Chapter 5

Intelligent Transport Systems

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5.1 An introduction to ITS

5.1.1 What is ITS?

The term ITS was coined in 1994, and stands for "Intelligent Transport Systems" or "Intelligent Transportation Systems." In a broad sense, an ITS is a system relating to mobility that has increased in sophistication through information technology (IT). However, the specific terms and concepts differ according to the country and situation.

The Japanese government and the specified nonprofit corporation, ITS Japan, use "*kodo doro kotsu shisutemu*," meaning "intelligent road and transportation systems," but the Institute of Electronics, Information and Communication Engineers, the Information Processing Society of Japan, the Institute of Electrical Engineers of Japan, and others use "*kodo kotsu shisutemu*," which in English means "intelligent transport systems."

As Fig. 1 shows, The Ministry of Land, Infrastructure, Transport and Tourism defines an ITS as "a new transport system constructed with the goal of alleviating road traffic problems such as accidents and congestion using state-of-the-art information and communication technologies to create an information network based on people, automobiles, and roads."[1)]

ITS Japan explains the concept as, "a system for solving a variety of problems that road traffic faces, such as accidents, congestion, and environmental measures, through the exchange of information between people, automobiles, and roads. It attempts to coexist with the environment and improve energy efficiency by eliminating accidents and congestion while at the same time optimizing the road network by utilizing state-of-the-art information and communication and control technologies. In addition, it has the potential to create new industries and markets with its diverse related technologies, and promises to be a driving force in changing the social system."[2)]

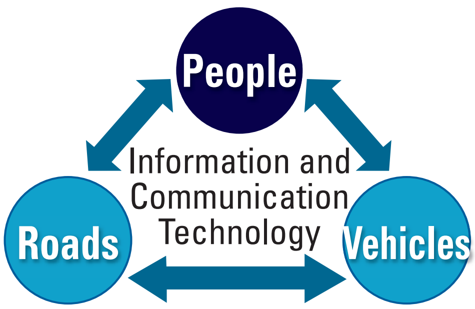


Figure 1. The Ministry of Land, Infrastructure, Transport and Tourism's ITS[1)]

In each academic society listed above, ITS are not limited to automobiles, but also include railways, aircraft, and shipping traffic as areas that can also benefit from the sophistication of mobile IT. This mobility-oriented concept is popular in other countries, especially in Europe.

5.1.2 Organizations promoting ITS

In a variety of countries, ITS are promoted by a wide range of organizations including governments, local governments, industries, and academic societies. For example, as of 1996 the ministries and agencies promoting ITS in Japan were called the "five concerned ministries," consisting of the National Police Agency, Ministry of International Trade and Industry, Ministry of Transport, Ministry of Posts and Telecommunications, and Ministry of Construction. After subsequent reorganization and renaming, there are currently many more ministries and agencies involved, including the Cabinet Secretariat, Cabinet Office, National Police Agency, Ministry of Internal Affairs and Communications, Ministry of Economy, Trade and Industry, and Ministry of Land, Infrastructure, Transport and Tourism. Also, ITS Japan, a specified nonprofit corporation, has been essential in the promotion of ITS in Japan. ITS Japan has taken the role of Secretariat of the ITS World Congress and ITS Symposium, and is responsible for the publication of academic journals such as the *International Journal of ITS Research*. It actively promotes ITS activities in the spirit of international cooperation among industry, government, and academia.

The ITS World Congress, described later, is a trilateral symposium held every year, rotating between Europe, Asia, and the United States, and centering around the European Road Transport Telematics Implementation Coordination Organization, which is a private-public organization for promoting ITS in Europe, the Intelligent Transportation Society of America, which is a nonprofit scientific and educational organization for the purpose of ITS promotion and serves as the official advisory committee of the US Federal Department of Transportation, and ITS Japan. Moreover, there are many other private–public organizations promoting ITS in each country and together with the efforts of a variety of universities and research institutes, ITS are receiving broad promotion.

In addition to the IEEE and Transportation Research Board in the United States and the three Japanese academic societies mentioned above, other academic societies, such as the Society of Automotive Engineers of Japan, the Japan Society of Civil Engineers, the Japan Society of Traffic Engineers, and the International Association of Traffic and Safety Sciences, are also involved in the promotion of ITS. ISO/TC 204 - Intelligent Transport Systems plays a central role in standardization, but coordination with International Telecommunication Union is still undertaken, especially in the field of information and communication.

5.1.3 Aims of ITS

According to the definition of ITS, the range and concept used in each field may change, but the purpose of ITS generally relates to the "safety, efficiency, environmental concerns, and convenience of traffic and transport via the thorough utilization of IT." Therefore, changes in information and communication, positioning, and underlying sensing technology by means of lifestyle and value changes as well as the advancement and dissemination of science and technology, always bring about changes in the ITS world.

