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IAFI

PROPOSALS FOR WORKING DOCUMENT TOWARDS A DRAFT NEW REPORT ON "USAGE OF COOPERATIVE VEHICLE-INFRASTRUCTURE ITS SYSTEMS"

1. Introduction

A new work item to develop a new APT Report on the usage of cooperative vehicle-infrastructure ITS systems was established during the 31st Meeting of AWG. Further, in the 32nd Meeting of AWG, further progress was made on the development of the working document for this report in AWG-32/TMP-48. According to the current workplan, the work to develop this draft new Report is expected to be completed at AWG-34.

There have been new developments in ITU-R WP5D and WP5A that have concluded with new published ITU-R Reports. Further, within the industry, academia and the ecosystem, new developments on advancing the use of ITS for socio-economic well-being and improved safety is increasing.

In India, Telecom Engineering Center of the DOT has published a Technical Report TEC 31218:2003 on "Technologies and Standards for Intelligent Transport System" that discusses various use-cases, applications and standards relevant to ITS.

2. Proposal

IAFI's proposals are provided in track changes (marked) and may be considered towards the further development of the new proposed report on "Usage of cooperative vehicle-infrastructure ITS Systems" in the attachment.

IAFI proposes that scope of the document focuses on the use-cases. IAFI also proposes that only the real deployment experiences are included in separate Annexures. Early trials and experiments may not reflect eventual deployments and therefore need not be part of the report as such. If required these could be included in an Annexure.

Attachments: as above

Contact: Name
Organization, Country
Email:

ATTACHMENT

WORKING DOCUMENT TOWARDS A DRAFT NEW REPORT ON “USAGE OF COOPERATIVE VEHICLE-INFRASTRUCTURE ITS SYSTEMS”

Table of Contents

1 Scope

This report addresses the usages of cooperative vehicle-infrastructure ITS (Intelligent Transport Systems) systems to support several applications such as safety driving, automated driving, road management and so on. The system is to utilize roadside infrastructures installed on the road, including traffic signals and LED display boards, and the roadside infrastructure communicates with road users such as motorbikes, bicycles, emergency vehicles, and pedestrians cooperatively. This report identifies use cases of cooperative vehicle-infrastructure

ITS systems with some demonstration experiment results, which have been considered in APT countries.

2 Related documents

ITU-R Recommendations:

ITU-R M.1453	Intelligent transport systems - Dedicated short range communications at 5.8 GHz
ITU-R M.1890	Operational radiocommunication objectives and requirements for advanced Intelligent Transport Systems
ITU-R M.2084	Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications
ITU-R M.2121	Harmonization of frequency bands for Intelligent Transport Systems in the mobile service

ITU-R Report:

ITU-R M.2228	Advanced intelligent transport systems (ITS) radiocommunications
ITU-R M.2444	Examples of arrangements for Intelligent Transport Systems deployments under the mobile service”
ITU-R M.2445	Intelligent transport systems (ITS) usage

ITU-R Handbook:

Land Mobile (including Wireless Access) - Volume 4: Intelligent Transport Systems. Year 2021

APT Reports:

APT/AWG/REP-61	APT Report on "The Usage of Road Sensor Network in APT Member Countries
APT/AWG/REP-18(Rev.2)	APT Report on "Usage of Intelligent Transportation Systems in APT Countries

3 List of acronyms and abbreviations

ADAS	Advanced driver-assistance systems
APT	Asia-Pacific Telecommunity
ARIB	Association of Radio Industries and Businesses (Japan)
AWG	APT Wireless Group
B2I	Bicycle-to-Infrastructure
C-ITS	Cooperative ITS communication
GNSS	Global Navigation Satellite System
IEEE	Institute of Electrical and Electronics Engineers

ISO International Organization for Standardization

ITS Intelligent Transport Systems

ITU International Telecommunication Union

I2I Infrastructure-to-Infrastructure

I2N Infrastructure-to-Network

LPWA Low Power Wide Area

OBU On-board unit

PTPS Public Traffic Priority System

TCC Traffic Control Center

V2I Vehicle-to-Infrastructure

V2P Vehicle-to-Pedestrians

V2V Vehicle-to-Vehicle

V2X Vehicle-to-Everything (Infrastructure/Vehicle/Pedestrians and others)

WLANWireless Local Area Network

4 Outline of this report

Outline of this report is described as following:

Explanation of overview for cooperative vehicle-infrastructure ITS systems,

- Configuration and flow of the systems,
- Definition and function of items which make up the systems, such as road users, infrastructures and cloud networks.

Introduction of 8 use cases for cooperative vehicle-infrastructure ITS systems.

- Issues that the use cases will solve
- Overview and outline of use cases (services)
- Communication information list (in table)
- Examples of communication systems in Japan (in table).
- Demonstration experiments in Japan (some of use cases)

Outline of use cases are as follows:

1. Accident prevention support for head-on collisions at intersections with poor visibility
2. Emergency vehicles driving support to shorten the arrival time
3. Public transportation priority system to ensure on-time operation of buses.
4. Automated driving support to provide blind spot area information from autonomous sensors for safe and comfortable driving
5. Road management information collection support to collect vehicle driving data and utilize for traffic information management
6. Prove data collection support to collect traffic flow data of road users for road design
7. Victim support on large-scale disaster for guiding disaster victims to evacuation sites in the event of a large-scale disaster and for detecting damaged areas on roads
8. Watching support / Crime prevention support for notifying parents of the whereabouts of children and the elderly

5 Overview of cooperative vehicle-infrastructure ITS systems

Cooperative vehicle-infrastructure ITS systems contribute to solving various social issues through cooperation between road users and roadside infrastructures. Typical configuration of cooperative vehicle-infrastructure ITS systems is shown in Figure5.1. The roadside infrastructure for cooperative vehicle-infrastructure ITS systems may be referred to as "ITS Smart Pole". It is a social infrastructure that can correspond to multiple use cases as shown in Chapter 6.

The roadside infrastructure detects road users such as bicycles and pedestrians, by installed sensors, and analyses to understand their behaviors. This information is then transmitted via V2X radio unit, which is installed in the roadside infrastructure, to a road user equipped with V2X radio device and runs in a different direction road. The road user, who received the information, is aware of another road user's approach from the other direction. On the other hand, the road user equipped with V2X radio device transmits the position, speed, and other travel information of itself to the V2X radio unit on roadside infrastructure, and the roadside infrastructure notifies the road user from the other direction that another road user is approaching on an LED display board or through a speaker.

The detected or received information from road users could be uploaded to the cloud networks from control unit of the roadside infrastructure to manage and analyze the information.

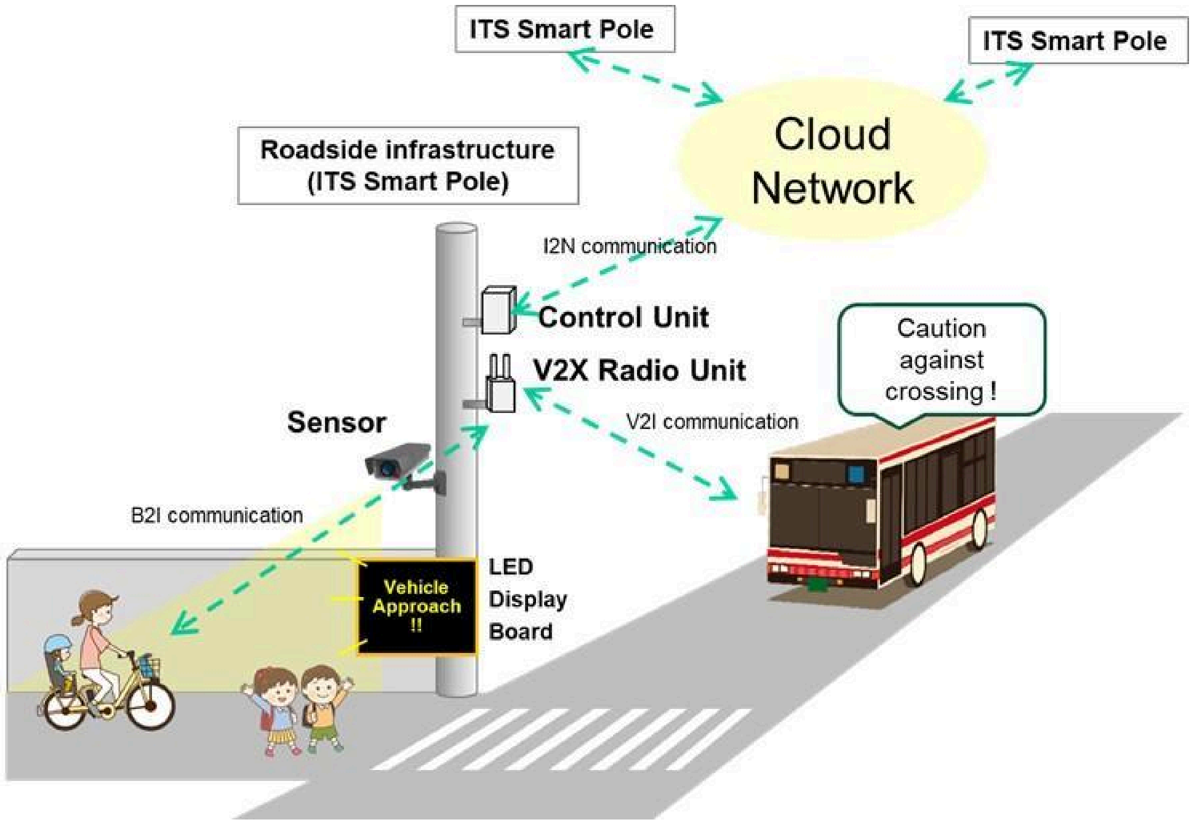


FIGURE 5.1 Configuration of cooperative vehicle-infrastructure ITS system

5.1 Road user

Road users shall be defined as follow.

- Four-wheeled vehicles include large vehicles such as trucks and buses, passenger vehicles and emergency vehicles such as ambulances and fire trucks

– Two-wheeled vehicles such as bicycles and motorbikes,
– Personal mobility vehicles such as segways and kickboards
– Pedestrians

Some road users are equipped with V2X radio device that can communicate with roadside infrastructure, while others are not.

5.2 Infrastructure

The infrastructures of cooperative vehicle-infrastructure ITS systems are installed at roadside locations such as signalized intersections, unsignalized intersections, and single streets. Specific locations include co-located traffic signals, utility poles, streetlights, building walls, pedestrian decks, and ground power facilities. The roadside infrastructures have abilities of functions and mechanisms as follows. The basic block diagram is shown in Figure 5.2.

