DEPLOYMENT STRATEGY FOR COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS IN JAPAN: TOWARD ETC 2.0

H. Makino, S. Suzuki & T. Tsukiji
ITS Division, National Institute for Land and Infrastructure Management,
Ministry of Land, Infrastructure, Transport and Tourism, Japan
makino-h87bh@nilim.go.jp
suzuki-s92tg@nilimg.go.jp
tsukiji-t92ta@nilim.go.jp

ABSTRACT

For widespread deployment of intelligent transport systems (ITS), the key is integration of various ITS services including existing legacy services. In 2011, ITS Spot Service was launched in Japan. A driver who installs an ITS Spot-compatible on-board unit can enjoy several mobility services, safe driving assistance services, and the conventional ETC (Electronic Toll Collection) service. In three years, the number of ITS Spot Service users has exceeded 500 thousand. In September 2014, the Japanese Ministry of Land, Infrastructure, Transport and Tourism announced its new vision for evolving ITS Spot Service to "ETC 2.0." This paper describes the deployment strategy, practical approach, and achievements of the Cooperative ITS service in Japan.

1. INTRODUCTION

With economic development, populations have been concentrating in cities, giving rise to overcrowding and traffic congestion problems around the world. As income levels rise with economic development, motorcycle and automobile ownership rates have increased. Owing to the gap between this rapid rise in vehicle ownership and the time it takes to secure the necessary investments to expand public transportation infrastructure, road traffic congestion has been on the rise, inhibiting economic growth globally. In addition, with the higher number of motor vehicles, problems with traffic safety also increase. Irrespective of a country's level of development, traffic accidents cause major losses of lives, assets, and opportunities every year. Against this background, the United Nations announced in March 2010 that 2011–2020 would be "The Decade of Action for Road Safety" and is promoting measures to increase traffic safety.

To address these challenges, officials are investigating measures such as the following: development planning for land use and promotion of land use based on these plans; regulations; subways and streetcars; public transportation maintenance, typically bus rapid transit; and vehicle flow regulations to inner cities. Other measures under consideration include the development of large-scale ring roads and maintenance of urban highway networks, as well as investments in road infrastructure such as vehicle parking facilities. These combined measures necessitate a comprehensive approach. Two points are vital. First, it is important to make efficient use of limited resources such as land in order to minimize any constraints on potential economic growth. Second, it is important to consider the feasibility of measures to be introduced and whether sustainable autonomous deployment of these measures can be achieved.

Intelligent Transport Systems (ITS) have the potential to solve these traffic challenges by using information and communications technology to exchange of information between road systems, vehicles, and people. ITS are currently being researched, developed, and deployed in many countries and regions. ITS have notable capabilities to add value to existing road infrastructure, to enhance deployment through stepwise introduction, and to evolve together with the development of information and communications technologies. Prominent ITS services include car navigation systems combining electronic roadmaps and positioning technology, collection and provision of real-time information about traffic congestion and accidents on the road system, Electronic toll/fee collection, and traffic signal control. Furthermore, technologies such as cruise control, adaptive cruise control, and lane keeping assist are already being actively deployed in individual vehicles.

In recent years, research and development of Cooperative ITS (C-ITS), or Connected Vehicle—which realize broader, more efficient ITS services through the sharing of functional capability and information between multiple ITS services—has been conducted in various countries and regions, notably Japan, Europe, and North America. C-ITS enable the provision of diverse services simultaneously and have the potential to greatly contribute to solving traffic problems, much more so than individual ITS services can do in isolation. However, in countries and regions around the world, C-ITS are currently suffering from a lack of large-scale introduction and widespread deployment. In spite of these difficult worldwide circumstances, C-ITS were introduced in Japan in 2011, enabling the provision of a wide variety of services. As of December 2014, the number of vehicles equipped with C-ITS technologies exceeded 500 thousand and the diffusion of C-ITS continues to progress steadily.

This study details the current status of ITS penetration and C-ITS research and development in Japan. The knowledge and experience gained from C-ITS introduction is described and dissemination strategies are discussed.

2. DEPLOYMENT OF ITS IN JAPAN

2.1. Master plan

The promotion of ITS as a government policy in Japan began in February 1995 and was positioned as the “Basic Guidelines on the Promotion of an Advanced Information and Telecommunications Society”. In 1996, a master plan, “Comprehensive Plan for Intelligent Transport Systems (ITS) in Japan” was formulated with the cooperation of five related ministries at the time. In 1999, the plan “Systems Architecture for ITS in Japan” was formulated.

