2

Outlook on the next steps of Intelligent transport systems (ITS) technologies in Japan: for overcoming Social and Environmental problems brought by Automobiles

KANJI TAKEUCHI
Information and Communications Research Unit
SEIJI MAEDA
Environment and Energy Research Unit

1 Introduction

Automobiles using gasoline-fueled internal combustion engines first appeared about 120 years ago. Since then, automobiles have become indispensable. Not only have they contributed to economic development, they have also enriched people's lives through the joy and pleasure of driving. Today, the automobile industry has become synonymous with Japan's manufacturing skill, driving the nation's economic growth and leading the world in quality, from parts to finished products. The industry has made a major contribution to Japan's economic and social development.

Already, there are about 800 million automobiles in the world. With global population expected to reach 9 billion in 2050[1], and especially because of the recent remarkable economic growth in the so-called BRIC nations (Brazil, Russia, India, and China), the number of automobiles is expected to grow at a rate of 100 million every five years. This market expansion is good news for automobile-related corporations, but at the same time, this rapid increase in motorization may lead to concomitant increases in traffic accidents, congestion, environmental impacts, and energy consumption, aspects that threaten quality of life. Worldwide deaths from traffic accidents in 2002 reached 1.18 million, meaning over 3,000 people die in traffic accidents every day[2]. This number is the equivalent of six or more jumbo jets crashing each day.

Unless positive aspects such as convenience and comfort can be maximized while negative aspects such as accidents, congestion, environmental impacts, and energy issues are minimized, a sustainable mobility cannot be achieved. Intelligent Transport Systems (ITS) are a promising solution and one which Japan is now engaged in investigating to contribute toward the world.

This report takes an overview of the status of and issues related to ITS in Japan's automobile society. Along with technical trends in ITS, the report looks at measures to establish a sustainable mobility that balances comfort with safety, security, and reduced environmental impacts.

2 Status of and issues in the automobile society

2-1 The status of ITS in Japan

ITS is defined as "using information and communications technology to form systems that address vehicles, roads, and people as a triune entity in order to improve safety, transportation efficiency, and comfort while protecting the environment" (Figure 1). In 1996 in Japan, a national project designed to lead the promotion of ITS was announced. It centers on four government agencies (reorganized from five previous agencies), the National Police Agency, the Ministry of Internal Affairs and Communications, the Ministry of Economy, Trade and Industry, and the Ministry of Land, Infrastructure and Transport, and relevant outside organizations. In addition, the non-profit organization ITS-Japan was formed by relevant organizations centered on industry, experts, and so on. It develops its promotional activities in collaboration with the four government agencies (Figure 2).

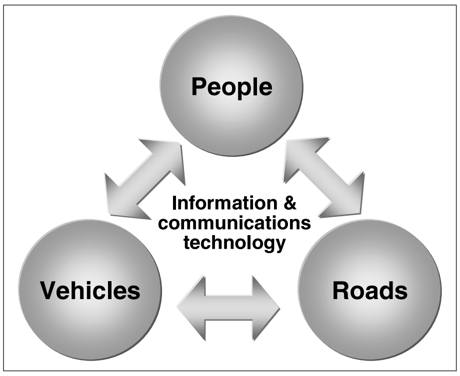

Figure 1 : Conceptual diagram of ITS

Prepared by the STFC based on Reference[3]

Table 1 depicts the history of ITS in Japan. Since the establishment of the overall concept in 1996, ITS has been positioned as a major Japanese policy. It is also listed in the 3rd Science and Technology Basic Plan as an important research theme in the fields of energy, information and communications, and social infrastructure.

As shown in Table 2, the nine areas contained in the August 1995 "Guidelines on the Implementation of Informatization for Roads, Transport, and Vehicle Fields" were designated by the (then) five government agencies for ITS development. To date, dissemination of car navigation systems and VICS*1 (Vehicle Information and Communication System) has been advancing since the second half of the 1990s. Dissemination of ETC*2 (Electronic Toll Collection system) began in 2001 (Figure 3). As of March 2006, car navigation systems were installed in over 22 million vehicles and VICS in over 15 million. As of June 2006, there were 12 million vehicles with ETC installed, and nearly 62 percent of Japanese expressways utilized the service. Japan thus leads the world in ITS device installation.

Development of elemental technology for "Assistance for safe driving" is progressing in parallel with these developments. The Advanced Safety Vehicle (ASV) has been developed in order to improve the safety and convenience of automobiles themselves through advances in

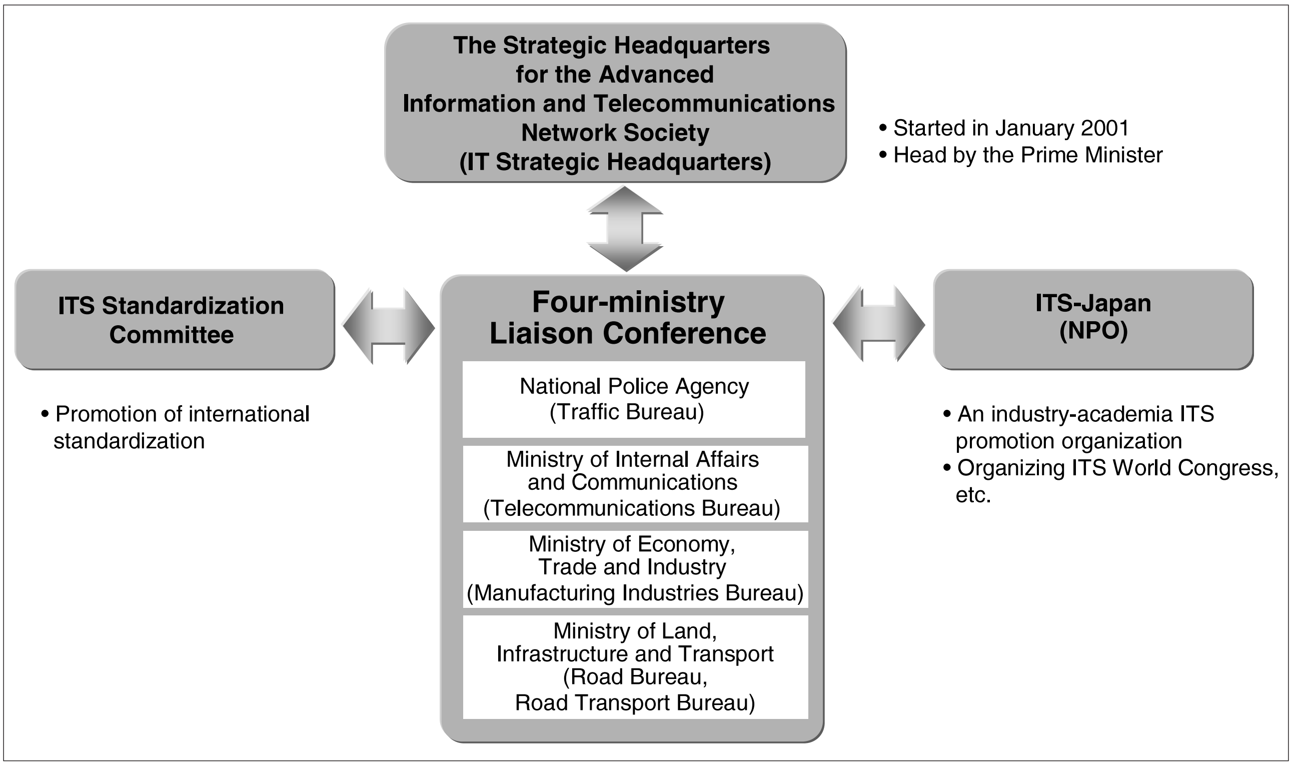

Figure 2 : Japan's ITS promotion Framework

Prepared by the STFC based on Reference[4]

Table 1 : Government policy evolution for ITS promotion in Japan (selected events since establishment of overall concepts)

Date announced	Policy	Summary
July 1996	Overall concepts for ITS promotion	The (then) five government agencies collaborate to establish a master plan for user services and development over the following 20 years.
January 2001	e-Japan Strategy	The vision of mobility and transportation in an ideal society includes the following: "The advanced Intelligent Transport Systems (ITS) will inform people how to get to their destinations using the most appropriate transportation means and via the quickest routes and will help them avoid traffic jams and accidents, thereby ensuring safe and comfortable traveling."
June 2004	e-Japan Priority Policy Program–2004	Promotion of ITS to utilize leading-edge information and communications technologies to address road transportation issues such as congestion, accidents, and environmental degradation.
October 2004	ITS promotion guidelines	ITS basic strategy developed by the ITS Promotion Council, which comprises users, industry, academia, and government, is announced at the ITS World Congress.
February 2005	IT Policy Package – 2005	Initiatives for more advanced ITS include promotion of Dedicated Short Range Communication (DSRC) systems, driving support systems to prevent accidents, and support to realize safe and smooth mobility for the elderly and people with disabilities.
January 2006	New IT Reform Strategy	Moves to the stage of IT utilization following on from the previous strategy of emphasizing the establishment and spread of IT infrastructure. Reduce accident deaths and the number of accidents through practical implementation of safe driving support systems through infrastructure harmonization.

Prepared by the STFC based on References[4,5]

Table 2 : The nine development areas of ITS

	ITS development area	Description of development and achievements in major elemental technologies
1	Advances in navigation systems	Advances navigation systems with VICS, etc. → car navigation, VICS, etc.
2	Electronic toll collection systems	Non-stop payment at toll gate, etc. → ETC
3	Assistance for safe driving	Hazard warning and automated driving → ASV, AHS
4	Optimization of traffic management	Route guidance, traffic signal control, etc.
5	Increasing efficiency in road management	Management of specially permitted commercial vehicles and others, traffic control information, etc.
6	Support for public transport	Management of public transportation operation, etc.
7	Increasing efficiency in commercial vehicle operations	Assisting commercial vehicle operations and management, automated platooning, etc.
8	Support for pedestrians	Route guidance for pedestrians, etc.
9	Support for emergency vehicle operations	Automated emergency notification, disaster and accident announcemrnt, etc.