– Sensors and cameras that can monitor road conditions and road users
– Control units to analyze and understand the behavior of detected objects in real time
– V2X radio units that can communicate with road users equipped with V2X radio devices.
– General-purpose radio units that can communicate with road users who are equipped with general-purpose radio device such as Wireless-LAN
– Wireless beacon receivers that can monitor road users with Bluetooth or other wireless beacon transmitters.
– System for notifying road users who are NOT equipped with V2X or general-purpose radio devices through LED display boards and speakers.
– Global Positioning Satellite reception and correction data generation for time synchronization.
– External I/F to connect to cloud network, and other infrastructures

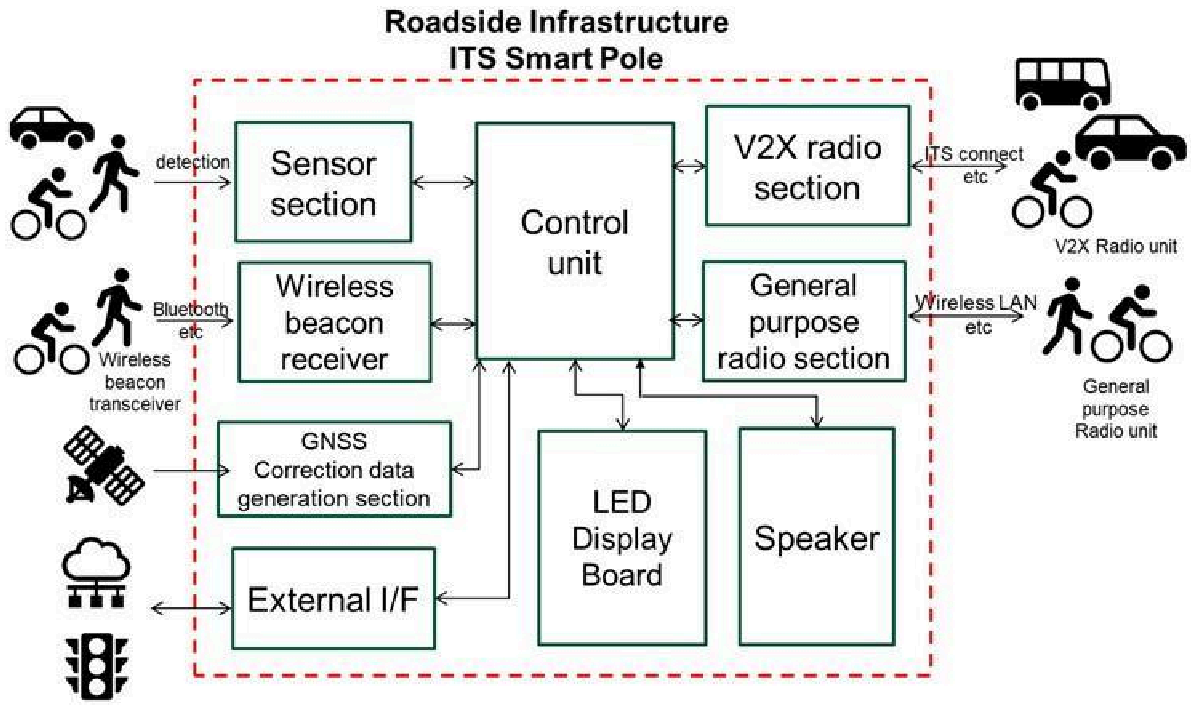


FIGURE 5.2 Basic block diagram of roadside infrastructure (ITS Smart Pole)

5.3 Cloud network

Information of road users detected by sensors on roadside infrastructure or received via V2X radio unit may be uploaded to the cloud network. In this case, the data could be managed, integrated, processed, or analyzed by cloud computing. Finally, the data could be utilized as mobility data platforms in cloud networks to the various services described in Chapter 6, as shown in Figure5-3.

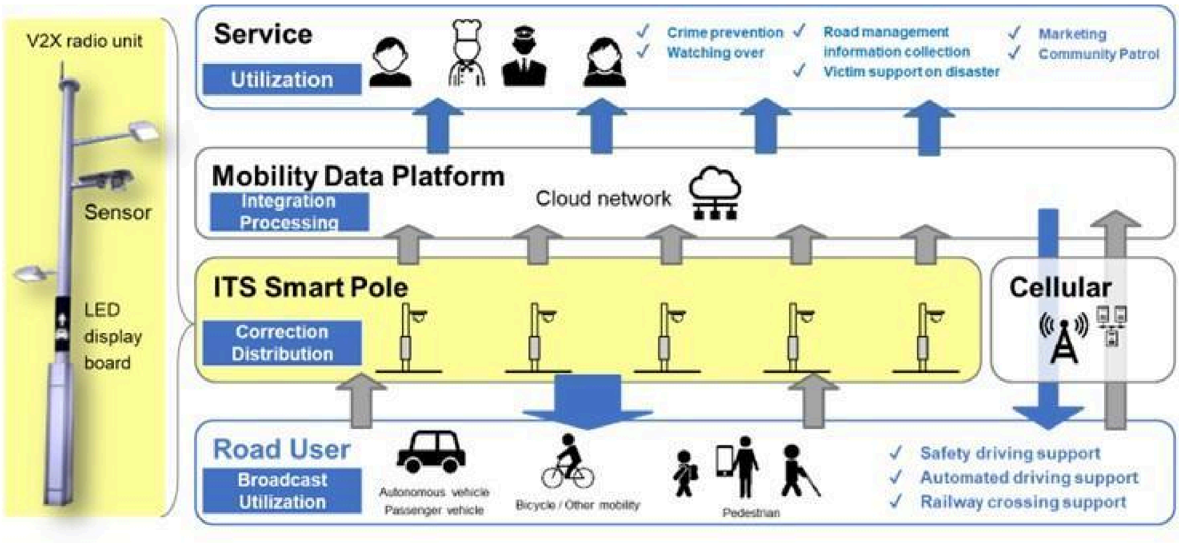


FIGURE 5.3 Layer configuration of ITS Smart Pole and the services

6 Use cases in APT countries

In recent years, traffic accidents, traffic congestions, and environmental degradations have become serious problems in APT countries due to population growth and increased car ownership. In addition, there are traffic issues caused by natural disasters. Cooperative vehicle-infrastructure ITS systems are an effective means of solving these problems and issues, and following chapters introduce the use cases and demonstration examples.

6.1 Accident prevention support

Traffic accidents are one of critical social issues in APT counties. Although the number of fatal and serious injury accidents have been on a declining trend in some APT countries (According to statistics from the National Police Agency in Japan, they were reduced by 40% in 2022 compared to 2013) due to improvements of automotive ADAS technology in recent years, there are still many challenges to be solved. One of the major causes in traffic accidents is collision accidents at unsignalized intersections. In addition, there is high percentage of the bicycle-related accidents with vehicles. This chapter describes an effective solution for collision accidents between vehicles and other road users, such as bicycles and pedestrians, at unsignalized intersection utilizing cooperative vehicle-infrastructure ITS systems.

<u>Overview of the service</u>

The service will notify road users (vehicles, motorbikes, bicycles, pedestrians) from priority routes about the presence of bicycles and pedestrians from non-priority routes at unsignalized intersections.

This warning assists drivers to slow down or stop before an intersection to prevent accidents. Roadside infrastructure (referred to as ITS Smart Pole) are installed at intersections and on roads in the service area, and sensors and radio beacons are installed on the ITS Smart Poles to detect moving objects on non-priority routes, and V2X radio units and LED display boards are installed to notify everyone involved. Sensors or beacons will detect moving vehicles on non-priority route and notifying moving vehicles on priority route through V2I communication or visual means.

Outline of the service

1. Roadside sensors or wireless beacons detect road users (bicycles/pedestrians) on non-priority route.
2. V2X radio unit and LED display board provide information of road users in the non-priority route to road users (vehicles, motorbikes, bicycles, pedestrians) in the priority route.
3. Moving road users on the priority route stop or slow down before entering the intersection based on the above notification information.
4. Even if road users in non-priority route rush out of street, road users will not cause a traffic accident.

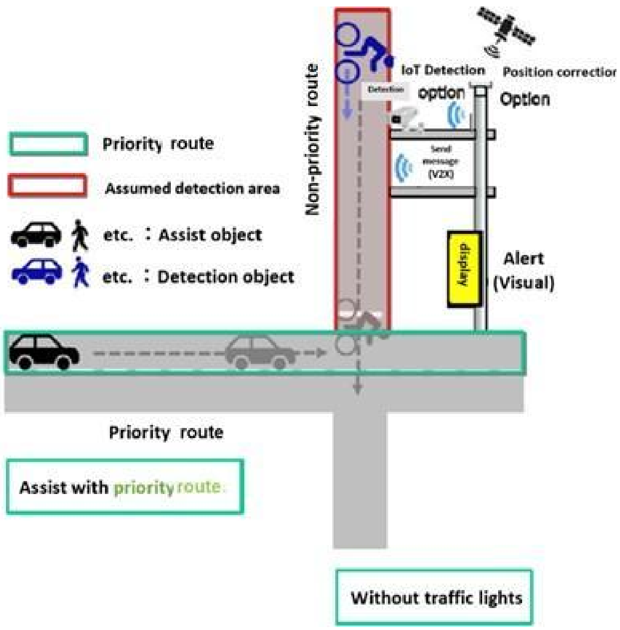


FIGURE 6.1 Service Image

TABLE 6.1 V2X Communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Object position information	Latitude, longitude, elevation etc.
Object status information	Object speed, object heading etc.
Object classification	Vehicle, motorbike, bicycle, pedestrian etc.

TABLE 6.2 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	ITS Smart Pole - Vehicle

6.1.1 Demonstration experiment example[1]

Demonstration experiments have been carried out to verify the use case of accident prevention support utilized cooperative vehicle-infrastructure ITS systems and one of the test case examples is described in this chapter.

Background / Purpose

The objective of the experiment was to verify the effectiveness of V2X radio unit installed on utility poles (roadside infrastructures) at unsignalized intersections with poor visibility in preventing accidents by detecting pedestrians running out of blind spots and notifying bus drivers of the danger.

Method

Sensors (radar, camera, etc.) installed on utility poles detect pedestrians, and the V2X radio unit transmits dynamic information (position, speed, direction, etc.) of pedestrians to the V2X OBU(on-board unit) on the bus via ITS Connect communication.

The location of the bus is accurately corrected by GNSS receiver, and when the OBU on the bus determines that there is a risk of an accident based on the dynamic information of pedestrians detected by sensors and the dynamic information of the bus, a hazard notice is sent to the bone-conduction earphones worn by the bus driver.