The next section will review the history of ITS.

5.2 History of ITS

5.2.1 The beginning of the ITS World Congress and the transition of Japan's ITS

The annual World Congress on Intelligent Transport Systems (hereinafter, World Congress) was first held in Paris in 1994, and the following year saw it held in Yokohama. The first World Congress was named and positioned as "The First World Congress on Advanced Transport Telematics and Intelligent Vehicle-Highway Systems," and the theme was "Towards an Intelligent Highway Transport System."[3)] The name was officially changed to contain ITS at the second World Congress. Japan enthusiastically embraced ITS following the Congress in Yokohama in 1995, and in 1996 the "Grand Plan to Promote Intelligent Transport Systems (ITS)" was established by five concerned (then-) ministries and ITS has been actively promoted ever since. Figure 2 shows the subsequent timeline.

The period from 1996 until mid-2004 came to be known as the first stage of ITS. As of 2014, 21 services in 9 fields have been launched, such as the widely used Vehicle Information and Communication System (VICS), which is representative of a sophisticated navigation system, and Electronic Toll Collection (ETC).[4)]

An ITS is one system made of many, and understanding of the underlying systems is important to understand the system as a whole. Many of these were small-scale systems created as dedicated systems for their various uses (system by system). Recently, systems tend to be applications or "apps" built on

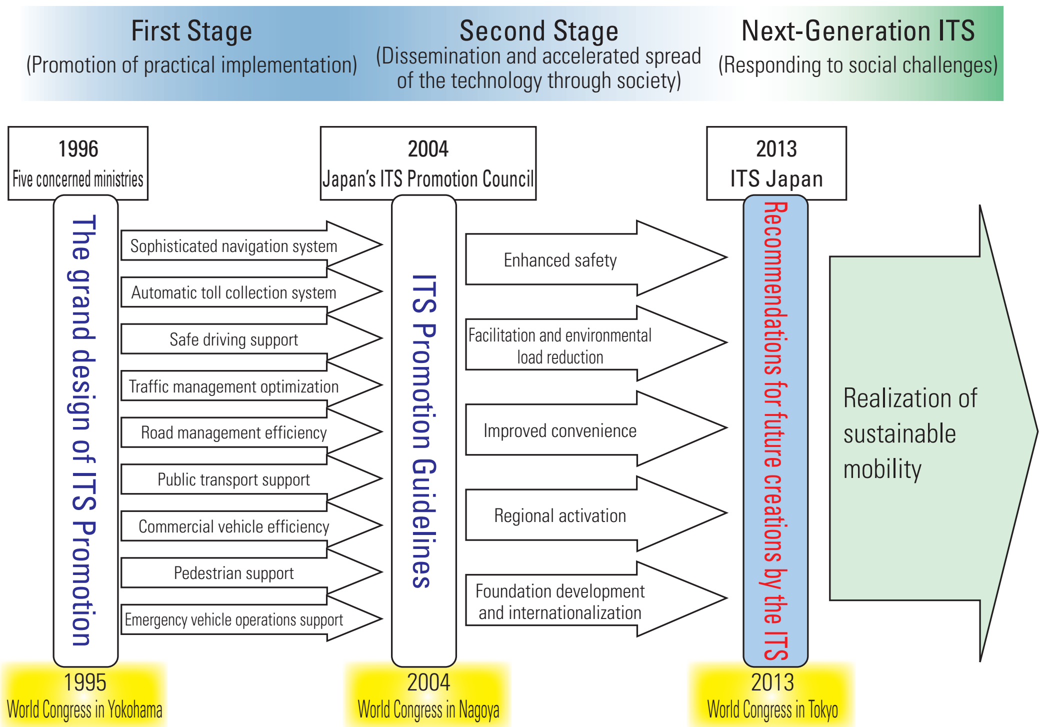


Figure 2. The flow of Japan's ITS[4)]

platforms. For example, the creation of a word processing application running on top of an OS platform on a home computer, which led to the disappearance of the word processor as a dedicated machine, or the increased rate of smartphone use after the development of apps that could run on mobile platforms such as Android or iOS, which ushered in a decline in the use of standard portable handsets or feature phones. Such a shift has also seen dedicated car navigation systems making the changeover to car navigation apps running on smartphones. In short, the shift from dedicated systems to platform oriented systems is a significant change (Fig. 3).