Prepared by the STFC based on References[4,6]

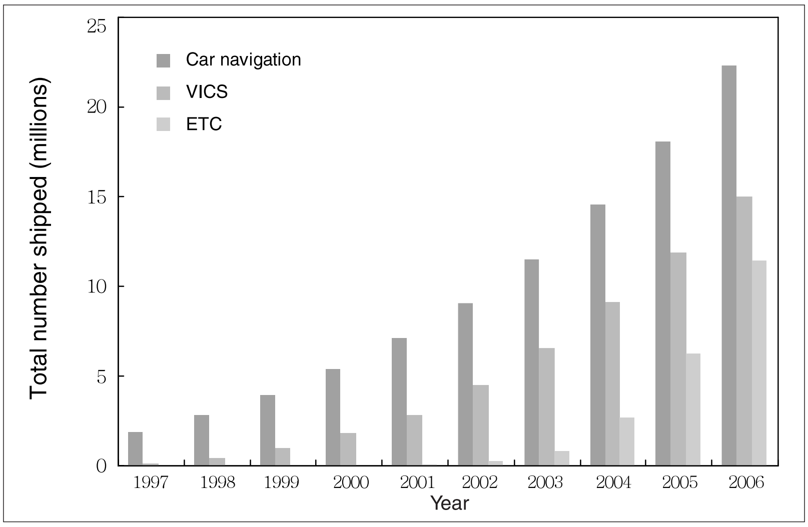

Figure 3 : Spreading of ITS devices

Prepared by the STFC based on Reference[7]

electronics technology. The Ministry of Land, Infrastructure and Transport has spearheaded the progress being made in the ASV through Phases 1 (FY 1991-1995), 2 (FY 1996-2000), and 3 (FY 2001-2005). The basic concept is that drivers are the primary actors in safe driving, and information and communications technology only supports them.

Figure 4 depicts the ASV concept. Collision warnings that alert drivers before they crash, lane-keep assist that helps them stay in their lanes, impact mitigation braking that assists driver braking before impact, night-vision cameras that ensure vision even during darkness, and many other active safety functions to stop accidents before they happen have been put into practical use. In addition to these functions, Japan is a world leader in both research and development and dissemination of car navigation systems, VICS, ETC, and other elemental technologies that comprise ITS.

2-2 Status of and issues in traffic accidents

What is the relationship between the dissemination of ITS and the status of traffic accidents?

Figure 5 shows the number of traffic accidents and the numbers of casualties and fatalities these accidents cause in Japan. Fatalities have been on a downward trend since 1990, but accidents and casualties have continued to rise. The number of casualties in 2005 was 1.16 million, roughly double the figure in the second half of the 1970s. The rises in accidents and casualties are associated with increased ambulance and police dispatches, as well as accident-related congestion. Including such indirect losses, the total economic cost of accidents is estimated at more than 4 trillion yen annually[9]. In light of this situation, in January 2003, the Japanese government declared its intention to halve traffic accident fatalities over the following 10 years. Furthermore, in January 2006, the "New IT Reform Strategy" of the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society (IT Strategic Headquarters) set the concrete numerical goal of reducing traffic accident fatalities to below 5,000 per year by the end of 2012 by using information and communications technology[10].

Figure 6(a) shows a breakdown of the causes of traffic accidents. The most common cause is late recognition, in other words, errors in recognition. With errors in judgment causing

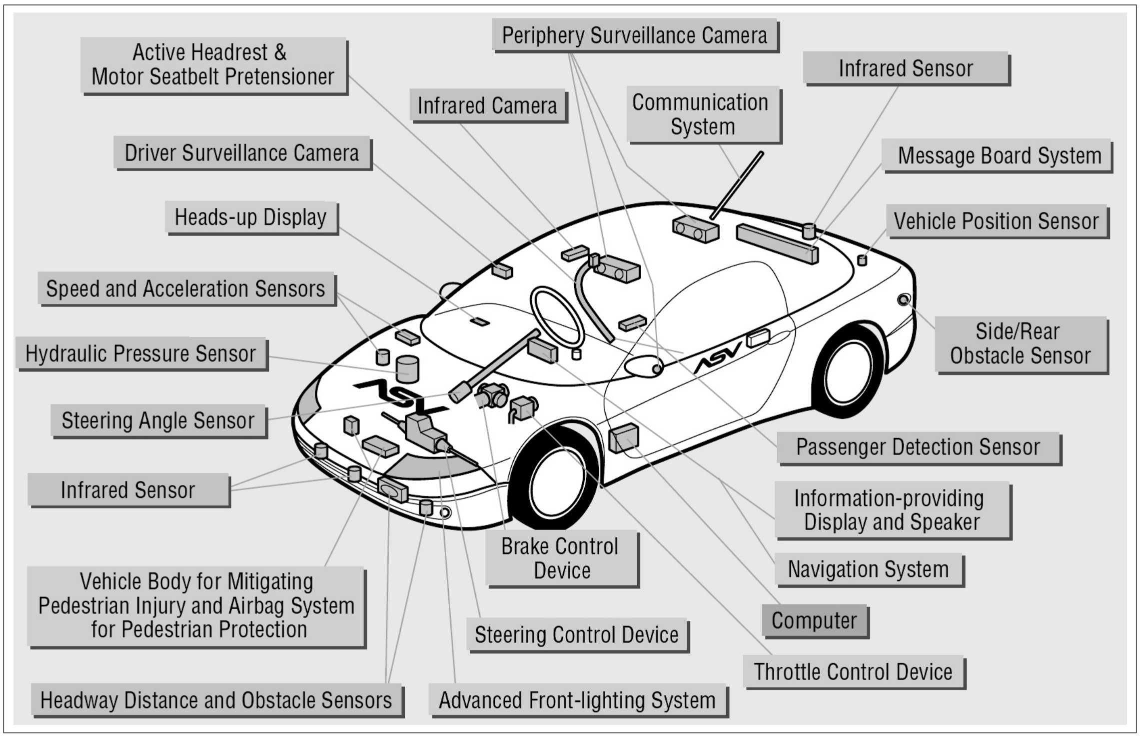

Figure 4 : ASV (Advanced Safety Vehicle) concept

Source: Study Group for Promotion of ASV, Ministry of Land, Infrastructure and Transport[8]

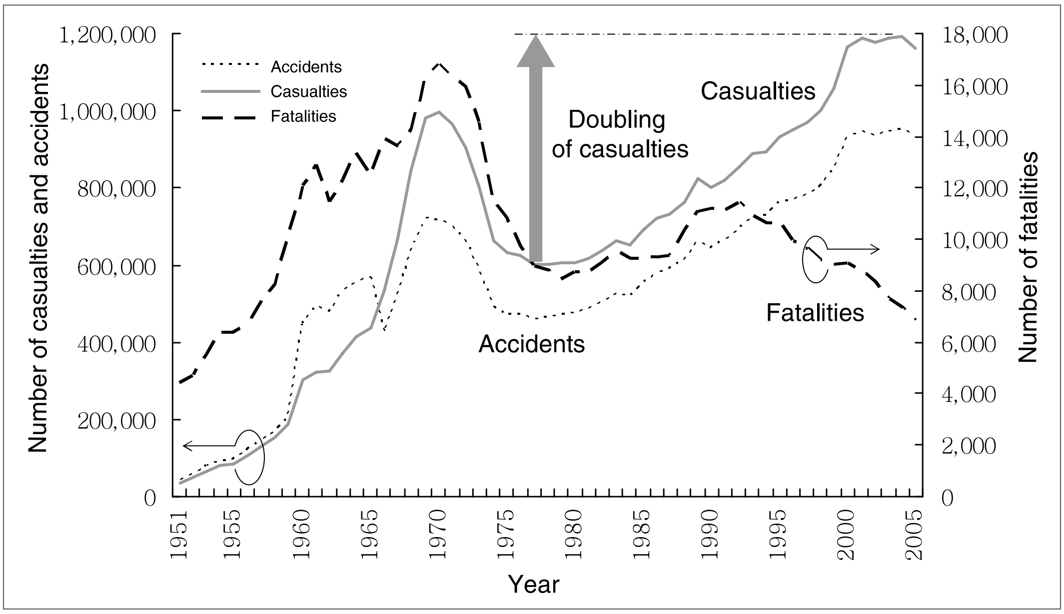

Figure 5 : Number of road traffic fatalities, casualties and accidents

Prepared by the STFC based on Reference[11]

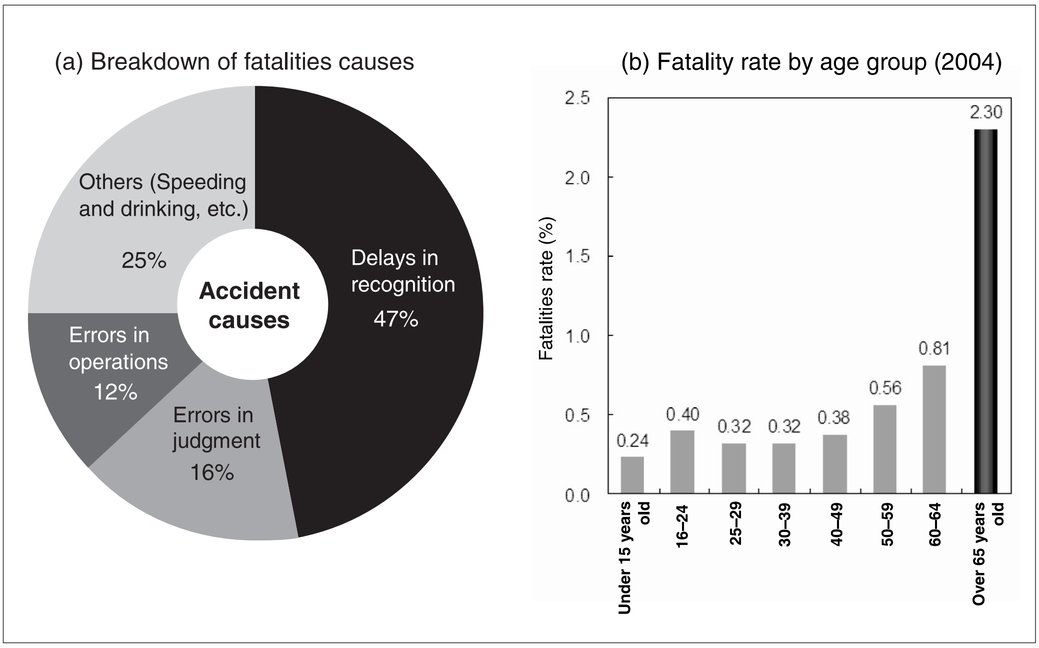

Figure 6 : Breakdown of fatalities causes and fatality rate in traffic accidents by age group