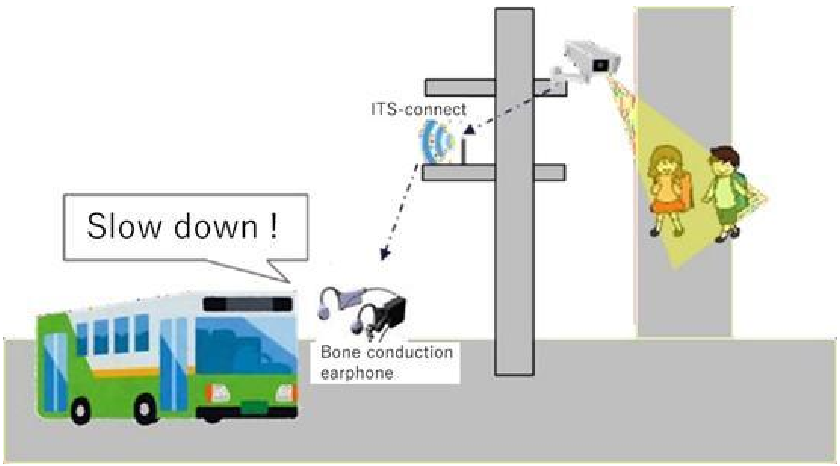


FIGURE 6.2 Demonstration experiment (V2I) illustration

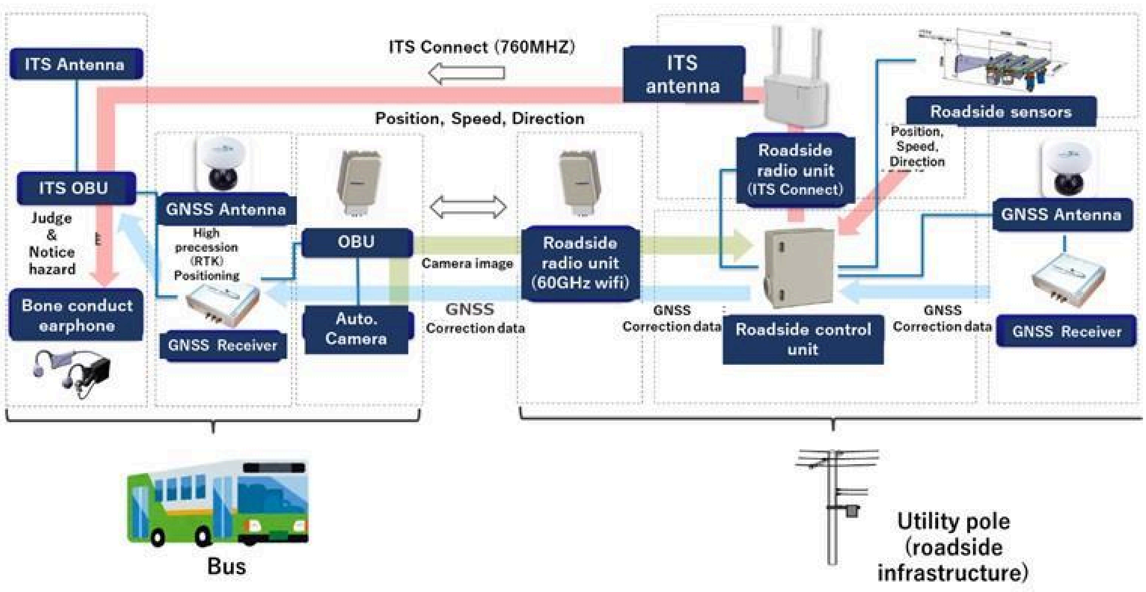


FIGURE 6.3 Demonstration experiment (V2I) system configuration

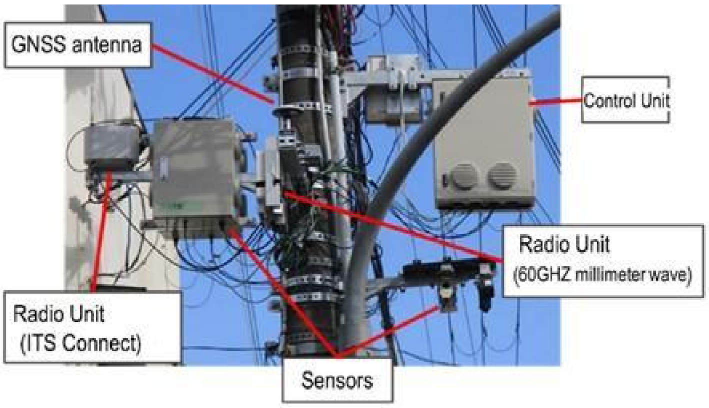


FIGURE 6.4 V2I related devices on utility pole (roadside infrastructure)

Result

The analysis results of bus driving behavior change are described as below.

Without decelerating triggered by the notification, the bus and pedestrians entered the intersection with a 2-second time difference, but when the hazard notice was replayed and the bus performed braking, the time difference between the bus and pedestrians entering the intersection was increased to 9.4 seconds.

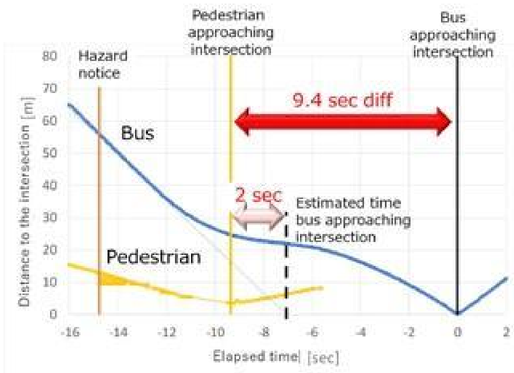


FIGURE 6.5 Distance between buses/pedestrians and the intersection, vs time

After receiving the hazard notice, the bus driver performed a braking action to slow down, and then the bus driver visually recognized that a pedestrian had entered the intersection and started braking again, slowing down, and then accelerating again, as shown in Figure6.6. Although this experiment was conducted at an intersection with poor visibility, the bus driver was able to decelerate the bus 3.5 seconds before the pedestrian entered the intersection.

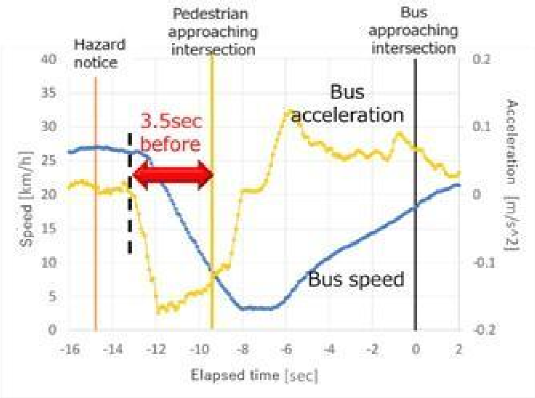


FIGURE 6.6 Bus speed and acceleration, vs time

The experiment was conducted with three bus drivers, and all three bus drivers uniformly confirmed that listening to the hazard notices increased the time gap between pedestrians and bicyclists and the time they entered the intersection.

TABLE 6.3 Average intersection entry time

Driver	Intersection (against pedestrian)	
	Without support	With support
Driver1	1.6	3.6
Driver2	2.0	9.1
Driver3	0.7	4.2
Ave	1.6 Improved	6.5

Conclusion

When the driver was notified of the danger at the appropriate time, 100% (5/5 times) of the drivers took the safe action of braking. The results obtained from this demonstration showed that the system is effective in preventing accidents at unsignalized intersections with poor visibility. Furthermore, the system is also expected to be a measure for preventing accidents involving rush-out road users for automated driving vehicles when they travel on public roads in the future.

6.2 Emergency vehicle driving support

In urban area, emergency vehicles such as ambulances and fire trucks are getting caught in traffic congestions, resulting in delay in reaching their destinations such as hospitals. Furthermore, there are frequent incidents of traffic accidents involving emergency vehicles during their emergency runs, posing social issues. To address these issues, it is considered that cooperative vehicle-infrastructure ITS systems are to assist the safe and smooth movement of emergency vehicles such as ambulances and fire trucks when they are approaching to target intersections and on roads.

Overview of the service

This service notifies surrounding vehicles through LED display boards installed near intersections and along the roads, allowing them to see that an emergency vehicle is approaching. This enables surrounding vehicles to understand the position and intention of the emergency vehicle and take appropriate actions, thus supporting the safe and efficient movement of the emergency vehicle.

In this service, roadside infrastructures equipped with V2X radio units and LED display boards, such as the ITS Smart Pole or VMS(Variable Message Sign) etc., are installed near intersections and along the roadside in the service area. Emergency vehicles are equipped with V2X radio OBU. Subsequently, the V2X OBU in the emergency vehicle transmits information such as its status of emergency operation and position data. This information is received by the roadside infrastructure, which then display an "Emergency Vehicle Approaching" message or icon on the LED display board, alerting surrounding vehicles and prompting them to be cautious.

Outline of the service

1. Emergency vehicles are equipped with V2X radio OBUs.
2. During emergency response, the V2X OBU in the emergency vehicle transmits information such as its status of emergency operation and position data.
3. The information transmitted by the V2X OBU is received by roadside infrastructures equipped with V2X radio units and LED display boards.
4. As the emergency vehicle approaches, the LED display board on the roadside infrastructure shows an "Emergency Vehicle Approaching" message or icon.
5. Once the emergency vehicle has passed, the display on LED display board ceases.

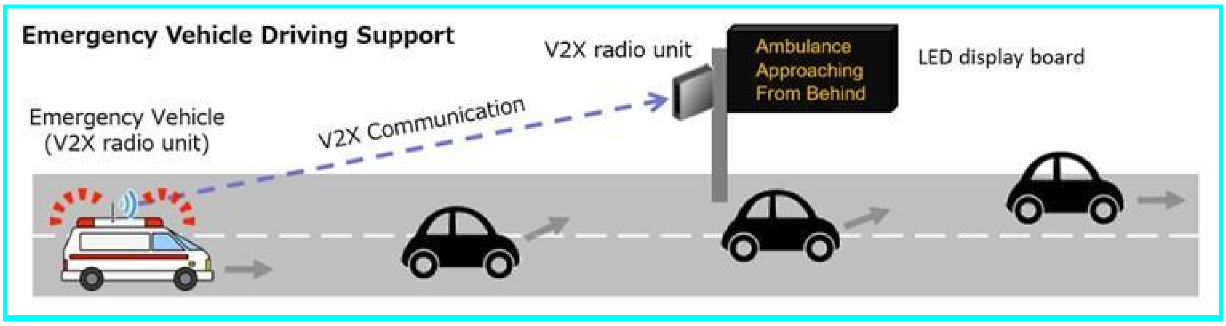


FIGURE 6.7 Service image

TABLE 6.4 V2X Communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Vehicle position information	Latitude, longitude, elevation etc.
Vehicle status information	Vehicle speed, vehicle heading etc.
Vehicle classification	Size, role, extended information for emergency vehicle

TABLE 6.5 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Vehicle - ITS Smart Pole/ VMS(Variable Message Sign)

6.2.1 Field demonstration case

Overview

A field demonstration was conducted by installing electric poles equipped with sensors and V2X radio units at an intersection, which allowed for the recognition of the types of vehicles and emergency vehicles approaching from the priority route. When vehicles or pedestrians entered the intersection, attention was drawn to them by displaying pictogram and arrows on LED display boards as a warning.

