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Proposal on cooperative ITS for safe and sustainable transportation in Japan

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Abstract
This paper is an overview of the proposal, from a mid- and long-term “academia” perspective, for the planning, design methodology, operational technologies and supporting social norms, systems and other non-technology related conditions for the functions and performance that should be provided by infrastructure such as road and other mobility space, taking into consideration a future in which there will be dramatic changes in the performance and functions of diverse transportation modes ranging from automobiles to pedestrians. It is hoped that the proposal will serve as guidelines for the promotion of intelligent transportation systems (ITS) that enable important matters and issues to be shared and considered when studying the approach to ITS and the future vision of ITS, in order to enable people from various perspectives including government, the private sector and research institutions to promote research and development, practical application and introduction based on a common frame of reference.

KEYWORDS:
Cooperative ITS, Public transportation, Automated driving

Introduction
Intelligent Transportation Systems (ITS) can be defined as “systems constructed using state-of-the-art information and communications technologies to integrate people, roads (infrastructure) and vehicles, in order to resolve a variety of transportation challenges such as traffic safety, smooth transit, environmental consciousness and comfort”. Such concepts first appeared in the 1970s. It was at the second ITS World Congress in Yokohama in 1995 that “ITS” was defined as a common term on the part of Japan, the United States and the EU.
Currently, advances in information and communication technologies have brought us into the age of “big data,” in which enormous quantities of information can be stored using cloud technologies. The use of personal devices such as smartphones that have communications features has spread rapidly, and devices that can send and receive large quantities of data are now possessed on an individual level. Against this backdrop, the traditional transportation system of private cars and buses has diversified to include car sharing, ride sharing and on-demand transit systems. For this reason, when thinking about ITS, it is necessary to consider overall transportation: not only conventional automobiles but also various other means of transportation to move people and goods from place to place.
Based on the most recent situation, the name “cooperative ITS” can be given to the following concept: “A system in which information on various people, goods, mobile systems, infrastructure and so on, in various situations and constantly subject to certain restrictions, is gathered in the cloud by means of communications technologies for sharing and use, resulting in ‘cooperation’ among people, goods, mobile systems, infrastructure and so on.”
We studied the “Proposal of Cooperative ITS for the Realization of Safe and Sustainable Transportation Society”, from a mid- and long-term “academia” perspective, for the planning, design methodology, operational technologies and supporting social norms, systems and other non-technology related conditions for the functions and performance that should be provided by infrastructure such as road and other mobility space, taking into consideration a future in which there will be dramatic changes in the performance and functions of diverse transportation modes ranging from automobiles to pedestrians.
In this paper, we report an overview of the proposal. This paper describes societal background, the changes in technology that have occurred in recent years and the development of ITS. Based on this

background, a picture of the achievement of ITS in the future and directions for future ITS development is described. Public transportation and automated driving is used as an example to study the issues that must be resolved for the future promotion of ITS. Cross-cutting issues is also described.

Background of cooperative ITS research

In the study of cooperative ITS, it is necessary to consider the history of advances in ITS up to the present as well as important viewpoints for the future, with consideration for the background of social and technological changes in Japan.
The area of social changes in Japan includes the following challenges: ensuring mobility for an aging population, dealing with issues related to energy, disaster resilience, and deterioration of Japan's fiscal situation. The area of technological changes includes advances in information and communications technologies, gathering and use of big data and open data, more advanced and diverse vehicles, and improved automotive safety. Since 1996, when "the Comprehensive Plan for ITS in Japan" was developed by five Japanese government ministries, ITS has progressed through its first stage and its second stage.