Prepared by the STFC based on References[12,13]

16 percent of accidents and errors in operation another 12 percent, approximately 75 percent of traffic accidents are caused by driver behavior immediately before the accident. In order to reduce traffic accidents, it is therefore necessary to take measures regarding driver action immediately before accidents occur. In addition, looking at traffic accident fatality rates by age group (Figure 6(b)), the rate is markedly higher for drivers 65 and older. This is reportedly not only because of vision declining with age, but also because of slower decision times. With the aging of Japanese society expected to accelerate, it is vitally important to address traffic accidents involving elderly people if tragic accidents are to be reduced.

In light of the above circumstances, the dissemination of ITS in its current approach of concentrating individual functions in onboard devices and ASV is not having a major effect on reducing the number of Japanese traffic accidents.

2-3 Status of and issues related to automobile carbon dioxide emissions

Next, this report will discuss the relationship between dissemination of ITS and carbon dioxide emissions. Carbon dioxide emissions from Japan's transportation sector in 2004 were 2.62 million tonnes, about 20 percent of Japan's total carbon dioxide emissions (Figure 7)[14]. Automobiles emissions amounted to 2.27 million tonnes of CO2, approximately 90 percent of total emissions from the entire transportation sector. While emissions have been declining since peaking in 2001, in fiscal 2004 they were still about 20 percent above 1990 levels. By type of vehicle, carbon dioxide emissions from commercial vehicles such as trucks, buses, and taxis are declining, but emissions from personal and company cars are steadily increasing.

The three factors influencing carbon dioxide emissions from private automobiles are fuel consumption performances of each vehicle, average driving speed, and total amounts of drive distance (vehicle kilometers)[15]. Figure 8 provides a summary of carbon dioxide emissions according to each factor. First, carbon dioxide emissions in relation to fuel consumption performances of each vehicle have been gradually declining in recent years. Since the 1998 revision of the

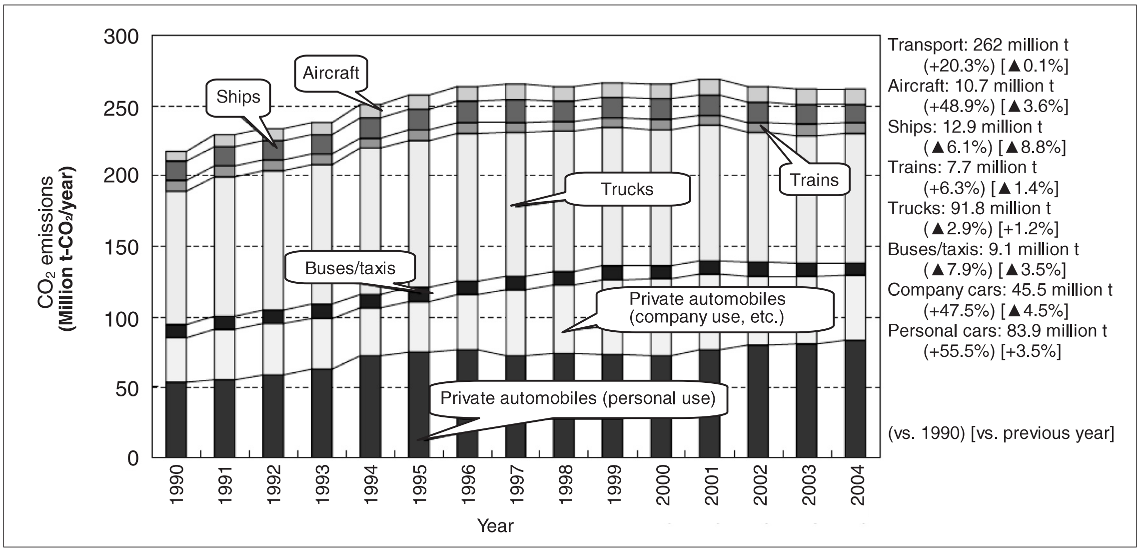

Figure 7 : Carbon dioxide emissions in the transportation sector

Source: Materials of the 35th Global Environment Committee, Central Environment Council, Ministry of the Environment[14]

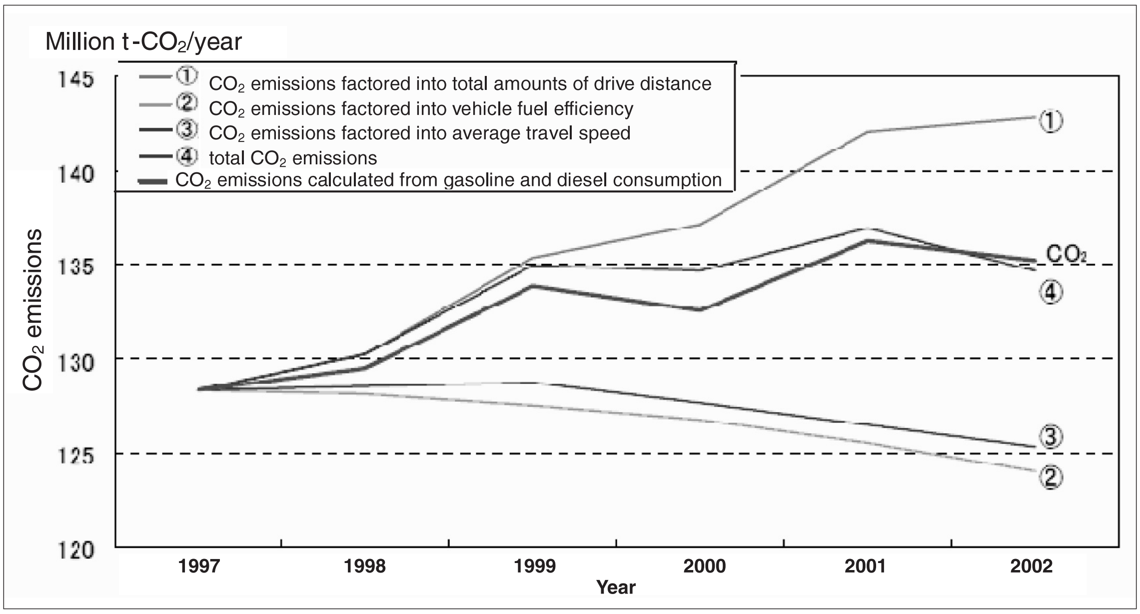

Figure 8 : Carbon dioxide emissions from private automobiles, by cause

Source: Materials of the 35th Global Environment Committee, Central Environment Council, Ministry of the Environment

Energy Conservation Law set "leading-runner" fuel consumption standards, manufacturer efforts have improved the average fuel efficiency of new private gasoline automobiles (mode of 10.15) from 12.3 km/l in 1995 to 15.4 km/l in 2004, an increase of about 20 percent[16].

Carbon dioxide emissions in relation to average driving speed are also gradually declining. This is strongly related to the widespread of ITS technology such as car navigation systems, VICS, and ETC. For example, the spread of ETC has sharply reduced tollgate congestion as a percentage of all congestion on expressways from 31 percent to a mere 4 percent[4], while route guidance provided by car navigation systems and VICS has reportedly reduced average travel time by 4.4 percent[17]. Reduced traffic congestion and increased average driving speed through ITS technologies should result in lower carbon dioxide emissions.

On the other hand, carbon dioxide emissions in relation to the third factor, total amounts of drive distance (vehicle kilometers), have increased rapidly in recent years, resulting in a failure to reduce overall emissions from private automobiles. ITS technology to date has not had a sufficient effect on private automobile drive distance (vehicle kilometers), in other words, on restraining demand.

Turning our attention to the nationwide distribution of carbon dioxide emissions, there are significant regional differences, with emissions in major cities and their environs strikingly high (Figure 9). This is because congestion in large cities has become chronic, reducing average driving speed and lowering fuel efficiency accordingly. Fuel efficiency for internal combustion engines is highest at about 50-60 km/h for gasoline vehicles and around 70 km/h for diesel ones (Figure 10). Average driving speed in major cities with chronic congestion is less than 20 km/h. Fuel wasted due to congestion totals around 9.1 million kl (crude oil equivalent) annually. This is about 11 percent of total fuel consumption[17]. There is still considerable room to reduce carbon dioxide emissions on an average-speed basis, especially in big cities.

Based on the above, the following are three effective approaches that can be linked to reducing carbon dioxide emissions in the transportation sector.

(i) Continue to improve fuel consumption performances of each individual automobile level.
(ii) In the transportation sector as well, control and optimize traffic demand for private cars.
(iii) Ease congestion in large cities through traffic flow measures.

ITS technology can play a large role in promoting approaches (ii) and (iii). Their further evolution is necessary.