Detail

The field demonstration was conducted by installing an ITS Smart Pole at an unsignalized intersection (in this case, a five-way intersection) where there was a risk of head-on collisions. The ITS Smart Pole was equipped with sensors and a V2X radio unit to detect information about approaching vehicles and then displays this information on LED display boards to alert and warn drivers and pedestrians at the intersection. ITS Connect is utilized in the system to receive information from emergency vehicles, and in response, it displays an "Emergency Vehicle Approaching" message or pictogram on the LED display boards.

Operation sequence (when a passenger vehicle or similar enters):

1. Sensors detect objects on the priority route (vehicles, bicycles, pedestrians, etc.).
2. The control unit processes the detected information.
3. LED display boards notify vehicles on the non-priority route about the approaching vehicles.
4. Encourage safe driving for vehicles on the non-priority route.

Operation sequence (when an emergency vehicle enters):

1. Detect the approach of emergency vehicles equipped with V2X OBU.
2. Process the detected information in the control unit.
3. Notify vehicles on the non-priority route about the approaching emergency vehicle using LED display boards.
4. Give the right of way to the emergency vehicle.

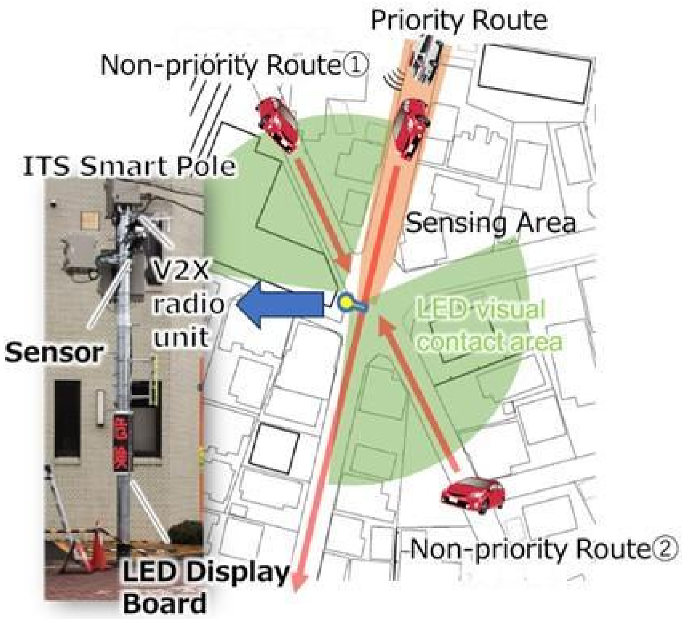


Figure 6.8 Field Demonstration Image

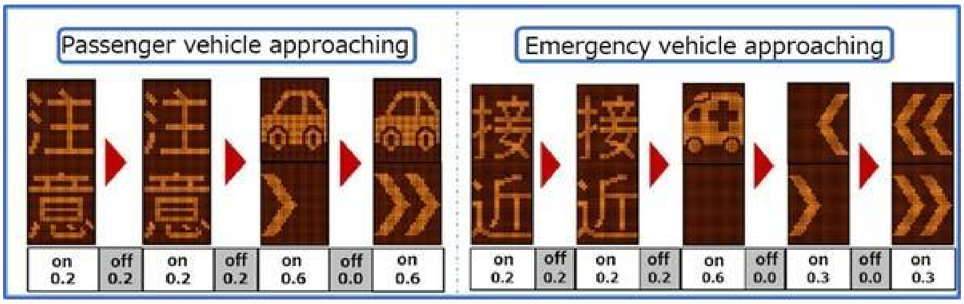


Figure 6.9 LED Display Image
※注意 -> " **Warning**" "接近" → "**Approaching**"

6.3 Public Transportation Priority Systems

Traffic congestion is also one of the major problems to be solved in APT countries, and the time and economic losses caused by congestion are significant (ex: estimated economic losses from congestion in Japan are around 12 trillion yen). It is known that congestion can be alleviated by using public transportation such as buses instead of using private vehicle and it is expected the number of public transportation user shall be increased, however many users are dissatisfied with "delays". Then PTPS(Public Transportation Priority System) has been introduced to address this issue.

PTPS is a system that supports the priority passage of public vehicles such as buses by implementing dedicated and priority lanes, signal control to minimize stop time, and warnings for illegal vehicles using the dedicated lanes. One use case of PTPS, called advanced PTPS, is described in the following chapter.

6.3.1 Advanced PTPS for route buses [2]

Overview of the service

This system selects support vehicles based on the bus delay status, controls the timing of traffic signals, and reduces the time it takes to cross intersections, thereby achieving smooth operation of public transportation such as route buses.

At the target signalized intersection, roadside infrastructure equipped with V2X radio units are installed, and PTPS OBU are installed on the route buses. The PTPS OBU calculates buses position, speed, direction, and delay time, and generates vehicle information. The generated information is notified to the TCC(Traffic Control Center) via the roadside infrastructure. The TCC aggregates information from multiple buses and selects the buses that should be given priority. By adjusting the timing of the traffic signals at the intersections where the priority buses pass to shorten the time required for intersection crossing. This operation serves as an example of an advanced PTPS.

Outline of the service

1. The PTPS OBU calculates bus position, speed, direction, and delay time, and creates the state information of the vehicle.
2. This information is notified to the traffic control center via the roadside infrastructure.
3. The TCC aggregates information from multiple buses.
4. The TCC selects the buses that should be given priority based on the aggregated information.

5. The TCC adjusts the timing of the traffic signals at the intersections where the priority buses pass to shorten the time required for intersection crossing.

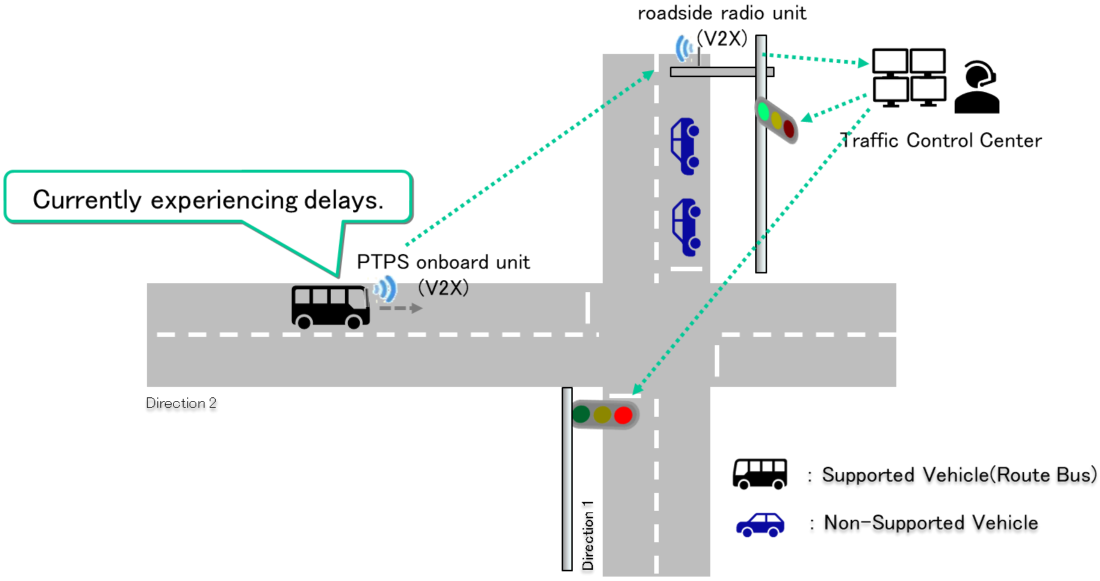


FIGURE 6.10 Service image

TABLE 6.6 V2X Communication information list

Item	Remark
Time information	Time in hours, minutes and seconds of UTC
Vehicle position information	Latitude, longitude, elevation etc.
Vehicle status information	Vehicle speed, vehicle heading etc.
PTPS Request	Information related to priority request, including bus operator number, route number, operation status, and priority request (Yes/No)

TABLE 6.7 Communication system example in Japan

Communication Method	Frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Bus - Roadside infrastructure
Fiber optic internet	-	Roadside infrastructure - TCC
Cellular Network	-	Roadside infrastructure - TCC

6.4 Automated driving support

Automated driving technology is one of the solutions for the social issues in the future. (For example, this technology could solve the lack of commercial drivers, aging society and also traffic accidents.). It has some technical challenges to achieve automated driving level 4 technology by implement the technology of automated driving vehicle alone and now it is considered that cooperative vehicle-infrastructure ITS systems will be necessary to realize automated driving level 4.

<u>Overview of the service</u>

This service provides expanding the operational design domain and smooth driving for automated driving vehicles. This is achieved by detecting objects in blind spots for autonomous sensors using roadside sensors and notifying these objects through V2I communication.

The roadside infrastructure (ITS Smart Pole) is installed at intersections and roads in the service area. Roadside sensors detect targets on the road that are blind spots for autonomous sensors. Information is sent to automated driving vehicles through V2I communication using the V2X radio unit.

The autonomous driving system determines the next action and operates the vehicle based on the information received from the ITS Smart Pole and the information from the autonomous sensors. This allows automated driving cars to drive safely and comfortably even at intersections and roads with many blind spots.

Outline of the service

1. Automated driving vehicles approach intersections and roads with many blind spots.
2. The roadside sensor of the ITS Smart Pole detects targets in the blind spot of automated driving vehicle.
3. The ITS Smart Pole sends detected target information to the automated driving vehicle by V2I communication.
4. The autonomous driving system determines the next action based on the information received from the ITS Smart Pole and the information from the autonomous sensors and operates the vehicle.

