Intelligent Transport Systems

1 Introduction

Intelligent transport systems (ITS) are being developed to help resolve various social issues in the modern transportation environment through the adoption of innovative technologies. Examples of these issues include traffic accidents, congestion, the increasing load placed on the environment by emissions, and so on. In recent years, information and communication technology has been utilized to connect vehicles with other elements of the traffic environment, such as roadside infrastructure, other vehicles, pedestrians, and motorcycles. This concept is referred to as vehicle-infrastructure cooperation. As a result, the scope and possible roles of ITS have expanded further, opening the way to greater possible application. As a result, ITS may also have a future as a fundamental technology for building a more prosperous and active society, as well as simply a means for helping to resolve issues.

In June 2013, as part of Japan's new IT strategy, the Cabinet Office issued the Declaration to be the World's Most Advanced IT Nation, which aims to make IT a cornerstone of Japan's growth strategy and a driving force in achieving sustainable growth and development.

That goal involves striving to realize the world's safest, most environmentally friendly, and most economical road traffic society. Specifically, in conjunction with drawing up a cross-ministerial roadmap, an implementation framework will be built and the development and commercialization of advanced driver assistance technologies and automated driving systems will be promoted.

Based on the above, a subcommittee for road traffic was established in October 2013 under a specialized investigation body charged with promoting the new strategy. To draw up the Public-Private ITS Initiatives & Roadmap based on the IT strategy and the schedule for the Declaration to be the World's Most Advanced IT Nation (determined by the IT Strategic Headquarters in June 2013), this subcommittee will set up working groups to discuss driving safety support and automated driving, as well as the application of traffic data in relation to the roadmap.

For driving safety and automated driving, in particular, a recommendation for the working groups that make proposals to the above subcommittee and the working groups established under a preparatory committee of the Strategic Innovation Promotion Program (SIP) governed by the Cabinet Office's Council for Science, Technology and Innovation to jointly conduct work on the study of the roadmaps while maintaining close coordination with other science and technology policies has been compiled.

The Public-Private ITS Initiatives & Roadmap was released on March 24, 2014. The IT Strategic Headquarters accepted it and set it in motion at the beginning of June 2014 (Fig. 1).

In the context of the Public-Private ITS Initiatives & Roadmap, it was determined that detailed studies will take place through cross-sectional efforts involving public-private coordination on critical issues, and that the Council for Science, Technology and Innovation would serve as the body providing a framework to foster public-private sector coordination and promote ITS-related policies.

To enable the Council for Science, Technology and Innovation to fulfill its role as a control center and realize scientific and technological innovation, the June 2013 Comprehensive Strategy on Science, Technology and Innovation and the Japan Revitalization Strategy Cabinet decisions provided for the establishment of the Strategic Innovation Promotion Program (SIP). The Council for Science, Technology and Innovation will carry out its own budget allocation that extends beyond ministerial and industry boundaries and, starting in 2014, the SIP will work on the promotion of everything from basic research to forward-looking end results (application and commercialization). To further develop ITS in Japan and