2.2. Information collection and traffic control center

Before the master plan was finalized in Japan, a variety of infrastructure was already in place that had been gradually introduced, including traffic counters and vehicle detectors, electronic variable message sign (VMS), closed-circuit television (CCTV) cameras, weather sensors, and fiber-optic communication networks. In 1973, a Metropolitan Expressway traffic control center began operations. In 1980, a real-time traffic information service for motorists that broadcasts via highway radio transmitters began operations on the expressway network.

2.3. Vehicle Information and Communication System (VICS)

In 1986, research and development of digital road maps began, and in 1988 a standard format for maps was finalized.

Research and development of road–to-vehicle communication systems began in 1988. In 1996, after the conclusion of public demonstration experiments in 1993, the Vehicle Information and Communication System (VICS) service was launched. This service communicated with an in-vehicle navigation system using dedicated short range communication (DSRC) and FM multiplex broadcasting from roadside antennas, providing information to motorists regarding traffic congestion and required travel times as shown in Figure 1. The VICS system made it possible to allow car navigation systems to select an optimal route based on real-time traffic information, thereby facilitating the avoidance of congestion points. As of June 2014, the number of VICS-compatible car navigation systems was more than 43 million, and this number continues to grow.

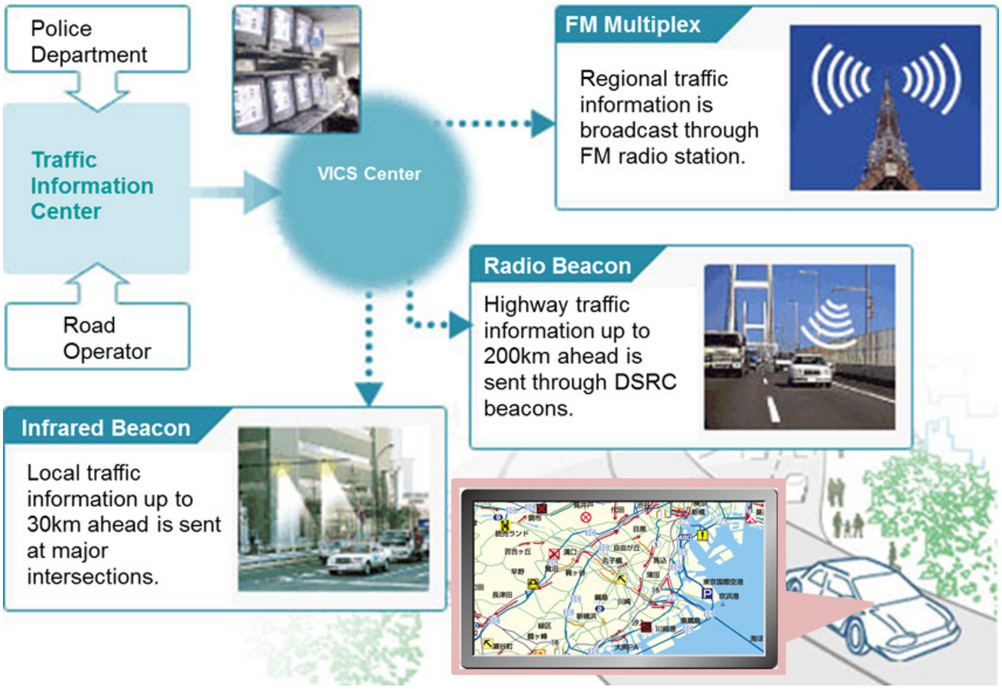

Figure 1 - Outline of VICS

2.4. ETC

Technology development for nonstop electronic toll collection was started in 1995. The nationwide introduction of the ETC (Electronic Toll Collection) service started in 2001 after the completion of validation experiments. In 2005, the ETC service was available at almost all expressway toll gates in Japan. At present, use of the service is widespread with more than 48 million ETC on-board units sold. Utilization rate of ETC payment at highway toll booths has remained at a level of more than 90% [1].

The Japanese ETC system has adopted ISO 15628, ISO 14906, and ISO 17574, aligning itself with international standards. The system uses an active DSRC that enables two-way communications in the 5.8 GHz band. As described below, this is a major advantage in the evolution towards C-ITS. The system adopts two-piece type on-board units (OBUs) which use contactless IC cards. Therefore, it is technically possible to have both a prepaid and post-pay system. It is also possible to use common IC card with public transportation fee payment and retail. That enables the migration easier when the users of ETC service updating their OBUs or joining into brand-new C-ITS services, because it isn’t necessary to change their user accounts.