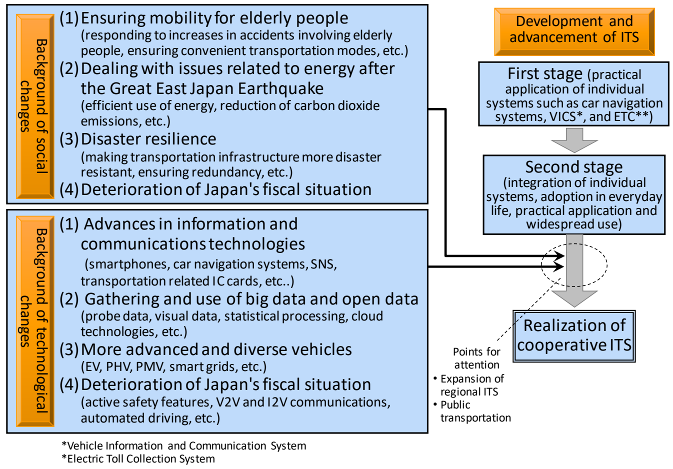

Figure 1 Background for the study of cooperative ITS in Japan

Based on the above, for the study of ways to achieve cooperative ITS in the future, it will be essential to consider two issues: the expansion of regional ITS and public transportation. On the local level, local traffic issues can be resolved by gathering traffic information and processing useful information and providing it appropriately to uses both within and outside the local area. Public transportation must provide a certain level of service that can be used by anyone and anywhere. It is also possible that personal mobility, the shared use of vehicles and ride-sharing of privately owned vehicles will become a new form of public transportation. It is possible that prioritizing the installation of on-board units in public transportation vehicles can cause public transportation to play a leading role in the introduction of cooperative ITS.

Future directions for cooperative ITS

Criteria for evaluation of cooperative ITS

In addition to the conventional criteria for evaluation of ITS, which include "improving safety", "reducing congestion", "reducing the environmental burden", and "improving comfort", ITS must also be evaluated in terms of "responding appropriately to mobility needs". We must keep in mind that these criteria are interrelated and may have synergistic effects on each other, or trade-offs may arise depending on the details of each initiative. In addition, when introducing new initiatives, it is important to evaluate the acceptability of a service for everyone, and not only for the people targeted by the service.
Considering future changes in social trends, the most significant aims of cooperative ITS are access for mobility-impaired persons, regional revitalization, support for visitors, and disaster prevention.

Key areas of development and future image for cooperative ITS

With the goal of comprehensively mapping the wide range of upcoming efforts for the future evolution of cooperative ITS, we have defined and outlined the following six directions as key areas for the future development of cooperative ITS.
The names of each of these six areas correspond to the primary target of services in each area.

- Development area 1, People: Advancement of mobility support
- Development area 2, Vehicles: Advancement of operation of vehicles and driving
- Development area 3, Goods: Advancement of physical distribution
- Development area 4, Roads: Advancement of road use
- Development area 5, Government: Advancement of support for administration
- Development area 6, Information: Advancement of use of information