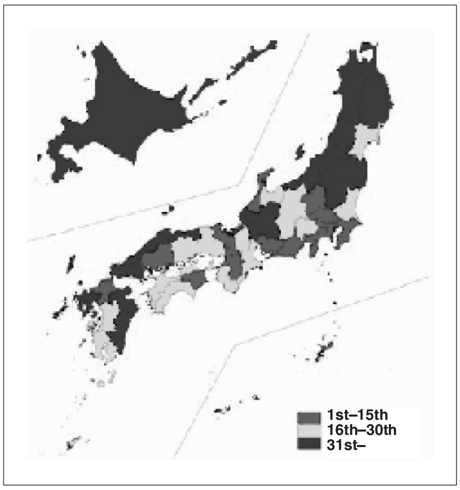

Figure 9 : Prefecture ranking by CO_2 emissions per vehicle kilometer

Source: Materials of the 35th Global Environment Committee, Central Environment Council, Ministry of the Environment

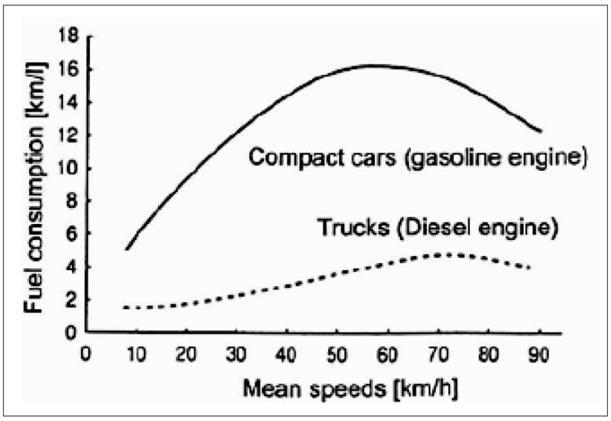

Figure 10 : Relationship between automobile driving speed and fuel consumption[18]

3 The evolution of ITS

3-1 Towards second-stage ITS

In order to achieve a sustainable mobility, the negative legacies of automobiles described above, traffic accidents and environmental impacts, must be overcome. While the broad penetration of car navigation systems, VICS, ETC, ASV, and so on as individual systems have clearly had significant effects, they cannot overcome these negative legacies as individual systems. By integrating traffic control systems with safe driving assistance systems, ITS is steadily shifting into its "second-stage," developing into a system that can resolve the negative legacies by joining "vehicles, roads, and people" into a triune entity in accordance with the definition of ITS (Figure 11).

No discussion of the evolution of ITS towards its second-stage is possible without considering the further use of electronics in automobiles. Figure 12 provides a summary of second-stage ITS from a technical perspective. After beginning with the mere replacement of mechanical parts, MPU (microprocessor) performance improved,

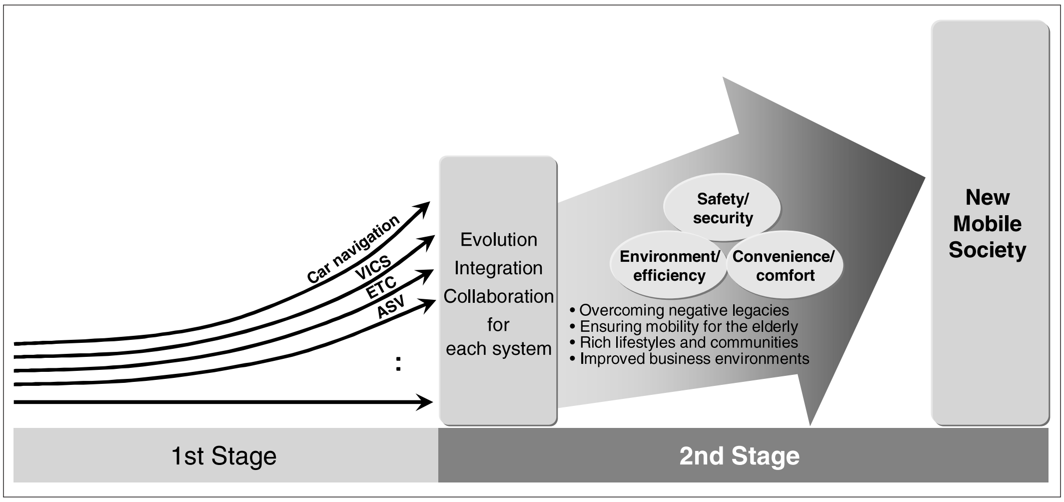

Figure 11 : Concept of second-stage ITS

Prepared by the STFC based on Reference[19]

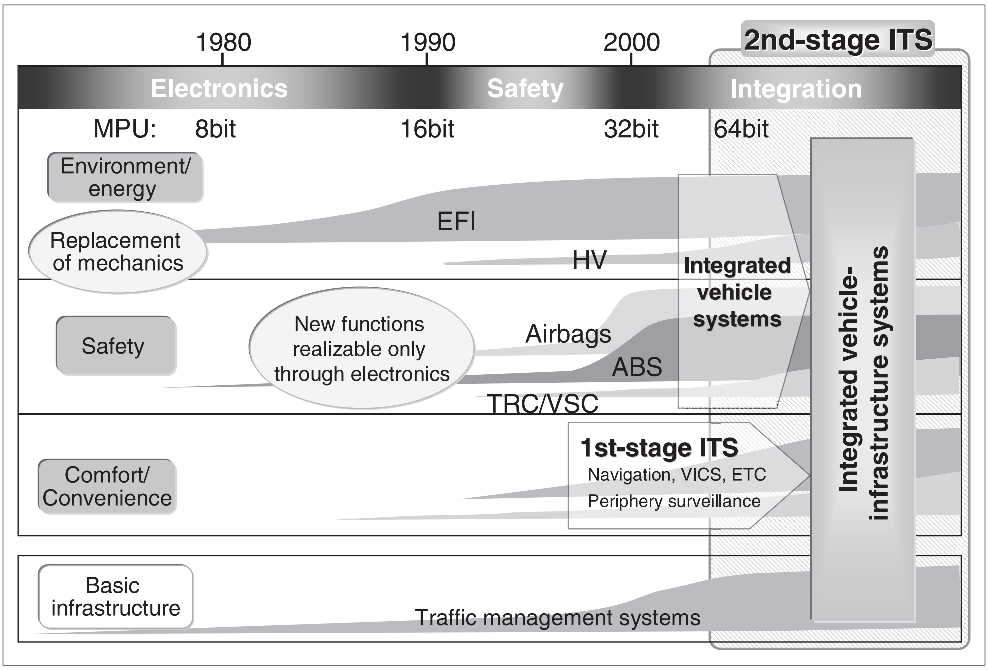

Figure 12 : The shift to second-stage ITS from a technical perspective

ABS: Antilocked Braking System
HV: Hybrid Vehicle
VSC: Vehicle Stability Control
EFI: Electronic Fuel Injection
TRC: Traction Control

Prepared by the STFC based on Reference[20]

and a shift to functions made possible only through electronics occurred. Development of integrated systems for vecicle such as ASV is progressing. In the future, it will not be an overstatement to say that automobiles are a mass of electronics. Information and communications technology will link integrated onboard vehicle systems with traffic control systems and other road infrastructure, enabling the achievement of vehicle-infrastructure integrated systems that coordinate automobiles and roads.

3-2 *Sharing of communication protocols*

For collaboration between systems, "road-vehicle communication" that transmits information between vehicles and roads is the first measure being adopted. In order to do this, sharing of communication protocols, a basic technology for road-vehicle cooperation systems, and the establishment of transmission speeds that enable communication even when cars are moving at high speed, are necessary. As depicted in Figure 13, 5.8-GHz wireless Dedicated Short Range Communication (DSRC) is being examined as a potential wireless communication protocol. Current onboard devices must incorporate three antennas to receive VICS communication regarding traffic information via optical beacons, radio wave beacons, and FM multiplex broadcasts, depending on the road and the local setup

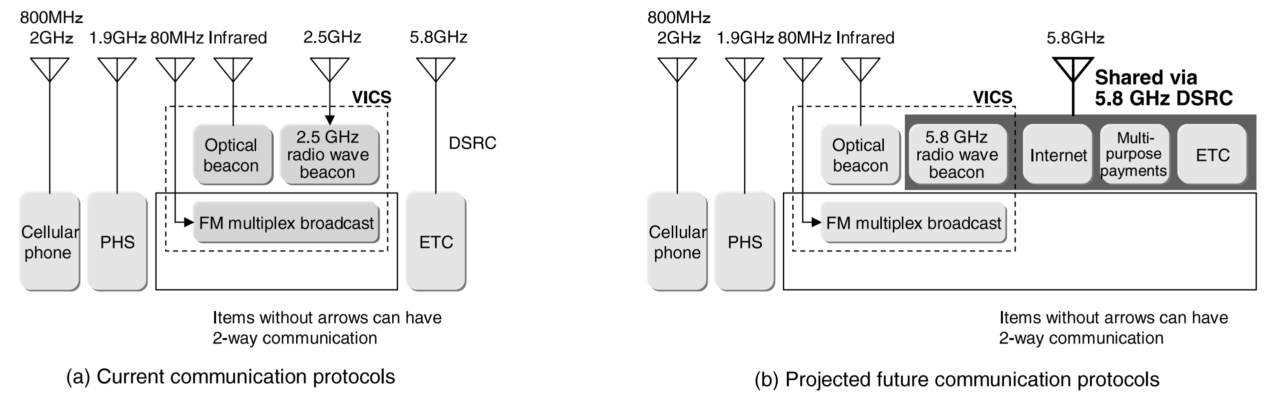

Figure 13 : The present and future of communication protocols for ITS devices

Prepared by the STFC based on Reference[21]

Table 3 : Types of communication protocols

	5.8GHz DSRC 	Optical beacon 	Radio wave beacon 	FM multiplex broadcast 
Possible locations for setup and reception	General roads, expressways (projected)	General roads	Mainly expressways	NHK FM broadcast service area
Communication configuration	Two-way (roadside ⇔ car)	Two-way (roadside ⇔ car)	Two-way (roadside ⇔ car)	One-way (roadside ⇒ car)
Communication area	~30m	About 3.5 m	~70m	10–50 km radius
Frequency	5.8GHz	Infrared	2.5GHz	80MHz
Communication speed/transmission capacity (theoretical figure)	4Mbps/50KB	1Mbps/10KB	64kbps/8KB	8kbps/50KB
Applications	VICS and next-generation road services	VICS only		

Prepared by the STFC based on Reference[22]

conditions (Table 3). Furthermore, use of ETC requires a separate 5.8-GHz DSRC antenna. The mixing of multiple communication protocols raises costs and interferes with dissemination. The 5.8-GHz DSRC currently used for ETC is now being considered as a unified communication standard, which can be used not only for cooperated road-vehicle communications using radio wave beacons, but also for ETC, Internet, and multipurpose billing including parking lots. Practical application is projected for 2007.