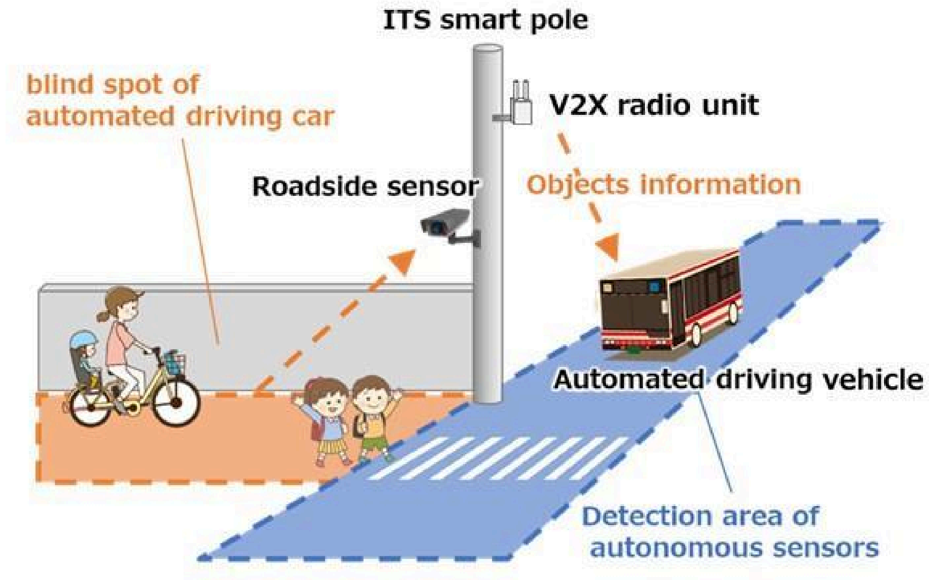


FIGURE 6.11 Service image

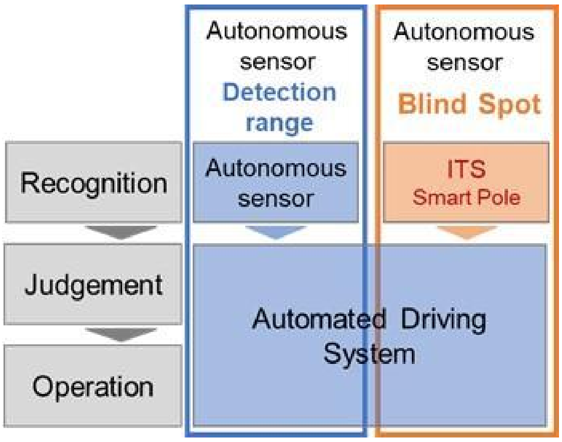


FIGURE 6.12 The role of ITS Smart Pole in the service

TABLE 6.8 V2X communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Object position information	Latitude, longitude, elevation etc.
Object status information	Object speed, object heading etc.
Objects size	Length, width etc.
Detection area	Detection area of the roadside sensor

TABLE 6.9 Communication Methods in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Automated driving car - ITS Smart Pole

6.4.1 Demonstration experiment example

Demonstration experiments have been carried out to verify the condition and effectiveness of automated driving support utilizing cooperative vehicle-infrastructure ITS systems and one test case example is described in this chapter.

Purpose

The purpose of this experiment is to clarify the validity of an available time in order to construct a system that provides safe and smooth right-turn support information by notifying an automated driving vehicle of the available time in the non-line-of-sight route. The additional objective is also to clarify the accuracy of estimated intersection arrival time of the target object which is calculated by the ECU (Electronic Control Unit) of the automated driving vehicle using information such as the position and speed of an object detected by the sensors at the intersection (refer to as transportation object information).

Method

Figure 6.13 shows the target non-line-of-sight intersection and the installed ITS Smart Pole. In the scene where an automated driving vehicle entering from a non-priority route turns right onto a priority route, the sensors on the ITS Smart Pole detect a wide range of vehicles, bicycles, pedestrians, and other objects moving and existing along the priority route, and deliver transportation object information to the automated driving vehicle via V2I communication.

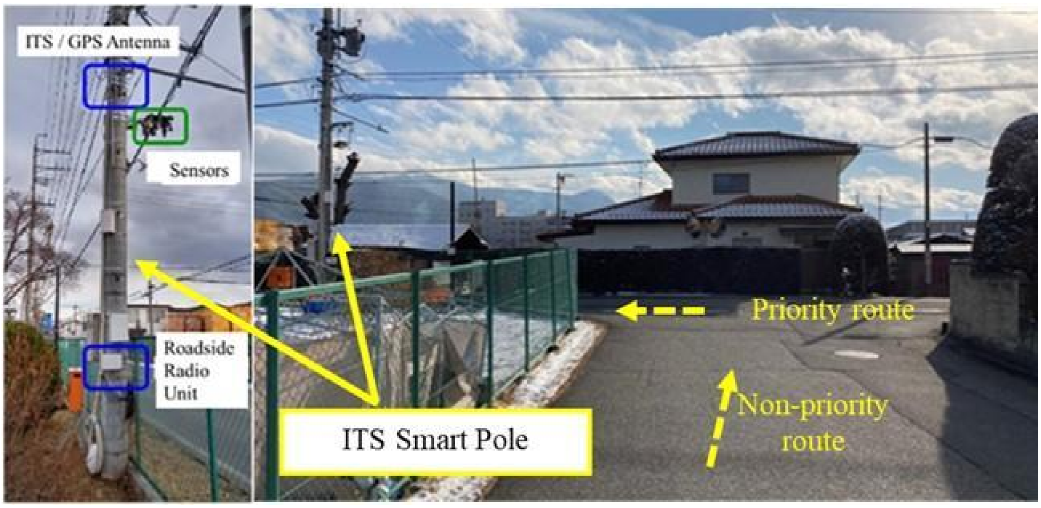


FIGURE 6.13 The target non-line-of-sight intersection and the installed ITS Smart Pole

FIGURE 6.14 The automated driving vehicle, the display for experimenters and the camera for measurement

The ECU calculates the estimated intersection arrival time of the target object using the transportation object information received via the on-board radio unit, and notifies the display panel attached for the experimenter's confirmation in three stages according to the notification definitions in Table 6.10: "Vacant Notification", "Informative" and "Alert".

The shortest intersection arrival time is included, “shortest” because notification of the nearest object information from the intersection is necessary when multiple arrival times exist, such as when there are multiple object signs on the priority route or when objects enter the intersection simultaneously from both sides of the intersection. The study of the optimal vacant notification time is for “X” pertaining to "Vacant Notification," and it is important so that the automated driving vehicle on the non-priority route does not give emergency braking, near-misses, etc. to the vehicle moving on the priority route between the start and completion of the right turn. In this experiment, the optimal value of ”X” was studied by reproducing the aforementioned scene with an experimental vehicle while verifying the behavior of the vehicle moving on the priority route and the driver's senses.

TABLE 6.10 Notification Definition of Right Turn Assistance Information

Notification Levels	Notification Definitions
Vacant Notification	The shortest intersection arrival time must be over “X” seconds.

Informative	The shortest intersection arrival time must be between 4.5 seconds and "X" seconds.
Alert	The shortest intersection arrival time must be less than 4.5 seconds.

In the evaluation of the estimated intersection arrival time of the target object, the error was calculated from the time difference between the estimated intersection arrival time calculated by the ECU and the actual intersection arrival time measured by the camera.

Result

The time "X" for the vacant notification is the sum of the time for the completion of the right turn by the automated driving vehicle and the distance of the vehicle following behind the automated driving vehicle after the completion of the right turn, which is the safety margin time without using emergency braking, near-miss etc. For the former right turn completion time, we measured the time from the start of the right turn to the completion of the right turn after the automated driving vehicle temporarily stops at the stop line on the non-priority route and enters the priority route, and as a result, it takes about 6 to 7 seconds. Therefore, while changing X to 8, 9, and 10 seconds, an automated driving vehicle was allowed to make a right turn from the non-priority route to the priority route, and an experimental vehicle was allowed to drive from the priority route at the legal speed of 50 km/h. As a result of evaluation by the driver of the experimental vehicle based on the effects of the right turn (driving behavior, near-miss, etc.), 10 seconds was determined to be the optimal value.

FIGURE 6.15 The automated driving vehicle right-turning

Table 6.11 shows that the error between the estimated intersection arrival time and the actual intersection arrival time was within 200 ms for the two trials. As an additional experiment, right-turns were made in automatic mode after receiving right-turn assistance information containing a 200 ms error to verify the effectiveness of the system. We confirmed that the automated driving vehicle was able to make a right turn safely with the right-turn assistance information, and that the error was within the acceptable value for the system.

TABLE 6.11 The Accuracy Results of Estimated Intersection Arrival Time

Item	Trial: #1	Trial: #2
Estimated Intersection Arrival Time	9.5s	9.5s
Actual Intersection Arrival Time	9.3s	9.6s
Error	-200ms	+100ms

Conclusion

In the study of the optimum vacant notification time, 10 seconds was considered to be the optimum value, based on the evaluation of experimental driving, for the time required for the completion of the right turn by the automated driving vehicle plus the safety margin time against following vehicles after the completion of the right turn.

In the evaluation of the estimated intersection arrival time calculated using the transportation object information of objects detected by the sensors at the intersection, it was confirmed that the error between the actual intersection arrival time and the estimated intersection arrival time calculated by the ECU was within 200 ms. We confirmed that the error was within the acceptable value for the system.

Finally, the effectiveness of the right-turn assistance information provided by the system was thus clarified.

6.5 Road management information collection support

In general, traffic volume and vehicle speed are being monitored by vehicle detectors to determine road traffic conditions. However, the detected data is momentary, and it is not possible to acquire data pertaining to vehicle behavior continuously in time and space. Therefore, it often takes time to detect the occurrence of sudden traffic events such as traffic accidents, traffic congestion, and falling objects. In addition, it is a challenge to plan countermeasures by capturing detailed traffic conditions and the occurrence/resolution of traffic congestions.

6.5.1 Road traffic condition data collection support

Overview of the service

Roadside infrastructure (ITS Smart Pole) collects information of vehicles traveling within its communication range. This information will be aggregated and analyzed to determine the propagation status of traffic congestion and its changes, and the results of this analysis will be used to plan traffic congestion countermeasures and determine their effectiveness.

The ITS Smart Pole can constantly receive information transmitted by vehicles equipped with V2X OBU traveling within its communication range. The transmitted information includes position information such as latitude and longitude. Based on such information, organizations responsible for road management operations will analyze and monitor traffic congestion factors.

By using the V2I communication, traffic information such as the propagation status of traffic congestion and its changes can be grasped at a high resolution. Furthermore, such traffic information can be used for planning traffic congestion countermeasures and determining their effectiveness.