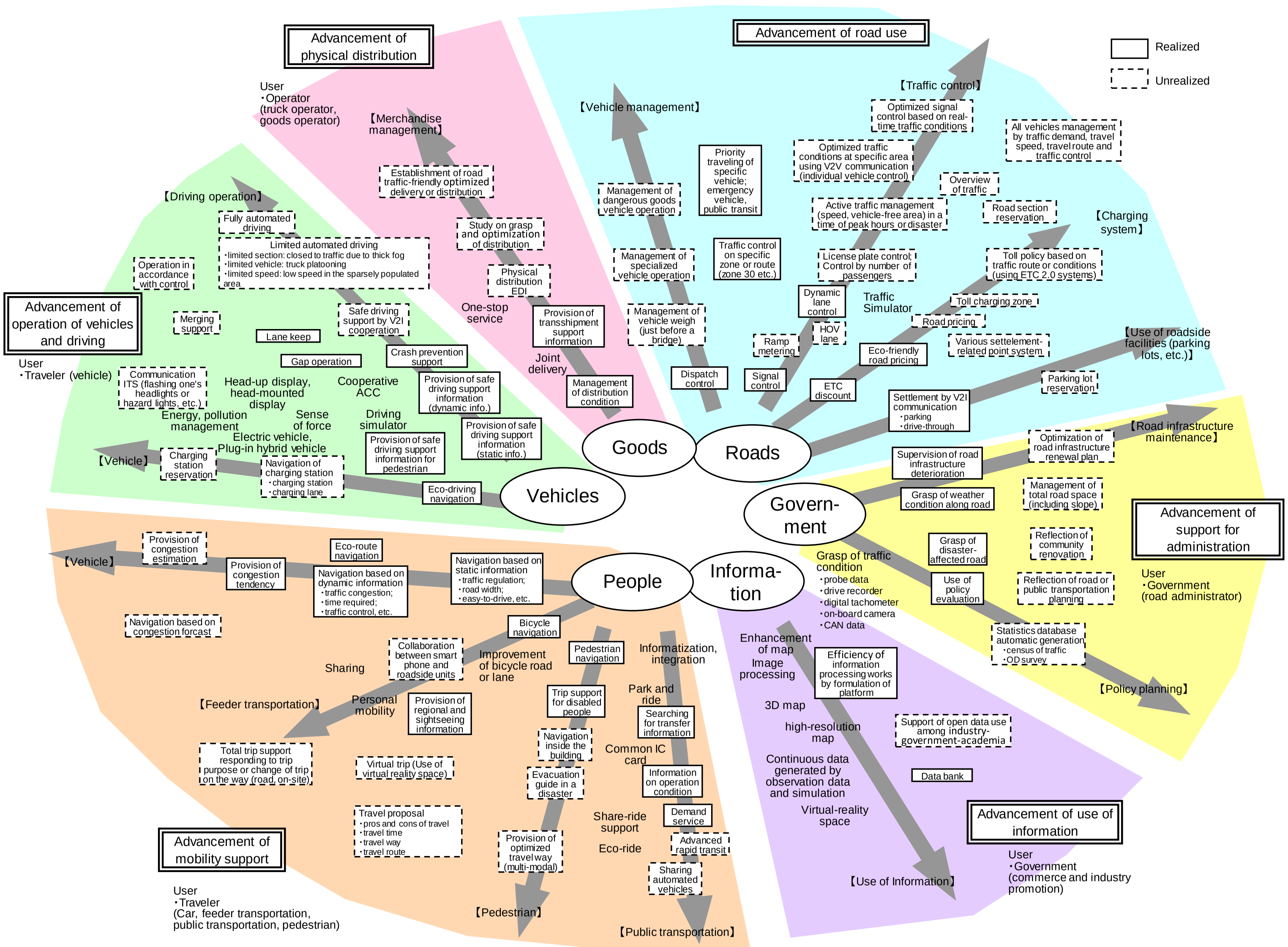

Figure 2 System diagram of cooperative ITS services

Development area 1, People: Advancement of mobility support

A proposal-based service will be achieved in which people will be able to seamlessly obtain relevant information on transit route and time fare in real time. The system will guide them to comfortable transit that takes into consideration user preferences. For drivers, progress in the provision of real-time information will enable accurate route guidance based on the future traffic status. The route guidance will provide quick routes or easy-to-drive routes in accordance with driver preferences. Pedestrians will be able to use their smartphones or other personal devices to appropriate information in accordance with their situation. For public transportation users, fares, schedules and other static information will be provided in a unified database. Public transportation operation plans will also be appropriately revised based on dynamic information relating to delays and car crowding, in order to provide ways of ensuring the ideal operation status, congestion status and means of transit for users.

This information on drivers, pedestrians and public transportation users will be gathered at the centers that manage ITS information on the local level. Information will be provided appropriately in accordance with the means of transportation selected by the transit user.

Development area 2, Vehicles: Advancement of operation of vehicles and driving

The vehicle safety will evolve in order from information provision to vehicle control to automated driving. For information provision, information displayed inside the vehicle will be realized, comparing between the information possessed by vehicles and drivers and the information on road restrictions and warnings. Vehicle control will evolve firstly autonomous vehicle technologies such as collision prevention and lane departure prevention. Subsequently, information on the position and direction of each vehicles and the information gathered by the infrastructure will be integrated. Automated driving will be achieved initially in limited areas and limited vehicles. Ultimately, all vehicles on all roads will be automated vehicles. The achievement of automated vehicles will result in a smooth flow of traffic, highly energy-efficient operation, reduced company costs and the securing of a means of transportation for vulnerable road users.

It will be possible for the vehicle communication technologies to be coordinated with pedestrians as well. Vehicles will connect with smartphones or other personal devices to help reduce accidents involving pedestrians.

Development area 3, Goods: Advancement of physical distribution

Individual goods will be managed using tags or the like that have various types of information including origin, destination, delivery deadline and handling. It will be possible to determine the status in real time at each stage in the shipping process. It will be possible to determine the quantity and destination for shipping, and to draw up effective logistics plans. Determining and managing the quantity and weight of shipped goods is expected to make a contribution to improving the safety and smoothness of vehicle transportation, improving the environment, and reducing the load on bridges and other road infrastructure.

Development area 4, Roads: Advancement of road use

The role of overall traffic management will be increasingly important. Ultimately, the movement of all vehicles will be managed to achieve an ideal overall traffic environment. To this end, first a combination of roadside sensors and probe data must be used to determine the traffic status in real time. Next, based on the traffic status and traffic demand, it will be possible to predict the road sectors in which congestion will occur. Probe data and other big data will be accumulated and analyzed, and highly precise traffic simulations will be used to increase the efficiency of congestion predictions.