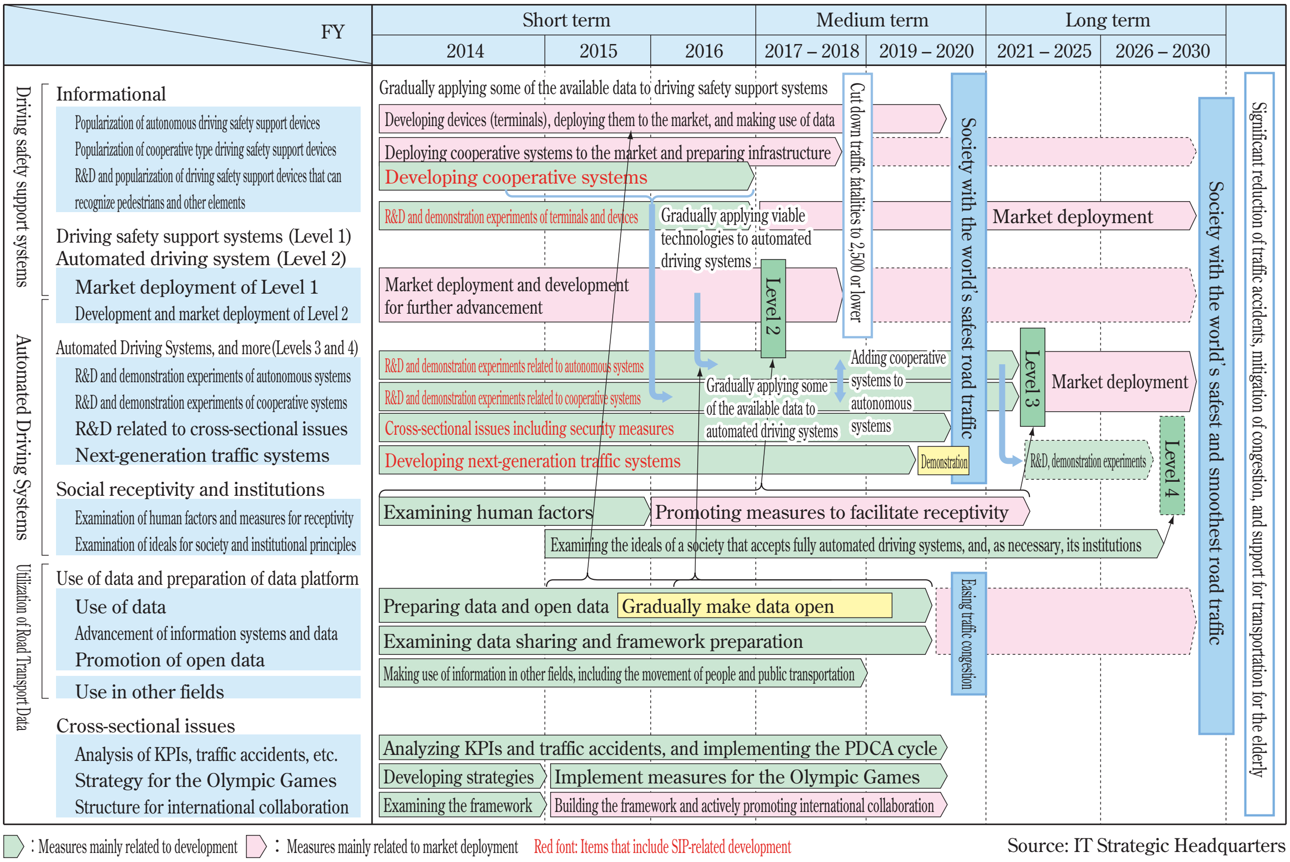


Fig. 1 Public-private ITS initiatives and roadmap.

contribute to the national goal of reducing traffic accident fatalities, automated driving will be set as a challenge to be pursued through coordination between government, academia, and industry.

In October 2010, the ITS World Congress was held in Tokyo and not only featured the gathering of many ITS specialists, but also provided an opportunity to introduce Japanese government-academia-industry initiatives to the world. This article presents some of those initiatives.

2 ITS Trends in Japan

2. 1. Vehicle Information and Communication System (VICS)

VICS is an information and communication system that compiles and processes road traffic information (related to congestion and traffic restrictions) at the VICS Center. This information is then transmitted by radio wave and infrared beacons and FM multiplex broadcasting for display in three forms (text, simple graphics, and maps) on navigation systems and other onboard devices. VICS operates 24 hours a day, 365 days a year. The following three means of transmission are used.