Outline of the service

1. Vehicles equipped with V2X OBU constantly transmit information such as latitude and longitude.
2. ITS Smart Poles installed on the roadside constantly receive information from vehicles equipped with V2X OBU that are traveling within its communication range.
3. Transmit the received information to the cloud and central equipment.
4. Record and aggregate the collected information.
5. Analyze the aggregated information to determine the propagation status of traffic congestion and changes in traffic congestion.
6. Utilize the information to plan traffic congestion countermeasures and determine their effectiveness.

Scenes of use (examples)

- Verification of the effect of lane change restrictions
- Verification of the effect of longitudinal gradients, etc.
- Confirming the impact on traffic congestion and the effectiveness of measures, and using the results to formulate further countermeasures.

- Data from traffic simulators, etc., will be used to evaluate the effectiveness of traffic congestion countermeasures.
- Utilized for studying the locations of vehicle detectors (including millimeter wave, LiDAR, etc.), CCTV(Closed-Circuit Television), and other information-gathering equipment.

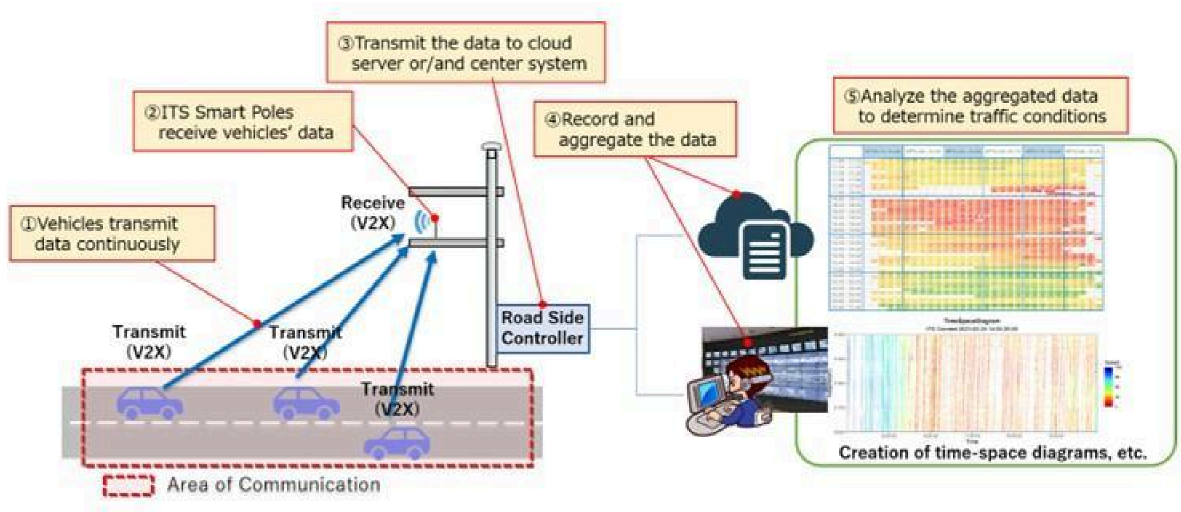


FIGURE 6.16 Service image

TABLE 6.12 V2X communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Vehicle position information	Latitude, longitude, elevation etc.
Vehicle status information	Vehicle speed, vehicle heading etc.
Vehicle classification	Size, role

TABLE 6.13 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Vehicles - ITS Smart Poles

6.5.2 Support for detection of obstacles on the road

Overview of the service

The ITS Smart Pole can constantly receive information transmitted by vehicles equipped with V2X OBU traveling within its communication range. Based on such information, organizations responsible for road management operations can detect accidents, falling objects, and other unexpected events on the road, and take necessary actions according to circumstances of the event. The actions include supporting the prompt dispatch of road patrol vehicles.

By using the V2I communication, it is possible to detect sudden events that have a significant impact on travel speeds at an early stage, and promptly implement appropriate actions. As a result, V2I communication enables us to improve the level of road management.

Outline of the service

1. Vehicles equipped with V2X OBU constantly transmit information such as latitude and longitude.
2. Smart Poles installed on the roadside constantly receive information from vehicles equipped with V2X OBU that are traveling within its communication range.
3. Transmit the received information to the cloud and central equipment.
4. Record and aggregate the collected information.
5. Analyze the aggregated information to detect any phenomenon that may cause a sudden event.
6. Take necessary actions promptly, such as supporting the prompt dispatch of road patrol cars.

Scenes of use (examples):

- Early detection of possible occurrences of sudden events on the road
- Providing alert information to vehicles using the road (following vehicles)
- Prevention of falling objects and secondary accidents

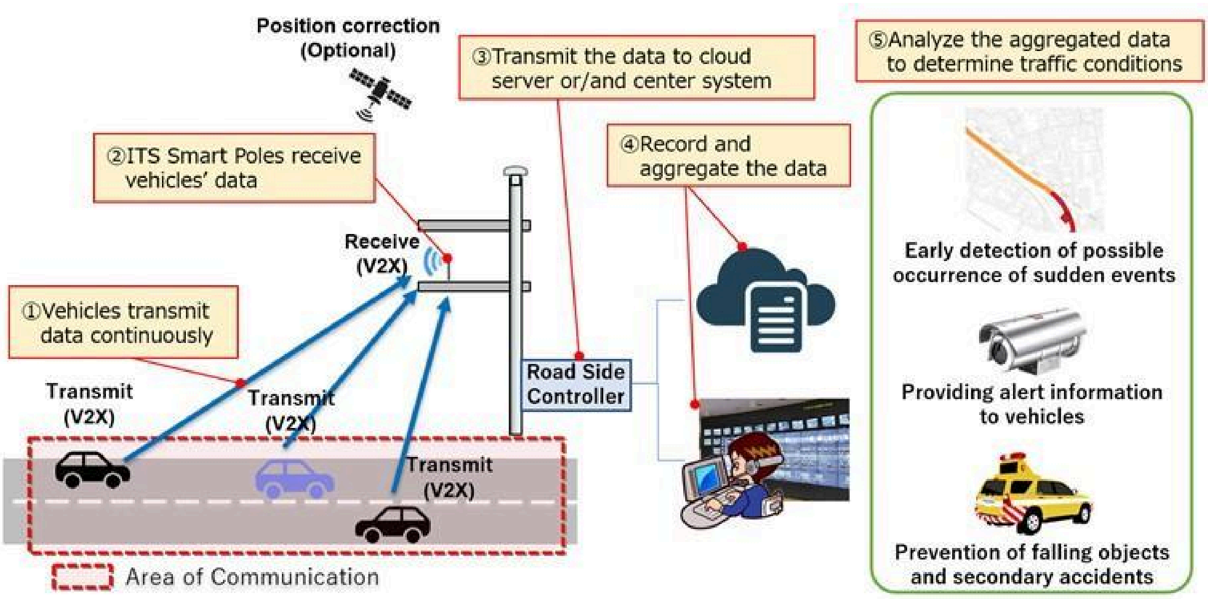


FIGURE 6.17 Service image

TABLE 6.14 V2X communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Vehicle position information	Latitude, longitude, elevation etc.
Vehicle status information	Vehicle speed, vehicle heading etc.
Vehicle classification	Size, role

TABLE 6.15 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Vehicles - ITS Smart Poles

6.5.3 Demonstration experiment example[3]

Demonstration experiment projects have been carried out to verify the use case of road management information collection support service utilizing cooperative vehicle-infrastructure ITS systems and one of the field test case examples in Japan will be introduced in this chapter.

Background/Purpose

The objective of this project was to understand the communication distance and to suggest the possibilities of using it as a new information collection infrastructure by compiling and organizing the information actually collected using V2I communications in ITS Connect

Method

An experimental vehicle equipped with V2X OBU is prepared to receive OBU transmission messages from general vehicles equipped with V2X OBUs on general roads and highways.

TABLE 6.16 shows an example of an OBU transmission message. By analyzing the reception log, the possible communication distance is calculated, and the method of data utilization is further examined.

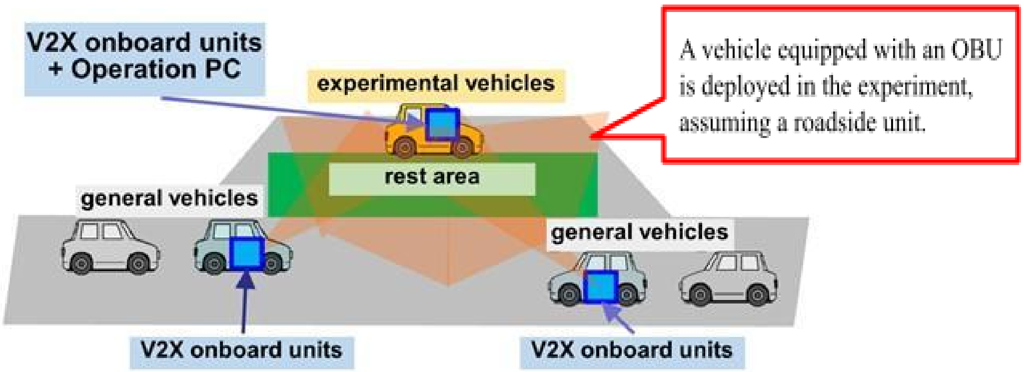


FIGURE 6.18 Diagram of experimental method diagram

FIGURE6.19 Picture of vehicle with V2X unit

V2X Antenna for OBU is used for roadside units and the characteristics are not optimized

TABLE 6.16 Example of OBU transmission message[4]

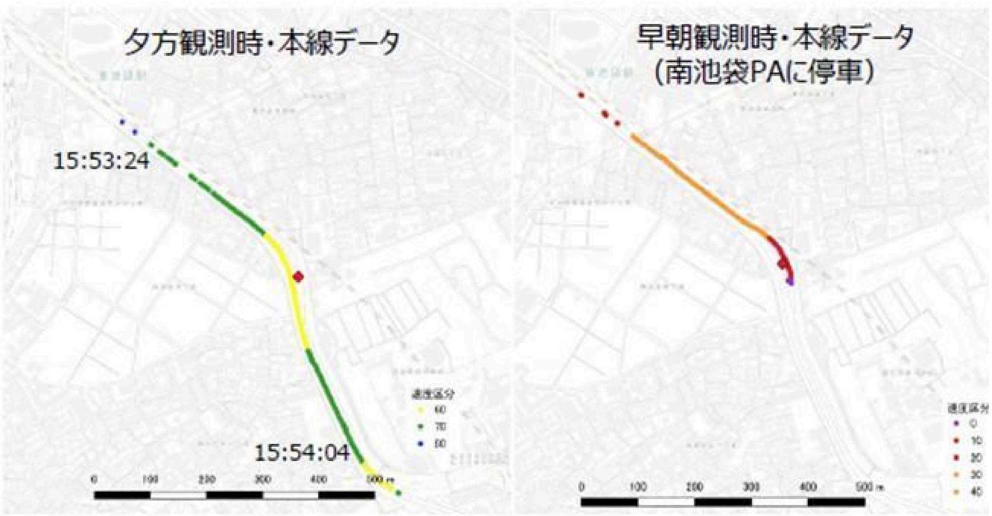
Data Frame / Data Element	Size	Comments
DF_Location Information	88bit	Required
DE_ Latitude	32bit	Required
DE_ Longitude	32bit	Required
DE_ Altitude	16bit	
DE_ Information on Location Acquisition	4bit	Required
DE_ Information on Altitude Acquisition	4bit	
DF_Vehicle Attribute Information	32bit	Required
DE_ Type of Vehicle's Size	4bit	Required
DE_ Vehicle's Purpose	4bit	Required
DE_ Vehicle's Width	10bit	
DE_ Vehicle's Length	10bit	
DF_Vehicle Information	72bit	Required
DE_ Velocity	16bit	Required
DE_ Azimuth Angle	16bit	Required
DE_ Longitudinal Acceleration	16bit	Required
DE_ Information on Velocity Acquisition	3bit	Required
DE_ Information on Azimuth Angle Acquisition	3bit	Required
DE_ Information on Longitudinal Acceleration Acquisition	3bit	Required
DE_ Shift Position	3bit	
DE_ Steering Angle	12bit	

Result

FIGURE 6.20 shows communication distance confirmation result. This figure shows the range of OBU transmitted messages that reached the experimental vehicle, indicating that communication is possible within a radius of over 1,000 meters.

