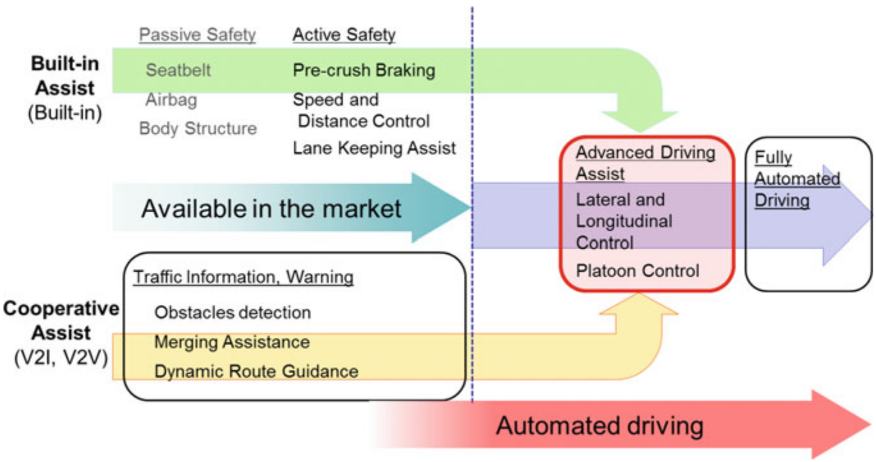


Fig. 1 Evolution of vehicles: connected and automated systems

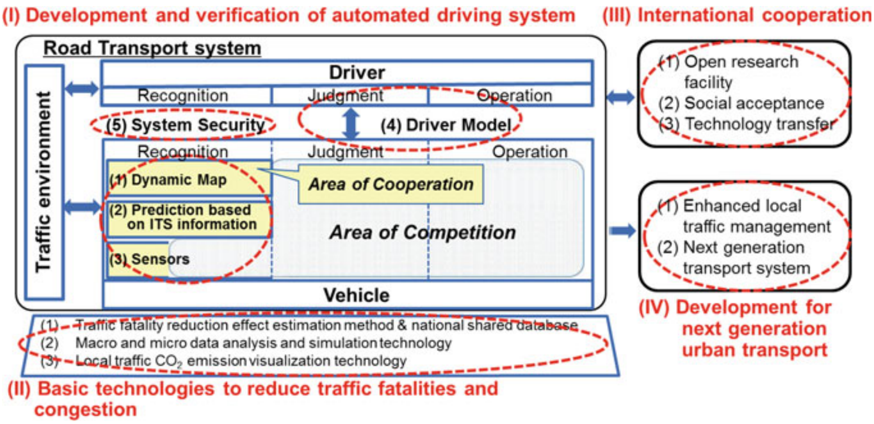


Fig. 2 Scope of SIP-adus project

Automated driving will be realized integrating on-board technologies, precise digital map, data acquisition through radio communication and global positioning. On-board technologies are already in product level competition. Auto manufacturers are demonstrating their technologies and announcing near future products. Therefore, the scope of SIP-adus does not include on-board technologies nor development of prototype automated cars. We are focusing on areas of cooperation, i.e. dynamic map, connected vehicles, human factors, impact assessment, next generation transport, security and international cooperation (see Fig. 2).

2 ITS Deployment as Technological and Operational Platform

The automated driving system project is designed on the portfolio of already operating Intelligent Transport Systems. Deployment of those systems was initiated in 1996 in 9 areas (see Fig. 3). Examples of those systems are described in this chapter from an organizational point of view, which will become foundation of automated driving systems.

2.1 Electronic Toll Collection

Operation of Electronic Toll Collection started in 2001 in Japan and soon expanded to nation-wide operation. Among a variety of requirements to guarantee the level of reliable operation acceptable for customers, interoperability between roadside equipment supplied by multiple manufacturers and on-board equipment also

Fig. 3 ITS deployment in 9 areas

supplied by as many manufacturers, and security of every step of transactions were the most challenging ones. For interoperability, standardization of technical specifications was not sufficient to guarantee interoperability. Manufacturers cooperating with the road operators shared information about potential failures and established methodologies for testing conformity to the radio regulation and interoperability. An organization specialized in radio equipment testing has expanded its scope to cover all the related tasks. For security, latest data encryption and authentication technologies were employed. However, dynamic security key management is very new for civilian services. After long and intensive work under collaboration of public and private sectors, a new organization was established for security management of ITS applications. Now, the same framework is applied to vehicle to infrastructure cooperation services, which is one of the important reasons why nation wide operation of cooperative services started so soon in Japan.