2. 1. 1. FM multiplex broadcasting

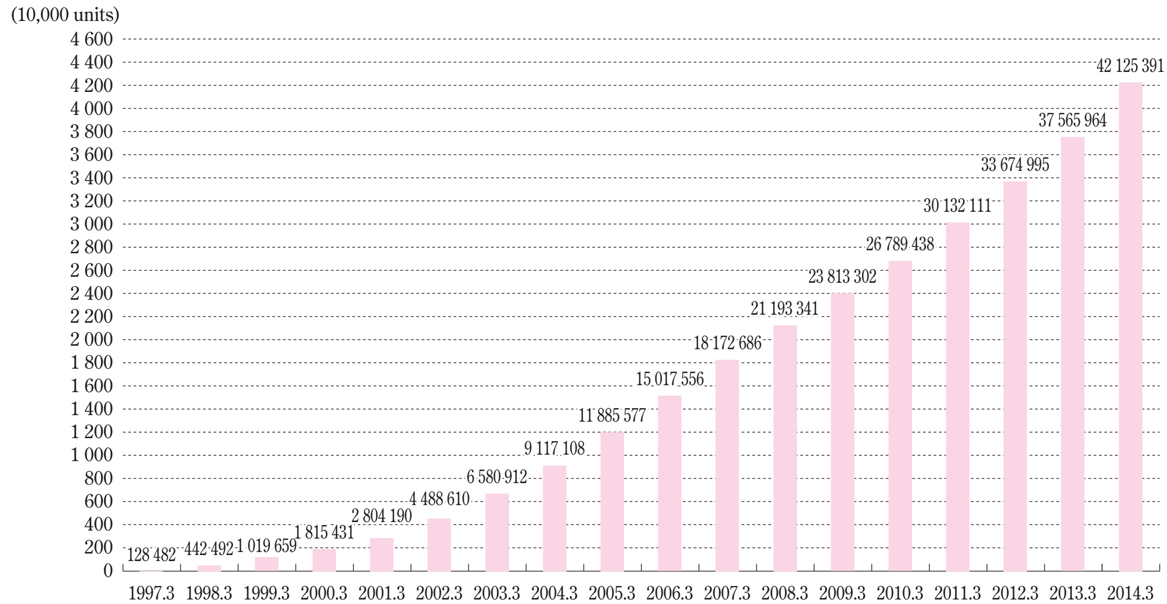
Regional NHK and FM broadcasters provide traffic information for roads in and around their respective prefectures. This includes information on congestion or travel times, on traffic restrictions due to accidents, disabled vehicles, roadwork, natural disasters, or weather conditions, and information on parking locations and the availability of spaces there.

2. 1. 2. Radio beacons

These are ITS spots (5.8 GHz) primarily set along expressways that generally provide information on road traffic within 1,000 km ahead of the vehicle (about 200 km for spots using the 2.4 GHz band). They provide information on travel time between interchanges, congestion, and junctions (including main parallel ordinary roads), as well as on traffic restrictions (e.g., road closures, lane or speed restrictions, requirements on the use of chains) due to accidents, disabled vehicles, roadwork, natural disasters, or weather conditions.

2. 1. 3. Infrared beacons

Set primarily along ordinary roads, these beacons generally provide information on road traffic within 30 km



Source: Compiled by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) based on VICS center data

Fig. 2 Number of onboard VICS units.

ahead of, and 1 km behind, the vehicle. They provide information on congestion or travel times, on traffic restrictions (e.g., road closures, lane or speed restrictions, requirements on the use of chains) due to accidents, disabled vehicles, roadwork, natural disasters, or weather conditions, and information on parking locations and the availability of spaces there.

In vehicles equipped with receivers, the automatic congestion avoidance function in the navigation system can use the information received from beacons to display the optimum route on the navigation screen, allowing drivers to use the information to drive in accordance with traffic circumstances.

The number of vehicle navigation systems in Japan exceeded roughly 61 million units at the end of March 2014. Of these, approximately 42 million are compatible with real-time VICS road traffic information (services started in 1996) (Fig. 2). VICS provides travel times, congestion statuses, and traffic restriction information to navigation systems in real-time for greater driver convenience. Appropriate route guidance from VICS is also effective in reducing CO_2 emissions and environmental load by smoothing traffic streams and improving fuel efficiency. As a result, VICS helped to reduce CO_2 emissions in 2010 by roughly 2.4 million tons.

2. 2. Universal Traffic Management System (UTMS)

The aim of UTMS is to help achieve a safe and comfortable traffic environment with a low environmental load. It achieves this through sophisticated use of information communication technology, including two-way communication between individual vehicles and traffic management systems using infrared beacons. This helps to enhance the safety and smooth flow of road traffic and also alleviates traffic pollution.