FIGURE 6.20 Communication distance confirmation result

FIGURE 6.21 shows an example of data utilization. This figure shows a plot of position vs. speed information extracted from an OBU transmission message of a vehicle traveling on an expressway. (a) is the transmitted data from a vehicle traveling on the main line, and (b) is the result of analyzing the transmitted data from a vehicle entering a parking area.
The figure shows that the speed decrease is more pronounced in the case of the PA parked vehicle on the right than in the case of the vehicle traveling on the main line on the left. Since it is possible to continuously collect such changes in vehicle speed, there is a possibility of collecting and understanding speed changes caused by traffic accidents and falling objects in real time.



(a) Cars traveling on the main line (b) Cars entering a parking area
FIGURE 6.21 Visualization results of velocity change

<u>Conclusion</u>
Based on the data obtained through this experiment and the aggregate results, it was confirmed that ITS Connect can be used to collect high-resolution data from individual vehicles over a

communication distance of 1,000 m or more. However, it is under condition where the wireless environment, including the antenna, is not optimized. If the wireless environment is good, communication distance of 2,000 m or more can be achieved. For reference, the data shown in Figure 6.22 has also been obtained. Furthermore, the visualization of the speed change showed the possibility of utilizing the collected data.

FIGURE 6.22 Communication distance (reference)

6.6 Prove data collection support

Road design is an important element to realize traffic safety and to avoid traffic congestions in APT countries. This chapter introduces another use case of cooperative vehicle-infrastructure ITS systems to obtain and analyze traffic flow/trace and utilize it for road design and management.

Overview of the service

The service provides probe data obtained by observing the routes and speeds of road users (vehicles, motorbikes, bicycles, pedestrians) passing through major intersections and roads over a long period of time.

In this service, roadside infrastructure(ITS Smart Pole)s collect information such as road users' route, speed, longitudinal acceleration, and type using roadside sensors and V2X radio unit. The data is stored in the database on a cloud network for a long period of time. Users can extract and view data for the desired time period. For example, Users can view the routes and speeds of bicycles during periods when roadside constructions are underway. This makes it possible to evaluate whether roads are unsafe not only during normal times but also during events such as construction work. It is expected that this service can be used to develop bicycle/motorbike paths and also to consider detour routes and the placement of safety guides in the event of an emergency.

Outline of the service

1. The roadside sensor of the ITS Smart Pole detects road users on the road and measures their position, speed, acceleration/deceleration, attributes, etc.
2. Road users equipped with V2X radio unit notify the ITS Smart Pole of their own position, speed, longitudinal acceleration, type, etc. via wireless communication.
3. The ITS Smart Pole sends the obtained information as probe data to cloud servers via wired or wireless wide area network.
4. The cloud server stores the received probe data in storage.
5. Observers can view probe data for the required period from a cloud server using an application installed on a PC or other terminal.

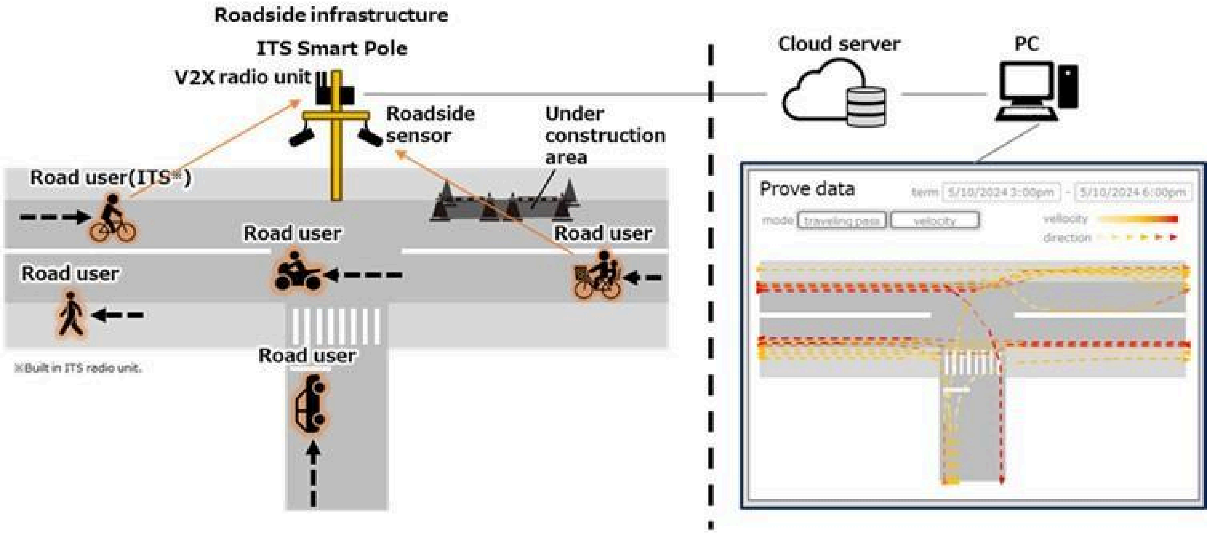


FIGURE 6.23 Service image

TABLE 6.17 V2X communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Position information	Latitude, longitude, elevation etc. (Including road users, sensor objects)
Status information	Speed, heading etc. (Including road users, sensor objects)
Classification	Vehicle, motorbike, bicycle, pedestrian etc.

TABLE 6.18 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Road users - ITS Smart Poles

6.7 Victim support on large-scale disaster

In recent years, the number of disasters, such as large-scale earthquakes in APT countries, has been increasing around the world. Although warning signs are observed and evacuation advisories are issued before a disaster strikes, there is a problem of people not being able to evacuate due to the short time required to collect information before a disaster strikes and the delay in information collection. Use cases for the solution to these problems using cooperative vehicle-infrastructure ITS systems will be proposed in this chapter.

6.7.1 Evacuation guidance support

<u>**Overview of the service**</u>

The service notifies people who have difficulty obtaining disaster information on routes to evacuation shelters in the area when evacuation advisories are issued by the national government or local government prior to a disaster occurring on routes desired by the local government, such as the main route.

Roadside infrastructure (ITS Smart Pole) with LED display boards attached is installed in the service area. Based on the decision results obtained from the local government, the ITS Smart Poles are instructed to display information on evacuation shelter guidance via the network. The ITS Smart Poles that receive the instruction displays the evacuation route and other information on the LED display boards, and the service is realized when the information is viewed by people who have difficulties in obtaining disaster information.

Outline of the service

1. Information and decision results obtained by the local government instruct the ITS Smart Pole to display evacuation shelter guidance information via the network.
2. The ITS Smart Pole that receives instruction information displays evacuation routes, etc. on LED display boards.
3. People staying in the area who have seen the information on the LED display boards will know the correct route to the evacuation shelter and take evacuation actions.
4. People who have difficulty accessing disaster information can avoid disasters and crises.

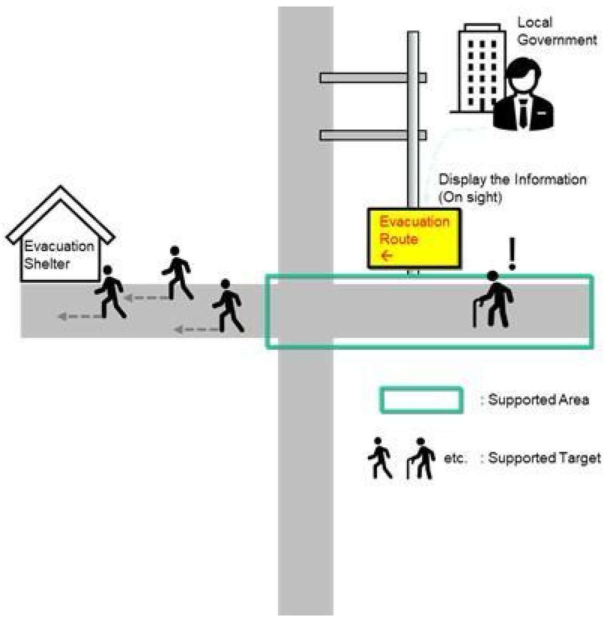


FIGURE 6.24 Service image

TABLE 6.19 Communication information list

Item	Remark
Information on evacuation shelter guidance	Information indicating the route to evacuation shelters sent by the local government

TABLE 6.20 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Local government system - ITS Smart Pole
Fiber optic internet	-	
Cellular network	-	

6.7.2 Road damage confirming support

Overview of the service

The service notifies authorized local government officials of the passability information* of roads from the time of occurrence of the disaster until the lifting of the disaster emergency system at intersections or single roads in the area desired by the local government. (*The passability information is the result of information on vehicle type, location, speed, etc. transmitted from V2X OBU of normal vehicles, emergency vehicles and vehicles exempt from regulations, are aggregated and processed as appropriate.)

Roadside infrastructure(ITS Smart Pole) is installed in the service area. The ITS Smart Pole receives and collects traffic information from multiple vehicles equipped with V2X OBU, and generates traffic performance information from the traffic information accumulated at regular intervals. The service is realized by displaying traffic information and traffic performance information on a digital map on the server of the disaster response headquarters or the cloud based on the traffic performance information distributed from the ITS Smart Pole, and confirming it with local government officials.