2.2 *Car Navigation*

In late 1980s, auto manufacturers and on-board equipment suppliers started to put their first generation of car navigation systems on market. They were already aware that individually developing a digital map database was not a realistic solution. They chose to cooperate with the competitors and the government. A government agency, Geospatial Authority of Japan, has a database of three-dimensional survey of the country. Japan Digital Road Map Association was established in 1988 to develop and maintain a database of digital map and topological structure of road network with unique location reference IDs for a variety of ITS services. Both public and private sectors share the database as common basis and financially

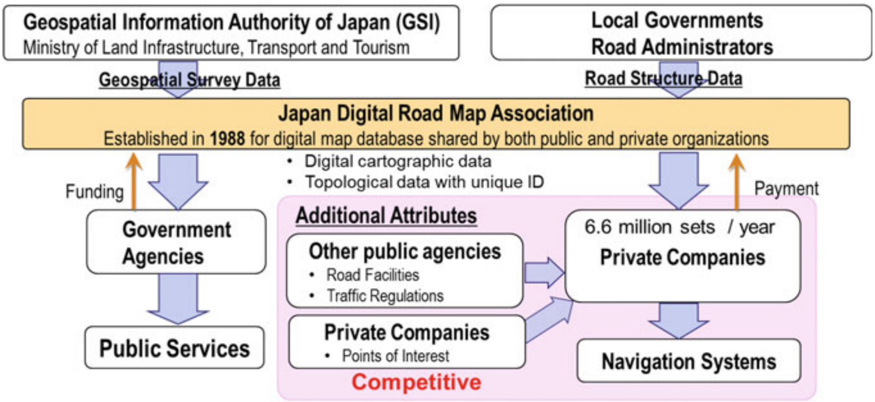


Fig. 4 Digital map for car navigation

support the activity. Private companies are competing by integrating additional attributes for car navigation services. This scheme (see Fig. 4) maintains the balance between cooperation for common basic database to be shared and competition for private service providers to develop creative services at lower cost for their customers.

2.3 Real-Time Traffic Information Service

Real-time traffic information service, named Vehicle Information and Communication System (VICS), started in Japan in 1996. Traffic information from highway operators and traffic police is integrated at the Traffic Information Center. The data are coded and broadcast by the VICS center. The car navigation system decodes and displays real time traffic information on the navigation screen overlaying the digital map. The data include level of congestion, road closure and alerts from public agencies. Because common digital map and referencing scheme are shared among all the related public agencies and car navigation system manufacturers, real-time traffic information is properly shown on any mobile terminals.

2.4 Vehicle to Infrastructure Cooperation

Vehicle to Infrastructure cooperation services have been in operation since 2011. There are 1,600 radio beacons on expressways and a similar number on arterial roads. Organizations created for earlier ITS deployment are integral parts of the cooperative systems. Since the same radio spectrum and communication protocol as those for Electronic Toll Collection are used, interoperability has already been assured. Although a new set of technologies for cyber security was implemented, the same framework of security management was applied as Electronic Toll Collection. A location referencing scheme for VICS is also utilized. Because the system is implemented on the already established platform, drivers can receive new services with minimal extra cost when they purchase new cars with car navigation and ETC on-board device. Accumulated portfolio of ITS deployment will be an enabler for accelerated deployment of highly automated driving systems for both establishing the supporting framework and fostering customer acceptance.

3 Current Status of SIP-Adus

Some of the progress SIP-adus made at an early stage of the project is described in this chapter. In other areas, project tasks are still in design stage.