In response to changes in the predicted traffic status, a combination of measures of enlarging traffic capacity and distributing or curbing demand will be employed. Measures to enlarge traffic capacity include optimized signal control and lane management that increases the number of lanes at times of congestion. Measures to distribute or curb traffic demand include peak road pricing, and detour discount policies, as well as the appropriate provision of information and the imposition of traffic restrictions.

For specially permitted vehicles and large vehicles, management of the routes and determination of the road load are needed to ensure roadside safety and reduce the load on bridges and other road infrastructure. Guidance on passable routes must be provided at appropriate locations using appropriate methods, and a mechanism is needed for imposing some type of penalty for vehicles that are in violation.

Determination of vehicle traveling status and optimal road management are also important at times of disasters or other emergencies. These systems will be able to provide evacuation guidance when a disaster occurs and help to ensure operational management of the roads that are used for emergency transportation.

Development area 5, Government: Advancement of support for administration

The on-board cameras in patrol vehicles will automatically determine the occurrence of obstructions on the road. The information detected by ordinary vehicles will be valuable when making a comprehensive determination of road obstructions. Effective use can be made of information on the driving and behavior of ordinary vehicles, information that is coordinated with vehicle control, and mechanisms for determining disasters and the occurrence of road obstructions from on-board camera images.

Probe vehicle and roadside sensor information will be managed as big data and used effectively for the dynamic resolution of traffic congestion, and for measures to ensure road safety, to evaluate the need to implement countermeasures and the results of implementation. The data will be processed statistically, enabling the information to be used in traffic policy, community development policies and other administrative activities.

Development area 6, Information: Advancement of use of information

Information on the movement of people, goods and vehicles can be determined by means of probe data, and public transportation use history as indicated by IC card use. High-definition maps of road infrastructure will be prepared to accommodate automated driving. Information on speed limits and other traffic restrictions will also be managed together with maps.

These types of information that are possessed by the government will be released publicly as open data. Construction of an information platform that enables information to be actively circulated will promote the gathering and open use of data. In local communities, centers for the management of ITS-related information will gather various types of information, making it possible to determine movement within and outside the community and the status of activities.

Case study for cooperative ITS (1) – Public transportation –

Development areas 1 - 6 are related to one another. Public transportation will be used as an example.

Major cities and regional cities have sufficient demand for the establishment of mass transit systems. In this area, bus service such as rapid arrival, on-time arrival and comfort should be improved (Figure 3).

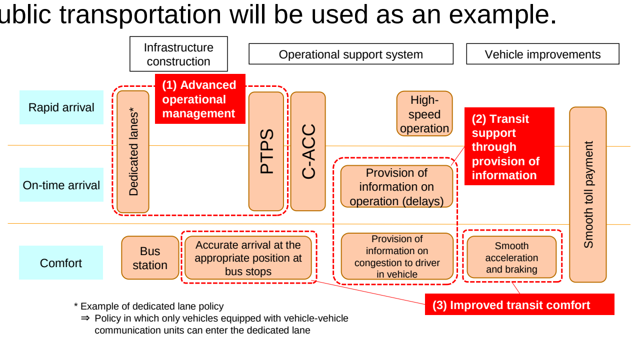

Figure. 3 Ideas for bus service to improve rapid arrival, on-time arrival and comfort

For transportation users, it is effective to support transportation by providing easy-to-understand information such as operational status and congestion in the vehicle (“people”). It is also possible to improve rider comfort and transportation capacity through the vehicle technologies such as smooth acceleration and braking, accurate arrival at the appropriate position at bus stops and platooning buses (“vehicles”). In addition to dedicated lanes and the use of a public transit priority system, advanced operational management can be effective, to make effective spatio-temporal use of dedicated bus lanes, for example by only permitting vehicles equipped with V2V communication units to enter the dedicated bus lane (“roads”).

In areas where it would be difficult to establish a mass transit system, it will be necessary to secure new types of public transportation. Shared vehicle services can help to establish a transit system that supports regional transportation. In areas with low traffic volume and few intersections, it will be easy to introduce automated driving systems. If the speed ranges and spatial areas are limited, it is possible to introduce fully automated vehicles. Such developments would involve multiple development areas including “people”, “vehicles”, “roads” and “information.”