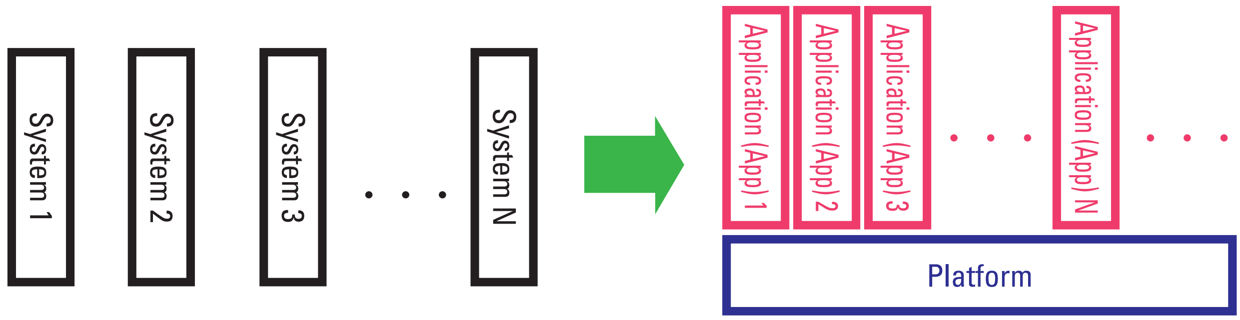


Figure 3. Platform-oriented. System implementation using applications running on a platform

In 2004, the Japan ITS Promotion Council released its "ITS Promotion Guidelines," the pillars of which are "safety and security, environment and efficiency, and comfort and convenience,"[4] and represent a top level purpose-oriented concept with the main thrust being that each system is integrated and running on a platform. For examples of various projects see Reference 4.

The first stage of promotion was the practical use of the technology, the second stage was the dissemination and accelerated spread of the technology through society, and since 2010, the realization of a sustainable mobile environment has been promoted as the next generation of ITS's response to social issues. For the future of ITS, in light of the changes in both the societal and technical contexts, efforts continue toward the expansion of regional ITS and the realization of a next-generation mobility society. These efforts can be summed up in eight points:[4]

1. Construction of a safe and secure transport system
2. Construction of a next-generation automobile society
3. A response to environmental needs
4. A response to the development of information and communication technologies
5. A response to the movement of next-generation people and goods
6. The introduction and promotion of an integrated regional ITS
7. Disaster response
8. A response to internationalization