3-3 ITS evolution for traffic accident reduction

Seventy-five percent of traffic accidents are related to errors in recognition, judgment, and operation, and thus based in actions taken immediately before accidents happen. As discussed in Section 2-2 above, research and development on improvements to ASV in order to reduce driver mistakes includes adding information provision functions that address errors in recognition, alarm and driving assistance functions that address errors in judgment, and operation assistance functions that address errors in vehicle operation. There is a limit, however, to the amount by which autonomous safety systems for individual vehicles such as ASV can reduce traffic accidents. Figure 14 shows the results of a simulation of traffic accident fatalities assuming the full implementation of autonomous safety systems for preventative action, accident avoidance, and collision mitigation. These results indicate that even if all vehicles were to be equipped with autonomous systems, fatalities cannot be entirely eliminated. This is because most traffic accidents occur due to errors in recognition or judgment at intersections with poor visibility, when passing, and so on. It is difficult to avoid such accidents solely though autonomous safety systems.

In order to further reduce fatalities, it is therefore necessary not only to improve autonomous safety systems, but also to achieve vehicle-infrastructure integrated systems that use information and communications between roads and vehicles, among vehicles, and between pedestrians and automobiles to aid driver recognition. This report will now discuss experiments with such systems.

(1) An experiment with cooperated road-vehicle ITS (driving assistance road system)

The Advanced Cruise-Assist Highway System Research Association technical research consortium is working on a safe driving assistance system using road-vehicle coopetarion called the Advanced cruise-assist Highway Systems (AHS).

On the Metropolitan Expressway, 21 percent of accidents occur on accident-prone curves (about 6 percent). In the Sangubashi curve area of the Metropolitan Expressway's No. 4 Shinjuku

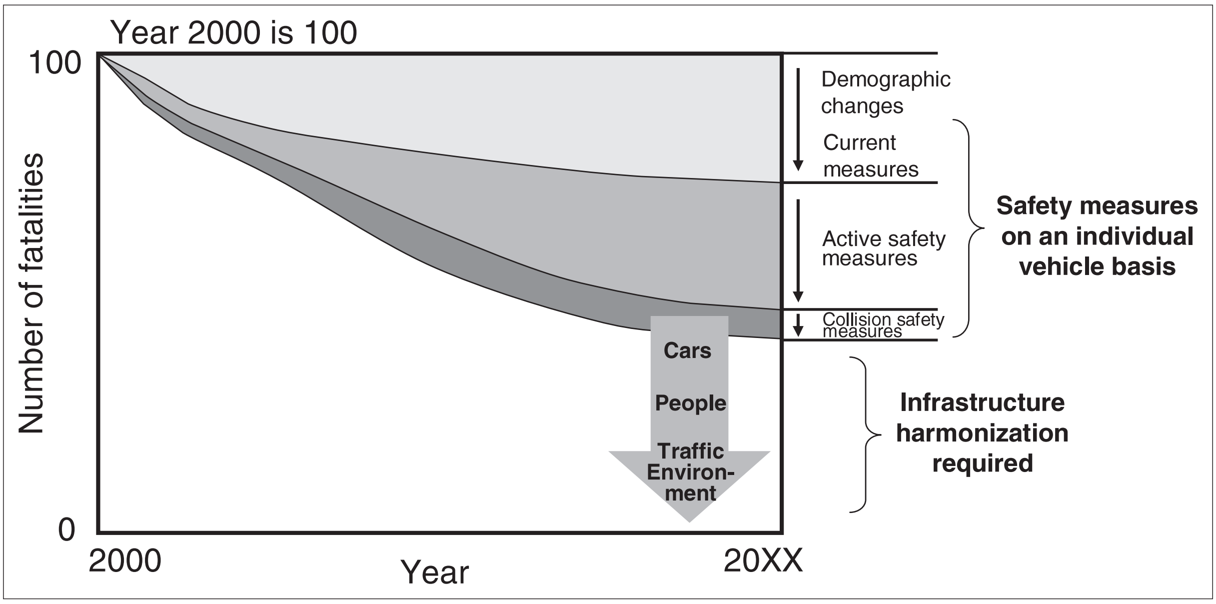

Figure 14 : Results of simulation of number of traffic accident fatalities

Prepared by the STFC based on Reference[23]

route, existing onboard devices (three-media VICS car navigation systems*3) were used in a three-month demonstration experiment with general vehicles beginning in March 2005. In the experiment, as depicted in Figure 15, when congestion occurs in the curve's vicinity, roadside infrared sensors detect the situation, and roadside VICS beacons 300 meters away send a warning about conditions around the curve to cars in the form of a simplified image. This system enabled a 60-percent reduction in accidents compared with the previous fiscal year. A questionnaire showed that 80 percent of elderly drivers found the system helpful. An electric bulletin board that constantly flashes a warning may come to be disregarded, but because this system only displays an alarm when there is actual congestion in the curve's vicinity, it has a powerful warning effect. This experiment was carried out with existing onboard devices, but in the future when 5.8-GHz DSRC is adopted and two-way communications speed improves, it will be technically feasible to control the entry of vehicles.

(2) An experiment with integrated pedestrian-vehicle ITS (system using IC tags)

Figure 16 depicts an example of a demonstration experiment with a pedestrian-vehicle integration system for communication between pedestrians and automobiles. Conventionally, drivers are unable to tell whether there are pedestrians in blind spots at intersections, but with integrated infrastructure systems, IC tags send signals

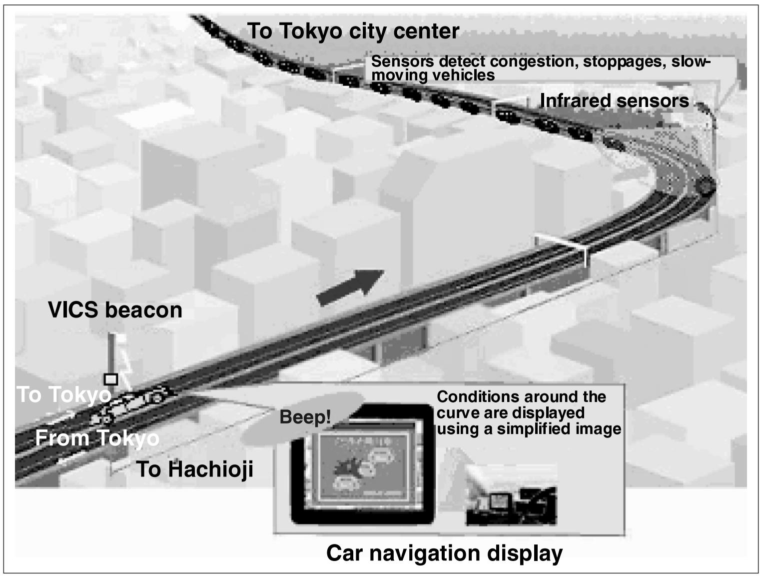

Figure 15 : Example of a road-vehicle cooperation system using ITS

Source: AHSRA webpage[24]

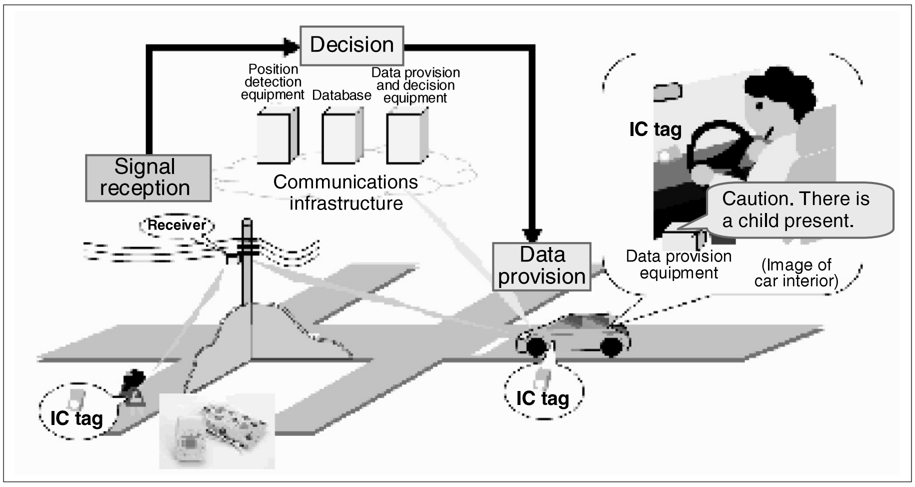

Figure 16 : Example of ITS response to an unseen person (pedestrian)

Source: Reference[25]

to receivers at intersections, and the data are provided to the vehicle's internal systems. This enables drivers to become aware of the presence of pedestrians before they can see them, with automatic braking applied in order to avoid accidents before they occur. Moreover, systems can be set up to warn pedestrians of the presence of automobiles as well. About 80 percent of drivers said they found the system useful.

On the other hand, if the information provided by an integrated pedestrian-vehicle ITS system is unclear, or if too much unnecessary data is provided, it can confuse drivers and actually increase the likelihood of driver errors. In addition, if drivers are over-reliant on the system, this may induce complacent driving without the necessary independent driver vigilance. Therefore, in order to achieve integrated pedestrian-vehicle ITS systems, a deeper understanding of the behavioral psychology of drivers, their perceptions, and their ability to process information is necessary, and appropriate human-machine interface (HMI) must be constructed. Integrated research in various fields other than information and communications technology, including cognitive science and ergonomics, is therefore being actively conducted by various academic groups (Table 4).