3.1 Modeling Road Environment

We are searching for the structure of dynamic map to be built on a shared map database. We are discussing layers with different time frame; static, semi-static, semi-dynamic and dynamic. Probe data collected by the vehicle sensors will be integrated into the database to update the dynamic map [3]. A prototype of basic map layer has been developed for the target area of early deployment, Tokyo bay area (see Fig. 5). The data are shared among the project members and being evaluated. We are going to build prototype of upper layers with semi-dynamic data as the next step.

3.2 Locating Vehicle Position

An automated vehicle will decide, which way to go, matching dynamic map, on-board sensor outputs and global positioning system readings. However, a sufficient number of GPS satellites are not always visible and the accuracy is not as good as we expect. So, we are evaluating other technology options, combination with other sets of GNSS satellites and accuracy enhancement using additional signals (see Fig. 6).

According to our measurement, we obtain lower accuracy with GPS alone. If we combine the data with those from another set of satellites, such as the Quasi-Zenith Satellite System, and enhancement, we obtain better result. We will continue searching for right balance of accuracy requirements for dynamic map, on-board sensors and global positioning system.

Fig. 5 Prototype of dynamic map

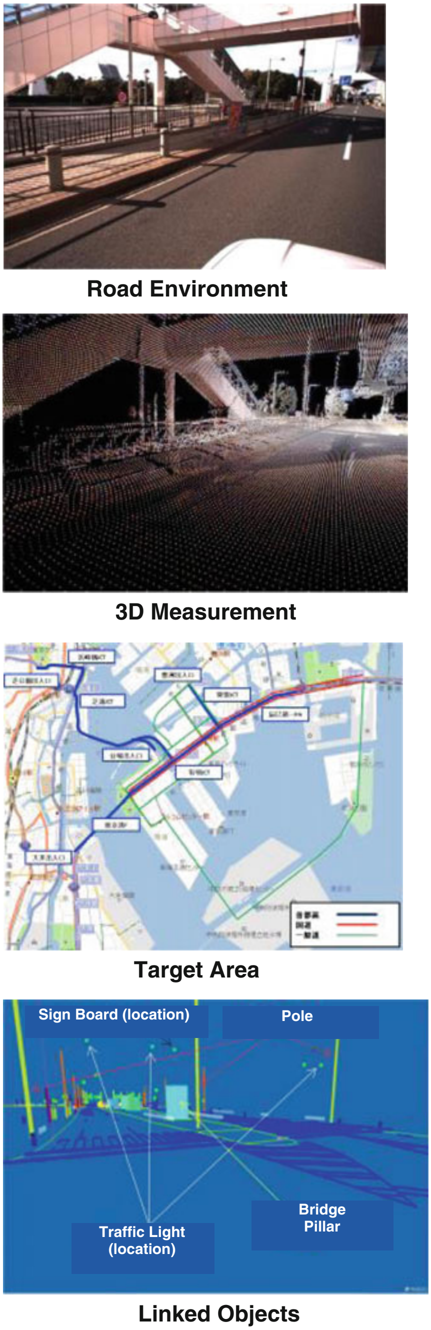
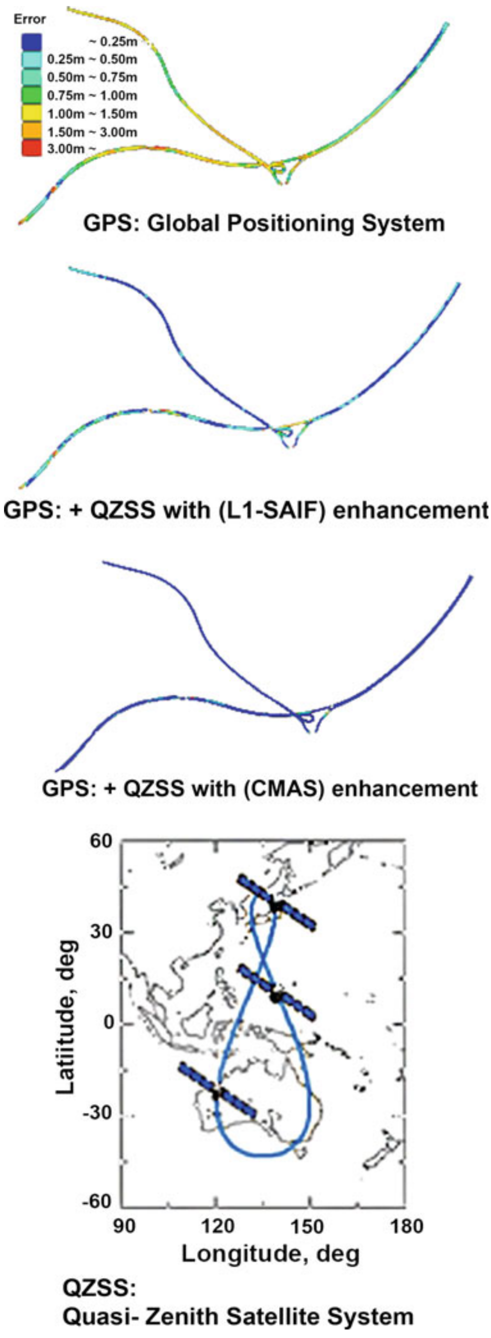