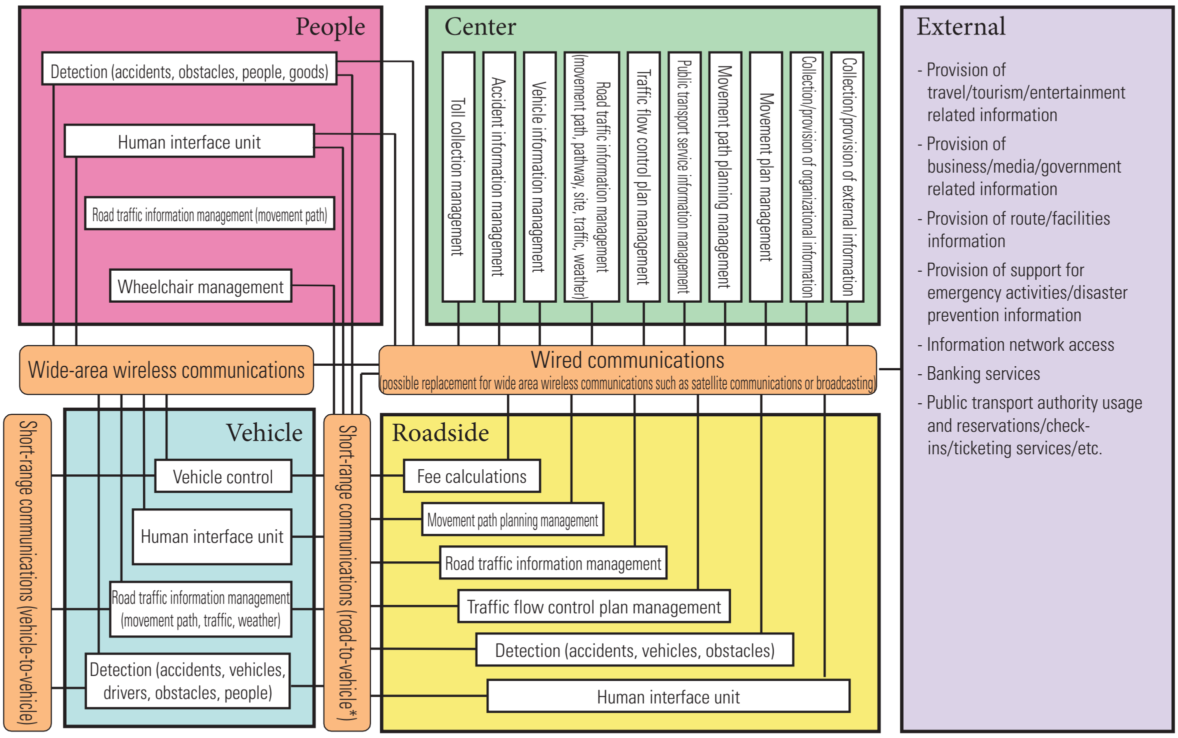
5.2.2 The history of related fields

Although the term ITS was coined in 1994, as previously mentioned, its origins can be traced back to the 1980s with programs that used sensing, information and communication, and signal processing and information processing to achieve a greater sophistication of traffic and transport, such as the Partners for Advanced Transportation Technology (PATH) Program in California in the United States and the PROgraMme for European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS) in Europe. Furthermore, if projects in Europe, America, and Japan such as automated driving, route guidance, and the provision of traffic information are included, the origins can be traced back to the 1950s.[5)] Please refer to existing literature[6)] that explains the needs and legislation required regarding the transition of research and development of automated driving, which began in the 1950s and comes up to the present day with Japan's ITS research and development projects on vehicle convoys traveling together in a line for increased energy efficiency.

5.2.3 System architecture

The system architecture conceptually represents interactions between the elements of each system and the system as a whole, as if laid out on a nautical chart, to achieve the system's objectives, and is intended to effectively advance the development of systems that require time to realize their large-scale practical applications and to spread through society. The purpose of system architecture development is to construct integrated systems efficiently, to ensure the scalability of the system, as well as to promote national and international standardization.

The system architecture in Japan that was formulated in the late 1990s (see Fig. 4) includes a complete picture (see Fig. 5) of the user service system, which is a premise of the plan.[7)]



*Short-range communication (road-to-vehicle) indicates narrow range communication that takes place between the roadside and the vehicle/people.

Figure 4. System architecture (interconnected subsystems)[7)]