Table 4 : Activities of academic societies

Name	Research group	Research subjects
Institute of Electronics, Information and Communication Engineers	Technical Group on ITS Technology	Primary fields are ITS policy, ITS communications technology, car electronics, ITS road transportation infrastructure technology, ITS sensing technology, and ITS information technology
	Technical Committee on Pattern Recognition and Media Understanding (PRMU)	Research subjects are pattern media such as images and sound, from basic theory on recognition and understanding to methods and applied technologies
Information Processing Society of Japan	Special Interest Group of ITS	Primary research fields are traffic management, driving assistance, image processing, communication protocols, network technology, information provision, and applications
	Special Interest group of Computer Vision and Image Media (CVIM)	Research through sensory information processing
	Special Interest Group on Ubiquitous Computing System	Regarding human-centered services and ubiquitous information processing in urban information infrastructure, including automobiles
	Special Interest Group of Mobile Computing and Ubiquitous Networking (MBL)	Regarding mobile computing, basic theory and technology, communication protocols, computer architecture, operating systems, applications, applied cases, management and operation, and social scientific considerations, etc.
Institute of Electrical Engineers of Japan	Technical Committee on ITS	Primary research fields are traffic measurement systems, traffic management systems, traffic information systems, driving assistance systems
	Japan Society of Traffic Engineering, ITS Research Committee	Application of traffic engineering that utilizes ITS technology (traffic demand management, etc.) to traffic issues
Society of Instrument and Control Engineers	Research Committee for Smart Vehicle System	Creation of next-generation intelligent vehicles (smart vehicles) that are high-performance, safe, comfortable, and people- and environment-friendly through integration of ITS and other leading-edge infrastructure and systemization technologies
Japan Society of Civil Engineers	Special Committee on Practical ITS Research, Subcommittee on Transportation Infrastructure Information Business	Suggestions for ITS from a civil engineering perspective
Universities	ITS Center, Institute of Industrial Science, University of Tokyo	Multiscale traffic simulation, from macro to micro, in complex, realistic experimental traffic environments through combining traffic simulators (TS), driving simulators (DS), and the most advanced image information technology
	Regional ITS Infrastructure Research Center, Research Institute, Kochi University of Technology	Contribute to vitalization of regional society by planning, proposing, and promoting ITS measures appropriate to regional societies based on sharing of the results of regional ITS and indus try-government-academia cooperation

3-4 The evolution of ITS for the reduction of carbon dioxide emissions

Development of new ITS technology integrating infrastructural and vehicle systems is also being carried out from the perspective of reducing carbon dioxide emissions. Below are examples of traffic demand control measures and traffic flow measures.

(1) Examination of a congestion prevention system using AHS technology

Areas of expressway congestion other than tollgates include sags, tunnels, and interchanges where traffic merges. Those places on expressways where downhill slopes become uphill slopes are called “sags.” Drivers are unconscious of the fact that they lose speed at such locations, causing congestion among the vehicles following them[26]. Similarly, the shift from light to dark at tunnel entrances causes drivers to slow down unconsciously, creating congestion among following vehicles (Figure 17). Development of the above-mentioned congestion prevention system using AHS technology is now being considered in order to prevent blocked traffic flow due to such driver psychology. This system uses sensors, road-vehicle communications technology, and onboard ITS devices to guide vehicles to lanes with more room and to caution the leading vehicles causing the congestion, thereby helping traffic to flow more smoothly.

(2) Study of road-vehicle cooperation real-time signal control

A problem with current signal control is its inability to respond flexibly to non-steady traffic conditions (accidents, construction, etc.). Harmonizing signal control with road-vehicle communications makes possible accurate collection of traffic data and effective traffic guidance and distribution through an advanced signal control method called “road-vehicle cooperation real-time signal control”[27,28]. This signal control method uses ITS technology to directly measure delays due to traffic waiting for

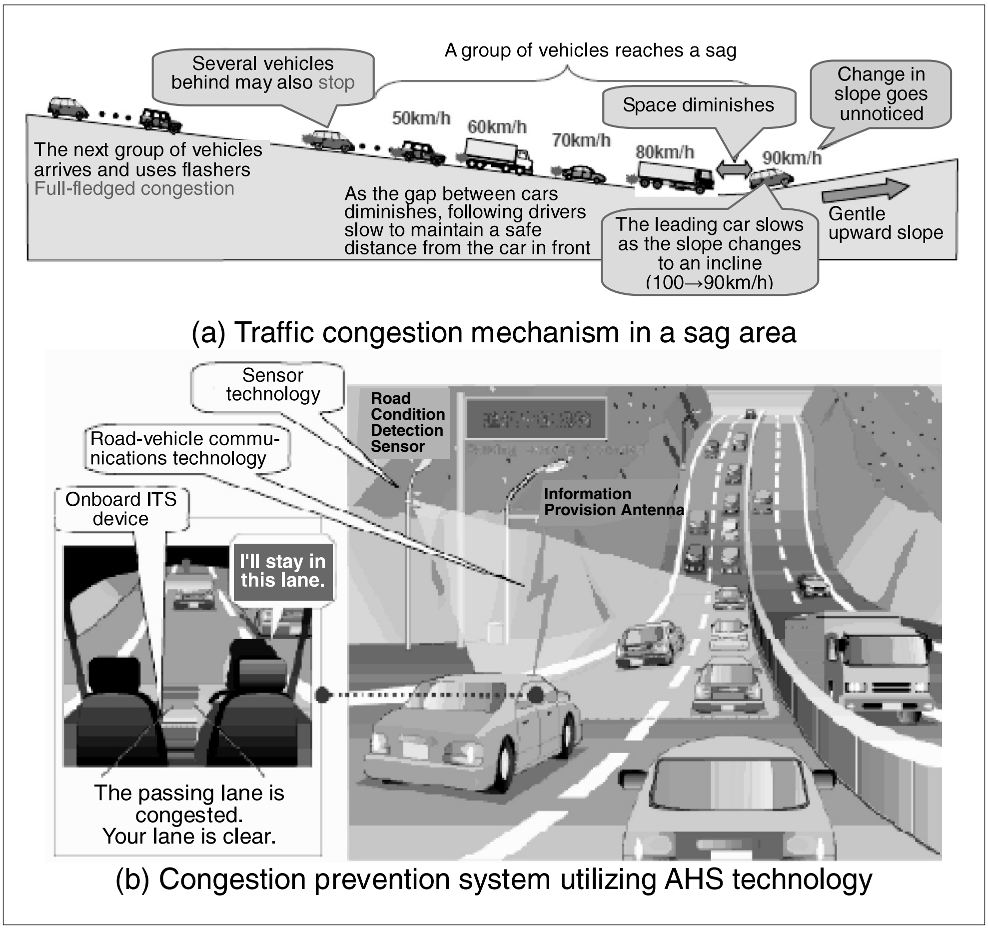

Figure 17 : The traffic congestion mechanism in a sag area and a congestion prevention system utilizing AHS technology

Source: Reference[4]

signal changes and automatically adjusts signal parameters to minimize those delays. It enables signal control that responds flexibly to changes in traffic flow. Experiments with this system on actual roads led to improvements of 5-20 percent in the time required to pass through the usage area[29].

Overseas, Sweden devised a signal control system called the "Green Wave System" in the early 1990s (Figure 18)[30]. This system attempts to control automobile speed so that cars can always pass through intersections with a green light, achieving smooth traffic flow. The infrastructure system detects traffic flow and calculates the correct speed for vehicles to pass through controlled intersections without needing to stop based on the signal timing, then roadside beacons communicate this information to vehicles. Based on the data they receive, the vehicles automatically adjust their speed to maintain the proper distance from the cars ahead of them, enabling them to pass through intersections without stopping. At the time the system was proposed, ITS-related technology was still immature, so testing of an actual system was never carried out. In an Australian experiment with nonstop signal speed in 1987, the number of stops at signal lights fell 50 percent, resulting in fuel savings of 6-15 percent[31]. In the future, this system is expected to be integrated with two-way road-vehicle communications technology and adaptive cruise control (ACC; cruise control that also uses brakes) technology for practical implementation.

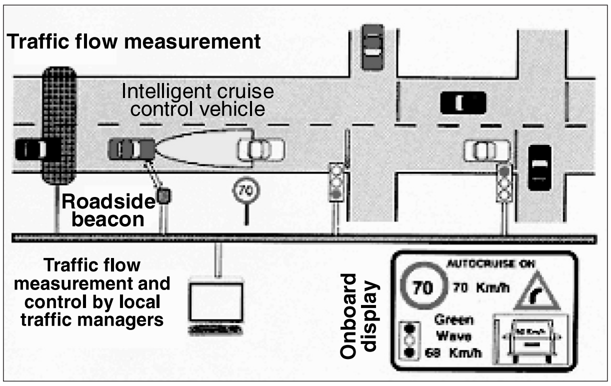

Figure 18 : Sweden's signal synchronization speed control system (Green Wave System)

Source: Reference[30]

(3) Transportation Demand Management (TDM)

Economic development has been the priority in road policy to date. As automobile traffic demand increased, securing greater traffic capacity and easing congestion have been the primary issues, leading to the building of bypass roads and beltways. From now on, balancing conservation of the global environment with maintenance of economic activity will be important, and road policy that adds the perspective of correcting traffic demand to that of securing more capacity should be pursued.

"Transportation Demand Management" (TDM) is a policy of using fees, regulation, guidance, and other soft aspects to control traffic demand by changing driver behavior. Concrete measures include "park and ride," "car sharing," "road pricing," and "use of public transportation." While such TDM measures are acknowledged as effective in reducing carbon dioxide emissions, their use has not spread because they decrease user convenience and are not cost effective. In recent years, however, TDM measures using ITS technology have been implemented nationwide as part of urban renewal[32].