The main applications of UTMS are as follows.

2. 2. 1. Advanced Mobile Information Systems (AMIS)

AMIS are systems that provide traffic information to onboard devices via infrared beacons in addition to traffic information signs and radio broadcasts. These systems aim to achieve natural dispersion of traffic streams, alleviate congestion, and so on. As of the end of 2013, all prefectures in Japan had adopted AMIS.

2. 2. 2. Fast Emergency Vehicle Preemption Systems (FAST)

These systems use infra-red beacons to detect emergency vehicles in areas where call outs are frequent and control traffic signals to give priority to the emergency vehicles. The aim of FAST is to shorten the time required for emergency vehicles to reach an incident scene or medical facility and to help prevent traffic accidents involving emergency vehicles. As of the end of 2013, 15 prefectures had adopted FAST.

2. 2. 3. Public Transportation Priority Systems (PTPS)

PTPS control traffic signals to give priority to buses and other public transportation. The system aims to reduce journey times and increase user convenience. As of the end of 2013, 40 prefectures had adopted PTPS.

2.2.4. Infrastructure-vehicle (I2V) cooperative Driving Safety Support Systems (DSSS)

The National Police Agency (NPA) of Japan is promoting the adoption of DSSS. DSSS level I (information provision type) systems were adopted in Tokyo in 2006 and Saitama Prefecture in 2007. This type of level I system uses roadside equipment to detect possibly dangerous situations in the road traffic environment and supplies that information to drivers. In addition, large-scale verification tests were carried out of DSSS level I (judgment type) systems in 2008. These systems combine information from roadside equipment with information such as the position and speed of the driver's vehicle and judge the necessity of providing information to the driver via onboard devices. The purpose of this information is to alert the driver to possible danger via audio warnings or displays. In addition to helping to prevent accidents in locations where the roadside equipment is provided, these systems also help to improve overall driver behavior through a learning effect.

In 2010, Tokyo and Kanagawa Prefecture introduced several DSSS level II systems that use infrared beacons as communication devices at intersections that are particularly prone to accidents. These systems include traffic signal recognition enhancement, rear-end collision prevention, stop sign recognition enhancement systems and crossing collision prevention systems. Operation started from July 1, 2011. Analysis confirmed that these systems were effective in supporting safe driving by improving the safety awareness of drivers through information provision. In 2013, verification tests to lower the cost of DSSS equipment were performed on simplified systems that continuously provide information to onboard devices using radio waves and have no connection with traffic management centers. The ITS World Congress in Tokyo served as a showcase to demonstrate some of those systems (Fig. 3).

2.3. Electronic toll collection (ETC) system

ETC is a system that enables non-stop automatic collection of tolls. It uses wireless communication between systems provided in booths at toll roads and onboard vehicle terminals to exchange the necessary information for payment without the vehicle having to stop at the gate.

ETC has gained widespread acceptance since its full-scale introduction of in March 2001. As of the end of December 2013, over 44 million onboard units had been set up, and 24 nationwide expressway and public road management companies use a single nationwide ETC system. Each day, approximately 7.1 million vehicles utilize ETC services, a rate of roughly 89%. ETC has virtually eliminated congestion at toll booths, which accounted for about 30% of expressway congestion throughout Japan. Consequently, ETC also helps to lower environmental load by reducing CO_2 emissions.

2.4. Smartway Project

The aim of the Smartway Project is to enhance traffic safety and to develop measures for improving congestion and the environment. In this project, a Smartway is defined as a next-generation road that uses ITS technology to link people, vehicles, and roads by information. Japan is working to achieve Smartways by researching and developing ways of providing next-generation services via I2V coordination through public-private partnerships. As part of the Smartway Project, the adoption of next-generation ITS services (called spot services) has been promoted in recent years. Various ITS spot services started throughout the country in August 2011, mainly concentrated on spot service infrastructure installed on expressways.