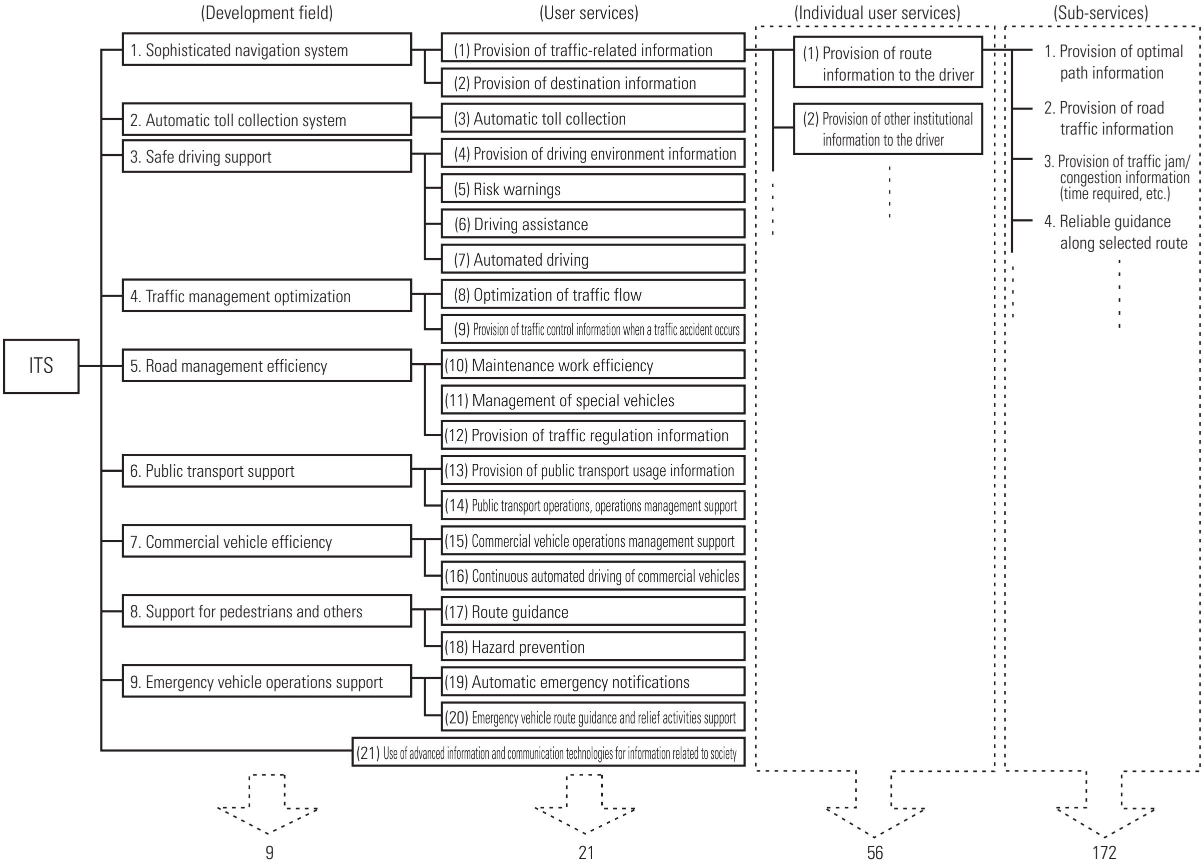


Figure 5. Overview of proposed system architecture development for user service system[7)]

5.3 ITS fields and research and development themes

5.3.1 Overview of the fields of ITS

The different fields of ITS, from their fundamental technologies to their surface applications, are many-layered and the expansion of these fields is similarly diverse. As Fig. 6 shows, the framework of ITS fields are supported by their respective fundamental technologies such as information and communication, positioning, and sensing, and there are numerous applications such as safe driving support services, traffic control services, and pedestrian services for the various functions provided by the

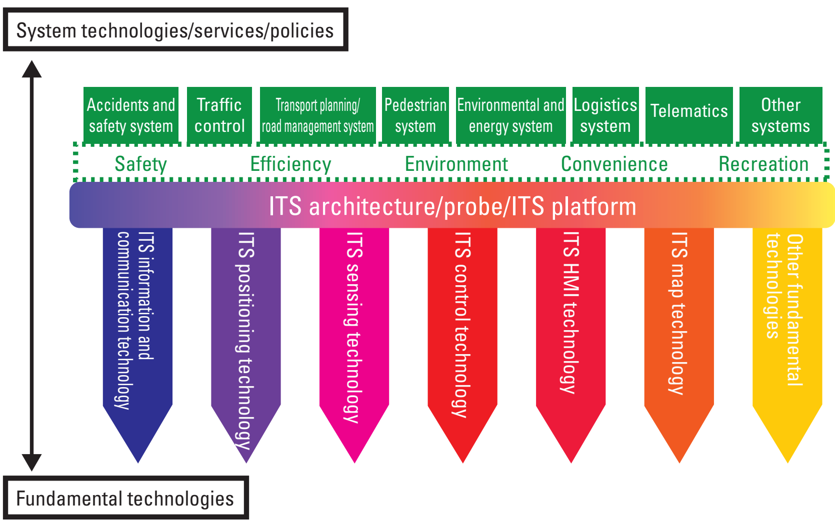


Figure 6. Framework of ITS fields

fundamental technologies in the middle layer of the platform.[8)]

The technologies that underlie the applications change with the passage of time. For example, the transition from dedicated information and communication, positioning, and sensing systems to all-purpose mobile phones, Wi-Fi, Bluetooth, and smartphones with built-in body sensing capabilities create the landscape in which new applications are released. In addition, the continued evolution of each fundamental technology and system technology also sees the evolution of the safe driving support system from simple danger warnings to assisted safe driving technologies to automated driving systems.

Figure 6 shows the universal and abstract concepts persistent through time from the fundamental technologies to the surface applications.

5.3.2 Changes in trends of the ITS world, and research and development themes

Originally, the essence of ITS was mostly awareness enhancement (Fig. 7). Safe driving support systems such as danger warning systems that inform the driver of risks looming beyond the range of their field of vision, wide-area real-time traffic information that cannot be known by drivers themselves, and the forecasting of potential areas of congestion all assist the driver in taking actions to avoid risks and inconveniences. They also inform drivers about current road surface conditions and can alert the driver thereby helping to prevent accidents. Technologies spread out from there to anti-lock braking systems (ABS) and collision avoidance systems assisting the driver in vehicle operation. Generally, these changes represent a transition from after-the-fact passive safety to before-the-fact active safety, paving the way for automated driving at various levels.