With the widespread deployment of ETC, traffic demand management (TDM) measures for congestion mitigation are straight form introduced and implemented. In Japan night-time, early-morning, and holiday discounts are applied as one of TDM measures. In addition to the nonstop toll collection by the ETC service at expressway toll booths, multilane free flow equipment are introduced to implement environmental road pricing. This encourages heavy vehicles to change their driving routes from within the city center to routes along the coast, and helps to reduce environmental pollution from vehicle emissions in the city.

In 2006, private service providers have started services using the identification number of ETC OBUs, enabling parking lot payments, ferry boarding procedures and payments and entry/exit control at gate of premises other than toll collection on the expressways.

The introduction and widespread adoption of ETC has had in a significant effect; the ETC collection lane at toll booths has approximately 11 times the processing capacity of a cash collection lane. Before ETC was introduced in 2000, approximately 30% of traffic congestion on inter-urban expressways occurred at toll collection gates. In 2009, congestion at toll collection gates had dropped to almost zero with the widespread adoption of ETC OBUs, as shown in Figure 2. This resulted in the yearly reduction of CO2 emissions by an estimated 210,000 tons [1].

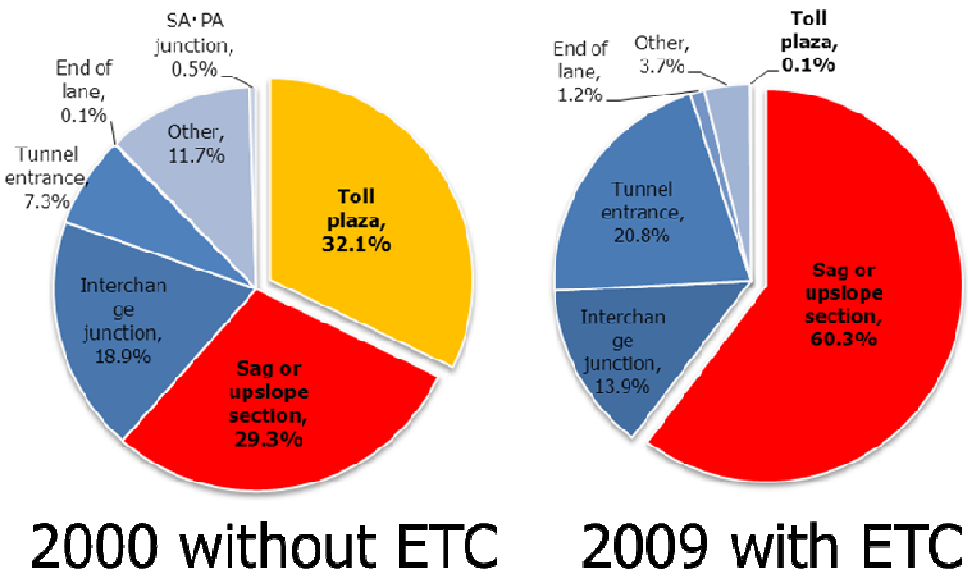

Figure 2 - Congestion on inter-urban expressways (ETC Handbook 2011)

3. COOPERATIVE ITS IN JAPAN

3.1. The Smartway concept

In 1999, the Smartway Project Advisory Committee announced the proposal of "Making Smartway a reality." In the proposal, Smartway is defined as follows:

"Smartway is a road that enables the exchange of information between vehicles, drivers, pedestrians, and other users. It improves safety and convenience for the users, and enhances environmental protection by ensuring smooth traffic flow. Expanding various ITS services leads to the creation of a wealthy and comfortable life for members of society. Specifically, Smartway is a road system into which road-to-vehicle communication system with sensors and a fiber-optic network and so on are embedded. These facilities are integrated with the road system and are used in order to provide a variety of services for ITS (each service supports common use and free exchange of information (i.e. it is an open platform)).”

The proposal insist that it is necessary to emphasize the following: the importance of validating the acceptability of society and users by actively conducting field operational tests (FOTs); and the need to build an industry–academia–government collaboration system for technological development and academic research. Figure 3 shows a conceptual diagram of the Smartway.