The Road Bureau of the Ministry of Land, Infrastructure Transport and Tourism (MLIT) established 1,600 ITS spots, mainly along expressways nationwide, where services started in August 2011. The spots are set at roughly 10 to 15 km intervals on inter-city expressways, and at roughly 4 km intervals on inner city expressways.

These ITS spots integrate VICS and ETC functionality and provide the three basic services of dynamic route guidance, safe driving support, and ETC in an all-in-one package. Services are expected to diversify into areas such as cashless payment for car parks or logistics support.

In autumn 2009, seven private companies launched ITS spot-compatible navigation systems and onboard devices. By the end of September 2013, there were 22 companies offering such products, and their popularity is expected to keep growing.

Panels, videos, and, in cooperation with their manufacturers, various ITS spot-compatible navigation systems and onboard devices, have been presented at the October CEATEC Japan 2013 trade show and various regional motor shows to make ITS spot services better known.

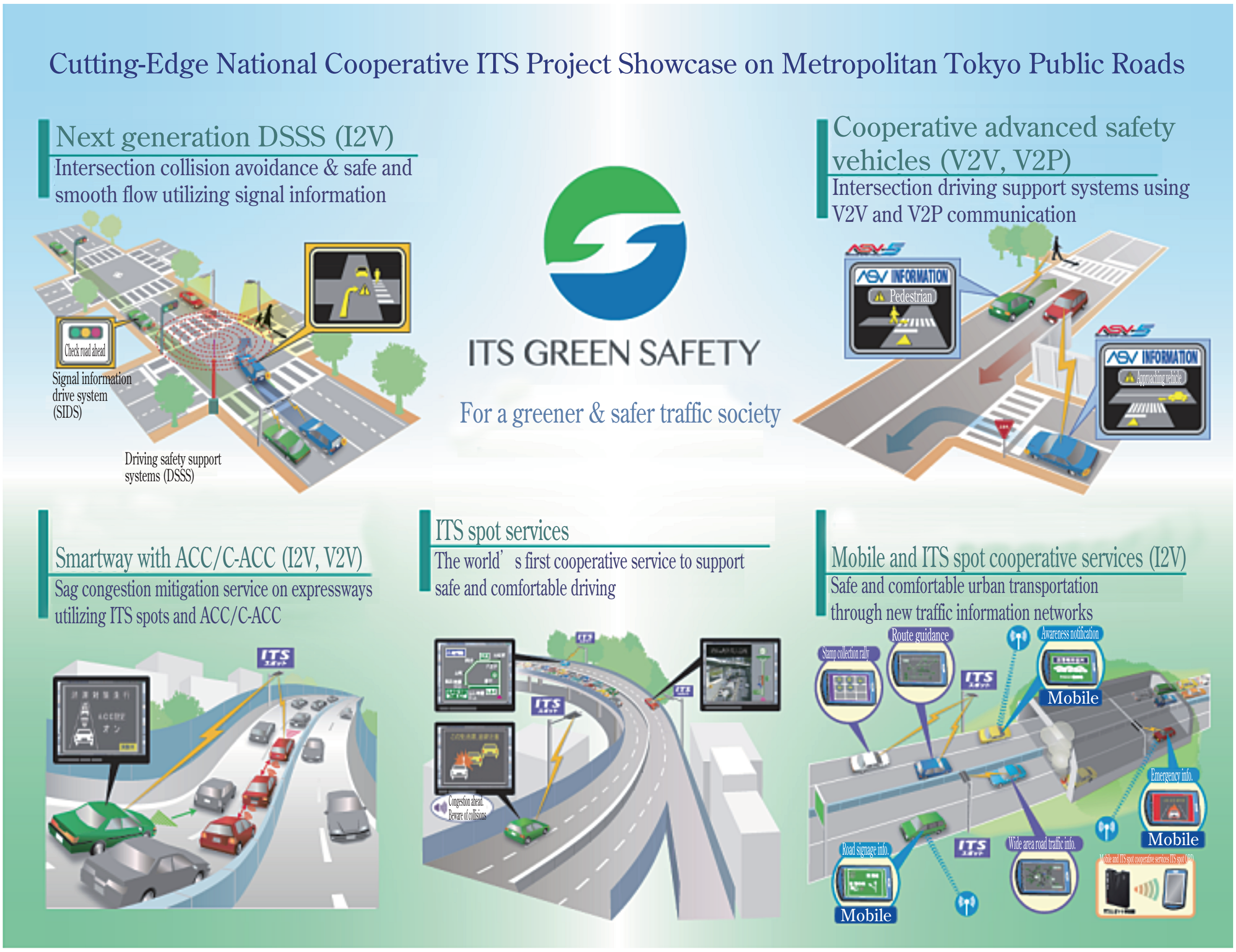


Fig. 3 ITS Green Showcase.

In addition, at the 2013 ITS World Congress in Tokyo, the ITS Green Safety Showcase, an initiative to resolve traffic problems through cooperative ITS, carried out the following three activities (Fig. 3).

2. 4. 1. ITS spot services

Participants experienced dynamic route guidance, safe driving support and ETC, the three basic services among currently available nationwide ITS spot services, by riding a demonstration bus following a model course along metropolitan expressways.

2. 4. 2. Traffic smoothing in expressway sag road sections

Participants experienced traffic smoothing achieved through road-to-vehicle and vehicle-to-vehicle coordination between vehicles equipped with adaptive cruise control (ACC) or cooperative adaptive cruise control (C-ACC) systems, which automatically regulate vehicle speed and the distance between vehicles.

2. 4. 3. Cooperative mobile communications and ITS spot services

A model course passing through the Tokyo Bay Aqua-Line allowed participants to experience the traffic information service that sends information from ITS spots to smartphones.

In addition, proactive initiatives to promote greater implementation of these services at nationwide *michi no eki* roadside stations, as well as expressway parking and service areas were carried out, and more such public-private partnership-driven activities will be undertaken.

2. 5. Advanced Safety Vehicle (ASV) Project