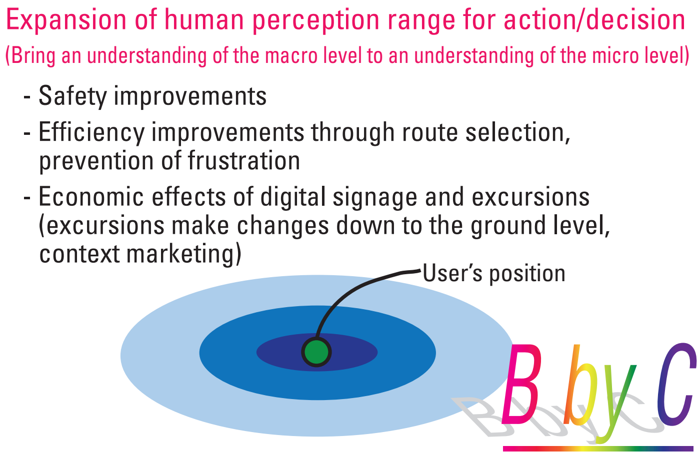


Figure 7. Awareness enhancement in the ITS fields

VICS is a system transmitting traffic information, and initially collected sensing data from relatively large road systems using infrastructure-mounted sensors such as loop coils or ultrasonic sensors. However, these data can fundamentally be collected only in areas close to the sensor locations. In contrast, systems developed over the past 10 years use probe car (floating car) data and then upload those data, including position, directly to servers on information networks. These systems are able to grasp traffic conditions by aggregating collected data and delivering traffic information to each vehicle. This method is able to select a single car from a group, and does not require any additional investment for infrastructure such as installing new sensors. The data collected are not limited by the installation positions of the sensor infrastructure, as long as the car passes a sensor, the data are collected. However, this type of probe system is not favorable overall. Although the installation locations of the infrastructure sensors are limited, the traffic data collected are fine-grained. In contrast, the probe system relies on absolute traffic volume and the proportion of sensors installed over the entire road system to determine the quality of the data. At lower traffic volumes the precision and accuracy of the data collected falls, and no data are collected at all if no vehicle containing a transmitter passes the target area, since a vehicle without a transmitter does not work as a probe.

One example of using this feature is the collection of probe car data immediately after the Great East Japan Earthquake on March 11, 2011. Figure 8 shows this example. The portions in blue show traffic data within a 24-h period after the earthquake. Note, however, that the figure does not always show the traffic data for all potentially passable roads, it simply shows four-wheeled passenger vehicles passing the sensor locations within a 24-h period. Furthermore, it does not show motorcycles or large transport vehicles using the roads; if a driver had not happened to use the road, no trace would have been recorded at all. It also does not show the passage of traffic on roads that are not colored blue. Yet, there is no doubt that these data were very important information in supporting activities during the disaster situation.

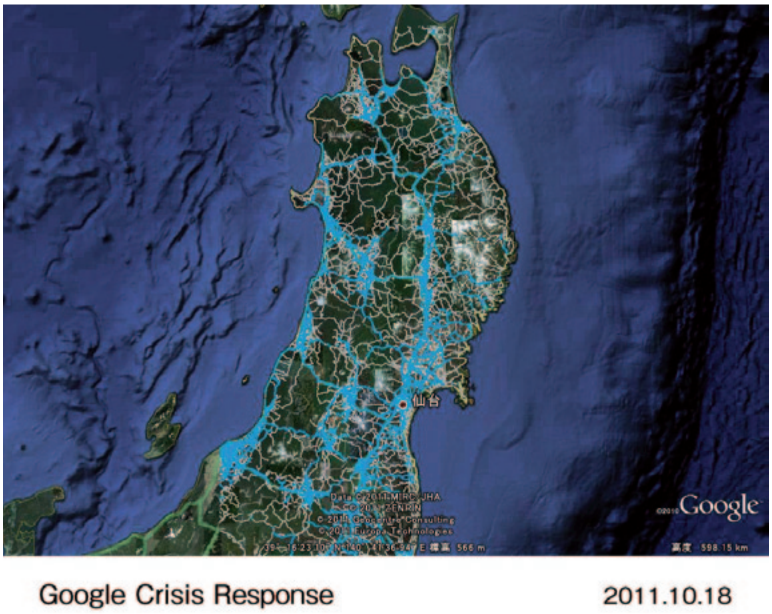


Figure 8. Example of probe information system (Honda Internavi traveling experiences immediately after the Great East Japan Earthquake)[9]

A system using probes to gather data from smartphones is able to gather data with even finer granularity. While probes installed in vehicles provide data for only that single vehicle, probes transmitting from a smartphone can render extremely fine-grained position and direction data from people on buses, trains, and riding in cars; pedestrians on streets and in underground malls; and people inside buildings. It is also possible to process various pieces of uploaded data on the server side depending on conditions.

The use of smartphones as probes certainly reduces the size of the entity operating the system from the national level to the size of major companies, and in the future it is entirely feasible that this level will again be reduced to encompass small and medium-sized organizations.

In addition, even though smartphone applications may be partly inferior to a dedicated car navigation system, the fact that many applications can replace dedicated systems is a clear indication of the move toward lightweight solutions.

ETC is a system that automatically collects user toll fees to pay for road construction and maintenance costs from vehicles using the road, so for this purpose it is not absolutely necessary that the user's vehicle pass through a gate. It is possible to levy the toll using indexed routing information from the position data. If this is to become a reality, a system function preventing users from eluding the toll charge will become necessary.