Let us examine "car sharing" as a case study. Car sharing involves the organized shared use of a single automobile by several members. It was seen as a way to reduce environmental impacts by lessening overdependence on automobiles and promoting use of public transportation, but the complexities of shared ownership prevented its spread[33]. Utilization of ITS in car sharing can ease some of this complexity, and car sharing enterprises are steadily spreading in Europe and the USA in particular. Because car sharing can reduce the cost burden for individual users, it has been successful as a means of promoting the spread of electric vehicles (EVs) and other low-pollution cars[34].

In Japan, although the number of cases of car sharing is gradually increasing, it has not spread to the extent seen in Europe and the USA. This is because factors such as (i) lack of understanding of the social benefits, (ii) the deep roots of car ownership as a status symbol, (iii) lack of awareness of car sharing as a means of comprehensive traffic demand management, (iv) difficulties securing parking, and (v) profitability

Table 5 : Energy conservation through ITS technology

Effect	ITS technology	Estimated CO_2 emission reduction	Notes
Smoother traffic flow through traffic management system	Signal control	1M t-CO_2 (*1)	Installation of traffic sensing signals
	ETC	06.M t-CO_2 (*1)	Reduction in tollgate congestion, elimination of stopped vehicles
Efficient driving through information provision system	Provision of traffic information (VICS)	1M t-CO_2 (*2)	Assuming VICS penetration of 20% and 4.4% reduction in travel time for equipped vehicles
	Route guidance (car navigation)	2M t-CO_2 (*2)	Assuming car navigation penetration of 30% and 2.4% reduction in route deviations for equipped vehicles
Efficient driving through vehicle control	Automatic cruise control system (ACCS)	0.02M t-CO_2 (*3)	Reduction in sag congestion on expressways, ACCS penetration 10%
	Vehicles with automatic cruise control	0.2M t-CO_2 (*1)	
Reduced amount of driving	Traffic demand management (TDM)	3.6M t-CO_2 (*1)	Lower share for automobiles in major cities
	Shared collection and delivery information provision system	1.1M t-CO_2 (*2)	Assuming 56.3% load rates in commercial cargo vehicles
	Car sharing	7.6M t-CO_2 (*4)	Assuming 5% car sharing rate

Calculated by the STFC from:
*1: Japan Automobile Manufacturers Association, "JAMA's Approach on Global Warming Countermeasures," JAMA Report No. 90
*2: Energy Conservation Center, "FY 1997 Energy-saving Measures and Effects through ITS"
*3: Energy Conservation Center, "FY 1996 ITS and Energy-saving Effects"
*4: Foundation for Promoting Personal Mobility and Ecological Transportation, "Report on examination of environmental impact reduction through car sharing and methods for its dissemination," March 2006

issues combine to create a vicious circle. None of these factors is unique to Japan, and all of them can be overcome by an accumulation of individual measures. In recent years, Japan has also seen an increasing number of people seeking lifestyles of health and sustainability (LOHAS) that consider mental and physical health and the global environment. Such people are likely to support car sharing as it becomes established.

(4) Probe data utilization service

Automobiles are equipped with up to about 150 kinds of sensors. The information obtained by these sensors is called "probe data." Automobiles themselves are considered mobile traffic monitoring devices. With probe data collected by wireless communications, vehicle behavior and position data can be understood and better traffic flow and behavior calculated, and even weather conditions and other natural phenomena can be monitored. Probe data are characterized by the fact that, unlike VICS, which is installed on main roads, they can provide information from small side streets as well as information on vehicles themselves. Collection of probe data can be accomplished through use of mobile phone networks or other existing communications infrastructure. Private sector businesses are leading the way in providing services using probe data. While ordinary VICS can provide traffic data for intervals of about 42,000 km, probe data can cover intervals of around 356,000 km[35]. In the future, integration of this data with car navigation systems and VICS functions will enable more detailed and accurate route guidance including factors such as weather conditions and data on individual lanes and road surfaces.

(5) Potential carbon dioxide reduction

As seen above, the adoption of ITS technology, which has evolved beyond conventional car navigation systems, VICS and ETC, and integrates infrastructure and vehicles, and the utilization of ITS combined with traffic measures, can help reduce carbon dioxide emissions. Table 5 shows the extent of this potential. The total potential reduction in carbon dioxide emissions from conventional car navigation systems, VICS, and ETC is 3.6 million tonnes, while the estimated potential reduction from second-stage ITS technologies is 13 million tonnes. Under Japan's plan to meet the goals of the Kyoto

Protocol, the transportation sector as a whole is to cut 46 million tonnes of CO_2. This indicates the significance of adopting second-stage ITS technology.

4 Trends in international standardization and Japan's role

There are two trends in initiatives on international standardization in the ITS field.

First, an initiative on international standardization in the ITS field is being formulated by the International Organization for Standardization's (ISO) technical committee TC204. TC204 comprises the 12 working groups (WGs) shown in Table 6. Japan is actively involved, participating as a voting member of TC204 and as the responsible country for WG3 and WG14.

The International Telecommunication Union (ITU) is an international organization that adopts rules and agreements on the use of frequencies on the ground and in space. Study Group 8 (SG 8) of the ITU's Radiocommunications Sector (ITU-R) carries out actual work on ITS. In May 2000, Japan's DSRC wireless communication protocol for ETC was adopted as ITU-R's international

Table 6 : ITS international standardization activities: ISO/TC204 working groups

Working group	Working group	Lead country
WG1	Architecture	UK
WG3	ITS database technology	Japan
WG4	Automatic vehicle and equipment identification	Norway
WG5	Fee and toll collection	Netherlands
WG7	General fleet management and commercial/freight	Canada
WG8	Public transport/emergency	USA
WG9	Integrated transport information, management and control	UK
WG10	Traveller information systems	UK
WG11	Route guidance and navigation systems	Germany
WG14	Vehicle/roadway warning and control systems	Japan
WG15	Dedicated short range communications	Germany
WG16	Wide area communications/protocols and interfaces	USA

Prepared by the STFC based on Reference[4]

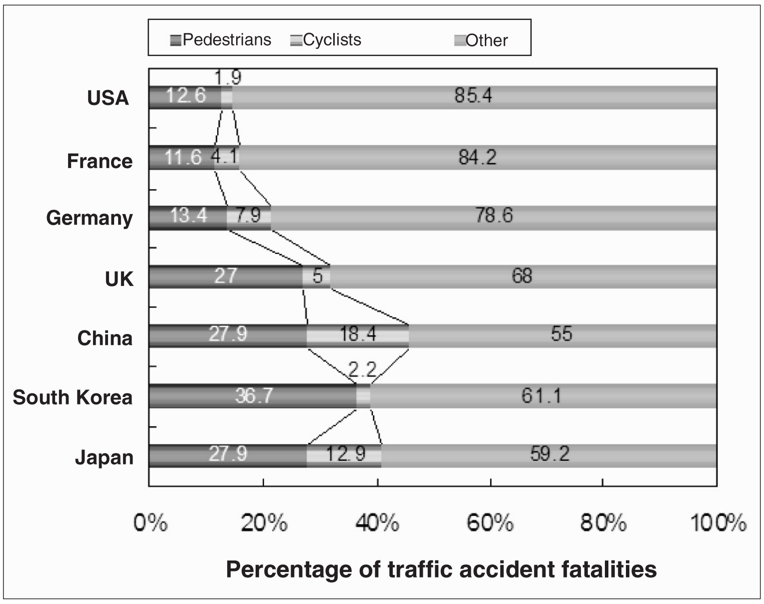

Figure 19 : Pedestrian fatalities as a percentage of all traffic accident deaths

Prepared by the STFC based on Reference[36]

recommendation. To date, Japan has succeeded in having the protocols it has developed and incorporated into international standards.

In the process of developing second-stage ITS infrastructure-integration, it inevitably involves adaptation to the local traffic conditions and needs. In the case of traffic accidents (Figure 19), for example, Japan has a very high percentage of accidents involving pedestrians, a trend found elsewhere in Asia. On the other hand, Europe and the USA have mainly vehicle accidents. Therefore, the advanced safety systems that Japan is pursuing, such as pedestrian-vehicle integration, may not always suit for Europe and the USA. Even then, for pursuing the international standardization, the collaboration with Europe and the USA must be carefully considered.

5 Future directions

As discussed above, the second-stage ITS, integrating vehicles and infrastructure and joining roads, vehicles, and people with information technology, is essential for overcoming the negative legacies of the automobile society, such as traffic accidents and environmental impacts. This report proposes the achievement of second-stage ITS from the following viewpoints.

(1) Research and development of human-machine interfaces that consider elderly people

Errors in recognition, judgment, and operation cause 75 percent of traffic accidents. As discussed above, elderly people have a high accident rate. Because Japan is the most rapidly aging country in the world, research and development that focuses on the elderly is vital. To date, research has centered on functional systems, such as airbags, lane-keep assist, and sensors, but now integrated interdisciplinary ITS research covering ergonomics and cognitive science from perspectives such as information processing, telecommunications, automated control, and traffic engineering is needed. In particular, the closed space of the automobile driver's seat, where people perform all their recognition, judgment, and operation control while moving, requires the most concentrated human-machine interface (HMI) in daily life. Further research on human-machine interfaces that are easy not only on elderly people but also on world standard users is necessary.

(2) Promotion of social acceptance of ITS implementation

In shifting to the vehicle-infrastructure integration system that is second-stage ITS, new onboard communications devices and capital investment in infrastructure are necessary. Unlike conventional ITS, which was primarily concerned with increased comfort and convenience, the benefits of second-stage ITS systems involve safety, security, reduced environmental impacts, and other aspects whose costs are difficult to measure. Greater efforts will likely be necessary in order to gain the acceptance of users and society for the new costs that will be incurred. Industry, government, and academia must work together to promote quantitative comparison of costs versus effects, sufficient assessment before implementation, ex-post evaluation, and information disclosure. Furthermore, just as emission regulations in the past promoted improved automobile performance, examination of possible regulations, for example, requiring new cars to install ITS devices or restricting the access of cars without the equipment to major urban areas is necessary. In any event, promotion of second-stage ITS implementation and diffusion will require public understanding. This can be brought about by educational activities on safety, energy, and the environment.