Since 1991, the Road Bureau of MLIT has promoted the development and popularization of ASVs equipped with DSSS that use leading-edge technology through collaboration between industry, academia, and the government. The 5th ASV promotion plan began in 2011. This plan aims to encourage the development of even more sophisticated DSSS capable of autonomous detection and DSSS that use next-generation communication technology, as an extension of those systems that have already been implemented. The plan also carried out demonstrations, on public roads, of advanced DSSS encompassing pedestrians through the use of vehicle-to-vehicle and vehicle-to-pedestrian communications as part of the ITS Green Safety Showcase at the 2013 ITS World Congress in Tokyo (Fig. 3).

In addition, the ASV Project is continuing to play a supporting role for the commercialized ASV technology it promotes (such as collision damage mitigation brakes, devices to alert the driver to unstable driving behavior, and electronic stability control (ESC)).

2. 6. Probe data

Probe data consists of information collected by individual vehicles (for example, positional and speed information) using wireless communication technology and used to support traffic management and drivers. In this case, vehicles are used as sensors to collect information about the traffic environment.

In addition to providing information about congestion using conventional VICS data, navigation systems have also been developed by automakers and specialist navigation system manufacturers to use probe data. Services that transmit traffic information about all roads, excluding narrow urban streets, as well as roads compatible with VICS have also been launched.

From the standpoint of the effective utilization of collected probe data, various activities are under way to share and use individual items of data. The mutual utilization of probe data helps to increase the volume of accessible traffic information, thereby enabling the provision of even more refined services. Therefore, it is likely that activities to share probe data through public-private partnerships will be promoted in the future.

The various ministries are carrying out investigations, one of which is the development of a model project on sophisticated traffic management conducted by the NPA over four years from 2009 using probe data (i.e., driving history data recorded by onboard devices). As described above, the NPA combined information from existing roadside sensors with probe data to develop technology that generates enhanced traffic information and traffic information capable of enhancing traffic signal controls. It has also utilized the generated information to improve equipment for achieving enhanced traffic signal controls. In 2013, based on four years' worth of results, two prefectures have instituted projects to implement even more precise traffic signal control systems utilizing probe data.