Fig. 6 GNSS accuracy



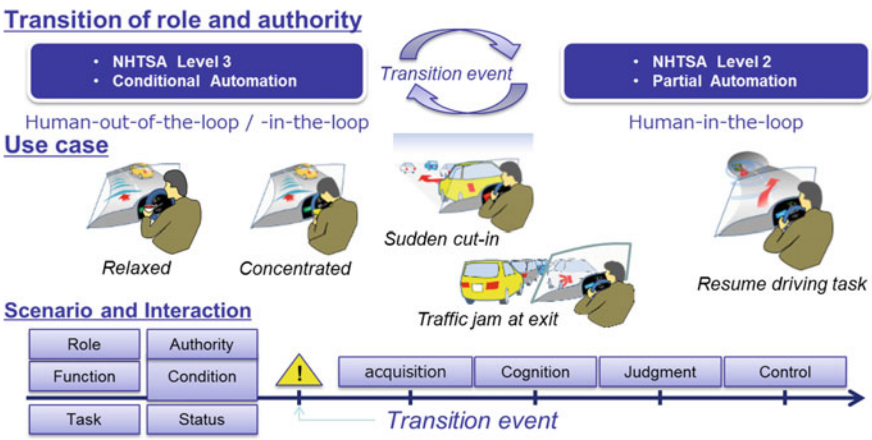


Fig. 7 Analytic approach to human factors

3.3 Human Factors

Human factors are also an important area of cooperation, because the implementation of automated driving technologies in commercial products is expected to happen stepwise. The operation of the vehicle will be shared between vehicle control system and human driver until fully automated driving becomes available. There are transitions of roles between vehicle control system and human driver (see Fig. 7). We identified important cases and we are analyzing a series of events, which trigger transition, along the timeline. We are going to observe human behaviors using Driving Simulators and try to find a set of rules acceptable for both human drivers and system design points of view [4].

4 Consideration on Benefits for Japan

Automated driving systems will contribute to solve problems directly related to road traffic, such as safety and efficiency. However, we will have benefits from automated driving technologies in more fundamental societal challenges, such as aging society.

4.1 Road Safety

Road traffic fatality was more than 16,000 per year around 1970 in Japan. Better road facilities, education and enforcement were effective countermeasures on those days. But the fatality started to increase again in 1980s for scoring economic activities. This time, new vehicle technologies and Intelligent Transport Systems significantly contributed to reduce fatality. Although the total number of road traffic fatality keeps declining slowly, rapid demographic change poses a new challenge. Today, about 54 % of victims of fatal traffic accidents are 65 years old or older. They are not only victims of the accidents but they also cause accidents. Fatal traffic accidents are classified by the types of violation. The most conspicuous observation is that inappropriate operations by aged drivers caused so many accidents. National Police Agency conducted a survey of families of victims of fatal traffic accidents. One of the highest priorities they wish is better countermeasures for aged drivers and they also anticipate wider penetration of collision avoidance technologies. Therefore, immediate application of automated technologies for driver assistance to the models already on market is our most imminent mission.