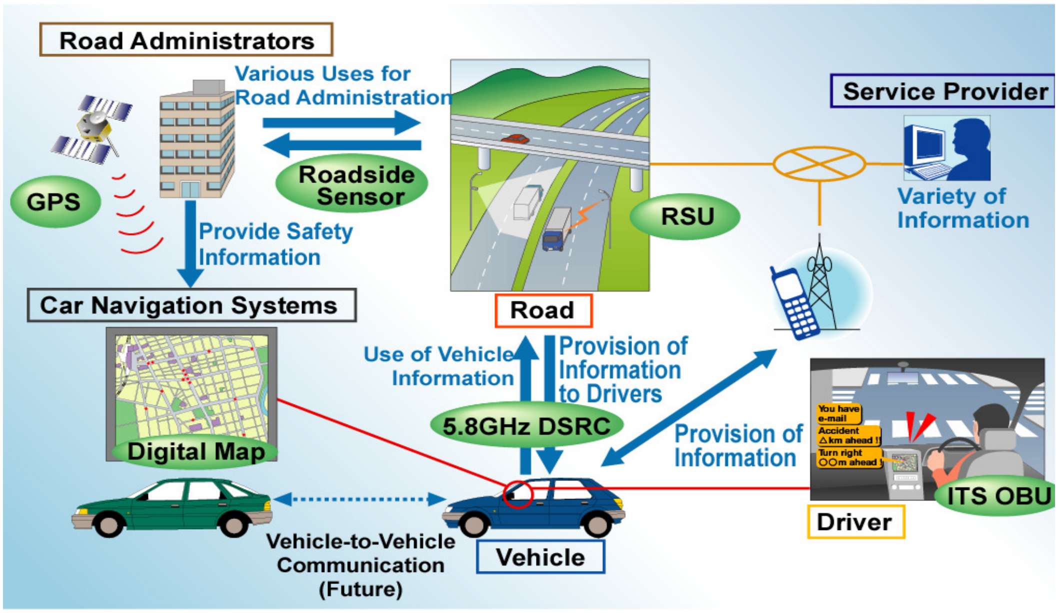

Figure 3 - Conceptual diagram of the Smartway

In 2004, the Smartway Project Advisory Committee announced the proposal “ITS, to the Second Stage.“ This proposal stated the desirability of the capability to access a variety of ITS services such as car navigation, VICS, ETC or brand-new one, from a unified single OBU. In addition, the proposal recommended the promotion of public-private joint research, the development of standards and specifications, and the establishment of a common base to realize those goals.

3.2. Development and launch of the ITS Spot Service

In 2005, a “Joint R&D on Next-Generation Road Service Provision Systems” was started in response to the above mentioned proposal from the Smartway Project Advisory Committee in 2004. The National Institute for Land and Infrastructure Management (NILIM) and 23 private companies participated in the public-private collaboration. “The Smartway open trial Demo 2006” was conducted at the NILIM test course in February 2006, and the final report of the joint R&D was published in March 2006. Furthermore, FOTs were conducted on the Metropolitan Expressway in 2007, and it was demonstrated that system development was in its final stage. In 2009, ITS Spot compatible OBUs became commercially available. In 2011, more than 1600 roadside equipment called “ITS Spot”, were installed along expressways throughout Japan. In August 2011, the C-ITS system started nationwide operations under the name of “ITS Spot Service [2][3].”

3.3. Features of ITS Spot Service

The ITS Spot Service adopted active DSRC technology on the 5.8 GHz band, the same band used in the ETC system. In addition to information provision from ITS Spot to OBUs, OBUs are able to upload probe data to the ITS Spots. OBUs use a basic application interface that combines numerous common functions, enabling the use of various ITS services. Moreover, a multipurpose contactless IC card is available for users as same as ETC system [4].

The ITS Spot Services introduced in 2011 offer mobility applications such as “dynamic route guidance” providing wide-area real time traffic information for car navigation system by a larger capacity of communication than a conventional VICS system, and so on. The ITS Spot Services also offer safety applications for example “forward obstacle warning”, “weather information”, and “road surface information.” The service also offers ETC application, which is completely backward compatible with the conventional ETC service. In a satisfaction survey conducted by NILIM, around 70-80% of users evaluated the services as effective as shown in Figure 4.