The ITS spots described earlier also allow probe data to be collected from vehicles. When a vehicle equipped with an ITS spot-compatible onboard device passes below an ITS spot, its driving and behavior histories are collected as probe data. The Road Bureau of MLIT will collect and analyze probe data obtained from a large number of vehicles (big data analysis) It plans to carry out initiatives that utilize big data to use the road network intelligently by, for example, identifying the causes of congestion and accidents and utilizing that information to formulate congestion and traffic safety measures.

2. 7. Other

Japan regards automated driving as a growing field and will be pursuing its implementation as laid out in the Declaration to be the World's Most Advanced IT Nation and the Japan Revitalization Strategy (June 14, 2013 Cabinet decisions) as well as the Comprehensive Strategy on Science, Technology and Innovation (June 7, 2013 Cabinet decision).

With respect to the use of wireless systems, the Ministry of Internal Affairs and Communication (MIC) is responsible for allocating the use of new frequencies and forming policies for technical standards, considering the usage situation of radio waves and interference with other wireless systems. In the field of ITS, MIC has already allocated frequencies and formulated technical standards for VICS, ETC, and ITS spot systems to allow new systems to be introduced and existing ones to be made more sophisticated. It has also worked to promote the popularization of these systems.

In addition to allocating part of the 700 MHz band freed up by the switchover to digital terrestrial television for the introduction of DSSS to help achieve a safe road traffic environment, MIC has conducted studies on interference with other systems. In December 2011, it set up frameworks by issuing revised ordinances. Since April 2013, these systems have been available nationwide, including in the Tohoku region where the switch to digital television had been delayed by the impact of the Great East Japan Earthquake.

In 2013, comprehensive testing was conducted on 79 GHz band radar systems, which have sufficiently high resolution to detect smaller bodies such as pedestrians. The validation of their performance at distance resolutions of 20 cm or less and angle resolutions of 5 degrees or less has been completed.

Looking ahead, a study of the possibility of introducing new communication systems that do not affect existing dedicated short range communications (DSRC) systems and can be used in conjunction with them began in 2013. This was prompted by the expected introduction of various ITS spot services related to environmental measures or to greater comfort and convenience, which DSSS using the 700 MHz band are ill-suited to cover. In light of ongoing studies on the use of the 5.9 GHz band for vehicle-to-vehicle and road-to-vehicle communications in the U.S. and Europe, another consideration is ensuring the future extendibility of services while keeping international harmonization in mind.

The Japanese Ministry of Economy, Trade and Industry (METI) initiated a project to investigate and research green vehicle technologies. This includes looking into potential applications and issues concerning technologies whose seeds Japan currently possesses and which, when developed and applied to individual vehicles or the traffic system as whole, are expected to result in significant energy savings and CO_2 reduction. The project also carried out initiatives related to increasing the social receptivity of technologies that have already been established and whose installation in individual vehicles is achievable within a known timeframe, but whose widespread adoption is hindered by insufficient investigation on social receptivity, including institutional frameworks. Concerning the latter, initiatives that leveraged the opportunity provided by the 2013 World Congress in Tokyo (venue: Tokyo Big Sight) to foster increased social receptivity for technologies developed as part of the energy-saving ITS project (between 2008 and 2012) are presented below.

2. 7. 1. Investigation on receptivity to platoon driving

To increase social receptivity and introduce the state-of-the-art in truck platoon driving to a broad audience, a platoon driving demonstration (three-truck platoon with each vehicle separated by four meters and moving at 80 km/h) along a National Institute of Advanced Industrial Science and Technology test course (in Tsukuba, Ibaraki Prefecture) was broadcast live at the Tokyo Big Sight. Throughout the World Congress, a large number of participants, including members of the public, visited the hall where the broadcast was shown, confirming the high level of interest in this technology (Fig. 4).

Fig. 4 Live broadcast of vehicle platoon driving showcase.