(3) Initiatives that contribute to sustainable development in Asia

As motorization proceeds in Asia, associated social problems such as traffic accidents and environmental impacts will become much more serious than ever before. The advancement of second-stage ITS must be expected to contribute to develop a sustainable transportation systems in Asia through strategic collaboration and cooperation within Asian countries.

Because second-stage ITS systems involve vehicle-infrastructure integration, they must suit the local traffic conditions and needs. The types of traffic accidents that occur in Japan more closely resemble those in other Asian countries than the kinds of accidents that occur in Europe and the USA, so the advanced safety systems of second-stage ITS developed in Japan probably match Asian needs better than European or American ones. Japan and other Asian countries can therefore develop common ITS technology bases. Another effective approach is to generate ideas for comprehensive experimental model cities with advanced vehicles and infrastructure from an early stage for areas in Asia that are ripe for development. Transportation infrastructure in the Asian region is currently incomplete. Therefore, it may be easier for these Asian countries to develop second-stage ITS infrastructures than that for Japan, with its completed infrastructure.

At the same time, if second-stage ITS systems are closely matched to Asian needs, the technology systems may not always suit for Europe and the USA. Even then, for pursuing the international standardization, the collaboration with Europe and the USA must be carefully considered.

Today's automobile industry faces international competition in a global market. In order to survive, Japan's continually developing automobile industry must remain a driving force behind Japan's entire economy. The future progress of motorization in Asia will create a favorable growth market for the automobile industry. Initiatives to collaborate with Asian countries on the development of second-stage ITS technology will not only contribute to sustainable development in Asia, they will also maintain the international competitiveness of Japan's automobile industry.

Acknowledgments

The authors of this report would like to thank Professor Sadayuki Tsugawa of Meijo University and Professor Yoshimi Furukawa of the Shibaura Institute of Technology for their valuable opinions, advice, and materials regarding the entire project. They would also like to thank Senior Deputy Director Seiji Moriyama of the Road Bureau of the Ministry of Land, Infrastructure and Transport; Senior Vice President Kohei Koide of ITS Japan; Senior Technical Advisor Haruki Fujii and Senior Researcher Shigeru Hasunuma of the Japan Automobile Research Institute ITS Center; Deputy General Manager Syungo Akizuki of the Government and Industrial Affairs Office, Honda Motor Co., Ltd.; General Manager Hideo Inoue and Project Manager Makoto Morita of the Integrated System Engineering Division, Vehicle Engineering Group, Toyota Motor Corporation; and Manager Toshiyuki Fujikura of the Technology Development Division, Nissan Motor Co., Ltd., for providing important reference materials and data.

Glossary

*1 VICS
an information system that transmits data on traffic congestion and restrictions edited and processed at the VICS Center to onboard car navigation devices in the form of text and images.

*2 ETC
a nonstop automatic collection system for use on toll roads. Antennas at tollgates communicate wirelessly with devices installed on vehicles to collect tolls.

*3 Three-media VICS car navigation systems
VICS that uses three media, optical beacons, radio wave beacons, and FM multiplex broadcasts.

References

[1] United Nations, "The 2004 Revision Population Database" as of June 29, 2006: http://esa.un.org/unpp/

[2] WHO, "World report on road traffic injury prevention: summary": http://www.who.int/world-health-day/2004/infomaterials/world_report/en/summary_en_rev.pdf

[3] ITS webpage of the Road Bureau, the Ministry of Land, Infrastructure and Transport: http://www.its.go.jp/ITS/j-html/whatsITS/

[4] Highway Industry Development Organization, "ITS Handbook 2005-2006"

[5] Ikeda, "The Information and Communications Situation Surrounding

Automobiles", Report of the forum exploring new technology in "energy-related" sector, Research and Development Association for Future Electron Devices (Japanese)

[6] National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan; Analysis of Socio-Economic Impact of Science and Technology Policy in Japan," March 2005 (Japanese): http://www.nistep.go.jp/achiev/ftx/jpn/rep089j/pdf/rep089j3.pdf

[7] ITS webpage of the Road Bureau, the Ministry of Land, Infrastructure and Transport: http://www.mlit.go.jp/road/ITS/j-html/index.html

[8] Study Group for Promotion of ASV, Ministry of Land, Infrastructure and Transport, "ASV Phase 3 Program": http://www.mlit.go.jp/jidosha/anzen/asv/ASV3HP/ASV_3_panfu/ASV_J_Final_Precise.pdf

[9] Cabinet Office of Japan, "Summary of Report on Survey Research on Economic Losses from Traffic Accidents," (Japanese): http://www8.cao.go.jp/koutu/chou-ken/sonshitsu.pdf

[10] IT Strategic Headquarters: http://www.kantei.go.jp/jp/singi/it2/kettei/060119honbun.pdf

[11] Cabinet Office of Japan, "White Paper on Traffic Safety in Japan 2006": http://www8.cao.go.jp/koutu/taisaku/h18kou_haku/h18koutuu-genkyo-1-1-1-1.pdf

[12] Advanced Cruise-Assist Highway System Research Association webpage: http://www.ahsra.or.jp/whats_ahs/02/index.html

[13] National Police Agency, "2005 White Paper on Police": http://www.npa.go.jp/hakusyo/h17/hakusho/h17/pdf/G0aisatu.pdf

[14] Ministry of the Environment materials from the 35th Global Environment Committee, Central Environment Council, Ministry of the Environment: http://www.env.go.jp/council/06earth/y060-35/mat01_2-1.pdf

[15] "Report on the Road Policy Council for the Prevention of Global Warming" (Japanse) : http://www.mlit.go.jp/kisha/kisha05/06/060826/02.pdf

[16] Ministry of Land, Infrastructure and Transport materials from the 17th Global Environment Committee, Central Environment Council, Ministry of the Environment: http://www.env.go.jp/council/06earth/y060-17/mat_02.pdf

[17] Energy Conservation Center, Japan, "FY 1997 Energy-saving Measures and Effects through ITS" March 1998 (Japanese): http://www.eccj.or.jp/pamphlet/its/97/index.html

[18] Tsugawa, "Reduction of the Environmental Impacts by Automobiles with ITS Technologies," ITS and Environment Forum, Society of Automotive Engineers of Japan 2006 Spring Congress

[19] ITS webpage of the Road Bureau, the Ministry of Land, Infrastructure and Transport webpage: http://www.its.go.jp/ITS/j-html/Smartway/20051220/h17/H17followup.pdf_Precise.pdf

[20] Shigematsu, et al., "Auto Technology 2006," Society of Automotive Engineers of Japan

[21] Materials of the 5th Smartway Project Advisory Committee: http://www.nilim.go.jp/japanese/its/1top/kyouken/pdf/kyouken6.pdf

[22] Vehicle Information and Communication System Center: http://www.vics.or.jp/data/media_list.html

[23] Toyota Motor Corporation webpage: http://www.toyota.co.jp/jp/tech/its/vision/index.html

[24] AHSRA webpage: http://sangubashi.ahsra.or.jp/pc/index.html

[25] Nissan Motor Co., Ltd. webpage: http://www.nissan-global.com/JP/NEWS/2005/_STORY/051116-01-j.html

[26] Makino, et al., "Sag-area traffic congestion countermeasures utilizing ITS technology," Address at the 26th Japan Road Conference, October 2005 (Japanese): http://www.nilim.go.jp/japanese/its/3paper/pdf/051201douro_2.pdf

[27] The University of Tokyo, Kuwahara

Laboratory webpage:
http://www.transport.iis.u-tokyo.ac.jp/research2005/050127.pdf

[28] Japan Automobile Research Institute, "Report on Strategic Technology Roadmap for the Automobile ITS Sector," March 2006 (Japanese)

[29] Asano, M. et al., "Adaptive Traffic Signal Control Using Real-time Delay Measurement," 11th ITS World Congress, Nagoya, 2004.
http://www.transport.iis.u-tokyo.ac.jp/PDFs/2004/2004-006.pdf

[30] Energy Conservation Center, Japan, "Report on the FY 1993 survey on improving fuel efficiency," March 1994 (Japanese):
http://www.eccj.or.jp/fuel/93/index.html

[31] Energy Conservation Center, Japan, "Report on the FY 1994 survey on improving fuel efficiency," March 1995 (Japanese):
http://www.eccj.or.jp/fuel/94/index.html

[32] Ministry of Land, Infrastructure and Transport, "White Paper on Land, Infrastructure and Transport in Japan, 2005"

[33] Foundation for Promoting Personal Mobility and Ecological Transportation, "Report on Examination of Environmental Impact Reduction through Car Sharing and Methods for its Dissemination," March 2006 (Japanese)

[34] Honda Motor Co., Ltd. Intelligent Community Vehicle System webpage:
http://www.honda.co.jp/ICVS/project/index.html

[35] Honda Motor Co., Ltd. Internavi Premium Club webpage:
http://www.premium-club.jp/index.html

[36] Ministry of Land, Infrastructure and Transport, "2000 Transport White Paper":
http://www.mlit.go.jp/hakusyo/transport/heisei12/1-1/zu1-1-73.htm

Kanji TAKEUCHI
Information and Communications Research Unit

The author used to work in a private company that focused on the commercialization of a high-power semiconductor laser used in optical disc devices and on R&D for optical transmission. He is currently interested in the analysis of the effects that various factors have on the private sector's R&D strategies in the information and telecommunication area. These factors include science and technology policies and the diversity of values among different people.

Seiji MAEDA, PhD
Environment and Energy Research Unit

Doctor of Engineering. Engaged in the development of energy storage and conversion systems and project development at a private company.
Areas of specialization: Electrochemistry and materials engineering
Current interests: Science and technology policies in the areas of energy and the environment, and innovation management

(Original Japanese version: published in September 2006)