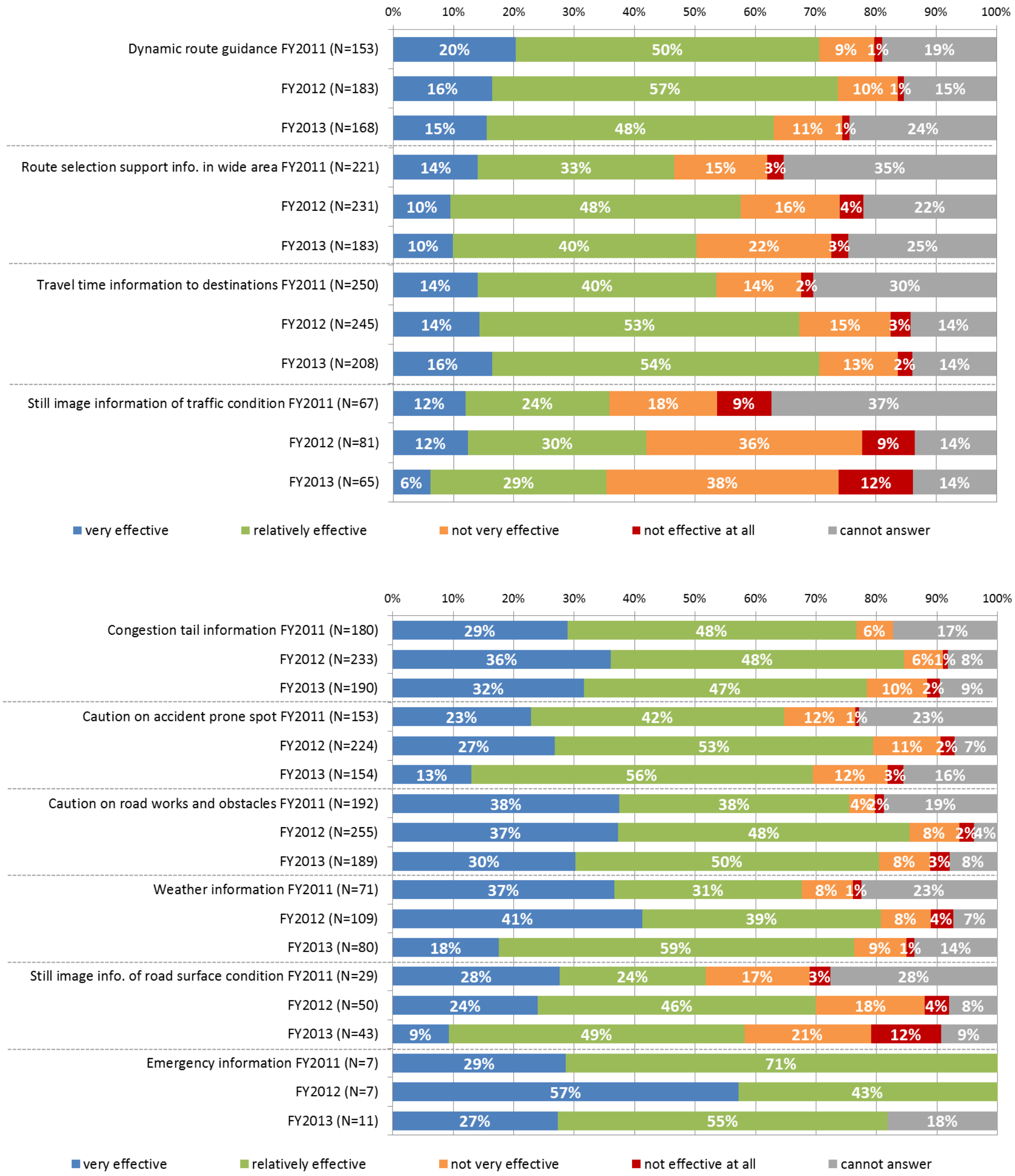

Figure 4 – Results of the satisfaction survey [4]

Collection of probe data utilizing the uplink function of the ITS Spot Service started in 2011. Initially the number of vehicles equipped with the ITS Spot compatible OBU was small, and the data was mainly used for research and analysis. Probe data consist of the two kinds of data: travel records and behavior records [5]. The travel records show the each vehicle's position and speed along its path. Though a manual observations or large scale installation of vehicle detectors' were necessary to understand traffic conditions previously, the probe data collected by ITS Spots make it possible to understand traffic situation 24/365. The behavior record can reveal dangerous points in the road network where a driver has suddenly applied the brakes or made sudden steering adjustments. As Figure 5 shows, countermeasures can be evaluated after implementation. The details of traffic problems can be more accurately understood by analyzing collected probe data, although this is partly dependent on the penetration of OBUs.