2. 7. 2. Investigation on receptivity concerning methods to evaluate CO_2 reduction effects

To introduce the methods and technology to quantitatively evaluate the contribution of ITS to reducing CO_2 to a broad audience, a Japanese translation of the Guidelines for Assessing the Effects of ITS on CO_2 Emissions - International Joint Report -, which summarizes the details of the agreement on the targeted ITS policies reached with researchers in the U.S. and Europe, was prepared and made available at the booth alongside last year's English edition.

Other projects include an assistance program established in 2011 by the Policy and Road Transport Bureaus of MLIT to provide support in ensuring, maintaining, and improving regional public transportation. Targeted at regions facing an imminent day-to-day transportation crisis, this program aims to offer means of transportation optimized for regional characteristics and circumstances, as well as to introduce barrier-free designs and systems with fewer restrictions to remove impediments to transportation.

3 ITS Trends outside Japan

3. 1. Asia/Pacific

The 20th ITS World Congress was held in October 2013 in Tokyo, with the theme "Open ITS to the Next". It attracted 21,029 participants, including 3,935 registrants, from 69 countries and regions, and 238 exhibiting corporations and organizations. At the Tokyo ITS World Congress, attention was strongly focused on automated driving and big data. A greater than usual number of participants from the Asia/Pacific region attended the event, turning it into a forum for the launching of ITS activities and the formation of a network in that region. In addition to the traditional sessions by specialists, the event incorporated the concept of enabling public participation. During the Congress, under the theme of fostering understanding of ITS, host organized events, such as the U.S., Europe and Asia/Pacific region three-party talk sessions and test rides, the Tokyo Metropolitan government talk sessions and the 20th Anniversary Exhibition were open to the general public. The Congress turned out to provide a truly open stage and gave a glimpse into the future of ITS that encompasses the participation of emerging countries and new industries.

3. 2. U.S.

The Research and Innovative Technology Administration (RITA), a unit of the United States Department of Transportation (USDOT), has pursued a five-year strategic research plan from 2010 to 2014 and promoted the development of cooperative systems under the Connected Vehicle Research program. This program is well known for its Safety Pilot Program to test infrastructure-to-vehicle (I2V) and vehicle-to-vehicle (V2V) conducted in Ann Arbor, Michigan and a road map for actual deployment in 2016 has been drawn up. With the current ITS Strategic Plan coming to a close in 2014, discussion of the next Strategic Research Plan for 2015 to 2019 is underway, with a proposal to set cooperative driving support and automated driving technologies at the core of the program and strive for integration with the traffic-related systems as a whole.

3. 3. Europe

The Europe 2020 strategy was announced in 2010. As part of the Horizon 2020 program established to implement that strategy for the period 2014 to 2020, the transport field has set Smart, Green, and Integrated Transport as a key objective. The program's 2014 plan is moving ahead with funds allocated to cooperative systems, automated driving, electric vehicles, and smart grid technology.

3. 4. International activities

At the 2013 ITS World Congress in Tokyo, the government ministries and agencies involved in ITS, namely the Cabinet Secretariat, Cabinet Office, NPA, MIC, METI and MLIT Road Transport Bureau held sessions and presented exhibitions and showcases on Japan initiatives and deployment involving their collaboration with industry and academia, and also engaged in meaningful exchanges with specialists from all over the world.

The various ministries and agencies are also actively engaged in standardizing their respective technologies and systems. Although there are various proposals and ongoing discussions, there is unfortunately not enough space in this article to list all of the individual initiatives being carried out by government organizations.

International harmonization relationships are being built through international partnership conferences and memorandums of understanding, not only with the U.S. and Europe, but also with Asian countries. Such initiatives will contribute significantly to Japan's future global harmonization efforts.

Lastly, as stated throughout the article, the 2013 ITS World Congress in Tokyo featured several proposals from Japan and also provided direction on issues such as automated driving and the use of traffic data in the context of the governments strategic growth policy. This will provide further impetus toward the early practical implementation of existing public-private DSSS initiatives. It is hoped that all parties involved will encourage industry, academia and government to collaborate closely on initiatives to effectively collect and distribute traffic information concerning DSSS, and congestion or natural disasters countermeasures so that progress can be made while coordinating with the U.S., Europe, and the Asia/Pacific region.