Now, let us discuss the role of positioning infrastructure as a fundamental technology. There is no doubt that the most prevalent positioning infrastructure is GPS. However, in recent years, methods for acquiring specific position data by using the MAC address and RSSI of Wi-Fi access points are notably becoming the second-most used technique for acquiring location information and position information, representing positioning social infrastructure. With the addition of Bluetooth low-energy (BLE), positioning infrastructure has come to have a heterogeneous system structure. Similarly, this is also a contributing factor in the move toward lightweight solutions. Positioning using GPS requires a national-level endeavor; however, positioning using Wi-Fi and BLE has now become possible for companies and smaller organizations. Of course, there are both strong and weak points in the environment for the application of GPS, Wi-Fi, and BLE. GPS excels in outdoor environments, particularly in mountainous regions, at sea, and the like where there are few tall buildings. Wi-Fi is robust in urban areas, particularly where users are inside buildings or underground shopping centers. BLE exerts its strength indoors. This is an additional contributing factor in the movement toward lightweight solutions.

Finally, there are expensive dedicated vehicles for detecting the condition of road surfaces damaged by disasters. In contrast, by using the acceleration sensor information from smartphones attached to the dashboard, a system for detecting certain vibrations in the vehicle caused by damage to the road has been put to practical use. The sensor accuracy of the dedicated vehicle is high but the speed of the vehicle is slow. On the other hand, the accuracy in systems using smartphones is low but data are continually collected while the user is on the move. This is a further example of a lightweight solution.

5.3.3 Topics in 2014 and future development[4)]

ITS Japan has summarized the seven priority areas for the future development of ITS as follows:

1. The reduction of traffic accidents and road congestion to zero using advanced driver assistance systems
2. The resolution of challenges to efficient transport through a movement support information platform
3. The innovation of multimode transport to support mobility inside cities
4. The comprehensive management of road traffic
5. Increasing the efficiency of logistics
6. The optimization of energy use
7. The promotion of international cooperation

As shown in Fig. 9, the ITS World Congress of 2013 showcased ITS Green Safety. Figure 10 provides an overview of the basic shift toward automated driving, while Figure 11 illustrates the Green Wave Project, one of the National Police Agency's projects for FY 2014.

Due to space limitations the points above represent the general flow of ITS in Japan, see the following documents for more detailed information. See Reference 4 for the overall flow. See Reference 10 for information concerning the fundamental technologies, V2V and V2I information sharing (Connected Vehicles). As for information concerning positioning, the combination of GPS,[11)] gyros, dead reckoning, map matching, and other such methods alongside Wi-Fi access points,[12)] cellular base stations, and the platforms using those technologies have a variety of error-causing factors.[13] Please refer to the indicated references for additional information, or see References 6, 14, 15, and 16 for information regarding

Figure 9. ITS Green Safety Showcases[4]