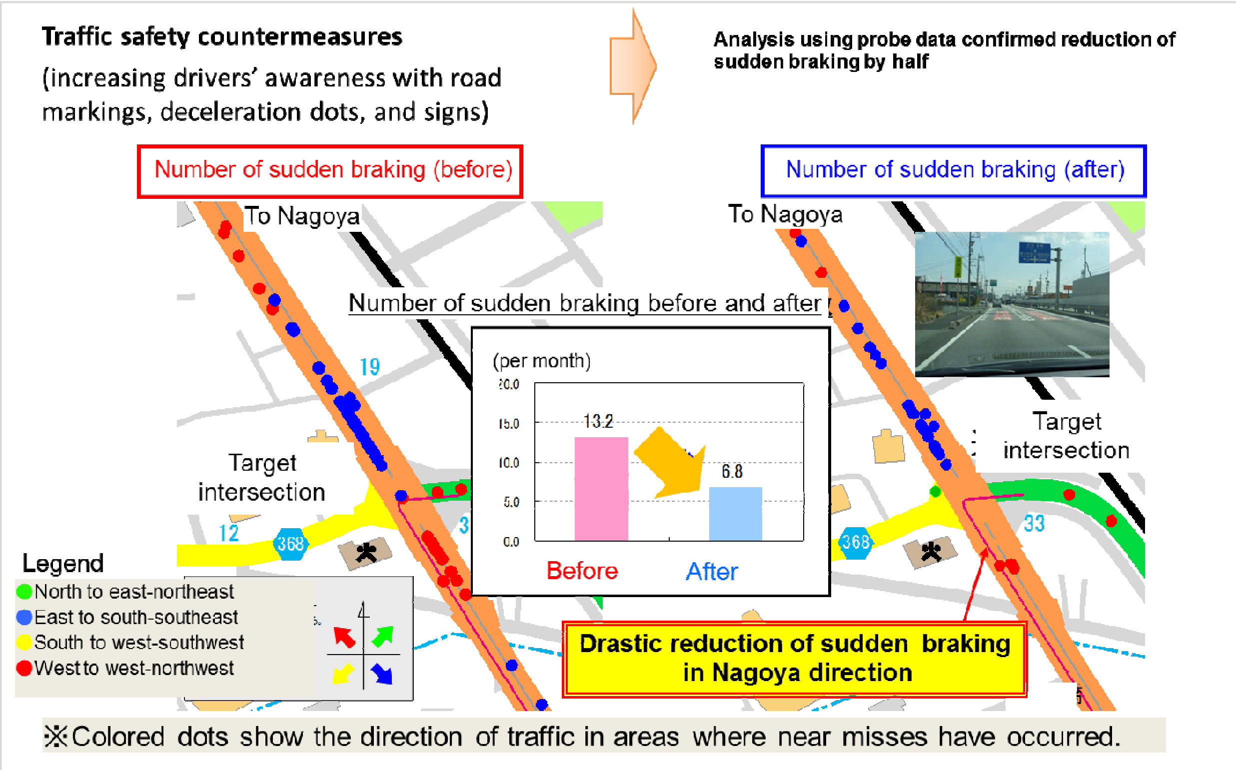

Figure 5 – Example of the analysis and evaluation using probe data

3.4. Evolution to ETC2.0

As of December 2014, there were approximately 500,000 ITS Spot compatible OBUs, and since the service started in 2011 its spread has progressed rapidly. In addition, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) is making efforts to double the number of roadside equipment from 1,600 to around 3,100.

In 2014, based on the wide spread of the ITS Spot Service, MLIT announced a policy to promote the ETC 2.0 service in which current ITS Spot Services and brand new services are integrated as shown in Figure 6. One of the services to be added is the utilization of route information generated from probe data. Specifically, incentive grants will be given to vehicle operators conducting smart route selection, such as using the outer ring roads. Heavy-duty vehicles' monitoring service and logistics freight support service using probe data are also expected [6].

To date, long-term road planning in Japan has used traffic census data gathered from vehicle detectors and large-scale manual survey, which are conducted only once every five years. In the future, officials plan to use data gathered from the ETC 2.0 probe system to measure travel speed and routes in such surveys and this is expected to greatly increase the efficiency of the survey and road planning.