4.2 CO_2 Emission Reduction

The shared platform to be created for automated driving, such as dynamic map database, will be utilized by a variety of applications. With traffic information from fixed sensors and moving vehicles combined and detailed digital road map, we can precisely reproduce movement of each vehicle on the computer. Then, we can get the total CO_2 emission volume in the area. Collaborating with traffic engineers from

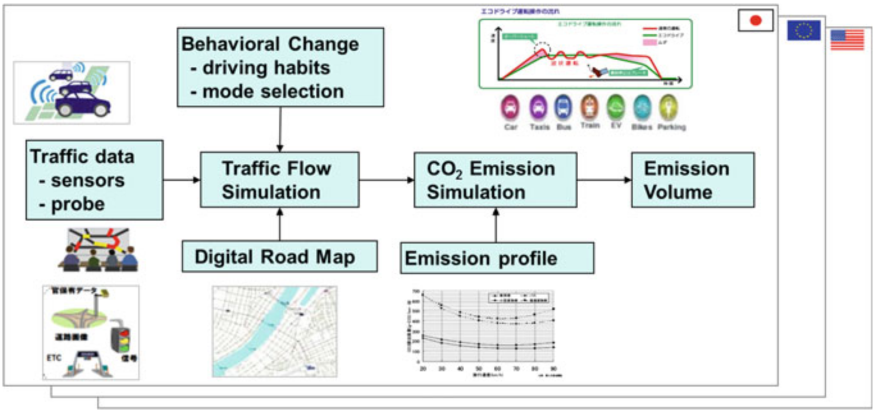


Fig. 8 Quantitative estimation of CO_2 emission

Europe and the United States, we have internationally recognized methodology (see Fig. 8) [5]. As a part of SIP-adus project, we are going to evaluate impacts of automated vehicles on energy consumption.

4.3 Active Aging

Aging and declining population is one of the most serious challenges for Japan. More than 25 % of Japanese population is 65 years old or older now. This share is expected to increase up to 40 % by the year 2050. The current social welfare system no longer works, which assumes that younger generations support all the people of 65 years old and above. We have to mobilize people of this age group to sustain the society. United Nations recognized it and proposed a policy framework: Active Aging. Automated driving technologies are expected to contribute giving people adequate mobility such that they can continuously play active roles in the society. For mega cities, such as Tokyo, where comprehensive coverage of subway network exists, a flexible transit system on the ground level is anticipated. In rural areas, depending heavily on private cars, we need safe driving assist and new compact cars for the older age group to travel [6]. Figure 9 is a conceptual image of Advanced Rapid Transit, to be deployed by the Tokyo Olympic and Paralympic Games in 2020 [7].

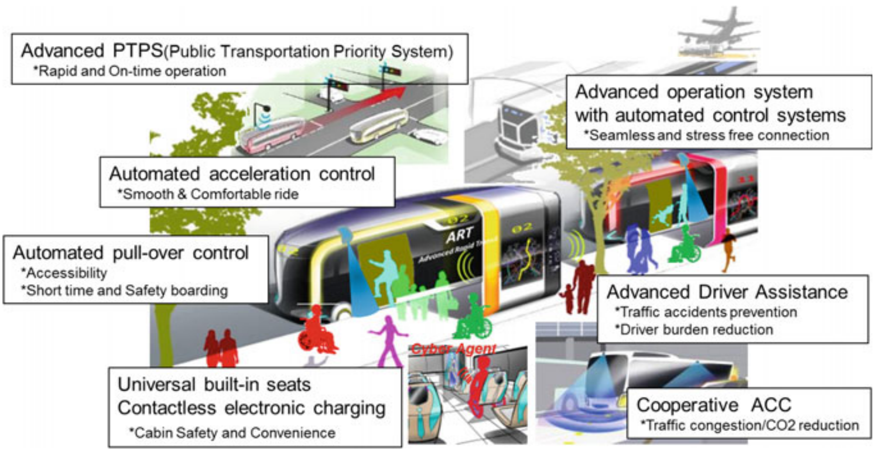


Fig. 9 Advanced rapid transit system

5 Conclusion

Automated driving technologies are actively developed and regulatory aspects are discussed to support automated vehicles to operate. Collaboration to establish a shared framework for interoperability, security management, dynamic map and human factors is also important. We will gain from automated driving technologies not only road traffic but also societal benefits.

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