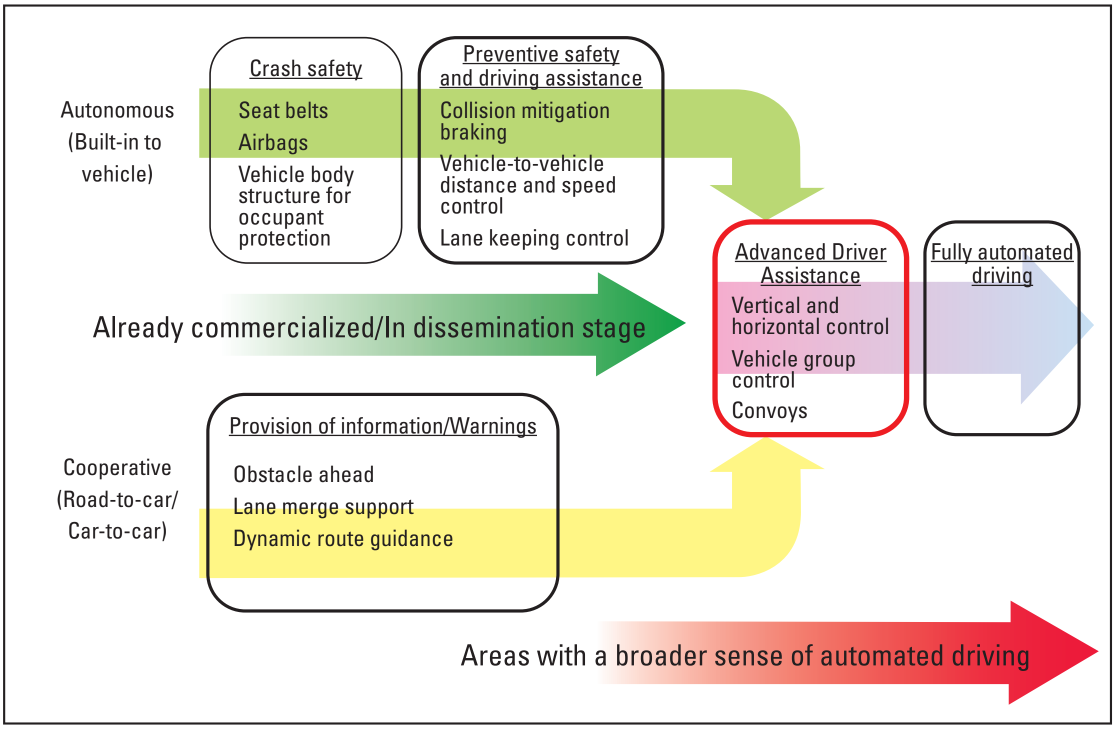


Figure 10. The basic shift toward automated driving[4]

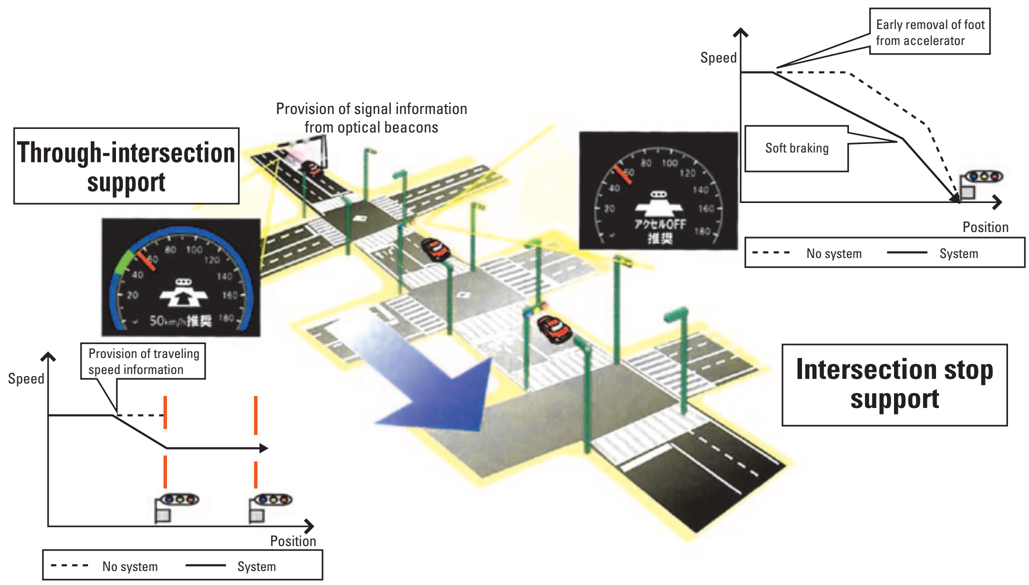


Figure 11. Examples of government ITS-related projects in FY 2014[4)]
(Source: National Police Agency)

automated driving from a variety of conceptual angles. Furthermore, although these may cover slightly different topics, see Reference 17 for information on location-based services from basics to practical applications, Reference 18 for electrical vehicle diffusion scenarios, and Reference 19 for design theory of new traffic systems.

An ITS is a sufficiently large-scale system to be referred to as a “system of systems” as described above, and looking at the system as a whole—from the fundamental technologies, to the system technologies, and ultimately to the services provided—we see it is in close contact with the real world, as a very wide ranging subject with a deep hierarchy. At its base exists a collection of vehicles and pedestrians, moving entities on the land, sea, and air, as well as positioning and information and communication. Furthermore, the actual concrete measures taken for positioning and information and communication sub-platforms suitable for mobile use will change with the times. In the past few years, a smartphone sensing sub-platform has been added, and dramatic changes have happened. It is necessary to cultivate the technologies that ITS use into the fundamental and system technologies that these forms of mobility require in order to help improve safety, enhance efficiency, reduce environmental load, boost convenience, and create more enjoyment through automated driving and big data processing. We need to become familiar with each individual technical field, and create a system that contributes to society through the mobility of people and things. To tackle such a wide breadth and such deep layers, readers are encouraged to deepen their knowledge on the fundamental and system technologies through the references provided in this chapter.

As for the future of ITS, it is necessary to provide ITS suitable for each region and promote the realization of a next-generation mobility society based on changes in social and technological conditions.

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Practical application projects for reference

Practical application of a public involvement-type system for planning and evaluating road traffic safety measures: 160–163