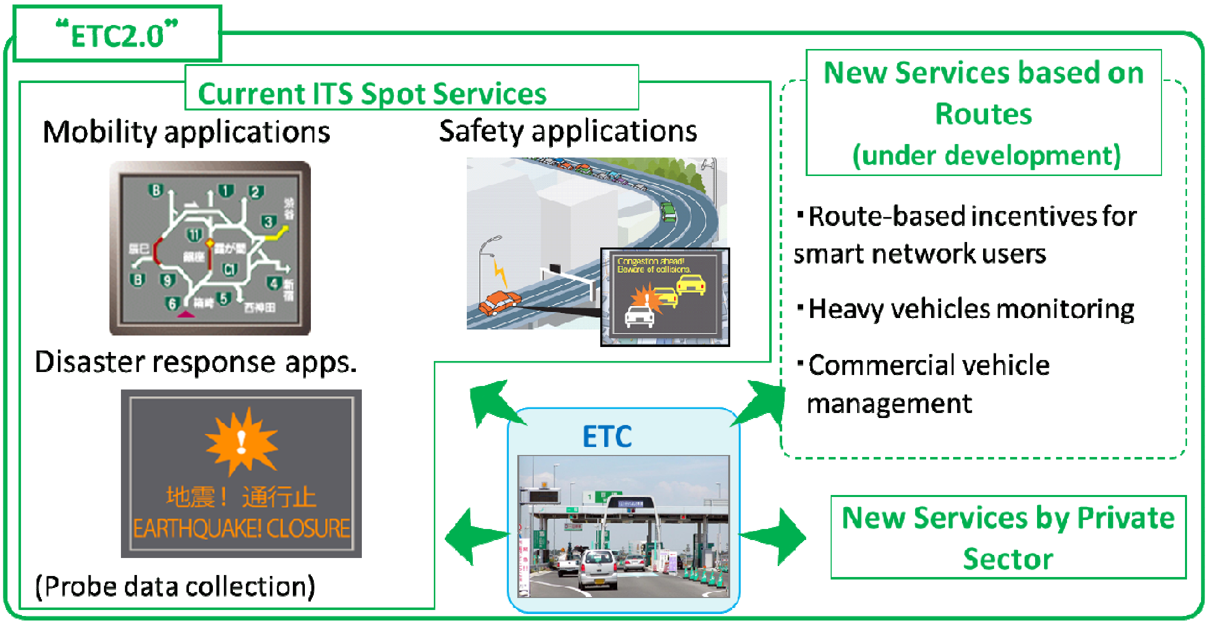

Figure 6 – ETC2.0 services

4. LESSONS LEARNED

As mentioned in the previous section, C-ITS have been launched in Japan and its deployment is expanding steadily. This section examines the strategies thought to have contributed to the introduction and expanded deployment of C-ITS.

4.1. Public-private partnerships and standardization

Public-private partnerships from the research and development stage make it possible to advance the comprehensive legislation necessary to clearly define traffic problems in need of solutions, to develop new technologies and services, conduct demonstrations, and to introduce the technology further. Moreover, it is also possible to find practical solutions through discussions regarding the appropriate level of role sharing between the public and private sector regarding the development and systematization of organizations such as those for security information management and equipment interoperability testing, which will be needed after introduction.

Joint research, demonstrations, and FOTs conducted through public-private partnerships will help to set the necessary specifications for the system, such as standardizing equipment specifications and defining data formats. This standardization will promote further expansion of the system and will ensure interoperability. Simultaneously that leads competition among the suppliers, which will reduce equipment costs and will allow the ingenuity of the market to come up with multiple solutions to achieve the goals of the system.

4.2. Integration with legacy ITS services

The ETC 2.0 service has rapidly expanded by maximizing use of conventional assets of VICS and ETC including users of each service. It is quite important to effectively integrate and efficiently make use of existing ITS systems and services which are already deployed in a country or region when C-ITS is introduced. In particular, ETC is one of the ITS services expected to enjoy a steady penetration. Therefore newly introduced C-ITS should be designed with ETC services which may be under operation previously.

4.3. Evolutional migration

When C-ITS are introduced into countries larger than a certain size, applications and systems can be introduced in a stepwise manner. It makes possible to promote of deployment. In fact the introduction and deployment of C-ITS in Japan has expanded rapidly due to the gradual improvement of the services. The phased introduction of VICS, ETC, ITS Spot Service, and ETC 2.0 has not caused abrupt changes nor inconvenience for the ITS service users. Even difficult-to-deploy services in the early phase of introduction can be deployed by evolving the service in a stepwise fashion and by continuing the deployment and development.

4.4. Basic package for C-ITS

Recognizing the introduction of ETC 2.0 as a C-ITS in Japan has brought about solutions to traffic problems, it appears the optimal path of C-ITS introduction is stepwise launch and deployment as shown in Figure 7.