Case study for cooperative ITS (2) – Automated driving –

To make a detailed study of cooperative ITS services, it is necessary to confirm the approach to the evolution of those services. These considerations will be discussed in detail using automated driving as an example.

Establishment of services from the perspective of both users and administrators

Automated driving systems for personal cars will lead to reduced driver burden. Therefore, drivers will perceive a direct benefit from the system. Accordingly, automobile manufacturers are expected to take the lead in development and deployment of such systems.

Automated driving systems for service cars will have considerable social significance, because of resolving the issues of the driver shortage and ensuring safe transportation. However, issues such as high cost will need to be resolved. Accordingly, introduction support from government, industry and academia will be needed.

From the perspective of road administrators, some automated driving services will have drivers feel a benefit, for example, policies to allow automated vehicles to exceed the speed limit. Other services will place restrictions on the driving, for example, a policy to automatically control the speed of automated vehicles in zones with a limit of 30 km/h. It will be essential to bridge the gap between the perceptions of drivers and road administrators to achieve the understanding of drivers.

Approach to service deployment

There are two approaches to the introduction of automated driving. In the case of deployment based on ease of introduction, approaches to evolution such as the following are possible.

- Technical ease (low speed → high speed, dedicated roads → all roads)
- Ease in terms of legal systems (driver in the car → driverless)
- Ease of operation and dissemination (for companies → for individuals)

In the case of deployment based on the benefit to users and society, deployment will target cases in which there is a benefit to society. For example, this might include platooning and "last one mile" service.

Clarification of issues at the stages of development, introduction and expansion

Issues must be clarified at each stage (development, introduction and expansion), and government, industry and academia must work together to find solutions. For government, this will include revising relevant legal systems, constructing needed infrastructure and storing necessary data. For industry, this will include promoting technical development, developing markets and achieving appropriate costs. For academia, this will include determining the benefit to society and assessing service performance.

Table 1 Keys to achievement of cooperative ITS

	Item	Description
Technical development	Assessment of private sector services	There are concerns that the smooth flow of traffic will be reduced as a result of mixing automated vehicles with different types of vehicle control, due to differences in the approach to safety and comfort in the same traffic flow. Government and academia should assess safety, smoothness and other aspects and establish certain standards for the algorithms that are used to control automated driving.
	Development of an intuitive HMI	Notification is needed when the vehicle control turns over system to driver. An intuitive human machine interface (HMI) must be developed using haptic technologies that transfer information through vibrations, impact and so on.
	Assessment that combines actual and virtual spaces	Effective assessments of services can be achieved by using the advantages of both assessments of actual vehicles on real roads and driving simulators or other virtual spaces. For example, the reliability of communications and system operation can be assessed on actual roads, and data measurements for validation can be conducted on test courses to achieve effective service assessments in a virtual space.
Legal systems	Interpretation under existing legal systems and operational ingenuity	Means that are devised for operation under the interpretation of existing legal systems, and a response to revisions to laws, will be needed. It will be important to seek methods that can resolve issues under existing legal systems. It is possible that the platooning can be interpreted as an expansion of towing (electronic towing) under the existing road traffic law. It is also possible that automated vehicles engaged in driverless operation can be interpreted as being remotely operated by the center that manages the operational status of the vehicle.
Operation and dissemination	Management and operation of automated vehicles by service companies	Automated vehicles are complex mechanisms and require appropriate maintenance and management. Efficient management of automated vehicles and the provision of services through rental or other means by rent-a-car companies, sharing companies and other operating companies would be effective. This would enable ordinary users to easily begin automated driving, and it could be expected to help the operating company distinguish itself from the competition and reduce operating costs.
	Potential for new services to complement public transportation	The sharing of automated vehicles could provide a new means of transportation in regional and sparsely populated areas where it is difficult to maintain public transportation, and for the "last one mile" in urban areas. It will be important to incorporate such systems into local transportation systems as a new and publicly available means of transportation to complement local public transportation. It will also be important to make it easy to provide financial and regulatory assistance to companies.
	Introduction of automated driving to companies, including legally mandated actions	The introduction of automated vehicles would be an effective way of reducing the operational burden of logistics companies and highway bus companies and achieving efficient operation. But introduction would pose a significant burden. It is assumed that purchasing assistance and other support measures will be provided to promote introduction, and that the introduction of automated vehicles will be mandatory at a stage when the societal need has become great.
	Provision of incentives for automated vehicles introduction	It is possible that automated vehicles will be permitted to travel at a faster speed than the current speed limit. It would also be effective to work with insurance companies to reduce the automobile insurance premiums for automated vehicles. Industry and government will need to work together to provide effective incentives that will be readily accepted by drivers.
	Establishment of objectives for infrastructure construction	New infrastructure will need to be constructed, such as white lines for distinguishing vehicle lanes, roadside equipment for V2I communications, high-definition maps for determining detailed locations. In addition, a certain level of maintenance of white lines and other infrastructure facilities will be needed. Government, industry and academia will need to reach a consensus regarding the targets for service introduction, and clear implementation plans, with the necessary infrastructure prioritized, constructed and maintained efficiently.