Outline of the service

1. Traffic information*1 is transmitted from vehicles equipped with V2X OBU: normal vehicles, emergency traffic vehicles, vehicles exempt from regulations.
2. ITS Smart Pole receives and collects the traffic information from multiple vehicles equipped with V2X OBU.
   *Option: Acquiring camera images.
3. ITS Smart Pole accumulates traffic information at regular intervals and generates traffic performance information*2.
   *Option: Extract video, photograph, etc. for a certain period of time before and after the passing time of a vehicle equipped with V2X OBU.
4. Generated and extracted data in Section 3 is distributed from ITS Smart Pole to servers or clouds at disaster response headquarters, via LPWA, cellular network, etc.
5. The traffic information and traffic performance information are displayed on a digital map on a server or cloud at the disaster response headquarters, etc.
   *1 Raw data such as position, speed, and vehicle type for each vehicle.
   *2 Traffic performance information at each fixed interval in a specific area on the road e.g. link, or the information further classified by vehicle type.

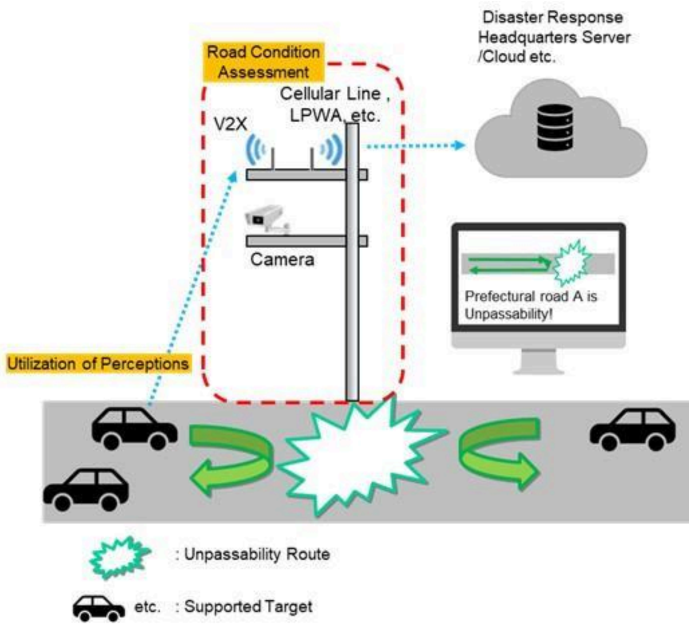


FIGURE 6.25 Service image

TABLE 6.21 Communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified
Time information	Time in hours, minutes and seconds of UTC
Vehicle position information	Latitude, longitude, elevation etc.
Vehicle status information	Vehicle speed, vehicle heading etc.
Vehicle classification	Size, role etc.
Traffic performance information	Information generated based on traffic information

TABLE 6.22 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Vehicle - ITS Smart Pole
LPWA	900MHz band	ITS Smart Pole - network
Cellular network	-	

6.8 Watching support / Crime prevention support

In recent years, crimes and accidents have become increasingly diverse, including child abductions and traffic accidents involving elderly persons with dementia. Guardians who take care of their children or elderly persons strongly need to collect information of individuals to prevent crimes and accidents. Therefore, the use case in which cooperative vehicle-infrastructure ITS systems assist guardians in gathering information will be presented in this chapter.

6.8.1 Watching support

Overview of the service

The service notifies guardians of the position of children, elderly persons, and other persons to be watched at intersections and on roads, and enable guardians to keep track of the position of the watched persons.

Roadside infrastructure(ITS Smart Pole) is installed at intersections and on roads in the service area, and the person to be watched wears a special transmitter or shoes with the transmitter attached.

The signals from the transmitter are received by the ITS Smart Pole, and the position information is distributed to service providers and local governments that can protect personal information.

The service is realized by distributing the information to the guardians who are the service subscribers.

Outline of the service

1. The person to be watched wears a special transmitter or shoes with the transmitter, or goes out on a bicycle with the transmitter.
2. The ITS Smart Pole receives personal identification information transmitted from the transmitter when the person to be watched passes by the ITS Smart Pole.
3. The ITS Smart Pole uploads the position information of each individual to the cloud.
4. The cloud retains the position information.

5. The guardian keeps track of the position of the person to be watched by notification from the cloud, or at the time whenever they need to confirm.

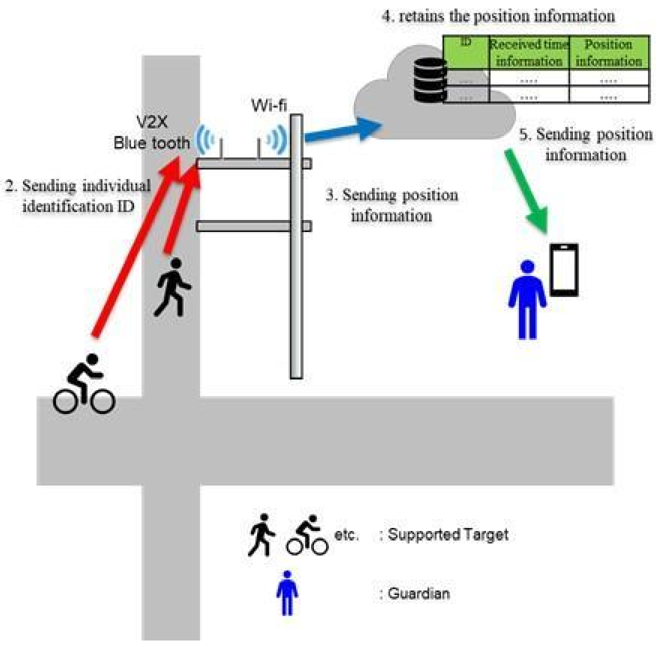


FIGURE 6.26 Service image

TABLE 6.23 Communication information list

Item	Remark
Individual identification ID	ID by which an individual can be identified (pedestrian , bicycle)
Time information	Time in hours, minutes and seconds of UTC
Position information	Latitude, longitude, elevation etc. (pedestrian, bicycle)
Status information	Speed, heading etc. (pedestrian, bicycle)

TABLE 6.24 Communication system example in Japan

Communication system	Applicable frequency	Path
ITS Connect (ARIB STD T109)	760MHz 10MHz band	Person who is watched - ITS Smart Pole
Bluetooth	2.4GHz	ITS Smart Pole- network
Wi-fi	2.4GHz, 5GHz	

7. Conclusion

International deployment of V2X-based cooperative systems is widely considered for the realization of ADAS and automated driving. In this context, it is now being demonstrated that cooperative vehicle-infrastructure ITS systems can be effectively utilized to solve various social issues such as traffic congestion, disasters, and aging population, in addition to the advanced ITS and safe driving support such as automated driving. This report clarified typical use cases of applications utilizing cooperative vehicle-infrastructure ITS systems in APT countries, and provided the deployment status of currently used wireless technologies and ITS applications, with demonstration experiments conducted in APT member countries. In addition, it shall be mentioned that the systems in each use case are not mutually independent but can share infrastructure as shown in Figure 7. The information provided in this report on ITS technologies and their deployment status will be useful for maximizing the use of cooperative vehicle-infrastructure ITS systems to solve several social problems in APT member countries.

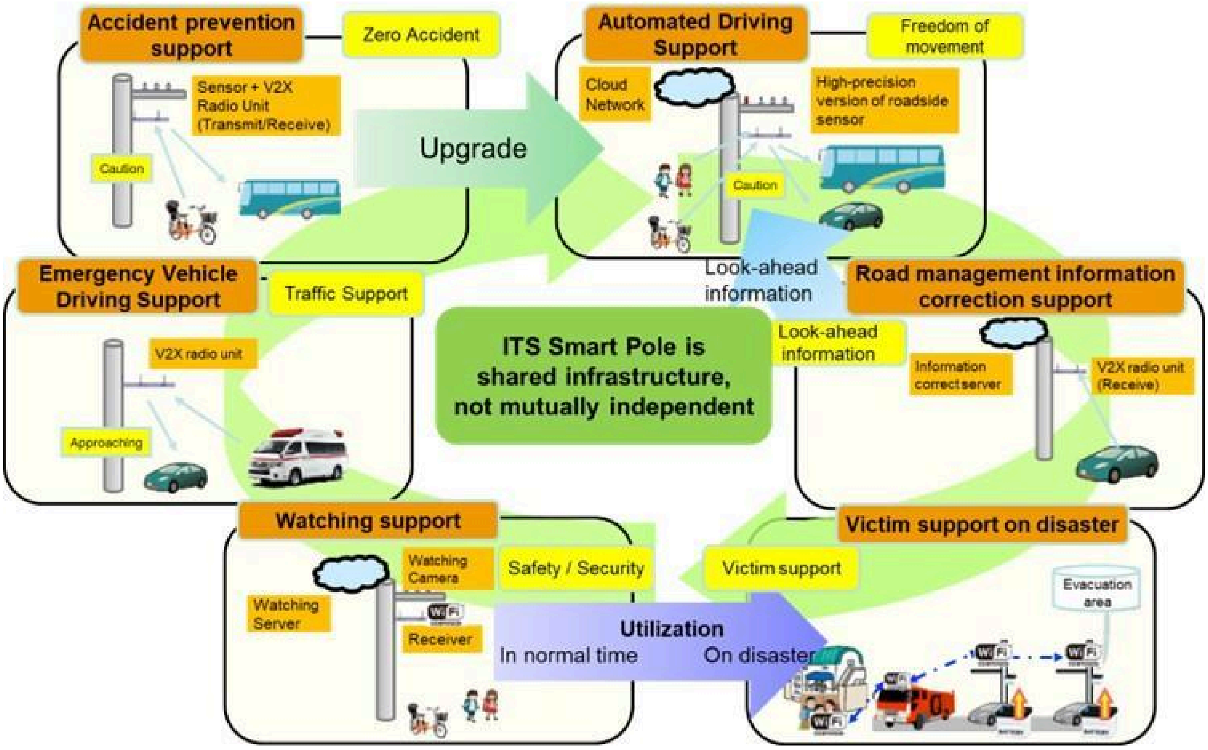


FIGURE 7.1 Multiple use cases covered by ITS Smart Pole

References

[1] Y Haibara et al. "Demonstration to support safe driving of public buses by sensors installed on utility poles in Himeji City, Hyogo Prefecture" published paper in 19th ITS Symposium 2021

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T Sato et al. "Traffic Monitoring by utilizing the probe data of ITS Connect (760MHz DSRC)" published paper in 68th Infrastructure Planning Conference

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[4] ITS Connect System Inter-Vehicle Communication Message Specification TD-001 Version 1.1

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