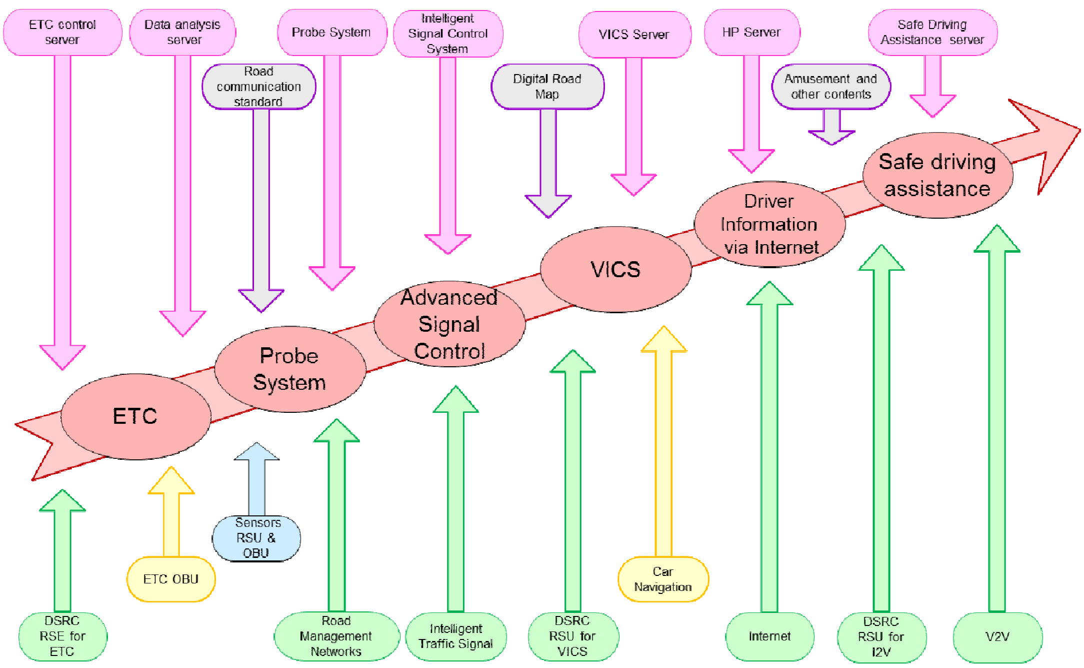

Figure 7 – Stepwise approach of C-ITS introduction and deployment

The first step is the introduction of platform of ITS: CCTV and ETC. CCTV cameras are essential for traffic monitoring. The introduction of ETC is also absolutely necessary to financing the road construction cost, and to make the steady deployment of C-ITS. Introduction of CCTV cameras should be efficiently designed with expandability for additional image processing technology in order to collect traffic data in the next stage. Furthermore, with the introduction of ETC, expandability for the future collection of probe data and the provision of traffic information and safe driving support information should be considered. Therefore the DSRC should have enough capacity for large volume of data transmission bi-directionally, enabling secure communication and above mentioned services in the latter stage. Besides it is desirable that ETC OBUs are equipped with GNSS receivers generating probe data.

In the second stage, where the number of OBUs has increased, traffic problems can be statistically analyzed using a combination of the traffic data generated from CCTV camera images and the probe data collected through ETC systems as above mentioned. That is, it will be possible to accurately understand locations that often experience congestion, including when and to what extent the congestion occurs, and to specify dangerous locations where drivers suddenly apply the brakes and so forth. By using this information, measures can be evaluated such as traffic signal timing and changes in road signage and markings. This increase in the plan–do–check–act cycle will make it possible to clarify traffic problems and solve them quickly.

In the third stage, a sufficient amount of data can be collected to obtain an understanding of real-time traffic conditions. In this stage, the signalling system can be adjusted on-the-fly when an incident occurs and information can be provided to drivers traveling in the same direction regarding congested areas, similarly to the VICS system. The creation and dissemination of digital road maps and the expansion of information provision services, such as those provided by car navigation systems, will increase the number of drivers able to receive information while on the move and ultimately make a major contribution to resolving congestion problems and environmental challenges. Various TDM measures are also able to be implemented based on the C-ITS platform.

The fourth stage is when the number of OBUs that receive information from roadside transmitters has increased sufficiently. In this stage, the effect of safe driving support information on the traffic system will be evident. Drivers will be provided with real-time, pinpoint information about the location of unseen obstacles, accidents and congestion tails via DSRC transmitters embedded in the road system, and this will greatly improve road safety.

In the fifth stage, vehicles are equipped with technologies such as automatic braking, adaptive cruise control, and lane keeping assist, enabling C-ITS services to provide even more advanced safe driving support information and increase convenience for the driver.

In addition to the stepwise introduction of C-ITS facilities and services above mentioned, C-ITS services for public transportation and heavy-duty vehicle management can likely be realized by augmenting each stage with smartphone probes and physically embedded weigh-in-motions.

5. SUMMARY

This paper has described the progression of large-scale introduction and rapid deployment of ETC 2.0 in Japan, advances in worldwide research and development, and demonstrations of C-ITS. Also, strategies have been discussed that are considered important for the widespread introduction and deployment of C-ITS. In addition, the basic package for C-ITS introduction and evolutional deployment is discussed recognizing experience in Japan

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