Need for comprehensive efforts of technical development, legal systems, and operation and dissemination

Comprehensive efforts of technical development, legal systems, and operation and dissemination will be the key to the practical realization of cooperative ITS. The specific considerations are shown in Table 1.

Cross-cutting issues for consideration

In the overall vision for future cooperative ITS and the approach to evolution, the following seven cross-cutting issues must be considered, based on the system diagram that was presented earlier (Figure 2).

Approach to data

There is a need to study the types of data that can be shared and should be protected, as well as their specific precision and control methods. The map data is essential infrastructure for achieving the individual services of navigation to support the movement of people, automated driving, traffic control and traffic management. A hierarchical control mechanism will be needed for the map data in order to clearly identify the parts shared for a variety of services and used for refinement. Data showing the history of the movement of people and vehicles can be shared to enable advanced navigation, support road administration and so on.

Potential for use of image processing technologies

Image processing technologies have wide-ranging application for improving the safety and smoothness of transportation, when combined with sensing technologies. Analysis and visualization of acquired and existing data, combined with appropriate display using mixed reality technologies can also be used to reduce environmental load and improve comfort. Sensing devices pose issues that include the mechanism for synchronization of time stamp data and location data, the need to construct and standardize interfaces, and the need to reduce power consumption. Cost reduction measures such as using the same sensor for multiple purposes will also be important.

Approach to devices

It would be extremely convenient if information could be provided using common devices in a variety of situations. Particularly effective would be the integration of car navigation information with smartphone information when one changes from driving to walking, and integration of ETC cards and public transit IC cards. However, in some cases device standardization causes these devices to become extremely expensive, making it unlikely that they will be widely used. The scope of standardization needs to be studied from the perspective of both cost and user convenience in order to find appropriate devices.

Approach to infrastructure

Existing infrastructure must be improved and new infrastructure must be constructed. This includes roads equipped with white lines (needed to achieve automated driving) that are managed based on certain standards. With the enhanced features of on-board units and the evolution of information and communications technologies, the road signs and other infrastructure placed on the roadside will shift to the provision of information directly to the driver inside the vehicle. In the future, the information that should be provided inside or outside the vehicle will need to be reconfigured.

Approach to communications

Communications must include not only V2V and V2I but also V2P and I2P. The need to review the approach to communications is expected to arise. This will include a review of channel addition and frequency bandwidth allocation with regard to necessary application security, the requirements for informational content when many-to-many communication applications conduct multiple simultaneous communications, coordination with Wifi and mobile communications networks in response to application requirements, a study of the applicability of new communications systems such as 5G in addition to DSRC, and support for large capacity data communications to accommodate application advancement.

Approach to dissemination

In order to effectively expand cooperative ITS policies, it will be necessary to plan appropriate measures to promote the dissemination of on-board units and roadside units. On-board units can be disseminated by means of market principles as long as they are attractive products that offer true benefits to drivers. One highly effective policy to promote dissemination would be requiring that the on-board unit be installed in specific vehicles. With regard to policies to promote the dissemination of roadside units, road administrators are expected to conduct installation. It will be important to show the general public that these units are needed.

Conclusion

This paper has presented six development areas for a newly redefined cooperative ITS — people, vehicle, goods, road, administration and information — and has presented the overall concept in as systematic a manner as possible. A system diagram for cooperative ITS service that maps all of the various cooperative ITS efforts that will be conducted in the future has also been presented. Public transportation and automated driving have been used as case studies for the realization of cooperative ITS.

It is hoped that this study will be useful to people with various positions in government, the private sector, research institutions and so on, as a guide to the future promotion of ITS that enables a shared consideration of the matters and issues to be considered when studying the approach to ITS and the future of ITS as a whole.

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